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ASSESSING THE EFFECTS OF BORROWER-BASED MACROPRUDENTIAL POLICY ON CREDIT IN THE EU USING INTENSITY-BASED INDICES

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Assessing the Effects of Borrower-Based Macroprudential Policy on Credit in the EU Using Intensity-Based Indices

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Abstract

We construct new intensity-adjusted indices of macroprudential policy announcements for 28 European Union (EU) economies. The indices are able to capture the restrictiveness and bindingness of the macroprudential policy actions and are used to assess the effectiveness of borrower-based macroprudential policy in reducing credit in the EU since 2003. Our results indicate that these instruments have successfully reduced household, housing, and, to a smaller extent, consumption credit in the longer run. Moreover, we find that the measured effects change by taking account of the various dimensions of the policy changes' intensity, including their legal enforceability.

Keywords: Macroprudential policy, policy effectiveness, household credit, panel data analysis

JEL-Classifications: E58, C23, G18, G28

1. Introduction

Following the Global Financial Crisis (GFC) of 2008-9, (re)new(ed) attention has been given to prudential supervision of financial institutions and financial regulation at the macro level. The GFC and its aftermath served as a manifest example of the failure of authorities to account for the risks to the macroeconomy arising from the propagation of shocks within the financial sector. The GFC eventually dramatically changed the economic landscape. Before the GFC, there was no formal mandate to execute this so-called macroprudential supervision of financial markets in advanced

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economies. More than ten years after the GFC, macroprudential policy is now very present in all advanced economies, leading to an environment where existing instruments are being monitored and new instruments are being implemented.

An important drawback in the empirical analysis of the effectiveness of countries' macroprudential policies, however, is the blunt quantification of macroprudential policy actions. Macroprudential policy comprises a broad range of instruments of which the objectives can be summarized as reducing the sensitivity of the financial system to shocks, curbing the build-up of systemic financial risks, and diminishing the spillovers of financial system distress to the real economy (Gadanecz and Jayaram, 2016). Despite these common overall objectives, macroprudential policy instruments are multi-dimensional in nature and various instruments target different aspects of systemic risk (see infra, section 3). This in itself hinders the comparability of the policy effects across countries and time, and across tools.

This work's first contribution to the literature is the construction of new data-driven indices of macroprudential policy implementations that facilitate a clean comparison across countries and time for given macroprudential tools. This contribution is two-fold. The refined indices first of all allow to pick up the restrictiveness of macroprudential regulatory actions. Existing cross-country studies typically use a cumulative index based on a '-1/0/+1' dummy for country-specific policy implementations to measure the effects of macroprudential actions on the macroeconomy. While this standard approach has the benefit of resulting in a clean and simple signal of the timing and the direction of changes in countries' macroprudential policy, the particular extent to which a policy is tightened or loosened is completely neglected. Tightening actions of different magnitudes all get the value '-1', and all loosening actions a value of '1' irrespective of the strength of the action, while the value is '0' when a policy is maintained at the same level. An ideal policy indicator should, however, be able to capture the restrictiveness of policy changes next to their timing and sign. Second, the new indices allow to discriminate among different instruments types. The standard dummy values are often assigned to macroprudential actions without discriminating between instruments or distinguishing between different groups of instruments (e.g., tools aimed at borrowers or at lenders). Taken together, the general dummy-type approach ignores the fact

that some actions may have affected the financial system more than others (Eickmeier et al., 2018), either by disregarding the extent and the drivers of the intensity of the action or the instrument type.

Recently, a handful of authors have attempted to address the intensity problem (see infra, section 2). Vandenbussche et al. (2015) and Eller et al. (2020) use numerical rules to weight a range of macroprudential policy actions into one aggregate index capturing the macroprudential policy stance in Central, Eastern, and South-Eastern European countries. Using a similar approach of numerical rules, Meuleman and Vander Vennet (2020) construct a macroprudential index that gives more weight to the activation of macroprudential tools compared to changes in already existing tools. Alam et al. (2019) and Richter et al. (2019) instead have incorporated the intensity of loan-to-value (LTV) limits for groups of advanced and emerging countries. Bergant and Forbes (2021) and Chari et al. (2022) use a similar strategy as Alam et al. (2019) to measure the level of LTV limits and combine this with information on the level of the countercyclical capital buffer (CCyB), and a '-1/0/+1' indicator for foreign exchange (FX) regulations to measure differences in macroprudential stances across countries and time. In contrast to this existing work, we use actual micro-level data to determine the restrictiveness of macroprudential policy implementations and this for a wide range of instruments. More specifically, we employ a granular quantification taking account of the various drivers that indicate how restrictive or binding the implementations are in a given economy, such as the timing, scope, quantitative threshold, and legal enforceability (see infra, section 3).

A second contribution of this work is that it adds to the ongoing debate on the effectiveness of borrower-based macroprudential tools in advanced economies. Borrower-based instruments in particular have been a widely employed tool in EU countries in the attempt to temper the fast growth of mortgage credit. Fluctuations in these credit variables are an important aspect of the overall financial cycle, often triggering major concerns about systemic risks with a potential impact on the real economy (Claessens et al., 2013). Nevertheless, there is at present no clear conclusion about the effectiveness of these tools in advanced economies. The majority of the existing studies focuses on a subset of borrower-based instruments in a group of both emerging and advanced economies. Moreover, only a more recent strand of the literature has examined the dynamic effects of macropru-

dential policy with inconclusive results about the longer-run effects on credit (see infra, section 2). We contribute to this discussion by employing the novel intensity-based indices to investigate the effects of borrower-based macroprudential policy on household, housing, and consumption credit in the EU.

Our work focuses more specifically on LTV, debt-service-to-income (DSTI), debt-to-income (DTI), and loan-to-income (LTI) limits, as their wide use in the EU in response to the GFC provides sufficient variation across countries and time to perform a meaningful analysis (Richter et al., 2019). We examine the effects of borrower-based tools together with other types of macroprudential instruments as different instruments have often been implemented simultaneously. With the inclusion of these other instruments types, we can control for any effects originating from the combined implementation of these borrower-based tools with other instruments. We find that borrower-based macroprudential policy is effective in reducing household, housing, and to a smaller extent consumption credit, especially in the longer run (after 14 quarters). What is more, our estimates suggest that controlling for the restrictiveness of macroprudential measures matters. More specifically, we find that it is important to consider the variety in legal bindingness as well as the intensity of the macroprudential implementations to quantify their effects on credit. Relative to a standard '-1/0/+1' index, our intensity-adjusted index signals different effects of the borrower-based policies on household and housing credit over a multi-year horizon.

The remainder of the paper is structured as follows. Section 2 contains an outline of the related literature. In section 3, the intensity-adjusted macroprudential indices are introduced while section 4 contains a description of our approach to limit endogeneity and policy anticipation concerns, the adopted econometric methodology, and the underlying data series. In section 5, we present the results including robustness checks. Summarizing conclusions are presented in section 6.

2. Related literature

By now there is a growing literature investigating the aggregate effects of macroprudential policy on credit in general and household/housing credit in particular (as discussed in Galati and Moessner (2018)). Cerutti et al. (2017) document that borrower-based and financial-institution-based policies

are effective in reducing credit growth rates. Borrower-based tools (including LTV and DTI limits) are associated with a 1.05 %-points lower household credit growth in a sample of 31 advanced economies. Kuttner and Shim (2012) find that LTV and DSTI limits significantly impact housing credit growth for a panel of 57 countries. Similarly, Alam et al. (2019) find significant impacts of loan-targeted demand instruments (i.e., LTV and DSTI limits) on credit to households, while the effects on household consumption are found to be weaker. As highlighted by Carreras et al. (2018), the literature mainly focuses on the assessment of the impact effects of macroprudential policy while only a more recent strand of the literature has investigated the longer-run effects of macroprudential policy. Richter et al. (2019), for example, focus on the effectiveness of LTV limits in 56 economies. Using a local projections approach, the authors conclude that tightening the LTV limit decreases real household credit by almost 6% after two years and mortgage credit by more than 5% (compared to 1.37% and 1.31% respectively after 1 quarter). Similarly, Poghosyan (2020) finds that lending standard restrictions[3] have a delayed negative impact on credit in EU countries. More specifically, the effect is not significant in the short run and reaches its peak at -1.5% only after 3 years. Carreras et al. (2018), using a cointegration approach on a sample of OECD countries, also find that the effects of macroprudential policy in general gradually build up over time. For borrower-based policies, they find that DTI limits reduce household credit by 1.1% after two years, while no significant effects are found for LTV limits. In contrast, Mokas and Giuliodori (2021) conclude that the impact of LTV announcements in the EU is only significant in the short run and fades out over time. This overview illustrates that although a growing strand of the literature focuses on the effectiveness of borrower-based macroprudential policies in advanced economies, there is no clear agreement on the significance and magnitude of the (dynamic) effects of these policies on credit.

The sample of countries under analysis is one determining factor in this respect. The lack of sufficiently long time series and the relative infrequent changes in macroprudential policies over time

[3]Following the MacroPrudential Policies Evaluation Database (MAPPED) of Budnik and Kleibl (2018)), the author includes LTV, DSTI, DTI, and LTI limits in addition to maturity and amortization restrictions, limits on interest rates on loans, limits on the volume of personal loans, other income requirements for loan eligibility, and other restrictions on lending standards in this category.

drive researchers inevitably to cross-country panels. When analyzing the effects of macroprudential policy instruments, a large part of the literature estimates average coefficients for broad country samples, often including both emerging and advanced economies. Given that instruments are typically defined differently across countries and jurisdictions and that not all countries face the same financial market and institutional characteristics, it is questionable whether making a statement about the effectiveness of a particular macroprudential tool based on the average effect for the entire sample is relevant. The impact of macroprudential policy is for example typically found to be more pronounced in subsamples of emerging countries (Richter et al., 2019; Akinci and Olmstead-Rumsey, 2018). Some studies therefore purposely focus on a more limited set of countries that exhibit comparable characteristics to obtain more meaningful average estimates. Kim and Mehrota (2018), using a VAR approach, for example look at a sample of only Asia-Pacific countries and show that tighter macroprudential policies reduce credit growth. A similar conclusion is made by Gambacorta and Murcia (2022), based on a panel study using bank-level data from five Latin-American countries. De Schryder and Opitz (2021) find that the household credit-to-GDP ratio decreases by 1,6 %-points while the domestic bank credit-to-GDP ratio is reduced by 1,8 %-points after a restrictive macroprudential policy shock in a subset of EU countries.

A related and crucial aspect of analyzing the effectiveness of macroprudential policy is having an appropriate measure of the policy implementations. The indices used in existing cross-country panel data studies in general do not incorporate the intensity of policy actions (see supra, section 1). This problem has only been addressed in a few recent papers. Vandenbussche et al. (2015) and Eller et al. (2020) have constructed an intensity index of the macroprudential policy stance based on numerical rules for changes in the strength of a wide range of prudential measures implemented in Central, Eastern, and South-Eastern European countries. More specifically, they assign different weights to changes in macroprudential tools (e.g., a 5 percentage-point reduction in the LTV limit is equivalent to a 1-index-point increase in their aggregate index) in an attempt to quantify the intensity of macroprudential activity in a given country. Vandenbussche et al. (2015) do not find significant effects of borrower-based instruments but find that capital requirements and limits on credit growth were effective in reducing house price and credit growth. Eller et al. (2020) addi-

tionally focus on a subindex for borrower-based instruments and conclude that these instruments significantly affect household credit and house price growth. Next, Meuleman and Vander Vennet (2020) extend the standard '-1/0/+1' approach by assigning a larger weight to a macroprudential implementation if a tool was newly activated compared to when there was a change in the level or scope of an already existing tool. The authors use their weighted index combined with bank-level data to investigate whether macroprudential policy has been able to contain the systemic risk of European banks. Alam et al. (2019) and Richter et al. (2019) instead incorporate the intensity of LTV limits for groups of advanced and emerging countries by looking at changes in the level of (average) LTV limits. An alternative approach is taken in Chari et al. (2022) in which the authors aggregate the changes in individual countries' macroprudential policies since 2000 using a '-1/0/+1' approach, considered to signal a neutral stance for all economies, to arrive at a stance measure that is comparable across countries and time. Moreover, Chari et al. (2022) construct a narrow measure of the macroprudential stance based on the levels of LTV limits (using the same approach as Alam et al. (2019)) and the CCyB to explicitly capture the intensity of the macroprudential changes. This measure is extended by adding information on FX regulations in the form of a '-1/0/+1' index, which is also used in the study of Bergant and Forbes (2021).

A shortcoming of the above-mentioned studies is that the macroprudential indices do not necessarily signal the restrictiveness of the policy implementations. Although the methods in the latter four above-mentioned papers can to some extent provide information on the effects of level changes in the regulatory limits or buffers, they do not necessarily capture the bindingness of the limit nor the importance of the targeted loan section. As argued by de Jong and de Veirman (2019), a given macroprudential limit can bind to different extents at different times. To pick up the bindingness, one needs to account for underlying financial market and economic dynamics, as shown by de Jong and de Veirman (2019) for the Netherlands. Using loan-level data from De Nederlandsche Bank, the authors find changes in LTV limits to have larger macroeconomic effects when the limit is binding for a larger fraction of borrowers. To quantify the bindingness of the LTV limits, they map changes in the limit to changes in the cross-sectional average of the LTV distribution driven by the imposition of the limit. In the current paper, we construct cross-country macroprudential indices

that capture the intensity of macroprudential policy changes. We elaborate on our approach in the next section.

3. Construction of intensity-based indices

We take a narrative approach to construct intensity-based indices of macroprudential policy implementations for all EU countries. The cross-country focus allows us to compare countries' evolution over time for a range of different macropudential tools and to obtain an acceptable degree of variation in the macroprudential implementations. At the same time, the index does not hinge on the input of loan-level data which is hard to obtain for multiple countries.

The macroprudential toolkit is first of all extensive, with different instruments targeting different aspects of systemic risk. Some instruments are more focused on the resilience of the banking system as a whole from a structural point of view (e.g., capital and liquidity requirements), while cyclical tools tend to improve the resilience during upturns in anticipation of any downturns (e.g., countercyclical capital buffers). Some instruments also target a particular sector. Borrower-based instruments such as LTV, D(S)TI, and LTI limits, for example, have been implemented to impose higher lending standards on the residential mortgage market. These instruments aim to dampen the feedback loop between housing market dynamics and financial markets due to the fact that housing loans constitute an important proportion of bank lending. Risk weights on mortgage loans also relate to the real estate and mortgage market but target the lender rather than the borrower. A cross-country intensity-based measure of macroprudential changes should therefore capture both the wide range of tools and their various uses.

The macroprudential data

We collect information on the implementations from the MacroPrudential Policies Evaluation Database (MaPPED) of Budnik and Kleibl (2018), as this is the most relevant, extensive, detailed, and publicly available source of information on macroprudential policy implementations in the EU in existence at present. This MaPPED lists information on 53 different instruments grouped in 11 categories (as listed in table 1) and contains almost 2000 macroprudential policy actions in the 28

EU member states[4] from 1995 to 2017. We further complement this dataset with more recent data from national legislation, central bank statements, and the European Systemic Risk Board (ESRB) Macroprudential Policies database, using the Integrated Macroprudential Policy (iMaPP) database from the IMF to cross-check these more recent implementations. The database eventually covers announcements on policy implementations from 1995 to 2019. We deliberately cut off our sample at 2019 to avoid picking up any effects from the COVID-19 pandemic.

Categories of macroprudential policy instruments according to MaPPED
1. Lending standard restrictions/borrower-based instruments (9 instruments)
2. Risk weights (3 instruments)
3. Capital buffers (8 instruments)
4. Minimum capital requirements (4 instruments)
5. Leverage ratios (1 instrument)
6. Limits on credit growth and volume (2 instruments)
7. Liquidity requirements and limits on currency and maturity mismatch (6 instruments)
8. Limits on large exposures and concentration (6 instruments)
9. Loan-loss provisioning (4 instruments)
10. Levy/tax on financial institutions and activities (2 instruments)
11. Other measures (8 instruments)

Table 1: Overview of the macroprudential categories following Budnik and Kleibl (2018)

This dataset informs us about multiple elements that determine the restrictiveness of a policy implementation for a given instrument, country, and time period such as their *timing* (announcement and enforcement date), *scope* (the field of application), *quantitative limits* (quantitative thresholds including tolerance margins or exceptions), and *legal enforceability*. We use this information to capture macroprudential policy in a more granular way, i.e., to take the intensity of policy changes into account and to differentiate between the various instruments, in contrast to the commonly used general '-1/0/+1' index. Table 2 lists some examples from the updated MaPPED to illustrate these different elements for several instruments.

[4]The United Kingdom ceased to be part of the EU on 31 January 2020 but is included as EU member given our sample period.

Country	Instrument	Ann	Enf	Example	Legal enforcement
BE	LTV limit	2019Q4	2020Q1	LTV limit of 90% for purchase of primary residence, 80% for buy-to-let. Higher tolerance margin for first-time-buyers.	Comply or explain
CY	LTV limit	2013Q1	2013Q1	LTV limit of 70% for housing loans.	Financial sanctions
NL	LTV limit	2012Q3	2013Q3	LTV limit of 106% for mortgage loans. Limit decreased by 1% yearly from 2013-2018.	Financial sanctions
PT	DSTI limit	2018Q1	2018Q3	DSTI limit of 50% for loans to households.	Comply or explain
GR	Risk weights	2005Q4	2005Q4	Risk weight of 100% mortgage backed by residential property and LTV higher than 75%. 50% risk weight for mortgage exposures with an LTV ratio below 75%.	Non-monetary sanctions
ES	GSII buffer	2017Q4	2019Q1	Capital buffer of 1% for Banco Santander.	Non-monetary sanctions
LT	OSII buffer	2015Q4	2016Q4	Capital buffer of 2% for AB SEB bankas, Swedbank, and Luminor. Capital buffer of 0.5% for AB Siauliu bankas.	Non-monetary sanctions
PL	SRB	2017Q1	2018Q1	Systemic risk buffer of 3% for all credit institutions.	Financial sanctions
SE	SRB	2014Q1	2015Q1	Systemic risk buffer of 3% for Nordea, SEB, Handelsbanken and Swedbank.	Non-monetary sanctions
FR	LCR	2014Q4	2015Q4	Liquidity coverage ratio of 60% required. Ratio increased by 10% yearly to 100% in 2018.	Financial sanctions

Table 2: Examples of macroprudential policy implementations in EU countries in our dataset. Ann = announcement date, Enf = enforcement date.

Quantifying the bindingness

We construct intensity-based indices that represent the different elements of restrictiveness (i.e., the scope, quantitative limit, and legal enforceability) for the first 7 of the 11 categories in table 1 and 19 of the 53 instruments[5] in the MaPPED. We construct the intensity-based indices for each macroprudential policy instrument separately as the different macroprudential policy instruments target various parts of the economy in a different way.

First, we quantify the scope and quantitative limits following a common methodology per instrument category. For tools aimed at borrowers of mortgage loans, we focus on the share of loans to which the limits are applied to, being the scope, next to the percentage of loans exceeding the limit before the implementation to determine the restrictiveness of the implementation. For risk

[5]The complexity of the imposed rules combined with insufficient micro-level data for the remaining four categories, responsible for 20 macroprudential instruments, makes that we do not construct intensity-based indices for those categories. These instruments either represent a limited amount of implementations in a small group of countries (see table A.8) or are often not considered to be part of the macroprudential toolkit. Similarly, we are not able to capture 14 out of 33 instruments within the 7 above-mentioned macroprudential categories due to the specificity and complexity of the imposed rules. However, these instruments are responsible for the minority of the implementations within each category (as listed in table A.7).

weights, we measure the scope of the regulation based on the proportion of loans above/below the LTV ratio threshold which is used to signal the riskiness of a loan. For capital buffers, on the other hand, the scope is measured based on the share of the targeted financial institutions in the total market. To measure the intensity of the changes in the instruments in the categories of minimum capital requirements, leverage ratios, liquidity requirements, and reserve requirements we focus on the variation in the imposed quantitative thresholds.

Next to the scope and (the restrictiveness of) the quantitative limits, the intensity-based indices also account for the variation in legal consequences in case of non-compliance to the imposed rules and pick up allowed exceptions. For example, it can be argued that legally binding actions where a financial institution has to pay fines and penalties in case of non-compliance are considered to be more restrictive than policy implementations using the 'comply or explain' method. Mokas and Giuliodori (2021), for example, find that the negative effects of LTV announcements are mostly driven by binding actions as opposed to actions taken on the basis of soft law (e.g., recommendations). Likewise, permitted deviations from the imposed rule or limit decrease the level of restrictiveness. We quantify the legal consequences and exceptions the same way for all categories of the macroprudential instruments given the common nature of this element of restrictiveness. [6] Given the often-heard argument that financial institutions will act upon regulatory measures even if there are no direct legal consequences because of reputational effects or potential reactions of the regulator (Kroen, 2022), we pay specific attention to the relevance of including a 'legal dimension' in the intensity-adjusted indices in section 5.2.

As indicated above, we also use actual micro-level data to determine how binding a particular implementation effectively was. Below, we explain how the micro-level data are used in the construction of the intensity-adjusted indices for 3 categories of instruments, being borrower-based instruments, risk weights, and capital buffers. The quantification of the instruments in the other 4 categories does not require micro-level data since this is based on variation in the imposed quantitative thresholds, legal consequences, and any permitted exceptions. The specific details on the

[6] Detail on the quantification of the legal consequences and exceptions can be found in Appendix A.

quantification of each element of restrictiveness for each of the categories are fully outlined in Appendix A.

For **borrower-based measures and risk weights for residential property**, we use data collected by the Household Finance and Consumption Surveys (HFCS). The HFCS database collects household-level data on households' finances and consumption for a large group of European countries[7]. The HFCS data provide information on different loan segments (e.g., overall mortgage lending, housing loans, or loans to first-time-buyers) and lending standards (LTV, D(S)TI, LTI ratios, and maturities) in great detail. The HFCS data has been collected in three separate waves (2010, 2014, and 2017) but each wave contains information on mortgage loans originated in the years before the survey wave, which allows us to pick up the time dimension and measure relevant information in the years before specific policy implementations. Moreover, the data allow to tailor indices to a specific country as the cross-sectional dimension of the database offers information on the country-specific characteristics of household lending (e.g., the variation in the importance of certain loan categories across countries). To capture the restrictiveness of an imposed quantitative threshold in the category of borrower-based measures, we calculate the percentage of loans in a given country and loan category that exceeds the imposed limit *before* the implementation of the limit. This gives us an indication of how binding the limit is, since this percentage indicates how many loans would be affected by the limit if the rule was already in place. The HFCS data is further used to measure the importance of the loan segment or field of application (i.e., the scope) targeted by the borrower-based measure (e.g., mortgage lending, loans for house purchases, or loans to first-time-buyers) by calculating the proportion of the specific loan segment in total mortgage lending by households *before* the implementation of the limit. Since a larger scope is considered to be more restrictive, a higher proportion will contribute to a larger value for the final index. For risk weight regulations, as mentioned before, we use the HFCS data to measure the scope of implementations by calculating the share of loans with an LTV ratio above/below the imposed thresholds *before* the

[7] Countries such as Bulgaria, Czech Republic, Denmark, Romania, and Sweden are not included in first three waves of the HFCS. For these countries, we cannot construct intensity-adjusted indices for implementations of borrower-based instruments or residential risk weights.

policy implementation.

While offering comparable cross-country data, the HFCS data is less detailed and covers a smaller sample of mortgage loans relative to country-specific loan-level datasets. For each wave of the HFCS, the sample of respondents for each country is chosen such that it is representative for the population in that country and time period. Being a survey, however, the number of observed mortgage loans is confined and limits the amount of selection criteria we can use to determine our sample of interest. For example for loans for house purchase to first time buyers, restricting the amount of years to approximate the state of the economy right before the macroprudential implementation becomes tricky in an already limited sample. The specificities of the HFCS data namely make that the construction of lending standards can only be done under certain conditions. More specifically, to construct, e.g., LTV ratios at origination, it is required that the loan is originated in the same year as the year of house purchase or the year that the survey was taken out, given that the HFCS only reports the value of the house at those two points in time (see table A.2). For this reason, we focus on measuring the lending standards using all the available years before the policy implementation. On average, 74% of the mortgage loans were issued in the last 10 years before the year of the survey, while 92% was taken out in the last 15 years. Using all the available years before the policy implementation allows to approximate the state of the mortgage market in a given country before the implementation while retaining sufficient data coverage.

Capital buffers specifically target a subset of financial institutions (e.g., systemically important institutions). The specific number and importance of the chosen institutions to which a capital buffer applies vary across countries. It is important to take this variation into account when determining the restrictiveness of the imposed capital buffers. To this end, we use yearly data from S&P global and the ECB's Statistical Data Warehouse to calculate market shares for a specific institution (i.e., total assets of the institution relative to the consolidated total assets of the country the institution is active in) which approximates the importance of that institution in a given country and time. These market shares are used to re-weight the imposed buffers such that we end up with market-share-adjusted capital buffers which captures both the scope and the quantitative threshold of these implementations and which can be used to compare the restrictiveness of the capital buffer

implementations across countries and time.[8]

Bringing it all together

Using the above-described logic and data, we obtain a quantitative value for each of the considered elements that determine the bindingness of a policy implementation. These values are next weighted into one final score for each specific implementation. The baseline weighting scheme gives the largest weight to the scope ('0.4') and the restrictiveness of the limit ('0.4') for borrower-based measures and risk weights, to the market-share-adjusted limit ('0.6') for capital buffers, and to the variation in the limit ('0.6') for the instruments for which we do not use micro-level data. The value for the legal consequences is given a larger weight ('0.15' for borrower-based measures and risk weights, '0.35' for capital buffers, or '0.4' for the instruments for which we do not use micro-level data) than the value for exceptions ('0.5' or '0' when there are no exceptions across all implementations of a given instrument). We use different weighting schemes and check the sensitivity of our results to the various schemes (see infra, section 5.2).The resulting intensity-based indices allow to examine the restrictiveness of the macroprudential implementations across countries and time for a given policy instrument. For examples of specific implementations of different macroprudential instruments being translated into an intensity-adjusted value, we refer to tables A.3, A.4, A.5, and A.6. Eventually, we construct intensity-based indices for the majority (on average around 74%) of implementations for 19 macroprudential instruments. Tables A.7 and A.8 provide an overview of the coverage of the intensity-based indices across instruments and categories.

In contrast to previous studies (e.g., Vandenbussche et al. (2015); Eller et al. (2020)), we deliberately do not aggregate the indices for all the different macroprudential instruments together. A first reason is that the methodology of constructing the indices varies over the different categories of instruments. Moreover, such general aggregation would prevent us to isolate the effects of different types of measures, in particular borrower-based macroprudential policies. However, we do

[8]For example, a capital buffer that is applied to all financial institutions in a given country will be weighted by 100% since these institutions represent 100% of the market shares in that country. When the capital buffer only applies to some specific financial institutions, it will be weighted by a percentage smaller than 100% which is equal to the market share those institutions represent.

sum up the intensity-based indices per category (as listed in table 1) to obtain variables including a sufficient amount of implementations to perform a meaningful analysis.

4. Methodology

4.1. Identifying the macroprudential changes

Our identification strategy relies on the idea that macroprudential measures do not respond to contemporaneous shocks in credit (i.e., in the same quarter). This assumption is reasonable since both the build-up of financial vulnerabilities as well as the decision process regarding macroprudential policy is typically long (Duprey and Ueberfeldt, 2020). As argued in Duprey and Ueberfeldt (2020), the latter especially holds when different policymakers (i.e., central banks, regulatory prudential authorities, and ministries of Finance) are involved since these different policymakers can each have different reaction functions resulting in a longer decision process. This decision process is in EU countries particularly influenced by multiple policy-making authorities within a complex supervisory system. More specifically, the ESRB coordinates the system-wide policy framework but has no binding powers. The implementation powers lie with the 28 national authorities in the Eurosystem, where the relative responsibilities of the national central banks, regulatory authorities, and ministries of Finance vary across countries. Furthermore, supervisors are more likely to react to credit dynamics in high-risk segments and associated lender risks and not to fluctuations in aggregate credit series which lowers endogeneity concerns when the dependent variables concern aggregate credit series. Abreu and Passinhas (2021), for example, argue that the implemented borrower-based measures in Portugal were specifically aimed to impact lending to borrowers with a high-risk profile with the goal to prevent the build-up of systemic risk.

A step we take to further reduce endogeneity concerns is to remove all the macroprudential implementations that were set with a countercyclical goal from our main variable of interest (i.e., the changes in borrower-based macroprudential policy) since these tools were tightened or loosened as a reaction to developments in systemic risk and the financial cycle (following Fernandez-Gallardo

and Paya (2020) and De Schryder and Opitz (2021)).[9] As such, we only capture the effects of policy implementations with a more structural character.

We also account for the fact that regulations often include transition periods between the announcement and the implementation of a policy change. More specifically, we focus on those implementations that were announced and enforced in the same quarter (i.e., 'news shocks'). As argued by De Schryder and Opitz (2021), when announcement dates and enforcement dates are far from each other, financial institutions might adopt the policies at a different time, which dilutes the results. Moreover, it is possible that some financial institutions are not inclined to lower or even increase their lending in this transition period, before they actually have to comply to the limit, which could lead to counter-intuitive results. In general, the anticipation of policy shifts could lead to biased results if the econometric model does not distinguishes between unanticipated and anticipated policy shifts (Leeper et al., 2013). The caveat of this identification approach, however, is that it strongly reduces the amount of observations in our main variable of interest.[10] Admittedly, it is still possible that the implementations could be anticipated before their official announcement by, for example, public debate. These effects are not captured when looking at the official announcement dates but, on the other hand, the exact specificities of the policies are very hard to predict (as Alesina et al. (2015) similarly argue about fiscal policy plans).

To test whether the policy implementations are anticipated and affect our regression results, we investigate whether our macroprudential shocks can be predicted by the private sector, similar to Ramey (2011), Duprey and Ueberfeldt (2020), and De Schryder and Opitz (2021). To perform this test, we first use data from the quarterly Bank Lending Survey (BLS) which provides information

[9]MaPPED lists information on whether a specific tool was implemented with a countercyclical design based on their questionnaire. The questions is answered with 'yes' if: (i) the level of the instrument automatically tightens when systemic risks intensify and loosens when they fade, or (ii) the level of the instrument is regularly (e.g., quarterly) revised and calibrated along with the intensity of cyclical systemic risk by, for example, linking the revisions of an instrument to the evolution of indicators of systemic risk (Budnik and Kleibl, 2018). We include these observations as a control variable that captures the implementations that could not be translated into an intensity-adjusted value to avoid any omitted variable bias. However, our results are robust to dropping the countercyclically defined observations from our analysis.

[10]The limited number of observations further diminishes the possibilities of sensitivity analysis, for example the use of sample splits across countries or time.

on bank lending conditions in the euro area for a subset of countries in our original sample.[11] In this survey, the BLS asks bank loan officers about their expectations regarding credit standards of, for example, loans for house purchases and consumption credit. Second, as outlined below in more detail, we take the change in the intensity-based macroprudential index (i.e., the change in the restrictiveness of the macroprudential instruments) for borrower-based measures and define it as our macroprudential shock. If the bank loan officers' expectations can anticipate the macroprudential actions, the shock would be endogenous. To test this, we regress the macroprudential intensity-based index for borrower-based measures in quarter t on the forecasts about credit standard changes made in quarter *t-1* for quarter *t*. Table 3 shows that the credit standards cannot significantly predict the shock.[12] Although this simple analysis cannot guarantee that the shocks are fully exogenous, it does give us confirmation to proceed with the outlined identification strategy.

Hypothesis	P-value
Do credit standard expectations on credit for house purchase forecast the macroprudential shock?	0.110
Do credit standard expectations on consumption credit forecast the macroprudential shock?	0.562

Table 3: Predictability tests based on BLS data. The table show the p-value for the regression of our intensity−adjusted macroprudential policy shock in t on the diffusion index of the forecast change in credit standards at time t − 1 for period t for the respective type of credit.

4.2. Model estimation

We examine the effects of borrower-based macroprudential policy in 28 European countries from 2003Q1 to 2019Q4 by estimating equation (1) using local projections (LPs) following Jordà (2005) and Richter et al. (2019). The LP methodology is particularly relevant as it enables us to estimate the dynamic effects on the dependent variables over time, hence over and above the effects on

[11]The BLS data is available from 2003Q1 until present for 17 countries in our sample, being Austria, Belgium, Cyprus (starting from 2009Q2), Germany, Estonia (starting from 2011Q2), Spain, Finland, France, Greece, Ireland, Italy, Lithuania (starting from 2015Q2), Luxembourg, Latvia (starting from 2014Q2), the Netherlands, Portugal, and Slovenia (starting from 2007Q2). This covers 10 out of the 14 changes in borrower-based macroprudential policy that were announced and enforced in the same quarter.

[12]The BLS survey data further allows to check whether changes in our macroprudential index Granger cause a change in banks' perceptions of credit standards. We find that a macroprudential policy tightening does tighten bank credit standards for loans for house purchase. We do not find a significant relationship for consumption credit although this is not surprising since macroprudential limits rarely put restrictions on consumption credit.

impact. The fact that LPs allow to analyze the persistence of macroprudential policy effects is very important as it usually takes some time for these effects to materialize. Moreover, LPs are more robust to misspecifications and more flexible to include non-linearities compared to a VAR approach which is, however, more efficient when the model is correctly specified (Jordà, 2005).

The econometric model is represented as follows:

$$\begin{aligned} Y_{i,t+h} = \gamma^h(L)Y_{i,t-1} \; + \; \beta^h(L)\Delta MAP^{borr}_{i,t} \; + \; \tau^h \mathbf{X_{i,t-1}} \; + \; \delta^h(L)\Delta \mathbf{MAP^{other}_{i,t}} \; + \\ \lambda^h(L)\mathbf{MAP^{non-int}_{i,t}} \; + \; \eta^h(L)\mathbf{MAP^{ant}_{i,t}} \; + \; \alpha^h_i \; + \; \theta^h_t \; + \; \epsilon_{i,t+h} \end{aligned} \tag{1}$$

where h stands for the horizon of the local projections, running from 0 to 16 quarters and bold terms represent vectors containing multiple variables. The dependent variable ($Y_{i,t+h}$) represents credit variables (see infra) for country i at time $t+h$. It is regressed on its lagged values ($Y_{i,t-1}$) to control for persistence of the credit series, the change in the intensity-adjusted index for borrower-based macroprudential tools ($\Delta MAP^{borr}_{i,t}$), and a set of changes in intensity-adjusted indices for other macroprudential tools ($\Delta \mathbf{MAP^{other}_{i,t}}$) to control for the simultaneous implementation of borrower-based tools with other types of macroprudential policy tools. We take the change in the indices (i.e., the change in the restrictiveness of the macroprudential instruments) as this series is comparable across countries. We additionally include a lag of the change in the macroprudential index for borrower-based measures and the other intensity-adjusted instruments to account for past implementations. Next, we add contemporaneous and lagged macroprudential actions for which we could not construct an intensity-adjusted index, aggregated per category ($\mathbf{MAP^{non-int}_{i,t}}$) using the '-1/0/+1' method that counts the amount of tightenings and/or loosenings in one quarter. Given that the indices for macroprudential policy, ($\Delta MAP^{borr}_{i,t}$, $\Delta \mathbf{MAP^{other}_{i,t}}$, and $\mathbf{MAP^{non-int}_{i,t}}$), only include macroprudential implementations that were announced and enforced in the same quarter (see infra, section 4.1), we also control for all contemporaneous and lagged implementations for which the enforcement date was more than one quarter later than the announcement date to avoid

omitted variable bias. We refer to these as the 'anticipated implementations' ($\mathbf{MAP^{ant}_{i,t}}$).[13] These implementations are dated at enforcement date, similar to Mokas and Giuliodori (2021), since this is the date at which financial institutions effectively have to comply to the rules (see supra, section 4.1). We check the sensitivity of our results with regards to this term in section 5.4.2. We further include a set of predetermined macroeconomic control variables ($\mathbf{X_{i,t-1}}$). More specifically, we control for economic conditions in a country by including the log of real GDP, for price levels by including the Harmonized Index of Consumer Prices (HICP), for the monetary policy stance by including the policy rate[14], and for the occurrence of systemic banking crises. We include country-fixed effects (α_i^h) to pick up any time-invariant differences across countries and time-fixed effects (θ_t^h) to control for common developments. Following standard practice, we correct the standard errors using the Driscoll-Kraay method to control for serial and cross-sectional correlation in the error terms (Driscoll and Kraay, 1998). Moreover, we hold the sample constant by dropping all observations that are not included in the local projection step with the largest horizon. The lag length for the lagged dependent variable is set at 4 quarters, while it is set at 1 quarter for all other variables.[15] All relevant data series are in real terms, deflated by the HICP, and seasonally adjusted using the X-13 ARIMA approach. The respective data sources are listed in table B.1.

For the credit variables, we use data on household credit from the Balance Sheet Items of the ECB Statistical Data Warehouse. More specifically, this dataset reports the stock of total loans (all maturities), loans for house purchase, and credit for consumption to household counterparts on a monthly basis from the early 2000s until 2023. These credit series are transformed from monthly to quarterly data and normalized by expressing them relative to the GDP. These credit-to-GDP ratios capture how credit evolves relative to the size of the economy. If this ratio is high, it could be a signal of a risk to financial stability. Table B.2 provides further details and descriptives on the

[13] This term is a vector containing both instruments in the intensity-adjusted format as well as in the standard '-1/0/+1' format that counts the amount of tightenings and/or loosenings depending on the instrument category.

[14] Given that our sample includes countries in- and outside the euro area, the monetary policy rate is not a common variable to all countries and will thus not be captured by our time-fixed effects. We use the shadow rate of Wu and Xia (2020) for euro area countries and the UK, see Appendix B for more details.

[15] The lag lengths are selected based on a general-to-specific modeling approach where the results are robust to increasing the lag length of all other variables up to 4 lags.

data series used in the estimations.

5. Results

5.1. Are borrower-based macroprudential policies effective in reducing credit?

Figure 1 displays the cumulative impulse response functions (IRFs) resulting from the LP estimation of equation (1) with the baseline borrower-based macroprudential policy index capturing LTV, DSTI, DTI, and LTI limits. In particular, it shows the evolution of coefficient β (i.e., the effect of a change in the restrictiveness of borrower-based macroprudential policy on the credit series) over the 4-year horizon while controlling for the implementation of other types of macroprudential instruments. We find that tightening borrower-based macroprudential policy has a sizeable negative impact on the household credit to GDP ratio (hereafter: household credit) and the credit for house purchase to GDP ratio (hereafter: housing credit) over the medium term. The effects on household credit are significant after 14 quarters with a negative effect of -5.08 %-points. After 16 quarters, borrower-based macroprudential policies substantially reduce household credit by -6.63 %-points. The IRFs for housing credit, constituting an important proportion of household credit, show a similar course. In the longer run, housing credit is significantly decreased from 13 quarters onwards with a magnitude of -3.12 %-points, further decreasing to -4.72 %-points after 16 quarters. We also observe a significant impact on the credit for consumption to GDP ratio (hereafter: consumption credit) of -0.79 %-points after 16 quarters. The fact that the borrower-based macroprudential policies specifically target the mortgage market rather than consumption credit likely explains the smaller effect compared to the effects on household and housing credit.

Our baseline results are in line with Kim and Mehrota (2018), Poghosyan (2020), and De Schryder and Opitz (2021) who find a significant impact of macroprudential policy on household credit in the medium and long run. A possible explanation for the delayed impact is that borrower-based policies often target high-risk borrower segments which makes that it takes some more time to have an impact on aggregate credit series. Another explanation is linked to the design of borrower-based policies and relates to the fact that the measures usually target newly issued loans which makes that the impact on the stock of loans only materializes after some time. Moreover, research

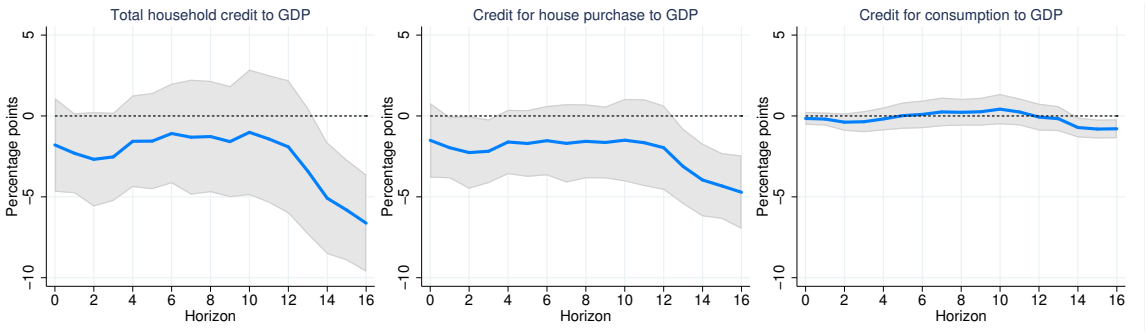

Figure 1: Impulse response functions of credit-to-GDP ratios to a shock in borrower-based macroprudential policy (LTV, DSTI, DTI, and LTI limits). Note: The solid blue lines show the point estimates of the reaction of the variable to a macroprudential policy shock over a horizon of 16 quarters. The grey areas reflect the 90% error bands.

based on loan-level data shows that the insignificance of the effect on aggregate credit series in the short run can be driven by compensation effects. Acharya et al. (2020) for example argue, based on Irish data, that an increased issuance of loans conforming the imposed LTV limit might have compensated the mechanical reduction of the issuance of non-conforming loans. Our IRFs further suggest that the impact on household and housing credit not only becomes significant but also more pronounced in the long run. Other studies that investigate the long-run impact of macroprudential policies, such as Carreras et al. (2018) and De Schryder and Opitz (2021), support this hypothesis. These authors, however, also find a significant negative effect in the short run/at impact using the '-1/0/+1' index. Next to the difference in the measurement of macroprudential policies, the study of De Schryder and Opitz (2021) focuses on all macroprudential tools in general instead of borrower-based tools and on a more limited sample of 13 countries, such that we cannot fully compare the results. Carreras et al. (2018) use a different sample as well, also considering countries such as the Australia, Canada and the US and only focus on LTV and DTI limits. Moreover, their cointegration approach differs from our empirical set-up. Mokas and Giuliodori (2021) on the other hand find the effects of borrower-based macroprudential policy to be more pronounced in the short-run than in the long run, where it loses its significance. The difference with Mokas and Giuliodori (2021) could be driven by the usage of the standard '-1/0/+1' index (see infra, section 5.3 for a comparison of our result with results using such standard index), a different definition of the macroprudential shock (e.g., they also include countercyclically and anticipated implementations into their shock

variable), and the fact that they do not control for the simultaneous implementation of other types of macroprudential policies.

Together, these findings suggest that tightening borrower-based macroprudential policy is effective in reducing household, housing, and, to a smaller extent, consumption credit although with a delayed impact.

5.2. How important is the legal bindingness of borrower-based macroprudential policies?

Given that we include multiple determinants of restrictiveness in our intensity-adjusted indices, in contrast to standard '-1/0/+1' indices, we can take a closer look into how these determinants affect the results. In particular, as mentioned in section 3, the baseline weighting scheme gives the largest weight to the scope and restrictiveness of the limit for borrower-based measures. A lower weight is given to the legal consequences, which is still larger than the weight assigned to the exceptions. To test the sensitivity of our results to this weighting scheme, we construct three additional weighting schemes, as listed in table 4. In the second weighting scheme, the weights are equally divided between the scope, restrictiveness of the limit, and legal consequences while in the third variation of the weighting scheme, more importance is given to the legal consequences relative to the baseline scenario and less to the scope. Finally, we consider a fourth weighting scheme which does not assign any weight to the legal dimension in the construction of the intensity-adjusted indices which means that this dimension is excluded from our index.

	Restrictiveness of the limit	**Scope**	**Legal consequences**	**Exceptions**
Baseline weighting scheme	0.4	0.4	0.15	0.05
Weighting scheme 2	0.32	0.32	0.32	0.04
Weighting scheme 3	0.4	0.3	0.25	0.05
Weighting scheme 4	0.45	0.45	-	0.1

Table 4: Weights assigned to the dimensions that determine the restrictiveness of borrower-based macroprudential instruments in each weighting scheme (the sum of each line is equal to 1). The weights for the other types of macroprudential policy instruments are adjusted using a similar reasoning for each weighting scheme.

Figure 2 shows that the results for the second (short-dashed lines) and third weighting scheme (dash-dotted lines) are very close to the baseline scheme (blue lines). The IRF for the fourth weighting scheme (long-dashed lines), however, suggest that the inclusion of the legal dimension in the intensity-adjusted indices is highly important when investigating the effects of borrower-based

macroprudential policies on credit. More specifically, even though the results are not very sensitive to the magnitude of the weight that is given to the legal consequences, the significance of the results in the long run disappears when the legal bindingness of macroprudential implementations is completely neglected and each implementation is considered to be equally binding in terms of legal consequences. These results highlight the importance of taking account of the variety in the legal bindingness of macroprudential policies, different from just comparing the effects of legally binding implementations to implementations based on recommendations (as in e.g., Mokas and Giuliodori (2021)). More specifically, our findings do not support the often-heard notion that banks will act upon any regulation, even in absence of a legally binding regulation.

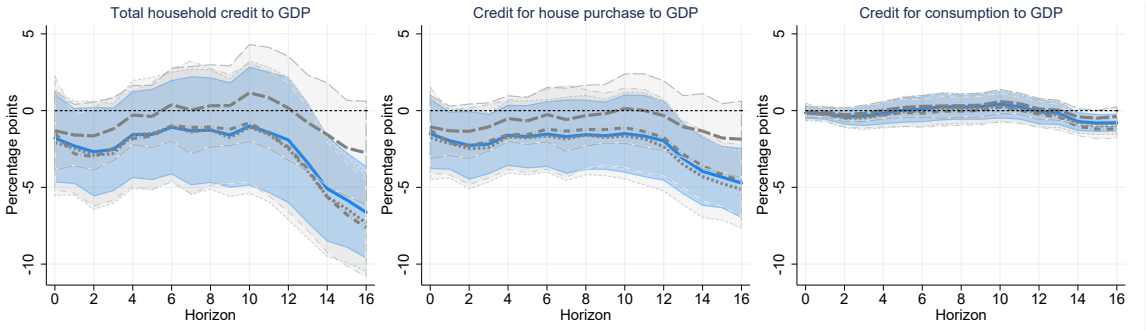

Figure 2: Impulse response functions of the reaction of credit-to-GDP ratios a shock in borrower-based macroprudential policy (LTV, DSTI, DTI, and LTI limits) using the different weighing schemes to construct the intensity-adjusted indices (baseline = blue lines, second weighting scheme = short-dashed lines, third weighting scheme = dash-dotted lines, fourth weighting scheme = long-dashed lines). Note: The thick lines show the point estimates of the reaction of the variable to a macroprudential policy shock over a horizon of 16 quarters. The shaded areas reflect the 90% error bands.

5.3. Does it matter whether an intensity-adjusted index is used to measure macroprudential policy?

In this section, we investigate whether and to which extent our results differ when using a standard dummy approach instead of the intensity-adjusted indices. To do this, we estimate equation (2) in which macroprudential announcements are now captured by '-1/0/+1' indices since this way of measuring macroprudential policy is often used (e.g., in Kim and Mehrota (2018), Eller et al.

(2020), and Gambacorta and Murcia (2022)).

$$Y_{i,t+h} = \gamma^h(L)Y_{i,t-1} \; + \; \beta^h(L)MAP^{`\#-1/0/+1'borr}_{i,t} \; + \; \tau^h\mathbf{X_{i,t-1}} \; + \; \delta^h(L)\mathbf{MAP^{`\#-1/0/+1'other}_{i,t}}$$
$$+ \; \lambda^h(L)\mathbf{MAP^{`\#-1/0/+1'non-int}_{i,t}} \; + \; \eta^h(L)\mathbf{MAP^{`\#-1/0/+1'ant}_{i,t}} \; + \; \alpha^h_i \; + \; \theta^h_t \; + \; \epsilon_{i,t+h} \tag{2}$$

The index counts the number of tightenings and loosenings for a given instrument in a specific country and quarter. Although there are other ways of measuring macroprudential policy implementations using a dummy or '-1/0/+1' approach[16], this type of index is most comparable to our intensity-adjusted indices that also take account of the fact that there can be multiple tightenings and loosenings in one quarter. The policy instruments are grouped in the same way as in section 5.1, meaning that the borrower-based index captures the values for changes in LTV, DSTI, DTI, and LTI limits. The other macroprudential instruments which were also intensity-adjusted are now also captured by a '-1/0/+1' index. To be able to compare the effects of the same implementations, we again include a separate term for implementations that were not translated into an intensity-adjusted value in the baseline analysis. The main variable of interest ($MAP^{`\#-1/0/+1'borr}_{i,t}$) captures implementations that were announced and enforced in the same quarter, while we once more include a term to control for anticipated implementations ($\mathbf{MAP^{`\#-1/0/+1'ant}_{i,t}}$).

The results are shown in figure 3, which plots the IRF using the intensity-adjusted indices estimated by equation (1) (blue) and the IRF using the '-1/0/+1' indices estimated by equation (2) (red). First of all, we notice that using the '-1/0/+1' index also results in finding a negative effect in the long run on household and housing credit after a tightening in macroprudential policy. This is in line with our baseline results and earlier work as described in section 5.1. However, the

[16] Another way of measuring macroprudential policy is by using an index that takes the value of '1' during quarters in which a policy instrument is in place (summed up for the different instruments) and zero otherwise as in Cerutti et al. (2017) and Claessens et al. (2013). We do not include this index in our comparison, since it does not allow us to discriminate between tightening and loosening actions. Next, it is possible to use an index that gets the value '+1' for a specific country and time when there were more tightening than loosening policy actions during a quarter '-1' if there were more loosening than tightening actions, and '0' if there is an equal amount of loosening and tightening actions or there was no policy action (as in Richter et al. (2019), Poghosyan (2020), or De Schryder and Opitz (2021)). Given that this index does not account for the fact that there can be multiple tightenings or loosenings in 1 quarter, we do not include this index in our comparison. Finally, multiple studies use the '-1/0/+1' index to construct measures of the stance of macroprudential policy (i.e., a cumulative index). Because we focus on the changes in restrictiveness in our analysis, we do not consider this type of index in our comparison.

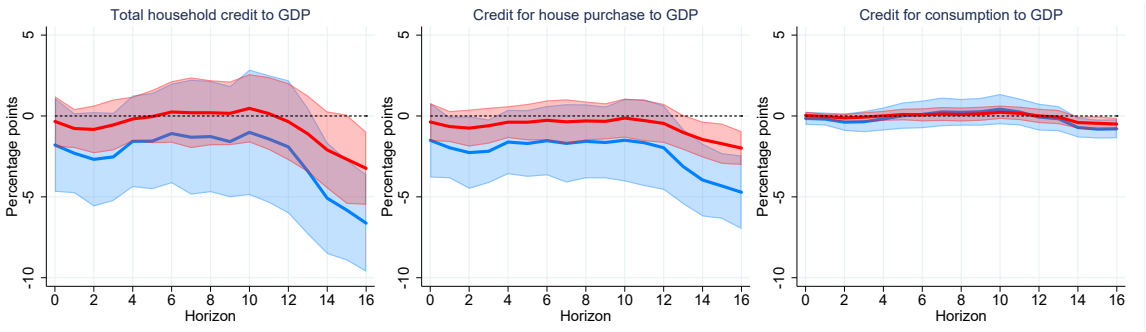

Figure 3: Impulse response functions of credit-to-GDP ratios to a '-1/0/+1' shock (red) and intensity-adjusted shock (blue) in borrower-based macroprudential policy (LTV, DSTI, DTI, and LTI limits). Note: The solid lines show the point estimates of the reaction of the variable to a macroprudential policy shock over a horizon of 16 quarters. The lighter shaded areas reflect the 90% error bands.

figure shows that there are some differences in terms of the magnitude and timing of the effects on household and housing credit. More specifically, when using the intensity-adjusted indices, we find clear negative point estimates of the effect of borrower-based macroprudential policy on credit throughout the whole horizon, in contrast to when using the '-1/0/+1' indices, for which the IRF fluctuates around the zero line for the first 12 quarters. Moreover, the estimates of the long-run effects are found to be twice as large when using the intensity-adjusted indices. This difference is also reflected in the fact that the blue and red lines fall outside of the other estimates' error bands towards the end of the horizon. These findings suggest that taking account of the various dimensions that determine the restrictiveness and intensity of the regulatory changes can lead to different results on the effects of borrower-based policies on credit in terms of timing and magnitude. A possible explanation for this could be that the intensity-adjusted indices are able to take account of the fact that multiple small (less restrictive) tightenings are not necessarily more effective than one large (very restrictive) one.

To conclude, we find that using standard indices that disregard the intensity of the regulatory changes can lead to different effects when estimating the effects of the multi-dimensional macroprudential policy toolkit. This is in line with Richter et al. (2019), who also find different results when using intensity-adjusted indices for LTV limits. While these authors conclude that the '-1/0/+1' approach overestimates the effects of LTV limits on output, we find that using a standard '-1/0/+1' approach leads to smaller and less significant results when looking at the effects of borrower-based

macroprudential policy on household credit until 2019. This confirms the argument of de Jong and de Veirman (2019) that not taking account of the fact that some actions may have affected the financial system more than other leads to incomplete and misleading results.

5.4. Robustness checks

We conduct a series of robustness checks to explore the sensitivity of our baseline results. We test whether our results are sensitive to different definitions of borrower-based macroprudential policy, to changing the measurement of the anticipated implementations, or to not controlling for anticipated implementations.

5.4.1. Different definitions of borrower-based macroprudential policy

As a first robustness check, we extend our borrower-based macroprudential index by additionally including maturity limits in the main variable of interest. This leads to very similar results (as shown in figure 4) with a reduction of household credit of -6.62 %-points in the long run. For housing credit, we find a reduction of -4.72 %-points after 4 years and for consumption credit a reaction of -0.79 %-points after 4 years. This confirms the finding that borrower-based macroprudential policy is especially effective in the longer run.

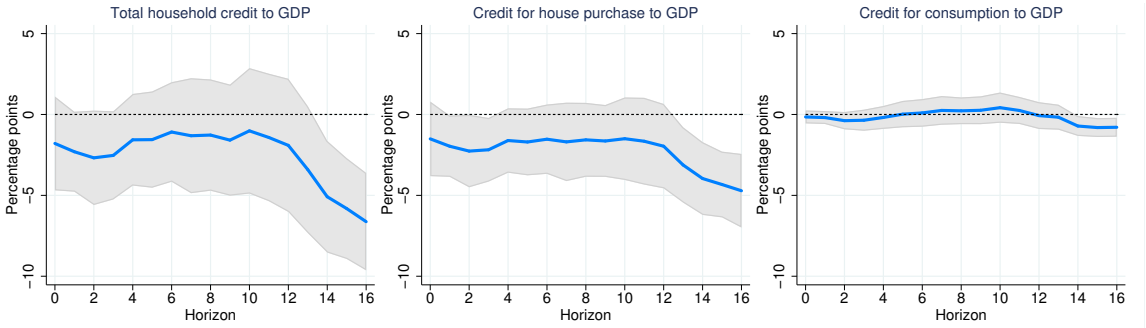

Figure 4: Impulse response functions of credit-to-GDP ratios to a shock in borrower-based macroprudential policy (LTV, DSTI, DTI, LTI, and maturity limits). Note: The solid blue lines show the point estimates of the reaction of the variable to a macroprudential policy shock over a horizon of 16 quarters. The grey areas reflect the 90% error bands.

Since more than half (i.e., 9 out of 14) of the implementations in the borrower-based index comes from changes in the LTV limit, we also look at the effects of this instrument separately (while including the other borrower-based instruments in the control variables). In this way, we

concentrate on one specific borrower-based instrument which facilitates the interpretation of the results. Figure 5 confirms the strong negative impact on household and housing credit from 13 quarters onwards, although these credit series also seem to be significantly reduced in the short run. The significant reaction of consumption credit now disappears. These findings are in line with Akinci and Olmstead-Rumsey (2018) and Mokas and Giuliodori (2021) who find more pronounced effects of LTV limits compared to other borrower-based instruments.

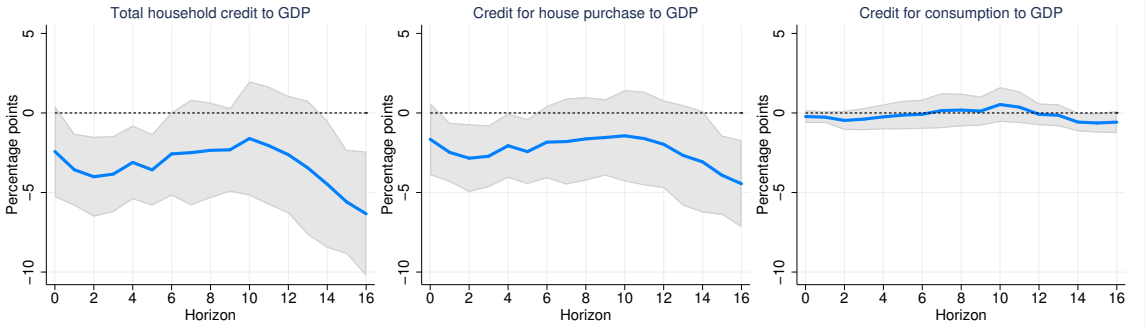

Figure 5: Impulse response functions of credit-to-GDP ratios to a change in the LTV limit. Note: The solid blue lines show the point estimates of the reaction of the variable to a macroprudential policy shock over a horizon of 16 quarters. The grey areas reflect the 90% error bands.

5.4.2. Anticipated actions

Next, we investigate the sensitivity of our results w.r.t. controlling for anticipated implementations, i.e., implementations that were not announced and enforced in the same quarter. As mentioned in section 4.2, the anticipated implementations are dated at enforcement date in the baseline model to take account of the fact that financial institutions can adapt the pre-announced/anticipated measures at different dates, while at enforcement date all financial institutions have to comply to the imposed rules. However, it is also possible to include these actions at announcement date, given that there potentially will be a reaction to these implementations already at announcement date. When doing this, the results (depicted in figure 6, show that the results look qualitatively and quantitatively very similar to the baseline results, although the effect on housing credit seems to become significant already after 2-3 years.

Another possibility would be to not control for anticipated implementation at all. More specifi-

cally, that means we leave out $\mathbf{MAP}^{\mathbf{ant}}_{\mathbf{i,t}}$ from equation (1). In this way, we only include implementations in our analysis that were announced and enforced in the same quarter. The course of the IRFs shown in figure 7 look very similar to the baseline, with slightly smaller coefficients of -5.96 %-points for household credit and -4.33 %-points for housing credit, and a slightly larger coefficient of -0.84 %-points for consumption credit after 4 years. This robustness check shows that the effects of the 'news shocks' that were announced and enforced during the same quarter are in general not influenced by the effects of the anticipated implementations.

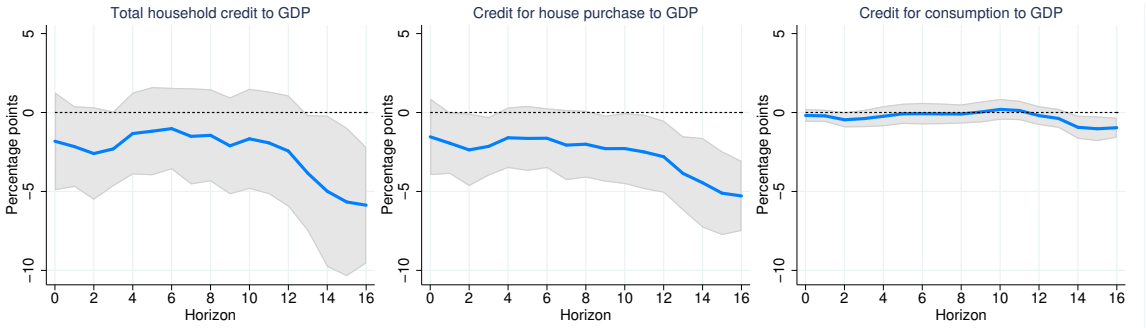

Figure 6: Impulse response functions of credit-to-GDP ratios to a shock in borrower-based macroprudential policy (LTV, DSTI, DTI, and LTI limits) when controlling for anticipated implementations at announcement date. Note: The solid blue lines show the point estimates of the reaction of the variable to a macroprudential policy shock over a horizon of 16 quarters. The grey areas reflect the 90% error bands.

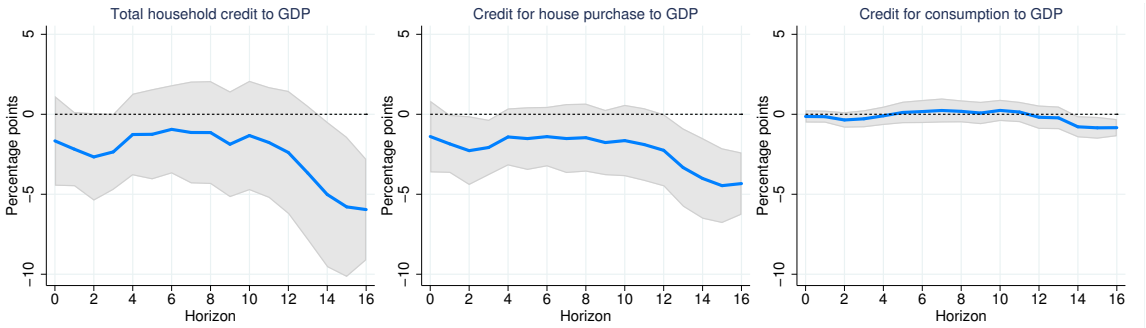

Figure 7: Impulse response functions of credit-to-GDP ratios to a shock in borrower-based macroprudential policy (LTV, DSTI, DTI, and LTI limits) when not controlling for anticipated implementations. Note: The solid blue lines show the point estimates of the reaction of the variable to a macroprudential policy shock over a horizon of 16 quarters. The grey areas reflect the 90% error bands.

6. Conclusion

In this paper, we use a narrative approach to construct novel intensity-adjusted indices for a large set of macroprudential policy instruments at the country level. In contrast to existing approaches, we consider the restrictiveness of macroprudential implementations by taking account of the different drivers of the intensity, i.e., the quantitative limit, scope, and legal enforceability, and this separately for different types of macroprudential instruments. These indices are subsequently used to assess the effects of borrower-based macroprudential policy on household, housing, and consumption credit in the EU between 2003 and 2019 while controlling for the simultaneous implementation of these borrower-based tools with other types of macroprudential policy instruments.

Our results indicate that borrower-based macroprudential policy in the EU has been effective in reducing household, housing and to a smaller extent consumption credit, although with a delayed impact. We find that the impact becomes increasingly strong in the long run, in line with other studies such as Carreras et al. (2018), Kim and Mehrota (2018), Poghosyan (2020), and De Schryder and Opitz (2021). Importantly, we find that controlling for the extent of legal enforceability in the intensity-adjusted indices is highly important when investigating the effects of borrower-based macroprudential policies on credit. Moreover, controlling for the different dimensions of the restrictiveness of the borrower-based tools by means of the intensity-adjusted indices is shown to lead to differences in terms of the magnitude and timing of the effects on household and housing credit relative to the standard '-1/0/+1' approach that counts the number of tightenings and loosenings in macroprudential policy instruments. Together, this suggest that using a standard dummy approach to measure the effects of macroprudential policy might not allow to capture the full effects of borrower-based macroprudential policy implementations which vary in their intensity. As confirmed by de Jong and de Veirman (2019) for the Netherlands, we conclude that it is important to account for the fact that macroprudential policy is multi-dimensional, that a macroprudential tool can bind to different extents at different times, and that not taking account of the fact that some actions may have affected the financial system more than other leads to incomplete and perhaps misleading results.

Our analysis has important policy implications, since they shed a new light on the effectiveness

of borrower-based macroprudential policy implementations. During the last years, macroprudential policy instruments have been increasingly implemented with different regulations and uses across countries. Our findings illustrate the importance of using intensity-adjusted indices when analyzing the effects of these multi-dimensional tools in future work. A better knowledge of the effects of the variation in quantitative limits, scope and legal enforceability of the macroprudential measures depending on the country- and time-specific situation is a crucial input for policymakers, for example to make a correct assessment of the macroprudential policy stance in a risk-resilience framework (ESRB, 2019) as put forward by the ESRB.

One drawback of our analysis is the restricted amount of observations on macroprudential changes. On the one hand, this is being driven by the fact that macroprudential regulation does not change frequently over time. In addition, some micro-level data are not (yet) available to construct intensity-adjusted indices for all countries. Moreover, we exclusively examine implementations that were both announced and enforced within the same quarter to abstract from the effects of anticipated policy changes. Although this choice is highly important to have a clean identification of the effects of the implementations, it significantly reduces the amount of observations. Taken together, the current intensity-adjusted indices are not able to provide evidence on the effects of macroprudential policy changes for the full spectrum of macroprudential instruments. With more incoming data, future research could investigate the effects for a broader range of macroprudential instruments.

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Appendix A. Construction of the intensity-based indices

This appendix explains in detail how the intensity-adjusted indices have been constructed across the different instruments of the macroprudential toolkit.

Appendix A.1. General reasoning

The intensity-adjusted indices are created by taking account of the various characteristics that are crucial to determine the restrictiveness of a policy announcement for a particular instrument in a given country and time period. To do this, we start from the MacroPrudential Policies Evaluation Database (MaPPED) database of Budnik and Kleibl (2018), as this is the most relevant, extensive, detailed, and publicly available source of information on macroprudential policy implementations in the EU in existence at present. This MaPPED lists information on 53 different instruments and contains almost 2000 macroprudential policy actions in the 28 EU member states from 1995 to 2017.[17] The MaPPED has been periodically updated until 2017. To pick up any missing information on more recent policy implementations, we complemented this with data from national legislation and central bank statements (using e.g., the ESRB Macroprudential Policies database and documents on the Basel regulations, cf. infra).[18] To be able to check if this update on the more recent policy implementation is complete, we compare our updated database with the iMaPP database. Although the iMaPP was updated to cover more recent policy implementations (until 2020), the information on the implementation in the EU are much less detailed and extensive compared to the MaPPED database. For the majority of the updated implementations, we find a match in the iMaPP database.[19] Our final updated database eventually covers information on policy announcements and implementations from 1995 to 2019.

The MaPPED divides the macroprudential toolkit in 11 different categories (as listed below in table A.1). Since the way the instruments target various parts of the economy differs across these 11 categories, different elements should be taken into account to construct the intensity-based indices. This will be explained in detail throughout the next sections. The rest of this appendix is structured following these 11 categories.

[17] For more information on the construction of the MaPPED, we refer to Budnik and Kleibl (2018).

[18] Since the MaPPED database is a result of a survey filled in by representatives of the national banks in the Eurosystem, it cannot be guaranteed that the information is interpreted in a consistent way. The same holds for the update of the database after 2017.

[19] For certain instruments (i.e., GSII and OSII buffers, the leverage ratios, and the NSFR) the information in the iMaPP database on EU countries is incomplete compared to the official communication and notifications recorded by the ESRB. For these instruments, we choose to follow the ESRB documentation.

Categories of macroprudential policy instruments according to MaPPED
1. Lending standard restrictions/borrower-based instruments
2. Risk weights
3. Capital buffers
4. Minimum capital requirements
5. Leverage ratios
6. Limits on credit growth and volume
7. Liquidity requirements and limits on currency and maturity mismatch
8. Limits on large exposures and concentration
9. Loan-loss provisioning
10. Levy/tax on financial institutions and activities
11. Other measures

Table A.1: Overview of the macroprudential categories following Budnik and Kleibl (2018)

Appendix A.2. Lending standard restrictions/borrower-based instruments

Borrower-based instruments impose certain lending standards with the aim to increase the resilience of borrowers and consequently financial institutions to adverse shocks. These instruments aim at dampening the feedback loop between housing market dynamics and financial markets due to the fact that housing loans constitute an important proportion of bank lending and are mainly targeted at households. According to the MaPPED, the category of borrower-based instruments can be further divided in 9 subcategories:

1. Loan-to-value (LTV) limits
2. Loan-to-income (LTI) limits
3. Debt-service-to-income (DSTI) limits
4. Debt-to-income (DTI) limits
5. Maturity and amortization restrictions
6. Limits on interest rates on loans
7. Limits on the volume of personal loans
8. Other income requirements for loan eligibility
9. Other restrictions on lending standards

We use the following example from the MaPPED to illustrate the characteristics of the announcement of a borrower-based instrument that determine its restrictiveness: *"The Central Bank of Cyprus announced in November 2003 that an LTV cap on residential real estate was being introduced (with direct enforcement). The LTV cap was set at 70% for loans financing the purchase or construction of immovable property. The compliance was checked using a 'comply or explain' mechanism"*. This example entails the following characteristics:

- The **timing** of announcement and implementation *(2003Q4 - M11)*
- The **scope** i.e., the share of loans to which the implementation is applied to *(Loans financing the purchase or construction of immovable property)*

- The **quantitative limit** imposed by the implementation *(70%)*
- The **legal consequences** that follow in case of non-compliance *(comply or explain)*
- Any **exceptions** on the imposed rules *(no exceptions)*

These characteristics will be analyzed for every borrower-based policy instrument separately, such that in the end there will be different intensity-adjusted indices for LTV, DSTI, DTI, and LTI limits, and one for maturity and amortization restrictions. The construction of these five separate indices follows the reasoning further explained in section Appendix A.2.1 to Appendix A.2.5. In some of the implementations, different instruments are combined (e.g. thresholds for both the LTV and DSTI limit). We consider these as a different category titled 'Combinations'. The instruments from subcategory 6 to 9 are not taken into account for the construction of intensity-based indices since they represent a limited amount of implementations in a small group of countries[20] and the complexity of the imposed rules make them hard to be quantified.

Appendix A.2.1. Scope

To capture the restrictiveness of a measure, a first step is to control for the importance of the particular loan segment in the total of household loans, i.e., the scope. In particular, the larger the scope, the broader the lending segment that is targeted (i.e., the higher the coverage) and the higher the share of the economy that is potentially hit by the instrument. A larger scope is hence considered to be more restrictive.

To do this, we use **actual data on household lending** collected by the Household Finance and Consumption Network, which conducts Household Finance and Consumption Surveys (HFCS) across the Eurosystem.[21] The survey collects information on a very extensive range of variables such as real assets and their financing, other liabilities and credit constraints, private businesses, financial assets, intergenerational transfers and gifts, employment, income, consumption, and savings of 84.000 European households (ECB, 2020). There are currently three waves of the survey for which data is made available for research (wave 1: 2010 - wave 2: 2014 - wave 3: 2017). The surveys for the fourth wave were conducted in 2020 and 2021 but the data is currently only available for 5 countries.

An important **advantage** of the HFCS is that it provides us with very granular data for a large group of European countries which allows us to calculate the scope of borrower-based macroprudential implementations in great detail. For example, households are able to indicate whether they have one or more mortgage loan(s), whether it was their first mortgage, collateralized by which property type, for which (primary and secondary) purpose, etc. The database also allows us to construct and measure characteristics of these loans at origination such as the LTV ratio, D(S)TI ratio, LTI ratio, and maturity (see infra, section Appendix A.2.2). Moreover, due to the cross-section dimension of the database, we can pick up country-specific characteristics of household lending (e.g., the variation in the importance of certain loan categories across countries). Although the HFCS data was collected in separate waves, each wave contains information on mortgage loans originated in the years before the survey

[20] For an overview of the amount of implementations and countries per (sub)category covered by the intensity-based indices, we refer to section Appendix A.13.

[21] https://www.ecb.europa.eu/pub/economic-research/research-networks/html/researcher_hfcn.en.html

wave, which allows us to pick up the time dimension of the regulations.

Compared to country-wide loan-level data, the HFCS data is less detailed and covers a smaller sample of the population. However, the HFCS are conducted in a way that the participating households are considered to be a representation of the total population in the country of interest and are thus representative to measure household lending, which is the target of the borrower-based policies. To quantify the scope of a macroprudential policy implementation, we calculate **the proportion of *mortgage loans*[22] that are part of a specific loan type or were issued to a specific group of borrowers** (e.g., loans for house purchase, loans to first-time buyers, ...) ***before* the policy announcement/implementation**. Since a larger scope is considered to be more restrictive, the value for this proportion will contribute to a larger value for the final index (see section Appendix A.2.5). For example, the first wave of the HFCS for Cyprus reports that there were 147 mortgage loans with the purpose to purchase or construct immovable property out of a total of 199 mortgage loans before 2003 (the year of the implementation). The value of the scope for this particular implementation will thus be '73.87%'.

Using HFCS data, however, also puts some restrictions to our data sample. First of all, the general imperfections of survey data compared to loan-level data apply. Second, the fact that the data is recorded in three waves but each waves captures household loans originated going back more than 30 years, makes that we have to decide which wave is most representative for calculating the scope of the implementations *before* this implementation was announced or in place. For implementations until 2010, we use data from wave 1, for implementation from 2011 until 2014, we use wave 2 while for implementations from 2015 onwards, we use wave 3. For implementations later than 2017, we make the assumption that the data from wave 3 is still representative.[23] Moreover, being a survey, the number of observed mortgage loans is confined and limits the amount of selection criteria we can use to determine our sample of interest. For example for loans for house purchase to first time buyers, restricting the amount of years to approximate the state of the economy right before the macroprudential implementation becomes tricky in an already limited sample. The specificities of the HFCS data namely make that the construction of lending standards can only be done under certain conditions. More specifically, to construct, e.g., LTV ratios at origination, it is required that the loan is originated in the same year as the year of the house purchase or the year that the survey was taken out, given that the HFCS only reports the value of the house at those two points in time (see table A.2). For this reason, we focus on measuring the lending standards using all the available years before the policy implementation. On average, 74% of the mortgage loans were issued in the last 10 years before the year of the survey, 92% in the last 15 years, and 97% in the last 20 years. Therefore, we consider that using all the available years before the policy implementation is representative to capture the state of the mortgage market in a given country right before the implementation. Next, HFCS data only registers the year of the origination of the loans, while we use the intensity-adjusted index on a quarterly basis. Moreover, not all countries that use macroprudential policy tools have participated in the survey (such as Bulgaria, Czech Republic, Denmark, Romania, and Sweden) or only since the second or third wave (such as Poland and Hungary). For the latter, we use the available waves. For some policy implementations with a

[22]Because of the more limited information on non-collateralized loans across the three waves, we focus on collateralized loans.

[23]The fact that announcement and enforcement dates can be in a different year, means that we use a different year to calculate the scope (and restrictiveness, see infra) *before* the implementation.

very specific targeted loan type (e.g., foreign currency denominated loan to unhedged borrowers), we cannot identify the scope based on the questions asked in the HFCS survey.

Appendix A.2.2. Restrictiveness of the quantitative limit

In a next step, we look at the imposed quantitative limits.[24] A lower quantitative limit is considered to be more strict.

To capture the restrictiveness of the imposed quantitative limit, **we calculate the percentage of the mortgage loans originated *before* the announcement or implementation for which the rule would be binding (i.e., which have a higher ratio/unit than the imposed limit[25]) for a given country and loan category**. To do this correctly, we first construct the LTV, DSTI, DTI, and LTI ratio for each mortgage loan at origination. The definitions can be found in table A.2 below. As can be seen from the table, due to the specificities of the HFCS data, we do not always observe all the information needed to exactly capture the ratios targeted by the macroprudential measures for all the loans reported in the data. However, our approach enables us to very closely replicate these ratios for a large share of the reported loans. Similar to the calculation of the scope, we use all loans issued in the time periods before the announcement or implementation to calculate this percentage. A higher percentage reflects a higher proportion of loans that would be affected by the imposed regulation if the limit was already in place and therefore increases the restrictiveness. For example, out of the 41 housing loans in Cyprus issued before 2003 (the year of the implementation) that we were able to construct an LTV ratio at origination for, there were 18 loans with an LTV ratio above 70% which would be bound by the imposed regulation. The value of the restrictiveness for this particular implementation will thus be '43.90%'.

In some cases, the limits have some quantifiable exceptions which we can take into account. In Slovakia, for example, the standard limit for the LTV ratio is 90%. However, in 2014, up to 20% of the loans were allowed to have an LTV ratio between 90% and 100%. Therefore, we subtract the allowed deviation from the limit from the percentage for which the rule would be binding. In case this substraction results in a negative number, the value for restrictiveness will be '0', reflecting the fact that the regulation will be not restrictive at all.

Appendix A.2.3. Legal consequences

The MaPPED database reports six options regarding the legal consequences in case of non-compliance to the imposed macroprudential limits and ranks them in the following way (from less restrictive to more restrictive, according to Budnik and Kleibl (2018)):

1. Does not apply (no consequences)
2. 'Other' consequences

[24] The quantitative limit is expressed in percentages for LTV and DSTI limits and in units for DTI, LTI (although these are still ratios), and maturity limits.

[25] For combinations of multiple limits (e.g., LTV and DSTI limits) we calculate the proportion of mortgage loans that have both a higher LTV and DSTI than the imposed limit.

[26] To support this claim, we look at the reported mortgage payments and annual income for the pool of households that was questioned from wave 1 through wave 3. Although there is some variation across countries, the mean across these households stays relatively constant throughout the waves, supporting our assumption.

Ratio	Definition	Remarks
Loan-to-value	Per year, per (pair of) loan(s): value of the loan(s) with the same purpose originated it this year, divided by the value of the property at the time of the origination of the loan.	HFCS data on the value of the household main residence property is only available at the year of the purchase and estimated in the year of the survey wave. For other properties, there is only the estimated value in the year of the survey wave. This reduces the amount of loans that we can construct an LTV ratio at origination for.
Debt-service-to-income	Per year, per loan: the sum of the debt service payments for the originated loan and all the previously originated loans up until that year, divided by the annual total gross income of a household divided by 12.	HFCS only records the debt service payments currently payed and the current total income, not the values recorded at the time of origination of the loan. Therefore, we have to assume that these values stay relatively constant over time.[26]
Debt-to-income	Per year, per loan: the sum of the outstanding debt for the originated loan and all the previously originated loans up until that year, divided by the annual total gross income of a household.	-
Loan-to-income	Per year, per (pair of) loan(s): value of the loan(s) with the same purpose originated it this year, divided by the annual total gross income of a household.	-
Maturity	Length of the loan at the time of borrowing/refinancing.	-

Table A.2: Definitions of the borrower-based ratios at origination based on HFCS data.

3. Comply or explain, warning, reprimand (soft measures which do not yet impose sanctions but may have reputational effects)
4. Additional reporting requirements (submission of action plan for compliance, additional on-site inspections, additional prudential reporting requirements, etc.)
5. Non-monetary sanctions and restrictions on activities (restrictions on current and new activities, restrictions on distribution of capital, imposition of more stringent prudential limits and requirements, replacement of directors, revocation of licenses, etc.)
6. Fines and penalties

Each policy implementation can face one or more of these legal consequences (with the exception of 'does not apply'). Based on this ranking, we give every category a particular score, which sums up to '1' for a macroprudential implementation that faces all the consequences as defined in categories 2 to 6. Again, a higher value represents a more restrictive rule. For obvious reasons, category 1 gets the value '0'. Category 2 and 3 get '0.1', category 4 gets '0,15' and finally category 5 and 6 each get '0.325'. The assignment of these values is to some extent arbitrary. However, we test the sensitivity of our results to different levels of importance of the legal consequences in our weighting schemes (see infra).

Appendix A.2.4. Exceptions

The macroprudential authority allows for an exception to the imposed limits in some cases. For example, the Estonian central bank allows loans that are guaranteed by KredEx to have an LTV limit of 90%, as opposed to the standard limit of 85%. In contrast to the previously explained exception in section Appendix A.2.2, these exceptions are not easily quantifiable. To handle

these cases, we assign a value of '1' or '-1' to this characteristic, depending on the direction of the exception (i.e., being more or less restrictive). When there is no explicit exception, this category gets the value '0'.

Appendix A.2.5. Bringing it all together

To calculate the score for a macroprudential implementation, the values that have been determined according to the explanation in section Appendix A.2.1 to section Appendix A.2.4 will be weighted such that the sum of the weights for each category is equal to '1'. In the **baseline scenario**, we allocate the largest weight to the scope and the restrictiveness of the limit (both '0.4') as these elements can be argued to be highly important in the determination of the intensity of the policy implementation. Legal consequences are weighted by '0.15' and exceptions by '0.05'.

Different versions of this weighting scheme are set up and we test for robustness of our results in section 5.4. In the **second scenario** of the weighting scheme, the values for the scope, restrictiveness of the limit, and legal consequences get an equal weight of '0.32'. Because exceptions are not used that often, and they are usually of less importance then the other elements, this category gets the weight of '0.04'. The **third scenario** gives more importance to the legal consequences ('0.25') relative to the baseline scenario, and less to the scope ('0.3'). The restrictiveness of the limit is weighted by '0.4' and the exceptions by '0.05'. Finally, we also set up a **fourth scenario**, in which we exclude the legal consequences from the weighting scheme to put more emphasis on the elements that were quantified using micro-level data. An overview of these weighting schemes can be found in table 4. The scope and restrictiveness then get the weight of '0.45' and the exceptions '0.1'. The example of Cyprus using the baseline weighting scheme is shown in table A.3 below.

Scope	**Restrictivness of the limit**	**Legal**	**Exceptions**	**Final value**
0.4	*0.4*	*0.15*	*0.05*	
73,87%	43,90%	1	0	**0.186**

Table A.3: Calculation of the intensity-based index for borrower-based instruments, based on the example of the LTV limit in Cyprus (November 2003)

The score is tied to the time (month) and country of announcement/implementation[27], such that the index has a panel dimension. Per loan category, this score lies between the value of '0' and '1' where a higher value indicates a more restrictive policy implementation. When a country implements macroprudential limits for more than one loan category in the same time period, the scores for these implementations are summed up together. This leads to a score that can be higher than '1' in some cases. The levels of the indices represent the restrictiveness of the announcements/implementations. The changes in the indices capture the change in restrictiveness across the announcements/implementations. The cumulative indices represent the paths of implementation for the macroprudential instruments. For the empirical analysis in the paper, the indices are aggregated to a quarterly frequency.

[27]When the announcement date is missing, we use the same date as the enforcement date.

Appendix A.3. Risk weights

Risk weights are rules that financial institutions have to follow when calculating their share of risk-weighted assets which are used to define the amount of capital a financial institution should hold (cf. infra). These rules impose a larger weight to loans that are considered to be more risky, based on the LTV ratio at origination. The goal of these measures is to make financial institutions more resilient to shocks in the mortgage market. The following example from MaPPED illustrates: *"From January 2014 onwards, Austrian banks had to change the risk weights for loans backed up by residential property to: (i) 35% if the loans were fully backed i.e., LTV<80%; (ii) 100% if LTV>80%."*

Risk weights are in the MaPPED further divided in three subcategories:

1. Risk weights on loans backed by residential property
2. Risk weights on loans backed by commercial property
3. Other sectoral risk weights

Appendix A.3.1. Scope

We use HFCS data to quantify the importance of the scope as the HFCS database reports information on loans to households backed by residential real estate and their LTV ratios. More specifically, we calculate the share of residential real estate loans with an LTV above/below the imposed threshold *before* the policy announcement/implementation. Since the HFCS data does not report on loans by non-financial corporations, which are responsible for a large share of commercial property mortgages, we cannot assume this data to be representative to measure the importance of loans backed by commercial property, in contrast to the representativeness of residential real estate loans. Therefore, we cannot construct intensity-adjusted indices for risk weights on loans backed by commercial property. Given the high divergence of the rules concerning other sectoral risk weights and the small amount of implementations within it (see section Appendix A.13) we do not quantify the implementations in this category either.

Appendix A.3.2. Type of financial institution targeted

Most of the risk weight regulation applies to financial institutions that use the standardized (SA) approach to calculate required capital. As highlighted by Damen and Schildermans (2021), however, some countries have imposed risk weight regulations to financial institutions using the internal ratings-based (IRB) approach (e.g., internal risk models) to calculate required capital as well, since these financial institutions typically have lower average risk weights. It is known that most large banks, which often are responsible for a large share of mortgage loans, use the IRB approach. Unfortunately, there is no detailed data readily available on the particular approach used by banks for the time period and countries we investigate. However, to take this distinction into account, we add a dimension to the index that measures the importance of the financial institutions covered by the regulation. For financial institutions using the SA approach (i.e., small banks), the value for this dimension is '0.25'. For financial institutions using the IRB approach (i.e., large banks), this is '0.75'.

Appendix A.3.3. Bringing everything together

Next, the imposed risk weight is simply taken as given[28] (e.g., 35%) since banks typically do not use higher weights than the imposed rules as this is costly for the bank. Following the intuition behind the risk weight regulation, we multiply the scope with the imposed risk weight and sum it up over the categories (i.e., loans with an LTV above or below a certain threshold). This sum is weighted in the baseline scenario by '0,4'. The importance of the financial institutions is also weighted by '0.4'. The quantification of the legal consequences follows the logic explained in section Appendix A.2.3. This value is weighted by '0,15' in the baseline scenario and the exceptions by '0.05'. Table A.4 illustrates the construction of the index using data for the previous Austrian example.

Scope	**Imposed risk weights**	**Product**	**Sum**	**SA vs IRB**	**Legal**	**Exceptions**	**Final value**
			0,4	*0,4*	*0.15*	*0.05*	
0,842	35%	= 0,295	= 0,453	0,25	0,65	0	= **0.379**
0,158	100%	= 0,158					

Table A.4: Calculation of the intensity-based index for residential risk weights based on the example from Austria (since January 2014)

As variations to the baseline weighting scheme, we use one where the sum, the importance of the financial institutions, and legal consequences are weighted equally by '0.32', with the exceptions weighted by '0.04'. Next, the third weighting scheme gives more weight to the legal consequences compared to the baseline scheme ('0.25') and less to the sum ('0.3'). In the last weighting scheme, we exclude the legal consequences and weight the sum and the importance of the financial institutions by '0.45', while the exceptions are weighted by '0.1'.

Appendix A.4. Capital buffers

Capital buffers are funds that financial institutions need to hold in the form of Common Equity Tier 1 (CET1) capital[29], often expressed in terms of percentages of total exposures or risk-weighted assets. These buffers are set in addition to a minimum basis of capital that a financial institution is required to hold (cf. section 6) and can be specific to institutions or economic conditions (European Council, 2020). A higher required buffer is perceived to be more restrictive. The information on capital buffer regulations since 2017 is extended using information from the ESRB M acroprudential database on national capital-based instruments. [30] The ESRB publishes the notification templates which are used by member states to declare a change in capital-based macroprudential policies which include data on the specifications of the rules, the decision, announcement, and enforcement dates. Capital buffers are in the MaPPED divided in 8 subcategories:

1. Countercyclical capital buffer (CCyB)
2. Systemic risk buffer (SRB)

[28] We have looked into the option of measuring the restrictiveness of risk weight implementations by comparing the required risk weight to the average risk weight (by comparing total assets to total risk-weighted assets). However, this measure is not able to distinguish between the different types of lending (i.e.. loans with an LTV ratio above/below a certain threshold) and thus the different weights behind this regulation.

[29] CET1 capital is the core capital of a bank and is considered to be the highest quality of regulatory capital, as it absorbs losses immediately when they occur (Bundesbank, 2020).

[30] https://www.esrb.europa.eu/national/_policy/html/index.en.html

3. Capital conservation buffer (CCB)
4. Buffers for global systemically important institutions (GSII)
5. Buffers for other systemically important institutions (OSII)
6. Profit distribution restrictions
7. Other capital requirements targeting most important institutions
8. Other capital surcharges and own funds requirements

Although in general capital buffers have been defined by the Basel rules, some capital buffers have been applied differently across countries. For example, in some countries the systemic risk buffer applies to the whole financial sector (including all financial institutions), in other countries it only applies to a number of institutions. Moreover, for the GSII and OSII buffer, each country determines individually which institutions are subject to a (different) additional buffer. The following example from MaPPED illustrates: *"In April 2014, De Nederlandsche Bank announced its intention to impose an additional capital buffer requirement on the three systemic banks in the Netherlands. ING Bank, Rabobank and ABN AMRO Bank face an SRB of 3%. These buffers will be phased in between 2016 and 2019, where the SRB buffer in 2016 of 0.75% will be raised in equal steps until it reaches 3% in 2019. This measure is legally binding, with non-monetary sanctions and restrictions on activities in case of non-compliance."*

The specific number and importance of the chosen institutions to which a capital buffer applies vary across countries. It is therefore important to take this into account when determining the restrictiveness of the imposed capital buffers in a given country. We do this by **using actual bank-level data to quantify the market share per institution** since this approximates the importance of that institution in a given country and time. Moreover, we take account of the level of the required buffers.[31] We do this for subcategory 1-5 (with a separate index per subcategory). The announcements in category 6-8 are not quantified because of their complexity. Again, these implementations represent a relatively small set of policy changes in a limited set of countries compared to the quantified measures (see section Appendix A.13).

Appendix A.4.1. Adjusting buffers using market shares

The market share is calculated based on yearly data from S&P Global[32] and Consolidated Banking data from the ECB Statistical Data Warehouse[33] using equation (A.1). The S&P Global database is frequently used for banking sector analysis, covering an extensive range of financial institutions worldwide. It reports (among others) institution-level total assets based on industry classification *(bank b)* and region *(country c)*. In order to correctly measure total assets in a particular country, we

[31] We have looked into the option of measuring the restrictiveness of capital buffers and requirements by comparing them to the actual capital ratios of a particular bank. Unfortunately, multiple issues arise. First, this would mean that all buffers and requirements expressed in terms of the same capital (e.g., CET1 capital), should be taken together and cannot be analyzed separately. Second, this would require knowing exactly which banks are subject to which buffers across countries and time. Although this could be possible for a single country (see e.g., Czaplicki (2022)), this is not straightforward for a large set of countries given that exact amount of additional bank-level capital buffers were kept confidential until recently. Finally, since this would be a bank-level exercise, we would have to find a way to aggregate the index to a country level.

[32] https://platform.marketintelligence.spglobal.com/web/client?auth=inherit#news/home

[33] https://sdw.ecb.europa.eu/browseExplanation.do?node=9689685

use yearly data on consolidated total assets at the country-level.[34] Calculations are always based on the last full year of data available relative to the announcement/enforcement date.[35] The caveat of this approach is that we have to rely on the data reported in the S&P global, which reports missing values for a minority of the targeted institutions and time periods. Similar to the HFCS data, this database has an annual frequency, while our indices are used on a quarterly basis.

$$\text{MarketShare}_{b,c,t} = \frac{\text{Total assets}_{b,c,t}}{\text{Total assets}_{c,t}} \tag{A.1}$$

A large share of the capital buffer implementations include a phase-in period where the buffers are gradually being increased over time. It is therefore necessary to differentiate between the calculations for announcement versus enforcement date.

Announcement date: The final value takes account of the implementations over the whole phase-in period using data based on the announcement date. Table A.5 illustrates the methodology based on the 'DNB example' from the MaPPED database. The numbers in the row 'value' are calculated by summing up the products of the buffer and the market share. The value of '0.564' represents the buffer weighted by the market shares in 2016, which would be equal to '0.75' if the buffer was applied to all financial institutions in that country (which is equivalent to weighting the buffer by a market share of 100%). The final value (see last column) is equal to the market share-adjusted buffer value in 2019. The rationale behind this is as follows: to take account of this phase-in period, we argue that we should look at the added restrictiveness that follows from another step of phasing-in. For example, the buffer in 2017 is 1,5%, which is 0.75 %-points higher compared to the buffer in 2016. Therefore, we sum up the changes in the values for each phase-in step (see column 'changes in values'[36].), which is equal to the adjusted buffer value for 2019. In this particular case, the difference between the adjusted buffers is the same for every step, since the buffers for all three institutions are being increased in equal steps. The final value is then assigned to the month the capital buffer is announced in.

	Market share (2013)	**Buffer (2016)**	**Buffer (2017)**	**Buffer (2018)**	**Buffer (2019)**	**Final value**
ING Bank	15.29	0.75	1.5	2.25	3	
Rabobank	27.5	0.75	1.5	2.25	3	
ABN AMRO Bank	32.37	0.75	1.5	2.25	3	
Value		**0.564**	**1.127**	**1.691**	**2.255**	
Changes in value		**0.564**	**0.564**	**0.564**	**0.564**	***2.255***

Table A.5: Restrictiveness of the SRB for the Netherlands based on the announcement date. All numbers are expressed as percentages.

Enforcement date: In this case, we look at the actual data from the time period at which the policy is enforced. In the example showed in table A.6, the buffer is enforced at four different moments, which means we will use four different data series to calculate four different final values.

[34] Total assets in euro per country. Counterpary: world - Reporting sector: domestic banking groups and stand alone banks, foreign controlled subsidiaries and foreign controlled branches - Reporting framework: full sample - Exposure type: all exposures.

[35] E.g., when a capital buffer is announced in 2015Q1/2/3/4, we use data from 2014. There is one exception for Nordea bank that moved in 2018 from Sweden to Finland. Therefore, in 2017, the consolidated total assets for Finland did not include data on Nordea bank yet.

[36] This row takes the difference of the adjusted buffer in *t* and the adjusted buffer in *t-1* where the buffer before 2016 was '0'

	Market share (2016)	Buffer (2016)	Market share (2017)	Buffer (2017)	Market share (2018)	Buffer (2018)	Market share (2019)	Buffer (2019)
ING Bank	16.11	0.75	15.57	1.5	15.96	2.25	15.53	3
Rabobank	26.85	0.75	26.16	1.5	24.48	2.25	24.05	3
ABN AMRO Bank	39.64	0.75	33.32	1.5	34.36	2.25	36.13	3
Final value		**0.62**		**1.13**		**1.68**		**2.27**

Table A.6: Restrictiveness of the SRB for the Netherlands based on the enforcement date. All numbers are expressed as percentages.

Appendix A.4.2. Legal consequences, exceptions, bringing it all together

The quantification of the legal consequences[37] and exceptions happens according to the logic explained in section Appendix A.2.3-Appendix A.2.4. To calculate the final index values, we follow a similar methodology as stated in section Appendix A.2.5. In particular, the values for the adjusted buffer (using market share data), legal consequences, and exceptions are aggregated using a weighted average approach. Again, a higher value of the index indicates a more restrictive policy implementation. The baseline scenario weights the market-share-adjusted by '0.6', legal consequences by '0.35', and exceptions by '0.05'. When there are no exceptions at all, legal consequences are weighted by '0.4'. The second version of the weighting scheme equally weights the market-share-adjusted and legal consequences by '0.475' in case of exceptions, and by '0.5' in case of no exceptions. The third weighting scheme gives more weight to legal consequences ('0.6') compared to the baseline scenario and less to the market-share-adjusted buffer ('0.4' or '0.35'), while the fourth weighting scheme removes the dimension of legal consequences completely with a weight of '0.9' for the market-share-adjusted buffer (or '1' in case of no exceptions) and '0.1' for the exceptions.

Appendix A.5. Minimum capital requirements

This category of instruments requires financial institutions to hold a minimum amount of capital expressed in terms of risk-weighted assets (European Council, 2020). A higher requirement is considered to be more restrictive. Minimum capital requirements consists of four subcategories, where an intensity-adjusted index is constructed for each subcategory:

1. Capital adequacy ratio (CAR)
2. Common Equity Tier 1 capital ratio (CET1)
3. Tier 1 capital ratio
4. Core Tier 1 capital ratio

The regulation of these measures is applied on a country-wide basis, meaning that there is no institution-level regulation such as in the case of capital buffers. It is therefore not necessary to adjust the required ratio for market shares. We use the Basel regulations to compliment the MaPPED database with information on (the variation in) the minimum requirements, legal characteristics, and certain exceptions. The baseline scenario weights the minimum requirement by '0.6', legal consequences by

[37]Remark: the ESRB does not provide information on specific categories of legal consequences. Therefore, this information is extracted from the MaPPED database using information from previous implementations of capital buffers.

'0.35', and exceptions by '0.05'. When there are no exceptions at all, legal consequences are weighted by '0.4'. The second version of the weighting scheme equally weights the minimum requirement and legal consequences by '0.475' in case of exceptions, and by '0.5' in case of no exceptions. The third weighting scheme gives more weight to legal consequences ('0.6') compared to the baseline scenario and less to the minimum requirement ('0.4'), while the fourth weighting scheme removes the legal dimension from the index with a weight of '0.9' for the minimum requirement (or '1' in case of no exceptions) and '0.1' for the exceptions.

Appendix A.6. Leverage ratios

A bank's leverage ratio equals its Tier 1 capital divided by its total (unweighted) exposure. A low leverage ratio indicates that a bank has a high level of debt in relation to its Tier 1 capital. Requirements on the leverage ratio were introduced initially as a supplementary instrument that could optionally be applied to individual institutions. This has only been done in case of the United Kingdom. In December 2017, the Basel Committee on Banking Supervision (BCBS) decided to make the provisional 3.0% target ratio a country-wide binding minimum requirement from 2018 onwards (BIS, 2019).

Since the institution-level regulation has not been applied often, it is generally not necessary to adjust the ratio for market shares. We will use the Basel regulations to extract information on (the variation in) the minimum ratio and legal characteristics. Since there are no exceptions in the leverage ratio regulation, we do not take this into account as a separate category. The baseline scenario weights the imposed requirement by '0.6' and legal consequences by '0.4'. As variations to the baseline weighting scheme, we use one where the imposed requirement and legal consequences are weighted equally by '0.5'. Next, the third weighting scheme gives more weight to the legal consequences compared to the baseline scheme ('0.6') and less to the imposed requirement ('0.4'), while the fourth weighting scheme removes the legal dimension from the index.

Appendix A.7. Limits on credit growth and volume

The category of limits on credit growth and volume consist of reserve requirements. These requirements define the amount of deposits that a credit institution has to hold on accounts with their national central bank (ECB, 2021).

The MaPPED database divides the category of limits on credit growth and volume in two subcategories where we choose to only quantify the first subcategory. The second subcategory consist of a set of very divergent rules and are therefore not quantified. Again, these implementations represent a relatively small set of policy changes in a limited set of countries compared to the quantified measures (see section Appendix A.13):

1. Reserve requirements related to banks' liabilities
2. Asset-based reserve requirements

The instrument in the first category is also known as the 'minimum reserve requirements'. Euro area members have to comply to regulation (EC) No. 1745/2003 of the European Central Bank of 12 September 2003 on the application of minimum reserves (ECB/2003/9). The ECB published information on the changes in the regulation on the minimum reserve requirement throughout the years. For details on regulation before 1999 or for non-euro area countries, we use the information listed in MaPPED.

Appendix A.7.1. Reserve coefficient and reserve base

For this instrument, we take account of the reserve coefficient (i.e., the portion of reservable liabilities that credit institutions must hold onto), where a higher coefficient is considered to be more restrictive. Next, some implementations involve changes in the reserve base (i.e., the sum of the eligible balance sheet items that constitute the basis for calculating the minimum reserve requirement). We capture these changes by using a '-1' for a loosening and '+1' for a tightening.

Appendix A.7.2. Legal consequences, exceptions, bringing it all together

As mentioned before, the quantification of the legal consequences stays the same for all instruments. In terms of exceptions, the ECB regulation on minimum reserve requirements also includes standardized deductions for credit institution that cannot provide evidence of its interbank liabilities in the form of debt securities issued with a maturity up to two years and money market paper. In 1999, this was set at 10%. In 2000, this was changed to 30% and lowered to 15% in 2016. We include this information by adding another element which takes the respective values of '-0.1', '-0.3' or '-0.15'. Since this exception is considered to be less restrictive, we assign a negative value.

The final value is again calculated using a weighted average approach, where the reserve coefficient is weighted by '0.4', changes in the reserve base by '0.2', exceptions by '0.05', and the legal consequences by '0.35'. The second weighting scheme equally weights the reserve coefficient and legal consequences by '0.425'. Changes in the reserve base are weighted by '0.1' and exceptions by '0.05'. The third weighting scheme gives more weight to the legal consequences ('0.55') relative to the baseline scenario and less to the reserve coefficient ('0.3'). Changes in the reserve base are weighted by '0.1' and exceptions by '0.05'. The fourth weighting scheme removes the legal dimension from the index, resulting in a weight of '0.75' for the reserve coefficient, '0.15' for changes in the reserve base, and '0.1' for exceptions.[38]

Appendix A.8. Liquidity requirements and limits on currency and maturity mismatch

The MaPPED database divides the category of liquidity requirements and limits on currency and maturity mismatch in six subcategories (again, a separate index is constructed for each subcategory):

1. Loan-to-deposit (LTD) limits
2. Short-term liquidity coverage ratios incl. Liquidity Coverage Ratio (LCR)
3. Liquidity ratios and deposit coverage ratios
4. Limits on FX mismatches
5. Other stable funding requirements incl. Net Stable Funding Requirement (NSFR)
6. Other liquidity requirements

[38]Because of the high value of the reserve base changes compared to the reserve requirement (in percentages), some of the implementations get a negative value in the fourth weighting scheme. We set these equal to zero.

Two of the most important instruments in this category are the LCR and the NSFR, both embedded in Basel III which represent two-thirds of the amount of implementations in the category of liquidity requirements and limits on currency and maturity mismatch. The LCR is designed to ensure that banks hold a sufficient reserve of high-quality liquid assets (HQLA) that allows them to survive a period of significant liquidity stress lasting 30 calendar days. The LCR requires internationally active banks to hold a stock of HQLA at least as large as expected total net cash outflows over the stress period (LCR of at least 100%). The LCR became a minimum requirement for all banking institutions in EU member countries on 1 January 2015, with the requirement set at 60% which rose by 10 %-points annually to reach 100% on 1 January 2018 (BIS, 2021a). However, member countries have the possibility to impose more stringent liquidity requirements. The intensity-based index for LCR will take into account the imposed requirement, more stringent rules across countries, and differences in legal consequences across countries, following the logic explained in section Appendix A.6. The index will take account of the phase-in period in the same way as explained in section Appendix A.4.1

The NSFR requires a financial institution to have at least as much available stable funding (ASF) as its required stable funding (RSF), which means an NSFR of at least 100%. A bank's total ASF is the portion of its capital and liabilities that will remain with the institution for more than one year. A bank's total RSF is the amount of stable funding that it is required to hold given the liquidity characteristics and residual maturities of its assets and the contingent liquidity risk arising from its off-balance sheet exposures. The specific amount of ASF and RSF is based on institution-specific characteristics (BIS, 2021b). The NSFR was introduced by Basel III in 2018 but has only become a binding regulation for all institutions in EU countries in June 2021.

The baseline scenario weights the imposed threshold by '0.6' and legal consequences by '0.4'.[39] Since there are no exceptions in the LCR an NSFR regulation, we do not take this into account as a separate category. As variations to the baseline weighting scheme, we use one where the imposed threshold and legal consequences are weighted equally by '0.5'. Next, the third weighting scheme gives more weight to the legal consequences compared to the baseline scheme ('0.6') and less to the imposed threshold ('0.4'), while the fourth weighting scheme removes the legal dimension from the index.

Before the implementation of these general Basel rules, countries individually decided on their liquidity requirements (e.g., subcategory 1, 3, 4, and 6) leading to a large diversity in rules even within one subcategory (e.g., different calculations rules, different definition of stress test period, focus on foreign currency liquidity, ratios with different numerators and denominators, ...), which makes it difficult to quantify this in a consistent way. The amount of observations we are not able to quantify is listed in section Appendix A.13.

[39] Similar to the capital-based instruments, we have looked into the option of measuring the restrictiveness of the limits by comparing the limit to the actual ratio for a specific bank. Again, this would require us to have a clear definition and list of financial institutions to which these requirements apply, which is not the case. Moreover, the problem of country aggregation is still present.

Appendix A.9. Limits on large exposures and concentration

This category of instruments aims at reducing the dependence of financial institutions to certain sectors or clients. Exposure limits are expressed as a maximum percentage of exposure that can go to a specific counterparty. These limits are often expressed in terms of percentage of own funds while concentration limits are usually expressed in terms of percentage of total deposits. The MaPPED divides this category in six subcategories:

1. Single client exposure limits
2. Intragroup exposure limits
3. Limits on qualified holdings outside the financial-sector
4. Funding concentration limits
5. Sector and market segment exposure limits
6. Other exposure and concentration limits

Unfortunately, we do not have detailed information on actual exposures or concentration of financial institutions. Moreover, around one quarter of the announcements were done before 1995 and around three quarter before the start of the Great Financial Crisis. Concentration and exposure limits are thus often not considered to be part of the core macroprudential toolkit (Lim et al., 2011). Therefore, we do not quantify the announcements for this category. The amount of observations we are not able to quantify is listed in section Appendix A.13.

Appendix A.10. Loan-loss provisioning

Similar to capital reserves, loan-loss reserves aim at absorbing future losses that a financial institution may face. While capital reserves focus on unexpected losses, loan-loss provisioning is designed to absorb expected losses. The MaPPED database divides this category in four subcategories:

1. Loan classification rules
2. Capital treatment of loan loss reserve
3. Minimum specific provisioning
4. General provisioning

In the majority of countries, loan-loss provisioning is based on individual borrower characteristics that could indicate a high probability of default. Some countries have set up some general rules, often based on the classification of loans according to their non-performance. Since it is very hard to find a uniform approach to treat these subcategories, we do not construct intensity-based indices for the implementations in this category. This is in line with other studies that do not consider loan-loss provisioning as part of the macroprudential toolkit (Eller et al., 2020).

Appendix A.11. Levy/tax on financial institutions and activities

This category contains the following subcategories:

1. Tax on assets/liabilities
2. Tax on financial activities

Similar to some of the previously-mentioned subcategories, this category consists of country-specific rules (with little to no common elements across countries) which makes it very difficult to come up with a uniform approach in quantifying the implementations. We do not construct intensity-indices for this category. Again, these implementation represent a relatively small set of policy changes compared to the quantified measures (see section Appendix A.13).

Appendix A.12. Other measures

This last category is the collection of all implementations that cannot be placed under any of the above-mentioned categories. There are 8 subcategories mentioned in the MaPPED:

1. Limits on deposit rates (3 countries)
2. Crisis management tools (2 countries)
3. Structural measures (4 countries)
4. Margin requirements (1 country)
5. Debt resolution policies (1 country)
6. Changes in regulatory framework (2 countries)
7. Other regulatory restrictions on financial activities (2 countries)
8. Other (15 countries)

Because of their complexity (more qualitative than quantitative rules) and the fact that these rules do not apply to a lot of countries, we do not construct intensity-indices for this category. Again, these implementation represent a relatively small set of policy changes compared to the quantified measures (see section Appendix A.13).

Appendix A.13. Overview of the intensity-based indices

This section provides information on the amount of observations that the intensity-based indices are able to cover within our final updated database. These tables are made based on the full sample of 28 European countries, covering implementations until 2019. Large differences between the number of observations for announcement and enforcement date can be due to the fact that some instruments are being implemented in different steps (phase-in).

	MaPPED	Updated MaPPED	Intensity index Ann	Intensity index Enf
Borrower-based instruments				
LTV limit	76	95	47	47
DSTI limit	31	69	41	41
DTI limit	2	13	9	8
LTI limit	1	4	3	3
Maturity and amortization restrictions	29	39	19	19
Limits on interest rates on loans	8	8	-	-
Limits on the volume of personal loans	38	38	-	-
Other income requirements for loan eligibility	6	6	-	-
Other restrictions on lending standards	46	50	-	-
Risk weights				
Risk weights on loans backed by residential property	86	91	21	24
Risk weights on loans backed by commercial property	55	55	-	-
Other sectoral risk weights	16	16	-	-
Capital buffers				
Countercyclical capital buffer (CCyB)	13	62	62	52
Systemic risk buffer (SRB)	17	43	20	28
Capital conservation buffer (CCB)	18	84	78	78
Buffers for GSII	5	15	8	20
Buffers for OSII	10	73	52	56
Profit distribution restrictions	17	17	-	-
Other capital requirements targeting most important institutions	12	12	-	-
Other capital surcharges and own funds requirements	20	20	-	-
Minimum capital requirements				
Capital adequacy ratio (CAR)	167	167	78	78
Common Equity Tier 1 capital ratio (CET1)	36	36	36	36
Tier 1 capital ratio	40	40	40	40
Core Tier 1 capital ratio	9	9	9	9
Leverage ratios	5	61	60	60
Limits on credit growth and volume				
Reserve requirements related to banks' liabilities	85	144	131	131
Asset-based reserve requirements	47	47	-	-
Liquidity requirements and limits on currency and maturity mismatch				
Loan-to deposit (LTD) limits	6	8	-	-
Short-term liquidity coverage ratios incl. LCR	102	166	28	93
Liquidity ratios and deposit coverage ratios	26	26	-	-
Limits on FX mismatches	36	37	-	-
Other stable funding requirements incl. NSFR	15	73	68	28
Other liquidity requirements	35	35	-	-
Limits on large exposures and concentration				
Single client exposure limits	193	196	-	-
Intragroup exposure limits	55	55	-	-
Limits on qualified holdings outside the financial-sector	104	105	-	-
Funding concentration limits	5	5	-	-
Sector and market segment exposure limits	38	38	-	-
Other exposure and concentration limits	24	24	-	-
Loan-loss provisioning				
Loan classification rules	56	56	-	-
Capital treatment of loan loss reserve	21	21	-	-
Minimum specific provisioning	44	44	-	-
General provisioning	26	54	-	-
Levy/tax on financial institutions and activities				
Tax on assets/liabilities	42	42	-	-
Tax on financial activities	3	5	-	-
Other measures				
Limits on deposit rates	7	7	-	-
Crisis management tools	57	57	-	-
Structural measures	5	5	-	-
Margin requirements	19	19	-	-
Debt resolution policies	45	45	-	-
Changes in regulatory framework	16	16	-	-
Other regulatory restrictions on financial activities	8	8	-	-
Other	42	48	-	-

Table A.7: Number of observations per (sub)category.

	MaPPED	Updated MaPPED	Intensity index Ann	Intensity index Enf
Borrower-based instruments				
LTV limit	15	20	14	14
DSTI limit	12	19	14	14
DTI limit	1	4	2	1
LTI limit	1	2	1	1
Maturity and amortization restrictions	11	17	12	12
Limits on interest rates on loans	5	5	-	-
Limits on the volume of personal loans	1	1	-	-
Other income requirements for loan eligibility	5	5	-	-
Other restrictions on lending standards	13	15	-	-
Risk weights				
Risk weights on loans backed by residential property	28	28	20	20
Risk weights on loans backed by commercial property	25	25	-	-
Other sectoral risk weights	5	5	-	-
Capital buffers				
Countercyclical capital buffer (CCyB)	11	28	28	28
Systemic risk buffer (SRB)	8	14	14	14
Capital conservation buffer (CCB)	28	28	26	26
Buffers for GSII	2	7	5	5
Buffers for OSII	5	26	25	25
Profit distribution restrictions	9	9	-	-
Other capital requirements targeting most important institutions	7	7	-	-
Other capital surcharges and own funds requirements	11	11	-	-
Minimum capital requirements				
Capital adequacy ratio (CAR)	28	28	28	28
Common Equity Tier 1 capital ratio (CET1)	28	28	28	28
Tier 1 capital ratio	28	28	28	28
Core Tier 1 capital ratio	6	6	6	6
Leverage ratios	2	28	28	28
Limits on credit growth and volume				
Reserve requirements related to banks' liabilities	7	28	25	25
Asset-based reserve requirements	5	5	-	-
Liquidity requirements and limits on currency and maturity mismatch				
Loan-to deposit (LTD) limits	5	5	-	-
Short-term liquidity coverage ratios incl. LCR	28	28	28	28
Liquidity ratios and deposit coverage ratios	7	7	-	-
Limits on FX mismatches	6	7	-	-
Other stable funding requirements incl. NSFR	6	28	28	28
Other liquidity requirements	12	12	-	-
Limits on large exposures and concentration				
Single client exposure limits	28	28	-	-
Intragroup exposure limits	25	25	-	-
Limits on qualified holdings outside the financial-sector	27	27	-	-
Funding concentration limits	2	2	-	-
Sector and market segment exposure limits	15	15	-	-
Other exposure and concentration limits	6	6	-	-
Loan-loss provisioning				
Loan classification rules	18	18	-	-
Capital treatment of loan loss reserve	9	9	-	-
Minimum specific provisioning	12	12	-	-
General provisioning	9	27	-	-
Levy/tax on financial institutions and activities				
Tax on assets/liabilities	17	17	-	-
Tax on financial activities	2	3	-	-
Other measures				
Limits on deposit rates	3	2	-	-
Crisis management tools	2	2	-	-
Structural measures	4	4	-	-
Margin requirements	1	1	-	-
Debt resolution policies	1	1	-	-
Changes in regulatory framework	2	2	-	-
Other regulatory restrictions on financial activities	2	2	-	-
Other	15	19	-	-

Table A.8: Number of countries covered per (sub)category.

Appendix B. Data appendix

This appendix includes information on the data used in our analysis. We deflated all relevant data using HICP. We further seasonally adjusted all relevant data using the X-13 ARIMA approach.

Variable	Description	Source
Loans to households	Monthly data on total loans to domestic households and non-profit institutions serving households by MFIs exclusing ESCB reporting sector in euro (stock)	ECB Statistical Data Warehouse
Loans for house purchase	Monthly data on loans for house purchase to domestic households and non-profit institutions serving households by MFIs exclusing ESCB reporting sector in euro (stock)	ECB Statistical Data Warehouse
Credit for consumption	Monthly data on loans for house purchase to euro area households and non-profit institutions serving households for euro area countries and to domestic households and non-profit institutions serving households for non-euro area countries by MFIs exclusing ESCB reporting sector in euro (stock)	ECB Statistical Data Warehouse
Macoprudential policy indices	See supra	MaPPED database, ESRB macroprudential database, Basel regulations, national legislations and central bank statements. Cross-checked using the iMaPP database
GDP	Quarterly data on gross domestic product at market prices, current prices (million euro)	Eurostat
HICP	HICP index (2015=100). Monthly data.	Eurostat
Policy rate	For the euro area and the UK we take the policy rates before 2004. After 2004 we use the shadow rate. For other non-euro area countries, we use the policy rate.	Wu and Xia (2020) (shadow rate) - BIS central bank policy rates (governmental long-term debt (10y) rate)
Crisis dummy	Dummy for systemic banking crises	Laeven and Valencia (2020)
Forecast of changes in credit standards	Diffusion index of the forecast change in credit standards at time $t-1$ for period t for consumption credit and credit for house purchase. This index takes account of the *extent* to which lenders think credit standards will tighten/ease.	Bank Lending Survey (BLS) − ECB Statistical Data Warehouse

Table B.1: Data variables and their sources.

	Mean	Std. Dev.	Min	Max	N
Baseline regression					
$\mathbf{\Delta MAP^{borr}_{i,t}}$					
Intensity-adjusted index for borrower-based macroprudential policy (LTV, D(S)TI, LTI)	0.62	0.64	-0.12	2.47	14 [40]
$\mathbf{\Delta MAP^{other}_{i,t}}$					
Intensity-adjusted index for maturity limits	-0.14	0.85	-0.73	0.46	2
Intensity-adjusted index for risk weights	0.29	0.32	-0.48	0.60	17
Intensity-adjusted index for capital buffers	0.27	0.33	-0.08	1.07	15
Intensity-adjusted index for the countercyclical capital buffer	0.05	0.07	0.00	0.13	10
Intensity-adjusted index for capital requirements	0.09	0.22	-0.49	0.63	34
Intensity-adjusted index for the leverage ratio	0.02	.	0.02	0.02	1
Intensity-adjusted index for reserve requirements	0.03	0.19	-0.15	0.34	6
Intensity-adjusted index for liquidity requirements	0.35	0.94	-1.05	0.86	4
$\mathbf{MAP^{non-int}_{i,t}}$					
Impl. not captured by the intensity-adjusted index for borrower-based (-1/0/+1)	0.33	1.86	-3.00	4.00	27
Impl. not captured by the intensity-adjusted index for risk weights (-1/0/+1)	0.10	1.20	-2.00	1.00	10
Impl. not captured by the intensity-adjusted index for capital buffers (-1/0/+1)	1.00	0.00	1.00	1.00	2
Impl. not captured by the intensity-adjusted index for capital requirements (-1/0/+1)	0.91	0.68	-1.00	2.00	22
Impl. not captured by the intensity-adjusted index for reserve requirements (-1/0/+1)	-0.32	1.23	-2.00	2.00	37
Impl. not captured by the intensity-adjusted index for liquidity requirements (-1/0/+1)	0.68	1.25	-1.00	4.00	22
Borrower-based instruments not captured by intensity-adjusted index (-1/0/+1)	0.09	1.67	-6.00	2.00	32
Risk weight instruments not captured by intensity-adjusted index (-1/0/+1)	0.33	0.98	-1.00	1.00	12
Capital buffer instruments not captured by intensity-adjusted index (-1/0/+1)	0.92	0.84	-1.00	3.00	26
Limits on credit growth and volume instruments not captured by intensity-adjusted index (-1/0/+1)	1.80	3.19	-1.00	11.00	15
Liquidity requirements instruments not captured by intensity-adjusted index (-1/0/+1)	0.93	1.32	-2.00	6.00	43
Limits on large exposures and concentration (-1/0/+1)	0.73	1.78	-3.00	5.00	62
Loan-loss provisioning (-1/0/+1)	0.49	1.37	-2.00	2.00	39
Limits on levies/taxes on financial institutions and activities(-1/0/+1)	0.44	1.21	-1.00	2.00	16
Other measures (-1/0/+1)	-0.55	2.53	-10.00	5.00	44
$\mathbf{MAP^{ant}_{i,t}}$					
Anticipated impl. for borrower-based policies (intensity)	0.23	0.78	-2.21	2.87	37
Anticipated impl. for maturity limits (intensity)	0.43	0.25	-0.15	0.82	11
Anticipated impl. for risk weights (intensity)	0.11	0.23	-0.31	0.54	33
Anticipated impl. for capital buffers (intensity)	0.10	0.13	-0.17	0.57	100
Anticipated impl. for the countercyclical capital buffer (intensity)	0.12	0.11	0.00	0.40	37
Anticipated impl. for capital requirements (intensity)	0.27	0.26	-0.17	0.78	53
Anticipated impl. for the leverage ratio (intensity)	0.13	0.12	-0.04	0.26	58
Anticipated impl. for reserve requirements (intensity)	0.06	0.10	-0.07	0.28	69
Anticipated impl. for liquidity requirements (intensity)	0.36	0.40	-1.17	1.54	98
Anticipated impl. for borrower-based policies not captured by the intensity-adjusted index (-1/0/+1)	1.13	1.52	-2.00	4.00	23
Anticipated impl. for risk weights not captured by the intensity-adjusted index (-1/0/+1)	0.10	1.09	-1.00	2.00	21
Anticipated impl. for capital buffers not captured by the intensity-adjusted index (-1/0/+1)	1.00	0.00	1.00	1.00	9

[40] These 14 implementations take place in Cyprus (2003Q4, 2006Q3, 2013Q1, 2013Q4), France (2019Q4), Greece (2005Q4), Ireland (2015Q1, 2019Q3), Latvia (2007Q2), the Netherlands (2007Q1, 2011Q3), Slovenia (2016Q3, 2018Q3), and Slovakia (2014Q4).

Anticipated impl. for capital requirement not captured by the intensity-adjusted index (-1/0/+1)	1.04	0.53	-1.00	2.00	26
Anticipated impl. for reserve requirements not captured by the intensity-adjusted index (-1/0/+1)	0.71	1.25	-1.00	2.00	7
Anticipated impl. for liquidity requirements not captured by the intensity-adjusted index (-1/0/+1)	1.17	1.11	-2.00	2.00	12
Anticipated impl. for borrower-based instruments not captured by intensity-adjusted index (-1/0/+1)	0.75	0.79	-1.00	2.00	20
Anticipated impl. for risk weights not captured by intensity-adjusted index (-1/0/+1)	0.29	1.16	-1.00	2.00	24
Anticipated impl. for capital buffers not captured by intensity-adjusted index (-1/0/+1)	0.86	0.53	-1.00	1.00	14
Anticipated impl. for reserve requirements not captured by intensity-adjusted index (-1/0/+1)	-1.25	3.30	-6.00	1.00	4
Anticipated impl. for liquidity requirements not captured by intensity-adjusted index (-1/0/+1)	0.23	1.42	-2.00	2.00	13
Anticipated impl. for limits on large exposures and concentration (-1/0/+1)	0.29	2.22	-4.00	4.00	34
Anticipated impl. for loan loss provisioning (-1/0/+1)	0.56	1.46	-2.00	4.00	18
Anticipated impl. for levies/taxed on financial institutions and activities (-1/0/+1)	0.91	0.68	-1.00	2.00	22
Anticipated impl. for other measures (-1/0/+1)	0.57	0.85	-1.00	1.00	14
$\mathbf{X_{i,t-1}}$					
Credit to households (relative to GDP)	48.72	26.22	5.81	133.48	1,769
Credit to households for house purchase (relative to GDP)	31.38	18.07	1.53	70.52	1,778
Credit to households for consumption (relative to GDP)	6.46	3.44	0.89	25.01	1,793
Real GDP (log)	10.38	1.89	5.08	13.65	2,661
HICP in logs	4.64	1.18	1.02	10.69	2,677
Policy rate	1.93	5.14	-7.63	33.00	2,316
Systemic banking crisis dummy	0.13	0.34	0.00	1.00	2,800
Different weighting schemes					
Intensity-adjusted index for borrower-based macroprudential policy (weighting scheme 2)	0.57	0.55	-0.09	2.06	14
Intensity-adjusted index for borrower-based macroprudential policy (weighting scheme 3)	0.56	0.59	-0.16	2.11	14
Intensity-adjusted index for borrower-based macroprudential policy (weighting scheme 4)	0.63	0.71	-0.22	2.72	14
Comparison with '-1/0/+1' index					
$\mathbf{MAP_{i,t}^{`\#-1/0/+1'borr}}$					
'-1/0/+1' index for borrower-based macroprudential policy	1.23	1.30	-1.00	4.00	13
$\mathbf{MAP_{i,t}^{`\#-1/0/+1'other}}$					
'-1/0/+1' index for maturity limits	-1.00	0.00	-1.00	-1.00	2
'-1/0/+1' index for risk weights	0.25	1.00	-1.00	1.00	16
'-1/0/+1' index for capital buffers	1.73	1.19	1.00	4.00	11
'-1/0/+1' index for the countercyclical capital buffer	0.82	0.60	-1.00	1.00	11
'-1/0/+1' index for capital requirements	1.04	1.17	-1.00	5.00	28
'-1/0/+1' index for the leverage ratio	1.00	.	1.00	1.00	1
'-1/0/+1' index for reserve requirements	1.33	0.52	1.00	2.00	6
'-1/0/+1' index for liquidity requirements	0.50	1.00	-1.00	1.00	4
Robustness checks					
Intensity-adjusted index for borrower-based macroprudential policy (incl. maturity limits)	0.53	0.68	-0.73	2.47	16
Intensity-adjusted index for LTV limits	0.67	0.76	-0.28	2.47	9

Table B.2: Descriptive statistics on the key variables used when estimating equation (1), equation (2), and the robustness checks. Impl. = implementations.