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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 data-driven intensity-adjusted indices for a broad set of macroprudential policy announcements in the European Union (EU) that are able to capture the restrictiveness and bindingness of the macroprudential policy actions. The indices are used to assess the effectiveness of borrower-based macroprudential policy in reducing credit in the EU from 1995 to 2019. Our results indicate that these instruments have successfully reduced household, housing, and to a smaller extent consumption credit, especially in the long run. Moreover, we find that standard dummy approaches used to measure macroprudential policy signal different effects of borrower-based policies in our sample and are more sensitive to outliers, resulting in deceptive and incomplete results.

Keywords: Macroprudential policy, intensity-adjustment, household credit, panel data analysis

JEL-Classifications: E58, C23, G18, G28

1. Introduction

The Global Financial Crisis (GFC) of 2008-9 dramatically changed the economic landscape. 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. One policy response to this failure consists of an increased oversight on financial institutions and (re)new(ed) attention to prudential supervision and financial regulation at the macro level. Before

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the GFC, there was no formal mandate to execute this so-called macroprudential supervision of financial markets in advanced economies such as European Union (EU) countries. More than ten years after the GFC, macroprudential policy is now very present in all advanced economies, where existing instruments are being monitored and new instruments are being implemented.

An important drawback in the analysis of the effectiveness of countries' macroprudential policy, however, is the blunt quantification of macroprudential policy actions. Macroprudential policy comprises a broad range of instruments of which the objective 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 this common overall objective, 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. The contribution is two-fold, these refined indices first of all allow to pick up the restrictiveness of macroprudential regulatory actions and second, the indices discriminate among different instruments types. Existing cross-country studies typically use a cumulative index based on a '-1/0/+1' dummy for country-specific policy implementations (see infra, section 3) 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. An ideal policy indicator should, however, be able to capture the restrictiveness of policy changes next to their timing and sign. Moreover, the 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 intensity of the action or the instrument type.

Recently, a handful of authors have attempted to address the intensity problem. 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 (see infra, section 2). Alam et al. (2019) and Richter et al. (2019) instead have tried to incorporate the intensity of loan-to-value (LTV) limits for groups of advanced and emerging countries. In contrast to this existing work, we use actual micro-level data to determine the restrictiveness of a wide range of macroprudential policy implementations. More specifically, we employ a granular quantification based on country-specific data series taking account of the various elements 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 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. Fluctuations in these credit variables are an important aspect of the overall financial cycle, often triggering major concerns about systemic risks and also potentially impacting the real economy (Claessens et al., 2013). Borrower-based instruments in particular have been an important tool in the attempt to temper the fast growth of mortgage and housing credit and have been widely employed in EU countries. 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 macroprudential policy with inconclusive results about the long-run effects on credit (see infra, section 2).

Our work focuses more specifically on loan-to-value (LTV), debt-service-to-income (DSTI), debt-to-income (DTI), and loan-to-income (LTI) limits, as their wide use in response to the GFC in the EU 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 combinations 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 2.5 years). What is more, our estimates suggest that controlling for the restrictiveness of macroprudential measures matters. A standard '-1/0/+1' index to measure macroprudential policy signals different effects of borrower-based policies in our sample and is more sensitive to outliers, resulting in deceptive results.

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 offers a description of the adopted methodology, data and our approach to limit endogeneity concerns. In section 5, we present the results including various 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 percentage 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 short-run effects of macroprudential policy. 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. More specifically, the effect is not significant in the short run and reaches its peak at -1.5% only after 3 years in EU countries. 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. 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 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. 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 over time drives 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 subsam-

[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.

ples 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. De Schryder and Opitz (2020) find that the household credit-to-GDP ratio decreases by 1,6 percentage points while the domestic bank credit-to-GDP ratio is reduced by 1,8 percentage points after a restrictive macroprudential policy shock in EU countries.

A related and crucial aspect of analyzing the effectiveness of macroprudential policy is finding an appropriate measure for 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 (i.e., a 5 percentage-point reduction in the LTV limit is equivalent to a 1-index-point increase in their aggregate index)[4] 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) additionally 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

[4]Since the methodology of Eller et al. (2020) is largely based on the work of Vandenbussche et al. (2015), we use one example for both studies.

LTV limits for groups of advanced and emerging countries by looking at changes in the level of (average) LTV limits. Although this method in the latter two papers can provide information on the effects of level changes in the regulatory limits, it does not capture the bindingness of the limit nor the importance of the targeted loan section (see infra, section 3).

A shortcoming of the above-mentioned studies is that the macroprudential indices are not based on underlying economic and financial market data which is necessary to effectively determine the restrictiveness of the policy implementations. As argued by de Jong and de Veirman (2019) a given macroprudential limit can bind to different extents at different times. 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 changing 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. The next section elaborates on our approach to construct cross-country macroprudential indices that capture the intensity of the policy changes for a relatively narrow set of countries without relying on loan-level data.

3. Construction of intensity-based indices

The macroprudential toolkit is 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 also relate to the real estate and mortgage market but target the lender rather than the borrower.

We take a narrative approach to construct intensity-based indices of macroprudential policy implementations by EU countries that capture both the wide range of tools and their various uses.

In particular, we collect information on these 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 A.1) and contains almost 2000 macroprudential policy actions in the 28 EU member states[5] from 1995 to 2017. We further complement this dataset with more recent data from national legislation and central bank statements. The database eventually covers announcements on policy implementations from 1995-2019. We deliberately cut off our sample at 2019 to avoid picking up any effects from the COVID-19 pandemic.

This dataset informs us about multiple elements that determine the restrictiveness of a policy implementation for a given instrument, country, and time 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. This information allows 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 instead of using a general '-1/0/+1' index which takes the value of '+1' when a policy was tightened, to '-1' when a policy was loosened, and being '0' when the policy is maintained at the same level (see infra, section 5.3). Table 1 lists some examples from the updated MaPPED to illustrate the importance of these different elements.

As indicated before, we use actual micro-level data to take account of these various elements that determine the restrictiveness of the policy implementation. In other words, we use micro-level data to capture how binding a particular implementation was. We construct the intensity-based indices for each macroprudential policy instrument separately, based on a common methodology per category. Different macroprudential policy instruments namely target various parts of the economy in a different way such that different elements should be taken into account to construct the intensity-based indices. For tools aimed at borrowers of housing loans for example, such as

[5]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 1: Examples of macroprudential policy implementations in EU countries based on the updated MaPPED. Ann = announcement date, Enf = enforcement date.

LTV, D(S)TI, and LTI limits, the imposed threshold compared to the actual ratio and the share of loans to which the limits are applied to will determine the restrictiveness of the implementation. In case of capital buffers on the other hand, the relative importance of the targeted financial institutions will instead be determining for the degree of bindingness. The relevance of the scope and quantitative thresholds for the overall restrictiveness of a macroprudential implementation is hence quantified differently depending on the instrument's category. Appendix A contains all details on the quantification of the intensity-based indices.

For borrower-based measures and risk weights, we use data collected by the Household Finance and Consumption Surveys (HFCS). The HFCS database consists of very granular data for a large group of European countries which allows us to collect information on different loan segments (e.g., overall mortgage lending or loans to first-time-buyers) and lending standards (LTV, D(S)TI, and LTI ratios) in great detail. Moreover, due to the cross-sectional dimension of the database, we pick up country-specific characteristics of household lending (e.g., the variation in the importance of certain lending measures across countries) such that the final indices are tailored to a specific country. More

specifically, to capture the restrictiveness of the imposed quantitative limit, we compare the limit to the median ratio of the specific measure in a given country, time period, and loan category. This gives us an indication of how binding the limit is, since imposing a lower limit than the current median ratio in a country is considered to be more far-reaching than imposing a limit higher than the current median ratio. 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 macroprudential 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 household lending. Since a larger scope is considered to be more restrictive, a higher proportion will contribute to a larger value for the final index.

Some lender-based instruments, such as 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 to calculate market shares for a specific institution (i.e., total assets of a the institution relative to total assets of the country the institution has its headquarters 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 we can use to compare the restrictiveness of the capital buffer implementations across countries and time[6].

Next to the scope and the restrictiveness of the quantitative limits, the intensity-based indices account for the variation in legal consequences in case of non-compliance to the imposed rules and pick up allowed exceptions (as listed in MaPPED). 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 is considered to be more restrictive than a policy implementation using the 'comply or explain' method. Mokas and Giuliodori (2021), for example, find that the negative effects of LTV an-

[6]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.

nouncements 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.

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. We use different weighting schemes (see Appendix A) and check the sensitivity of our results to the various schemes (see section 5.4.4). The baseline weighting scheme gives the largest weight to the scope and the restrictiveness of the limit for borrower-based measures and to the market-share-adjusted limit for the lender-based measures. The value for the legal consequences is given a larger weight than the value for exceptions. The resulting intensity-based indices allow to examine the restrictiveness of the macroprudential implementations across time for a given country and a particular policy instrument.

Tables A.5 and A.6 provide an overview of the coverage of the intensity-based indices across instruments and categories. Eventually, we construct intensity-based indices for the majority of implementations[7] in seven important macroprudential categories (i.e., borrower-based instruments, risk weights, capital buffers, minimum capital requirements, leverage ratio, liquidity requirements and limits on currency and maturity mismatch, and reserve requirements)[8].

We take the change in the indices (i.e., the change in the restrictiveness of the macroprudential instrument) and define it as our macroprudential shock to use in the estimations (see infra, section 4.1) as this series is comparable across countries. Figures A.1 to A.6 show the evolution of the intensity-adjusted indices per category across countries. 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

[7]Due to data restrictions, we are not able to quantify all the policy implementations. For the HFCS for example, the first wave of the survey was only conducted in 2010, which means that our data sample cannot include time periods before that wave.

[8]The complexity of the imposed rules in the other four categories such as loan-loss provisioning and levies/taxes on financial institutions and activities make them very difficult to quantify. These instruments, however, often represent a limited amount of implementations in a small group of countries or are often not considered to be part of the macroprudential toolkit.

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

4. Methodology

4.1. Model estimation

We examine the effects of borrower-based macroprudential policy in 28 European countries from 1995Q1 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 effects on the dependent variables over time, hence over and above the effects on 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:

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

where h stands for the horizon of the local projections, running from 0 to 16 quarters. 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 ($Y_{i,t-1}$), 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 ($\Delta\widetilde{MAP}^{other}_{i,t}$) to control for the simultaneous implementation of borrower-based tools with other types of macroprudential policy tools. We additionally include lags of 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 ($\widetilde{MAP}_{i,t}^{non-int}$) using the '-1/0/+1' method. We further include a set of additional control variables ($\widetilde{X}_{i,t-1}$). More specifically, we control for the 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[9], 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 and control variables is set at 4 quarters, which is common for the analysis of quarterly data. The other intensity-adjusted instruments and non-intensity-adjusted macroprudential observations are only lagged once to retain reasonable degrees of freedom. All data series are in real terms, deflated by the HICP, and all the relevant series are seasonally adjusted using the X-13 ARIMA approach. The respective data sources are listed in Appendix B.

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 2021. These credit series are transformed from monthly to quarterly data and normalized by expressing them relative to the GDP. The 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 on the data series.

[9]We use the shadow rate of Wu and Xia (2020) for euro area countries and the UK, see Appendix B for more details.

4.2. Tackling endogeneity concerns

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 European Systemic Risk Board (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 responsibilities of central banks, regulatory authorities and ministries of Finance vary across countries. Furthermore, endogeneity concerns are reduced by the intuition that 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. 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.

Another step we take to reduce endogeneity concerns is to remove all the macroprudential implementations that were set with a countercyclical goal 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 (2020))[10]. As such, we only include the policy implementations with a more structural character.

We also account for the fact that regulations often include transition periods between the an-

[10]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).

nouncement and the implementation of a policy change. More specifically, the effect of a macroprudential 'news shock' is considered by focusing on the announcement dates. 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 (similar to the argument of Alesina et al. (2015) 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), De Schryder and Opitz (2020), and Duprey and Ueberfeldt (2020). To perform this test, we use data from the quarterly Bank Lending Survey (BLS) which provides information on bank lending conditions in the euro area for a subset of 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. If these expectations can anticipate the macroprudential actions, our shock would be endogenous. To test this, we regress our 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*. The first two lines in table 2 show that the credit standards cannot predict our shock[12]. Although this simple analysis cannot guarantee our shocks to be fully exogenous, it does give us confirmation to proceed with the outlined identification strategy.

Hypothesis	Conclusion	P-value
Do credit standard expectations on credit for house purchase forecast the macroprudential shock?	No	0.164
Do credit standard expectations on consumption credit forecast the macroprudential shock?	No	0.407

Table 2: Predictability tests based on BLS data

[11]The BLS data is available from 2003Q1 until present for 15 countries in our sample, being Austria, Belgium, Cyprus (starting from 2009Q2), Germany, Estonia (starting from 2011Q3), Spain, Finland, Greece, Ireland, Italy, Lithuania (starting from 2015Q2), Luxembourg, Latvia (starting from 2014Q2), Portugal, and Slovenia (starting from 2007Q2).

[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.

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 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). The effects on household credit are, however, only significant after 12 quarters with a negative effect of -1.42%. After 16 quarters, borrower-based macroprudential policies substantially reduce household credit by -2.94%. Since housing loans constitute an important proportion of household credit, the IRFs for housing credit look similar. In the longer run, housing credit is significantly decreased after 11 quarters onwards with a magnitude of -1.05%, increasing to -2.01% after 16 quarters. We observe a small significant effect on housing credit after 3 quarters, although this effect is very short-lived. In the long run, we also observe a significant impact on the credit for consumption to GDP ratio (hereafter: consumption credit) of -0.73%. 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), De Schryder and Opitz (2020), and Poghosyan (2020) who find a significant impact of macroprudential policy on household credit in the medium and long run as well. One possible explanation for this result could be that it takes some time for the effect of these policies to materialize since, as argued before, borrower-based policies often target high-risk borrower segments such that the impact on aggregate credit series could be delayed. 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

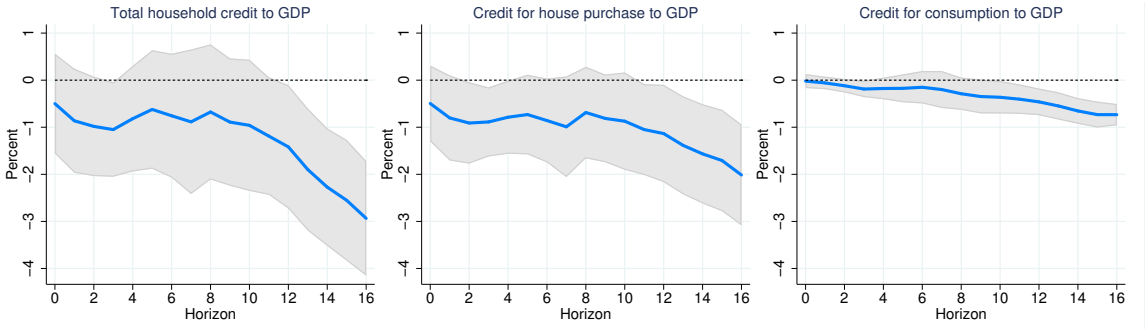

Figure 1: Impulse response functions of credit-to-GDP ratios to a shock in borrower-based macroprudential policy (LTV, DSTI, DTI, and LTI limits) in the full sample of 28 EU countries. Note: The solid blue lines show the point estimates of the reaction of the variable to a macroprudential policy shock over a horizon of 16 quarters. The grey areas reflect the 90% error bands.

Schryder and Opitz (2020), 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 (2020) 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) even 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 standard indices), a different definition of the macroprudential shock (e.g., they also include countercyclically motivated implementation), and the fact that they do not control for the simultaneous implementation with other types of macroprudential policies.

In a next step, we extend our borrower-based macroprudential index by additionally including maturity limits in the shock variable. This leads to very similar results (as shown in figure 2) with a somewhat smaller reaction on household credit (-2.08%) for household credit. For housing credit, we find a reaction of -1.47% after 4 years and for consumption credit a reaction of -0.51%. The

small significant short-run effect for housing credit now disappears, which confirms the finding that borrower-based macroprudential policy is especially effective in the longer run.

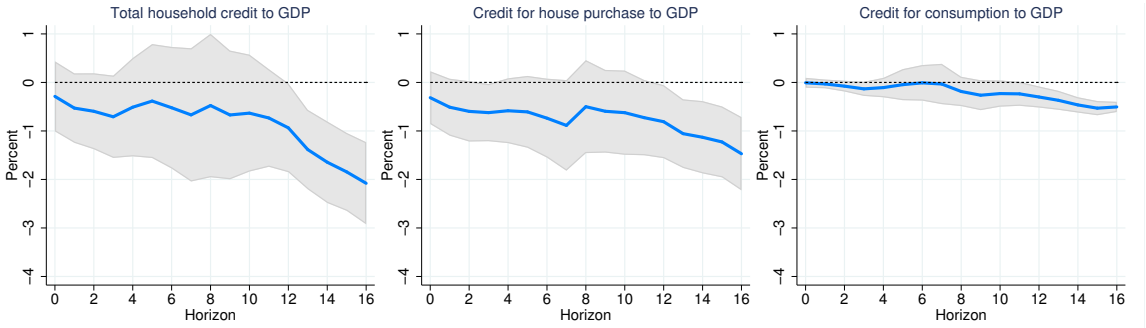

Figure 2: Impulse response functions of credit-to-GDP ratios to a shock in borrower-based macroprudential policy (LTV, DSTI, DTI, LTI, and maturity limits) in the full sample of 28 EU countries. Note: The solid blue lines show the point estimates of the reaction of the variable to a macroprudential policy shock over a horizon of 16 quarters. The grey areas reflect the 90% error bands.

Since a large part 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 3 shows again very similar IRFs with a strong negative impact on household and housing credit after 3 years, although the coefficient estimates are somewhat more muted. Also the reaction of consumption credit is fairly similar, albeit already significant after 7 quarters. Research 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.

Together, these findings suggest that borrower-based macroprudential policy is effective in reducing household, housing credit and to a smaller extent consumption credit, although with a delayed impact. In line with multiple previous studies, the impact also seems to become stronger in the long run. Moreover, these results take account of the implementations of other types of macroprudential policies.

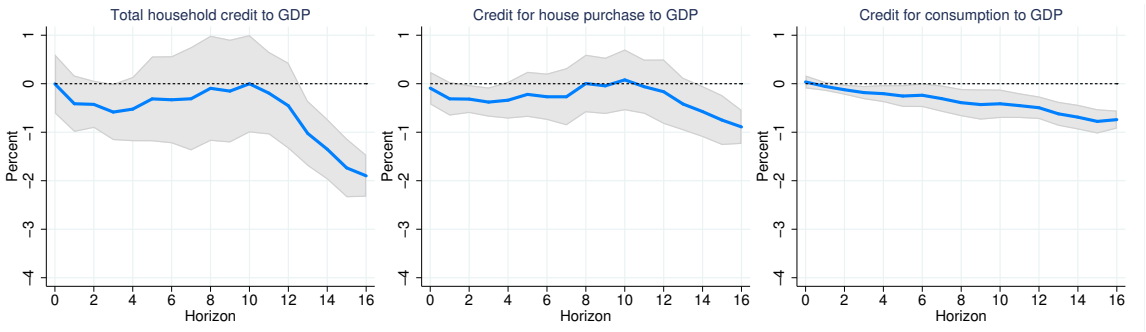

Figure 3: Impulse response functions of credit-to-GDP ratios to a change in the LTV limit in the full sample of 28 EU countries. Note: The solid blue lines show the point estimates of the reaction of the variable to a macroprudential policy shock over a horizon of 16 quarters. The grey areas reflect the 90% error bands.

5.2. Macroprudential policy in a monetary union

Buch et al. (2021) argue that macroprudential policy can play an important role in a monetary union such as the euro area, where countries have no option to set different monetary policy or exchange rates and some institutional limitations on fiscal policy are introduced. More specifically, although countries in a monetary union are highly integrated, there can still be sizeable heterogeneity along dimensions that can significantly affect financial stability risks such as differences in the business and credit cycle (Maddaloni and Peydró, 2013). Multiple theoretical studies based on New Keynesian models have shown that country-specific targeted macroprudential policy is effective and important in reducing imbalances and asymmetries (e.g., in core versus periphery areas) under a common monetary policy within a monetary union (Brzoza-Brzezina et al., 2015; Dehmej and Gambacorta, 2019). Finally, Houben et al. (2014) argue that macroprudential policy is expected to be more determining in the euro area than elsewhere, because it has a financial sector that is fragmented along national lines and it lacks common macroeconomic instruments to address diverging financial cycles.

Motivated by these findings, we examine in this section how borrower-based macroprudential policy impacts our credit series in countries that are part of the euro area. More specifically, we check whether changes in the macroprudential index have more sizable effects in the group of euro area countries. The results are shown in figure 4. We find that the long-run effects are more pronounced in euro area countries compared to the baseline results with a negative impact on household credit

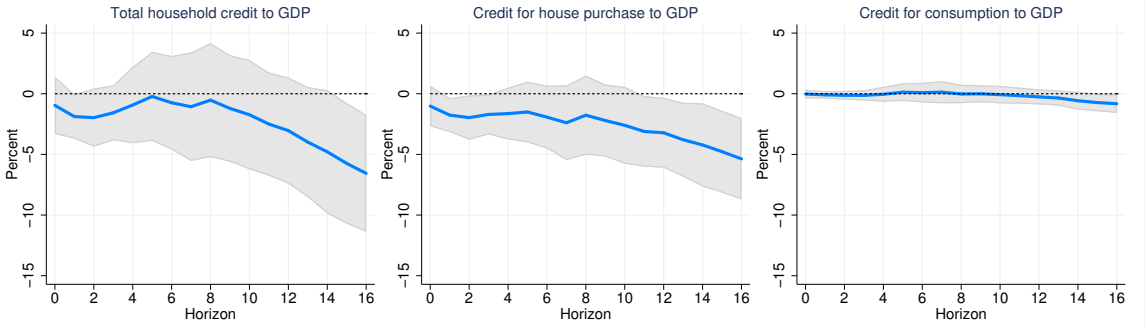

Figure 4: Impulse response functions of credit-to-GDP ratios to a shock in borrower-based macroprudential policy (LTV, DSTI, DTI, and LTI limits) in 19 euro area countries. Note: The solid blue lines show the point estimates of the reaction of the variable to a macroprudential policy shock over a horizon of 16 quarters. The grey areas reflect the 90% error bands.

of -6.56% and on housing credit of -5.37% after 16 quarters. Also in the short run, there is a small significant effect on household credit, although this effect is very short-lived. The effect on consumption credit, however, is now insignificant. Although the average effect on household and housing credit is larger for euro area countries, it must be noted that the standard errors are also more wide compared to our baseline result. These results therefore indicate similar qualitative effects of macroprudential policy relative to the entire group of EU countries - if anything, the results point to milder effects on consumption credit.

5.3. Does it matter which 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. In a first step, we estimate equation (2) in which macroprudential announcements are now captured by a '-1/0/+1' index since this way of measuring macroprudential policy is widely used (e.g., in Richter et al. (2019); De Schryder and Opitz (2020); Poghosyan (2020), see section 5.1).

$$\begin{aligned} Y_{i,t+h} = \gamma^h(L)Y_{i,t-1} \; + \; \beta^h(L)\Delta MAP_{i,t}^{`-1/0/+1'borr} \; + \; \tau^h(L)\widetilde{X}_{i,t-1} + \\ \delta^h(L)\Delta\widetilde{MAP}_{i,t}^{`-1/0/+1'other} \; + \; \alpha_i^h \; + \; \theta_t^h \; + \; \epsilon_{i,t+h} \end{aligned} \tag{2}$$

The index gets the value '+1' for a specific country and time when there were more tightening

than loosening policy actions during a quarter. If there were more loosening than tightening actions, the index gets the value '-1'. If there is an equal amount of loosening and tightening actions or there was no policy action, the index gets the value '0'[13]. The policy instruments are grouped in the same way as before, meaning that the borrower-based index captures the values for changes in LTV, DSTI, DTI and LTI limits. The other instruments which were also intensity-adjusted are now also captured by '-1/0/+1' index. The results are shown in figure 5. Remarkably, we now find insignificant IRFs for all three credit variables. A possible explanation for this could be that the '-1/0/+1' simply indicates whether there was a net tightening or loosening, while the intensity-adjusted indices are able to take account of the fact that there is a difference in the restrictiveness of the implementations. This shows that it is highly important to account for the bindingness, importance, or scope of these policy measures.

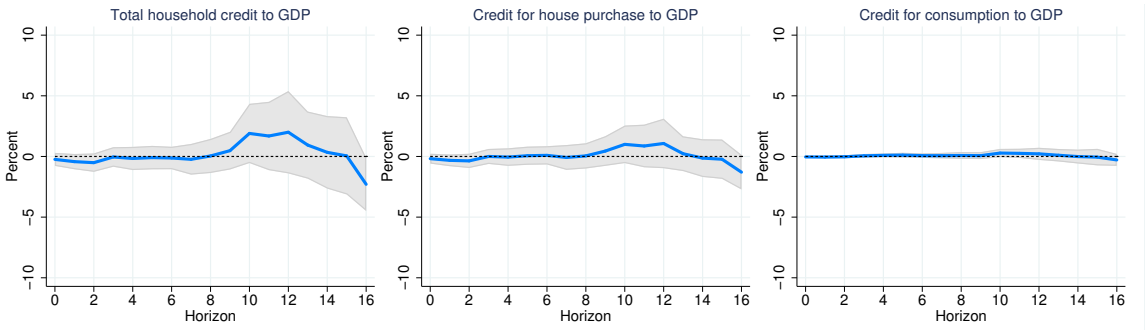

Figure 5: Impulse response functions of credit-to-GDP ratios to a '-1/0/+1' shock in borrower-based macroprudential policy (LTV, DSTI, DTI, and LTI limits) in the full sample of EU countries. Note: The solid blue lines show the point estimates of the reaction of the variable to a macroprudential policy shock over a horizon of 16 quarters. The grey areas reflect the 90% error bands.

In contrast, Poghosyan (2020) also investigates the effects of borrower-based macroprudential policy in the EU using a '-1/0/+1' index and finds a significant negative reaction of household credit in the long run when analyzing the full sample. One possible explanation for this is the fact that, in contrast to the work of Poghosyan (2020), our analysis includes data on a sizeable amount of

[13]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.

macroprudential policy implementations after 2017. When restricting the time period of the analysis to 1995-2015 (as in Poghosyan (2020)), we indeed find a negative significant reaction on household and housing credit in the long run (see figure 6). In this scenario, we find a negative impact on household credit after 2 years which somewhat fades out after 3.5 years. The effect on housing credit is significant after 10 quarters with similar coefficients compared to our baseline results using the intensity-adjusted indices. This suggests that, when expanding the sample to 2019, the standard '-1/0/+1' index is not able to correctly account for the changes in macroprudential policy. During the last years, macroprudential policy instruments have been increasingly implemented with different regulations and uses across countries. This result again illustrates the importance of the intensity-adjusted indices since these are able to take account of the various elements that determine the different macroprudential setting across countries, in contrast to the standard indices.

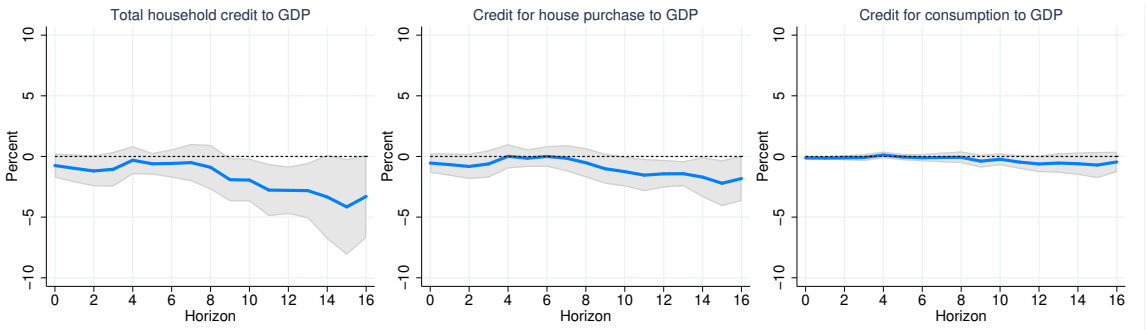

Figure 6: Impulse response functions of credit-to-GDP ratios to a '-1/0/+1' shock in borrower-based macroprudential policy (LTV, DSTI, DTI, and LTI limits) in the full sample of 28 EU countries from 1995-2015. Note: The solid blue lines show the point estimates of the reaction of the variable to a macroprudential policy shock over a horizon of 16 quarters. The grey areas reflect the 90% error bands.

Another frequently used way of capturing macroprudential policy is to count the number of tightenings and loosenings for a given instrument in a specific country and time as a measure for macroprudential policy (e.g., in Kim and Mehrota (2018) and Eller et al. (2020)). Therefore, in a next step, we estimate equation (3) where macroprudential policy is captured by this type of index.

$$Y_{i,t+h} = \gamma^h(L)Y_{i,t-1} \; + \; \beta^h(L)\Delta MAP^{`\#-1/0/+1'borr}_{i,t} \; + \; \tau^h(L)\widetilde{X}_{i,t-1} + \\ \delta^h(L)\Delta\widetilde{MAP}^{`\#-1/0/+1'other}_{i,t} \; + \; \alpha^h_i \; + \; \theta^h_t \; + \; \epsilon_{i,t+h} \tag{3}$$

The use of such index results in positive IRFs, which are even slightly significant in the medium run (see figure 7). When taking a closer look at the differences between the intensity-adjusted index and the index that counts the amount of tightenings and loosenings for borrower-based macroprudential policy in figure 8, one can notice large differences in countries such as Slovakia and Poland. This difference is due to the fact that from 2014 onwards, there have been a substantial amount of implementations in these countries. This standard index does not consider the bindingness, importance, or scope of these measures and simply counts the amount of tightenings and loosenings, while the intensity-adjusted indices are able to take account of the fact that multiple small tightenings are not necessarily more effective than one large one. When removing these specific countries from the sample, figure 9 shows that the positive reactions become insignificant. In contrast, removing these countries does not change our baseline results (see section 5.4.1) meaning that the intensity-adjusted indices are more robust to outliers (i.e., a large amount of implementations in the same quarter). Again, this indicates that it is highly relevant to control for the differences in importance of the policy changes.

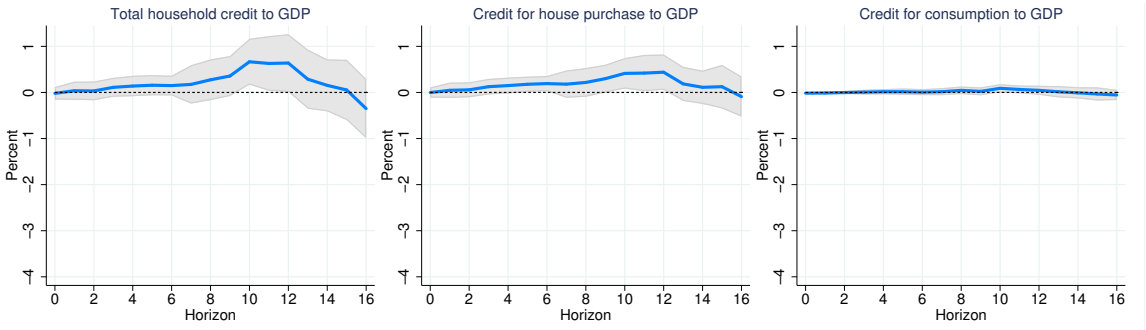

Figure 7: Impulse response functions of credit-to-GDP ratios to an index that counts the amount of tightenings and loosenings for borrower-based macroprudential policy (LTV, DSTI, DTI, and LTI limits) in the full sample of 28 EU countries. Note: The solid blue lines show the point estimates of the reaction of the variable to a macroprudential policy shock over a horizon of 16 quarters. The grey areas reflect the 90% error bands.

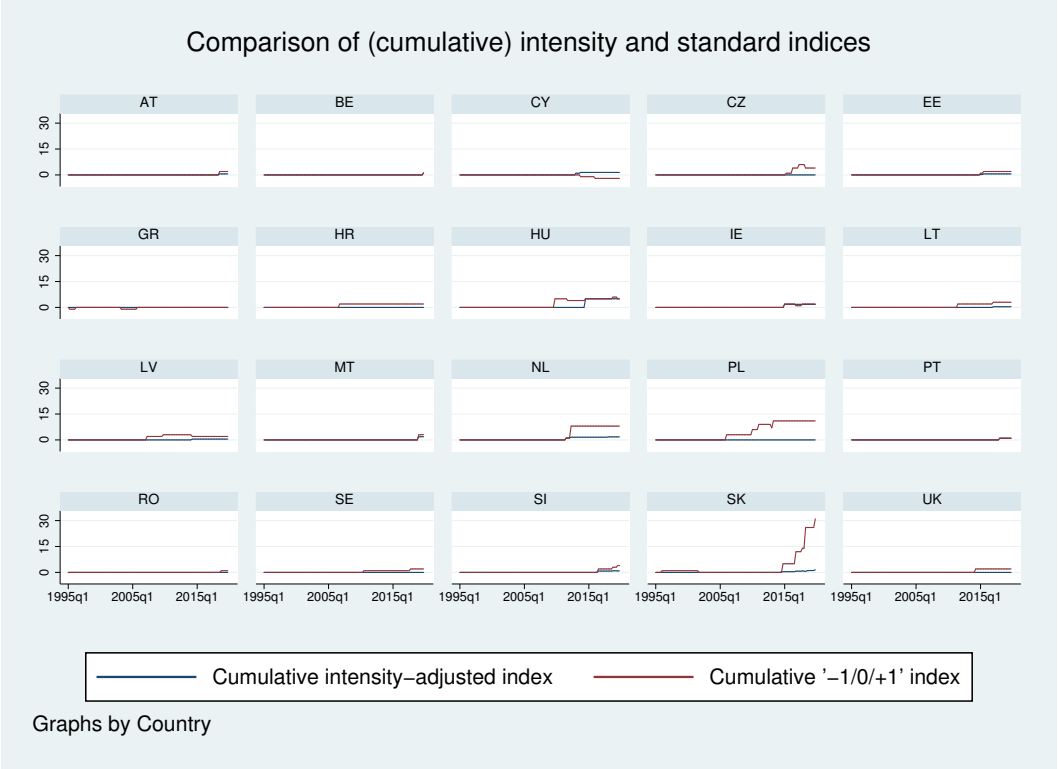

Figure 8: Intensity-adjusted index for borrower-based macroprudential policy and the index that counts the amount of tightenings and loosenings for borrower-based macroprudential policy. The indices are shown cumulatively for comparison and visibility reasons (i.e., the cumulative series are not used in the regression analysis). We removed the countries where there were no announcements from 1995Q1 until 2019Q4.

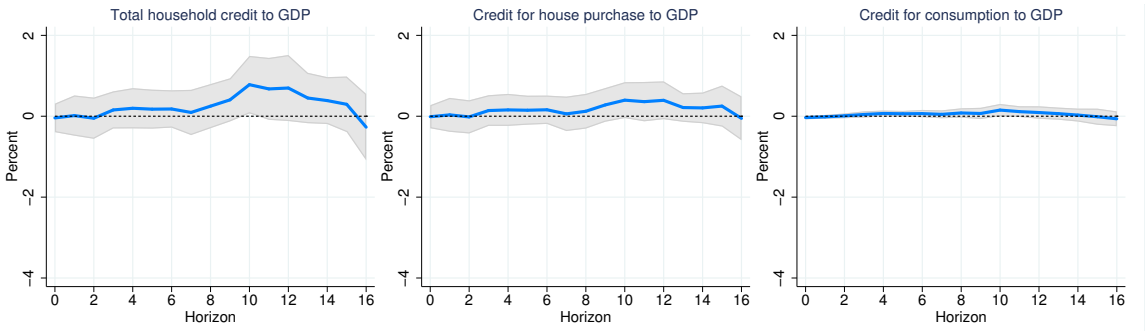

Figure 9: Impulse response functions of credit-to-GDP ratios to an index that counts the amount of tightenings and loosenings for borrower-based macroprudential policy (LTV, DSTI, DTI, and LTI limits) when removing Slovakia and Poland from the sample. Note: The solid blue lines show the point estimates 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.

To conclude, similar to Richter et al. (2019), we find that using intensity-adjusted indices changes the results on the effects of macroprudential policy. While these authors conclude that the '-1/0/+1' approach overestimates the effects of LTV limits on output, we find that using a dummy approach leads to insignificant results when looking at the effects on household credit until 2019. Because of the simple approach that disregards the intensity of the regulatory changes, standard indices are thus not able to capture the effects of the multi-dimensional macroprudential policy toolkit to the same extent. 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 the composition of the sample, to the timing of the macroprudential policy shock or to different constructions of the intensity-adjusted indices and find that our baseline result are broadly consistent.

5.4.1. Country outliers

To check whether our results are sensitive to country outliers, we estimate equation (1) iteratively while deleting 1 country from our sample[14]. Figure 10 shows that 27 out of 28 IRFs fall within the error bands of the baseline estimates, showing no noticeable differences with our baseline results. When removing Hungary from the sample, the estimated effects lie outside this error band with a negative reaction of -7.49% for household credit and -5.74% for housing credit. The error bands of this IRF (the dashed lines) show, however, that the dynamics of credit after a macroprudential policy shock stay very similar with a significant effect after 12 quarters for household credit and after 10 quarters for housing credit. This exercise confirms our conclusion that borrower-based macroprudential policy has been effective in reducing household and housing credit, especially in

[14]Another option would be to split the sample over time (e.g., before and after the GFC). However, this would lead to unreliable estimates, since it reduces the amount of observations in our intensity-adjusted borrower-based macroprudential policy index, especially for the period before the GFC.

the long run. The results are further in line with the earlier conclusion in section 5.2 since Hungary is one of the non-euro area countries.

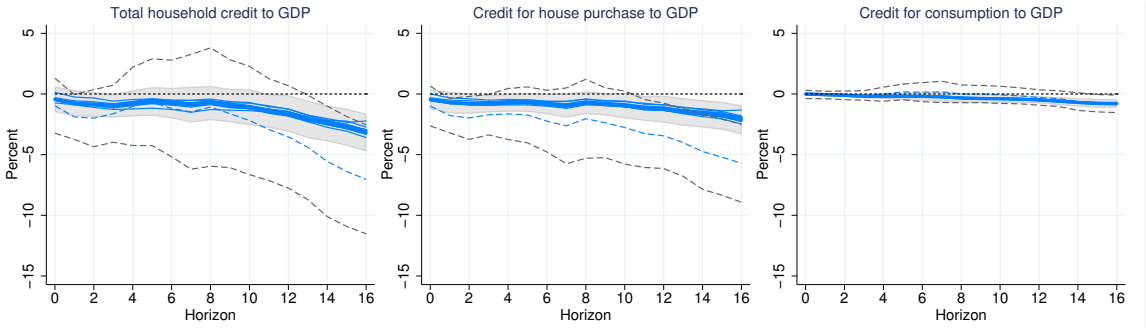

Figure 10: Impulse response functions of credit-to-GDP ratios to a shock in borrower-based macroprudential policy on the full sample while removing one country at a time. Note: The blue lines show the point estimates of the reaction of the variable to a macroprudential policy shock over a horizon of 16 quarters. The grey areas reflect the 90% error bands of the baseline scenario. The dashed lines reflect the point estimate and the 90% error bands of the estimate of the full sample without Hungary.

5.4.2. Announcement versus enforcement date

As a next robustness check, we investigate the sensitivity of the results with respect to the timing of macroprudential changes. The macroprudential indices in this section are dated at the enforcement date instead of the announcement date, capturing both policy changes that were pre-announced (announced in t-i but enforced in t) versus surprise actions ('news shocks'). We compare these results, as shown in figure 11, with results from our baseline model. Similarly, the IRFs show to be significant in the medium- and long-run (after 12 quarters) with coefficients of -2.95% for household credit, -1.88% for housing credit, and -0.73% for consumption credit after 16 quarters suggesting there are no substantial anticipation effects. In contrast to the baseline results, there also is a significant impact in the short run (between quarter 1 and 3). This effect is, however, quite small and short-lived. Moreover, these findings should be interpreted with caution since including anticipated policy shifts could lead to biased results if the effects of anticipated shifts are systematically related with the news shocks (as with multiple-year fiscal consolidation plans).

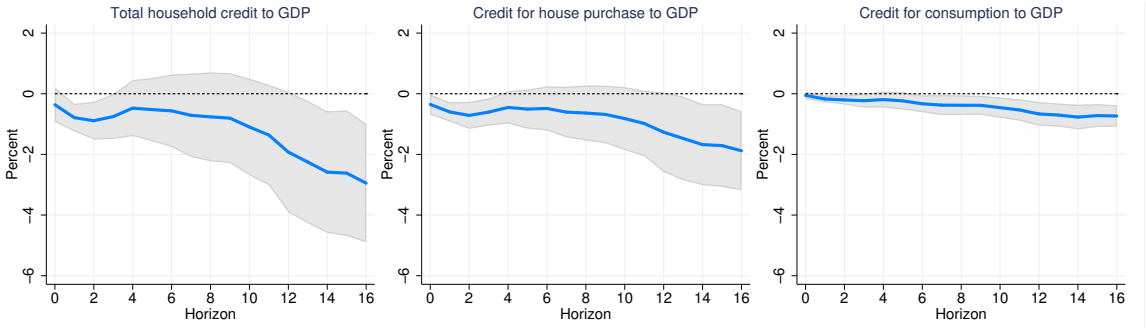

Figure 11: Impulse response functions of credit-to-GDP ratios to a shock in borrower-based macroprudential policy (LTV, DSTI, DTI, and LTI limits) dated at enforcement date. Note: The solid blue lines show the point estimates of the reaction of the variable to a macroprudential policy shock over a horizon of 16 quarters. The grey areas reflect the 90% error bands.

5.4.3. Cumulative intensity-adjusted indices

An alternative way of using the intensity-adjusted indices is to measure the effects of the restrictiveness of the macroprudential policies in place (i.e., the level) on the credit series instead of using a shock approach that captures the changes in the restrictiveness. Therefore, in this next robustness check, we estimate our baseline model while substituting the macroprudential shocks by cumulative versions of our intensity-adjusted indices. The results of this estimation can be found in figure 12. Using this measure, we find very similar dynamics with, however, more moderate effects of borrower-based macroprudential policy on household (-1.35%), housing (-1.23%) and consumption credit (-0.35%) in the long run compared to the baseline results.

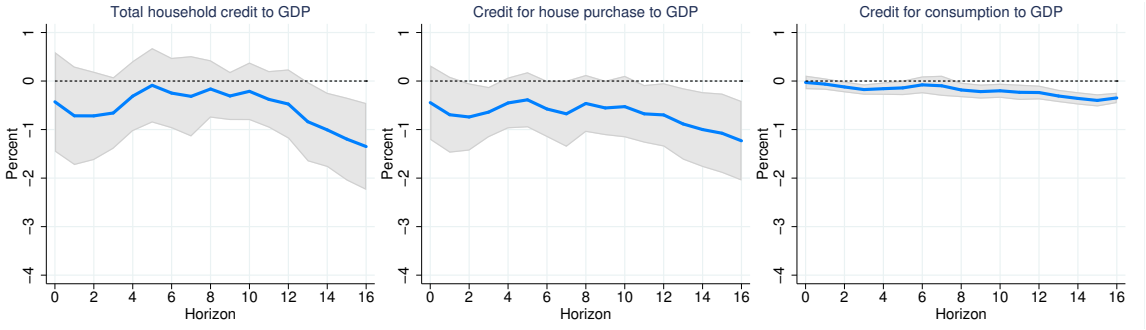

Figure 12: Impulse response functions of the reaction of credit-to-GDP ratios to stance of borrower-based macroprudential policy (LTV, DSTI, DTI, and LTI limits). Note: The solid blue lines show the point estimates of the reaction of the variable to a macroprudential policy shock over a horizon of 16 quarters. The grey areas reflect the 90% error bands.

5.4.4. Weighting schemes

As mentioned in section 3, the baseline weighting scheme gives the largest weight to the scope and the restrictiveness of the limit for borrower-based measures and to the market-share-adjusted limit for the lender-based measures compared to the value for the legal consequences. In this robustness check, we use a different weighting scheme where the weights are equally divided between the scope, restrictiveness of the limit and legal consequences for borrower-based measures, and between the market share and legal consequences for lender-based measures. The exceptions are still weighted by a small fraction. For details on the different weighting schemes, we refer to Appendix A. The results can be found in figure 13 and are very similar to our baseline results for all credit variables, while now the reaction of credit to a shock in macroprudential policy becomes significant around 1 or 2 quarters earlier than in the baseline scenario. In a third variation of the weighting scheme, more importance is given to the legal consequences relative to the baseline scenario and less to the scope or market-share. We obtain similar results to the results using the second weighting scheme (see figure 14).

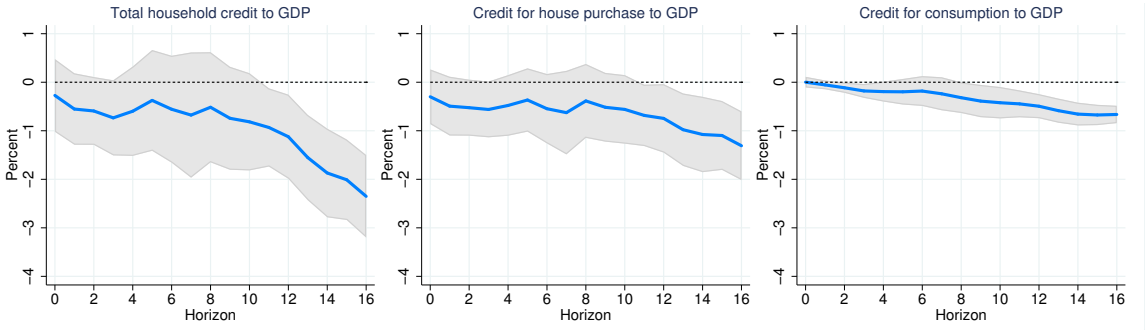

Figure 13: Impulse response functions of the reaction of credit-to-GDP ratios a shock in borrower-based macroprudential policy (LTV, DSTI, DTI, and LTI limits) in the full sample of 28 EU countries using a different weighing scheme (version 2) to construct the intensity-adjusted indices. Note: The solid 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.

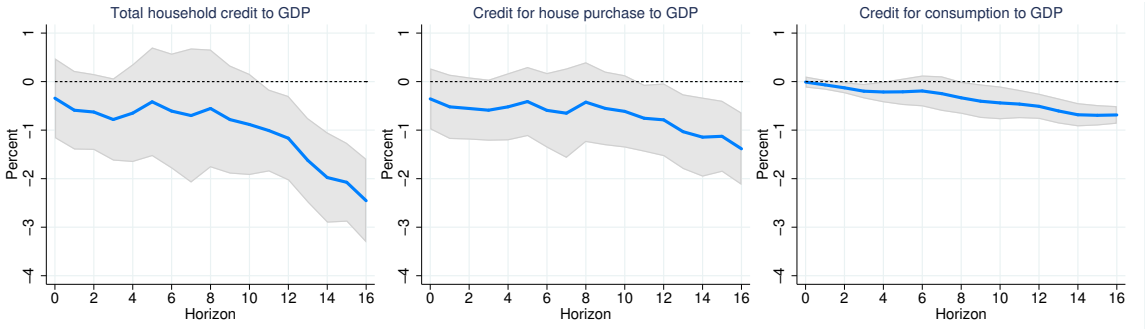

Figure 14: Impulse response functions of the reaction of credit-to-GDP ratios a shock in borrower-based macroprudential policy (LTV, DSTI, DTI, and LTI limits) in the full sample of 28 EU countries using a different weighing scheme (version 3) to construct the intensity-adjusted indices. Note: The solid 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 policy announcements on a large set of macroprudential policy instruments at the country level. In contrast to the existing approaches, we use actual micro-level data to determine the restrictiveness and bindingness of a policy implementation. These indices are subsequently used to assess the effects of borrower-based macroprudential policy on household, housing, and consumption credit in the EU between 1995Q1 and 2019Q4 while controlling for the simultaneous implementation of borrower-based tools with other types of macroprudential policy instruments.

Our results indicate that borrower-based macroprudential policy in the EU was effective in reducing household, housing credit 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), De Schryder and Opitz (2020), and Poghosyan (2020). Our findings furthermore show that macroprudential policy is a crucial tool to stabilize financial imbalances, which is especially relevant for member states of the euro area given the more limited possibilities to differently treat individual countries within a common monetary policy framework.

Importantly, we find that using intensity-based indices changes the conclusions compared to the results obtained when using standard dummy approaches. In particular, our estimates suggest

that the typical '-1/0/+1' index and the alternative index that counts the amount of tightenings and loosenings in a quarter underestimate the effects of borrower-based macroprudential policy on household, housing, and consumption credit, and are more sensitive to outliers compared to the intensity-adjusted indices. Together, this shows that standard dummy approaches used to measure macroprudential policy are not able to capture the effects of borrower-based macroprudential policy tools which vary in their intensity. As confirmed by de Jong and de Veirman (2019) for the Netherlands, we conclude that it is important to take account of the fact that macroprudential policy is multi-dimensional, that a macroprudential limit 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 or misleading results.

Our results have important policy implications, since they shed a new light on the effectiveness of macroprudential policy implementations. A better knowledge of these effects 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.

Given the lack of variation in the different instruments at the national level, the current intensity-adjusted indices are not able to provide evidence on the effects across countries of a given change in one particular macroprudential instrument. Future research could further investigate this limitation.

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Appendix A. Construction of the intensity-based indices

This appendix explains in detail how the intensity-adjusted indices are being 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[15]. The dataset is periodically updated until 2017 and is complemented with data from national legislation and central bank statements to update the database and pick up any missing information on more recent policy implementations (using e.g., the ESRB database and documents on the Basel regulations, cf. infra)[16]. The database eventually covers information on policy announcements and implementations from 1995-2019.

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.

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 ratio
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 shocks in the residential mortgage market. Moreover, 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

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

[16]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.

proportion of bank lending. 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: *"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 limits, for DSTI limits, for DTI limits, for 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. 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[17] 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

[17]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.

(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[18]. 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 not yet published.

An important **advantage** of the HFCS is the fact 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 reports the crucial characteristics of these loans such as the LTV, DTI, and DSTI ratio, and information on mortgage payments and interest regulations. Moreover, due to the cross-section dimension of the database, we can pick up country-specific characteristics of household lending (e.g., in case the importance of certain lending measures varies across countries).

The HFCS are conducted in a way that the questioned households are considered to be a representation of the total population in the country of interest and are thus representative to measure household lending. To quantify the scope of a macroprudential policy implementation, we calculate **the proportion of household loans 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, ...). 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).

Using HFCS data, however, also puts some restrictions to our data sample. The first wave of the survey was only conducted in 2010, which means that our data sample cannot include time periods before that wave. All macroprudential policy implementations/changes that happened before this date, are thus not included in the intensity-based indices. Since the survey has not been conducted every year, we are using data from the first wave for all macroprudential announcements/implementations between 2010 and 2013. For implementations between 2014 and 2016, data from the second wave is used and for implementations from 2017 on, data from the third wave is used. Moreover, not all countries that use macroprudential policy tools have participated in the survey (such as Czech Republic and Romania) or only since the second or third wave (such as Poland and Hungary).

Appendix A.2.2. Restrictiveness of the quantitative limit

In a next step, we look at the imposed quantitative limits[19]. A lower quantitative limit is considered to be more strict. In some cases, the limits have some quantifiable exceptions for which we calculate an adjusted limit. In Slovakia, for example, the

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

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

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%. By taking the average of the two extreme cases[20], we establish the percentage of 90,5% as the adjusted score. In 2015, up to 15% of the loans were allowed to have an LTV ratio between 90% and 100%. Using the same logic, the adjusted score for the quantitative limit is 90.38%. The lower score reflects the tightening compared to the previous measure.

To capture the restrictiveness of the imposed quantitative limit correctly, we **compare this number** (e.g., 70%, or the adjusted score, calculated as explained above) **to the median ratio of the specific macroprudential measure** in a given country, time period, and loan category. The median ratio is again calculated using HFCS data. To illustrate, the median LTV ratio for loans for house purchase in 2017 in Slovakia was 49,2%, compared to the median LTV ratio for all loans that was 40%.

By comparing the limit to the median ratio, we get an indication of how binding the limit is, since imposing a lower limit than the current median ratio in a country is considered to be more far-reaching than imposing a limit higher than the current median ratio. Therefore, we compute the difference of these two values. To obtain a number between zero and one, we normalize this series. The higher the value for this normalized difference, the more restrictive the implementation is considered.

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
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 category two to six. Again a higher value represents a more restrictive rule. For obvious reasons, category one gets the value '0'. Category two and three get '0.1', category four gets '0,15' and finally category five and six 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). The intuition behind the quantification of the legal consequences is the same for all the other categories of macroprudential instruments.

[20]Case 1: 0% of the loans is higher than 90% *(score: 0.9)*. Case 2: 20% of the loans has an LTV ratio between 90% and 100%, where we take the average, here 95%, as an approximation for the LTV limit on all these loans *(score: 0.8*0.9+0.2*average(0.9;1) = 0.91)*.

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 (more/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'.

The score is tied to the time (month) and country of implementation, such that the index has a panel dimension. 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 at the same moment, 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. The intuition in this paragraph is common to the intensity-adjusted indices for all macroprudential categories.

Appendix A.3. Risk weights

Risk weights are rules that financial institutions have to take into account 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 percentage. 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%."*

As highlighted by Damen and Schildermans (2021), in some countries, the risk weight regulation only applies to financial

institutions using internal ratings-based (IRB) approach (e.g. internal risk models) to calculate required capital or to financial institutions that use the standardized (SA) approach. Most large banks use the IBR for a considerable part of their portfolio. However, another part of the portfolio is still evaluated through the SA approach and the majority of the risk weight implementations in the MaPPED were indicated to apply to SA approach calculations. Since there is no data readily available on the particular approach used by banks for the time period and countries we investigate, we are not able to take account of this distinction in our intensity-adjusted indices.

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

We are again able to use HFCS data to quantify the importance of the scope as the HFCS database reports information on loans to households backed by different types of property (e.g., residential real estate loans) and their LTV ratio's. 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.

The imposed risk weight is simply taken as given (e.g., 35%) since banks typically do not use higher weights than the imposed rules since 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 '0,6'. The quantification of the legal consequences follows the logic explained in section Appendix A.2.3. This value is weighted by '0,4' in the baseline scenario. Since there are no exceptions in the risk weight regulation, we do not take this into account as a separate category. Table A.2 illustrates the construction of the index using data for the previous Austrian example.

Scope	**Imposed risk weights**	**Product**	**Sum**	**Legal**	**Final value**
			0,6	*0,4*	
0,372689826	35%	0,130441439	0,16124	0,65	**0,25899378**
0,030800787	100%	0,03080			

Table A.2: 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 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 sum ('0.4').

Given the high divergence of the rules in the third category, the small amount of implementations within it (see section Appendix A.13), and the data limitation on commercial property mortgages, we only quantify the first category.

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[21], 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 European Systemic Risk Board (ESRB) database on national capital-based instruments[22]. 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 data. Capital buffers are in the MaPPED divided in 8 subcategories:

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

[21] 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)

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

Appendix A.4.1. Adjusting buffers using market shares

The market share is calculated based on yearly data from S&P global[23] using equation (A.1). This frequently-used database for banking sector analysis covers 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)*. Calculations are always based on the last full year of data available relative to the announcement/enforcement date[24]. The caveat of this approach is that we have to rely on the data reported in the S&P global, which also reports missing values for a minority of institutions and time periods.

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

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.3 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 '0.318' 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 percentage point 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'[25]), 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	18.29%	0.75	1.5	2.25	3	
Rabobank	15.54%	0.75	1.5	2.25	3	
ABN AMRO Bank	8.64%	0.75	1.5	2.25	3	
Value		**0.318**	**0.637**	**0.955**	**1.274**	
Changes in value		**0.318**	**0.318**	**0.318**	**0.318**	***1.274***

Table A.3: Restrictiveness of the SRB for the Netherlands based on the announcement date

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.4, the buffer is enforced at four different moments, which means we will use four different data series to calculate four different final values.

[23] https://platform.marketintelligence.spglobal.com/web/client?auth=inherit#news/home
[24] e.g., when a capital buffer is announced in 2015Q1/2/3/4, we use data from 2014.
[25] 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	21,6%	0.75	24,13%	1.5	25,33%	2.25	28.71%	3
Rabobank	16.96%	0.75	17.19%	1.5	16.86%	2.25	19.01%	3
ABN AMRO Bank	10.10%	0.75	11,21%	1.5	10.89%	2.25	12.07%	3
Final value		**0.39**		**0.79**		**1.19**		**1.8**

Table A.4: Restrictiveness of the SRB for the Netherlands based on the enforcement date

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

The quantification of the legal consequences[26] 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').

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 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 ratio for market shares. We will 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 buffer 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 adjusted buffer 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 buffer ('0.4').

[26]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.

Appendix A.6. Leverage ratio's

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 (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').

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 '-1', '-3' or '-1,5'. 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'.

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

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 percentage points annually to reach 100% on 1 January 2018 (BIS, 2021a). However, the 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 will 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'. 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').

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, ratio's 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.

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. Exposure 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 the 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

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 implementation 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 present the indices graphically, showing the change in the indices per category i.e., the series used in our empirical analysis in section 4.1. The graphs are based on the announcement dates. This section furthermore provides information on the amount of observations that the intensity-based indices are able to cover compared to (updated) MaPPED database. These tables are made based on the full sample of 28 European countries, ranging from 1995 to 2020. 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).

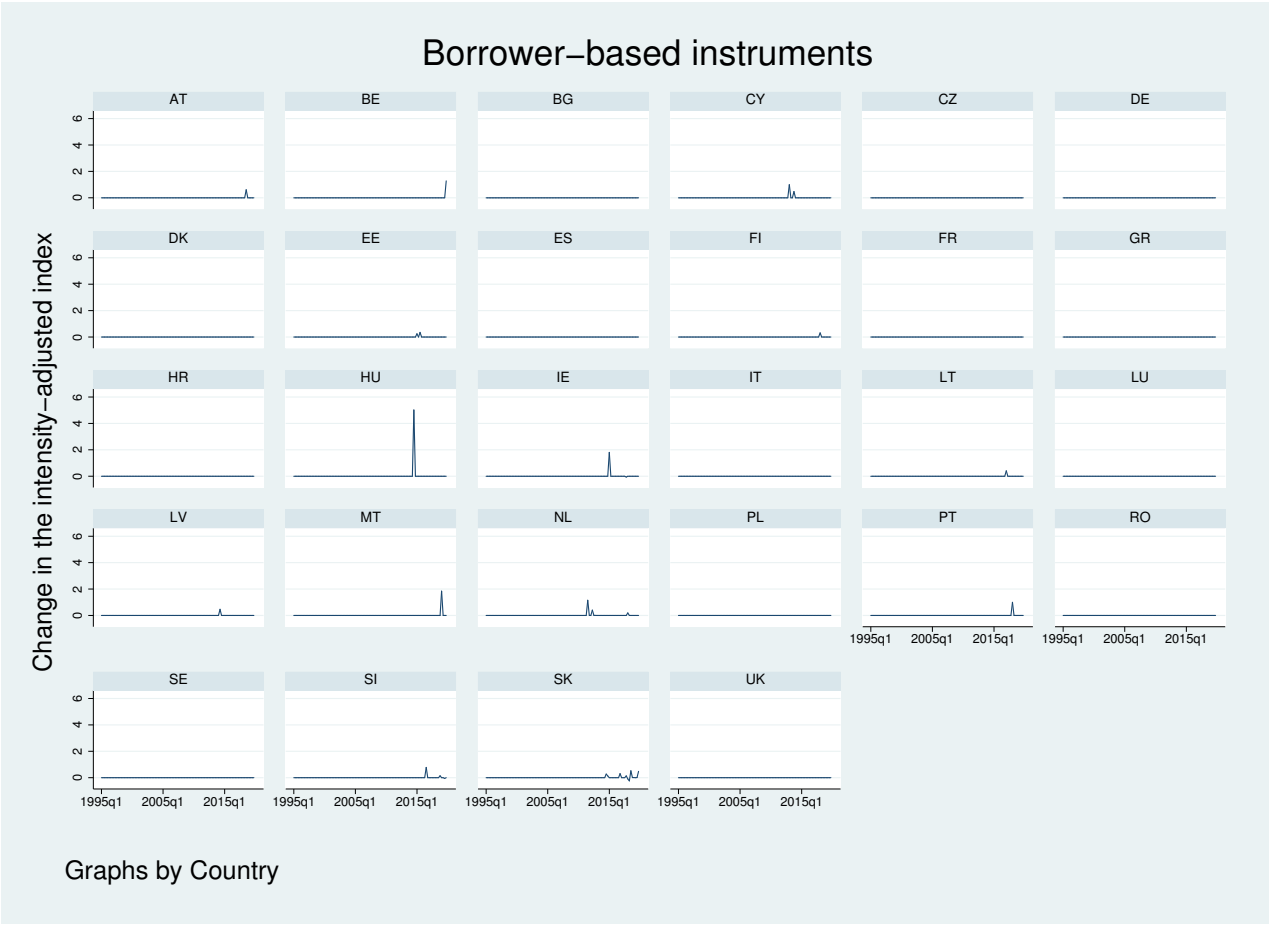

Figure A.1: This figure shows our macroprudential shock for borrower-based instruments (including LTV, D(S)TI, and LTI limits) across countries. The shock is the change in the intensity-adjusted index for borrower-based instruments. The flat lines show that there were no policy announcements or that we could not construct an intensity-adjusted index for these announcements.

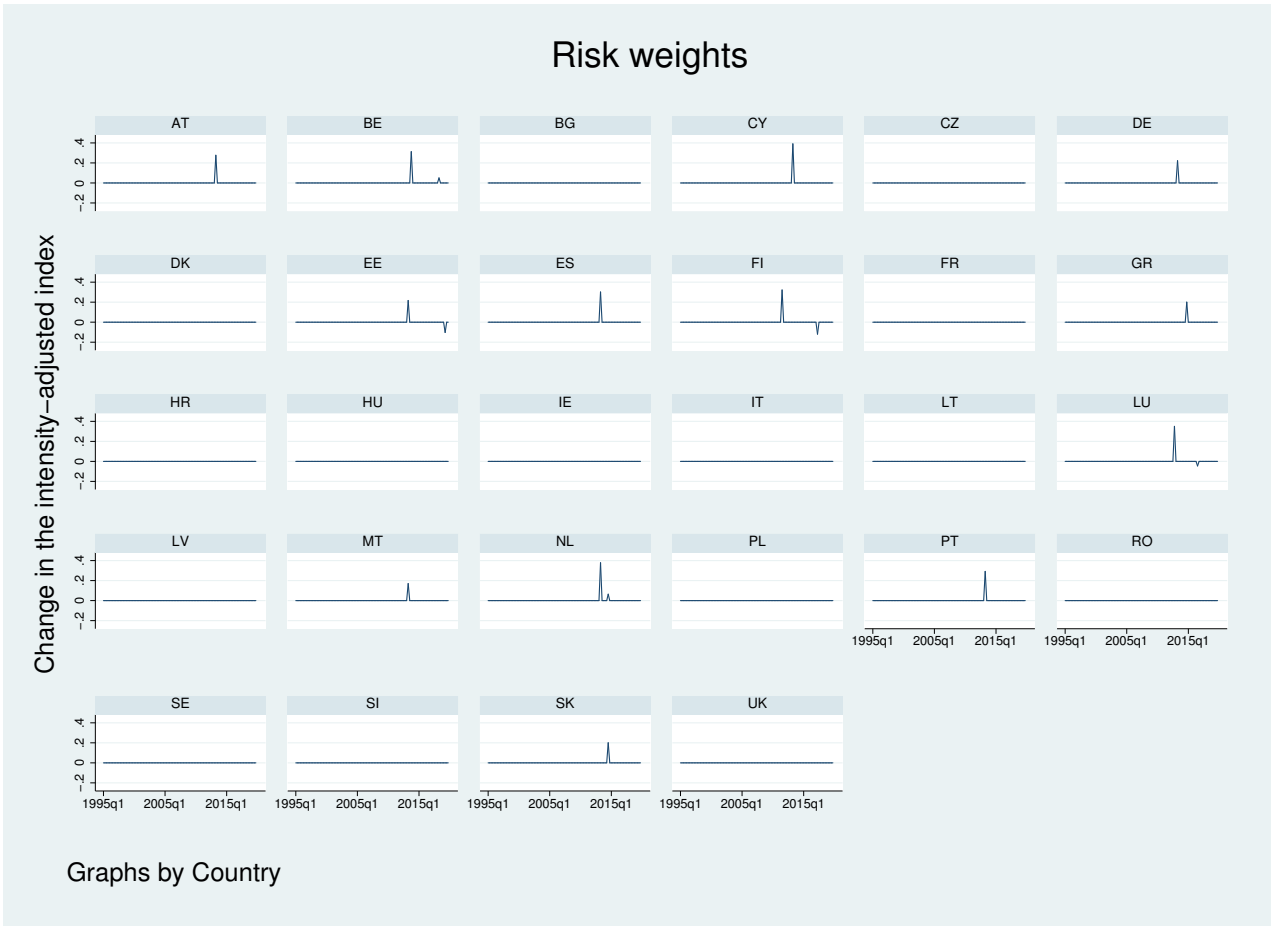

Figure A.2: This figure shows the change in the intensity-adjusted index for risk weights across countries. The flat lines show that there were no policy announcements or that we could not construct an intensity-adjusted index for these announcements.

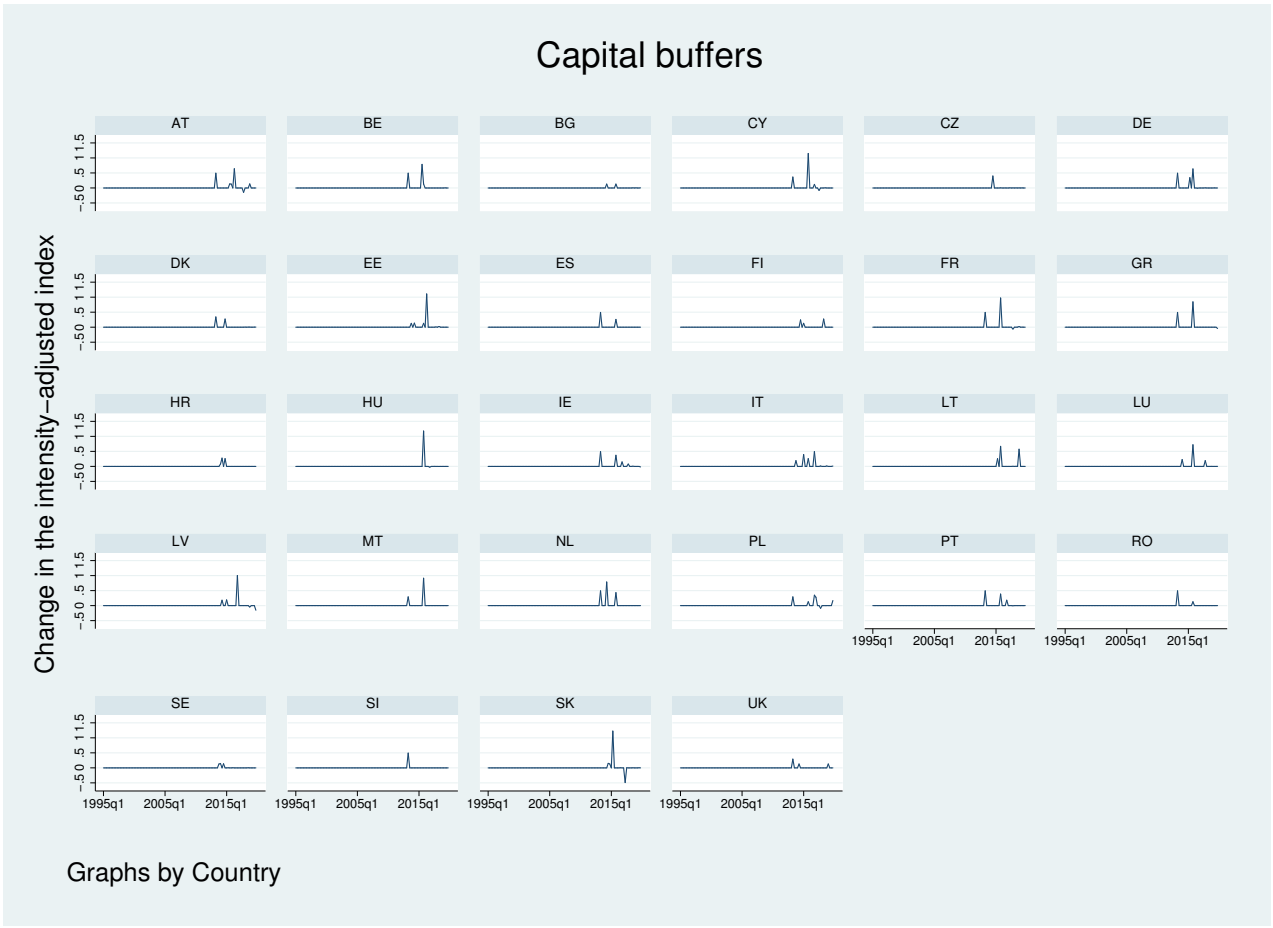

Figure A.3: This figure shows the change in the intensity-adjusted index for capital buffers across countries. The flat lines show that there were no policy announcements or that we could not construct an intensity-adjusted index for these announcements.

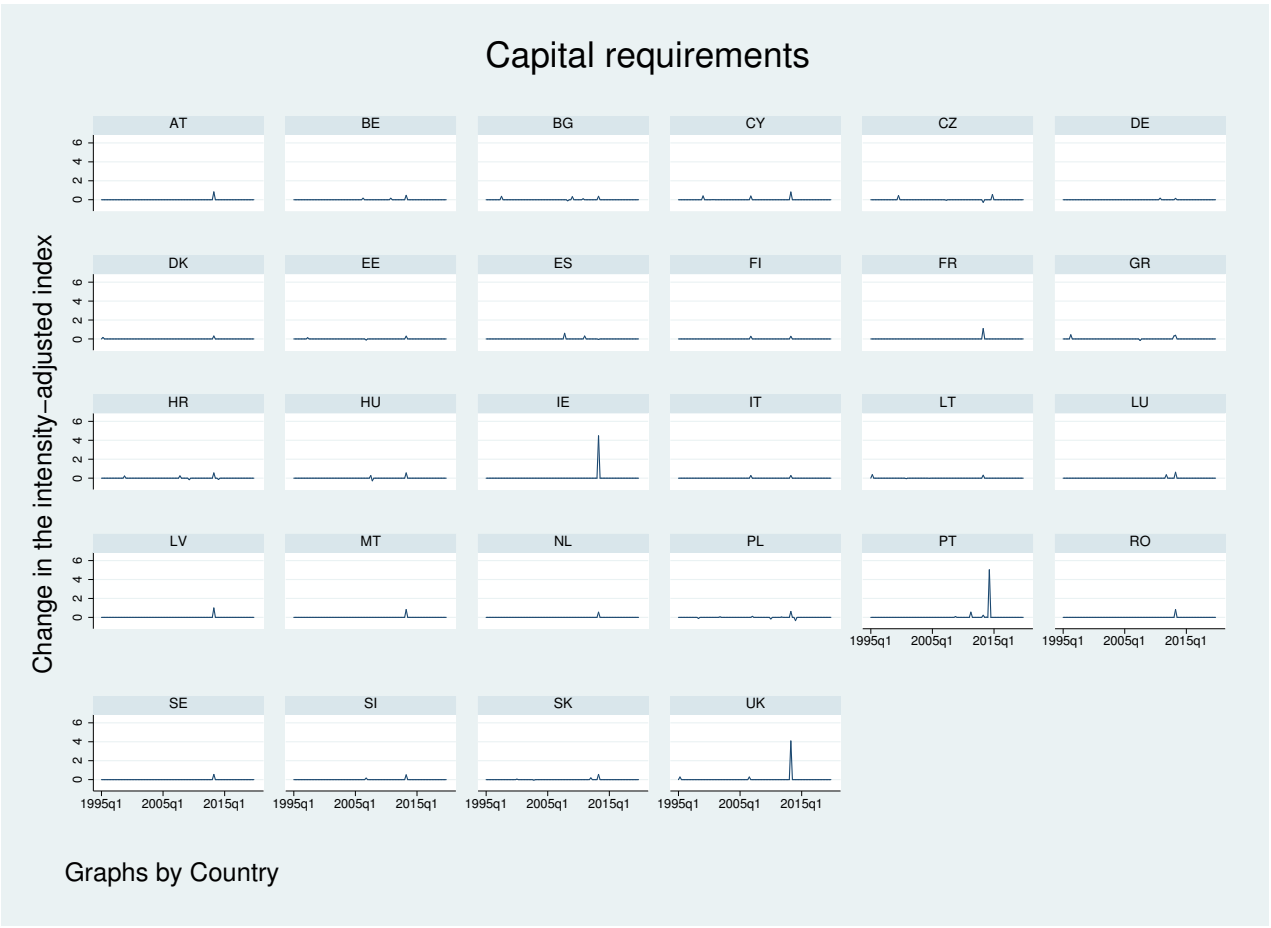

Figure A.4: This figure shows the change in the intensity-adjusted index for capital requirements across countries. The flat lines show that there were no policy announcements or that we could not construct an intensity-adjusted index for these announcements.

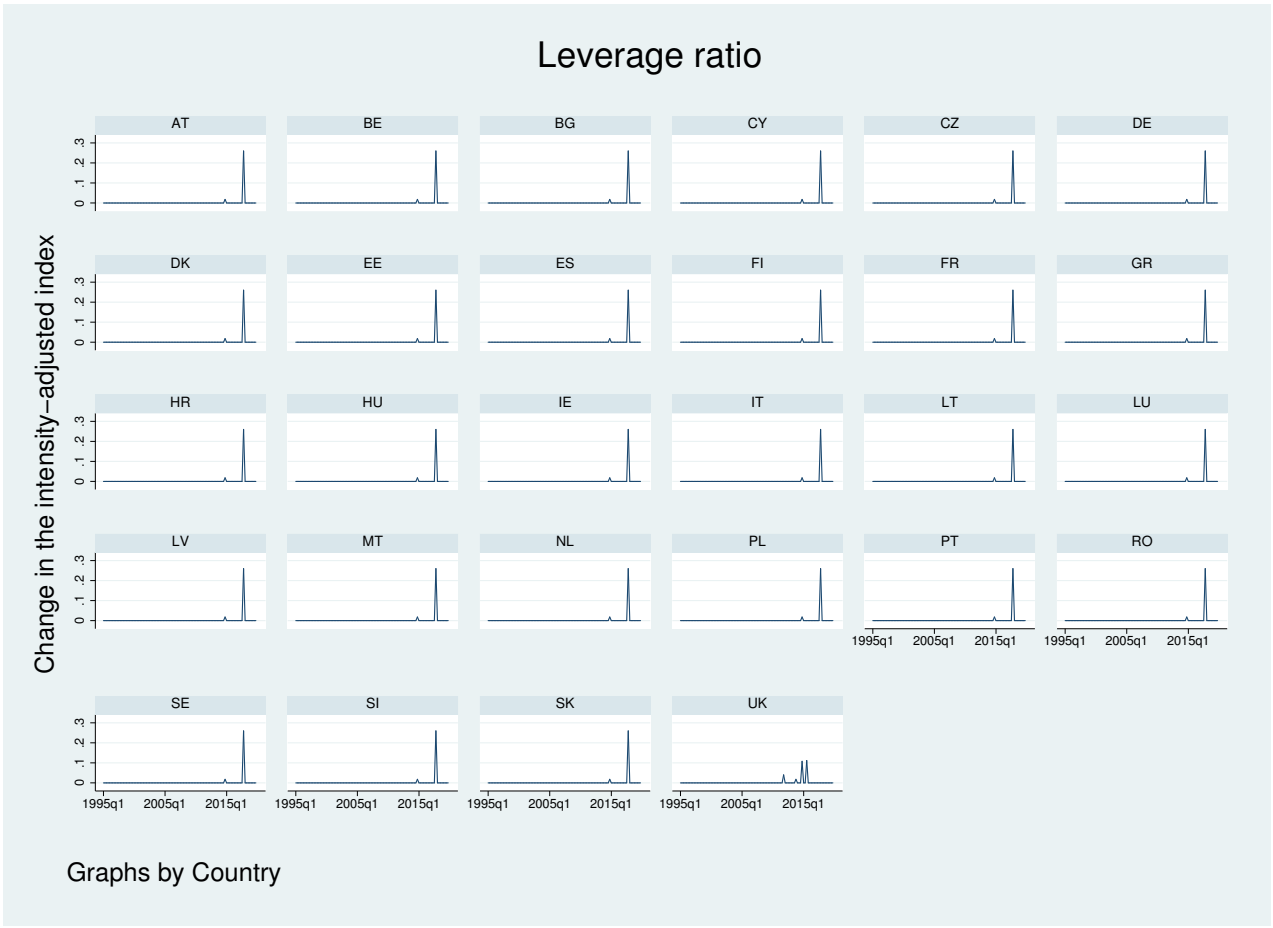

Figure A.5: This figure shows the change in the intensity-adjusted index for the leverage ratio across countries. The flat lines show that there were no policy announcements or that we could not construct an intensity-adjusted index for these announcements.

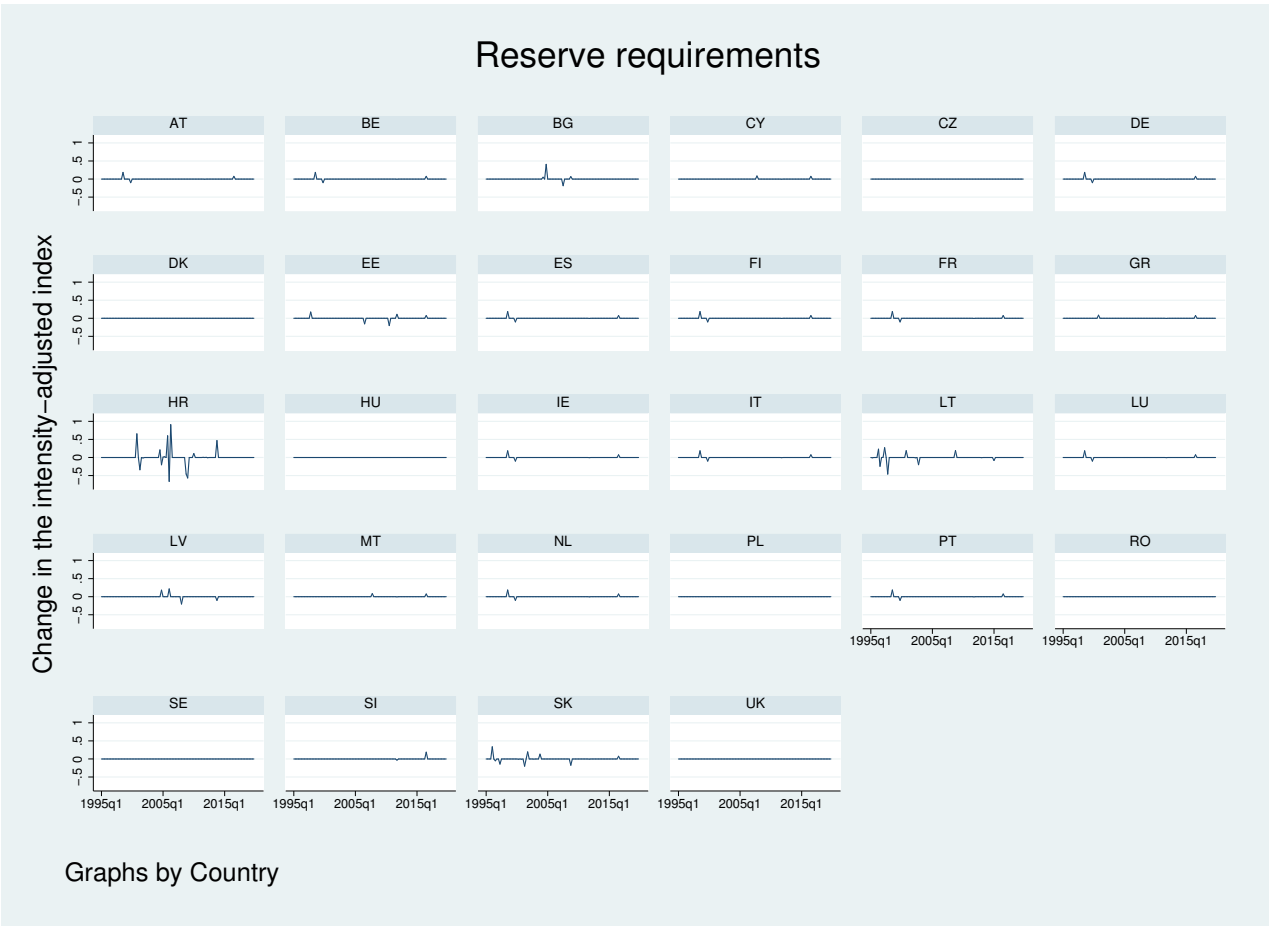

Figure A.6: This figure shows the change in the intensity-adjusted index for reserve requirements across countries. The flat lines show that there were no policy announcements or that we could not construct an intensity-adjusted index for these announcements.

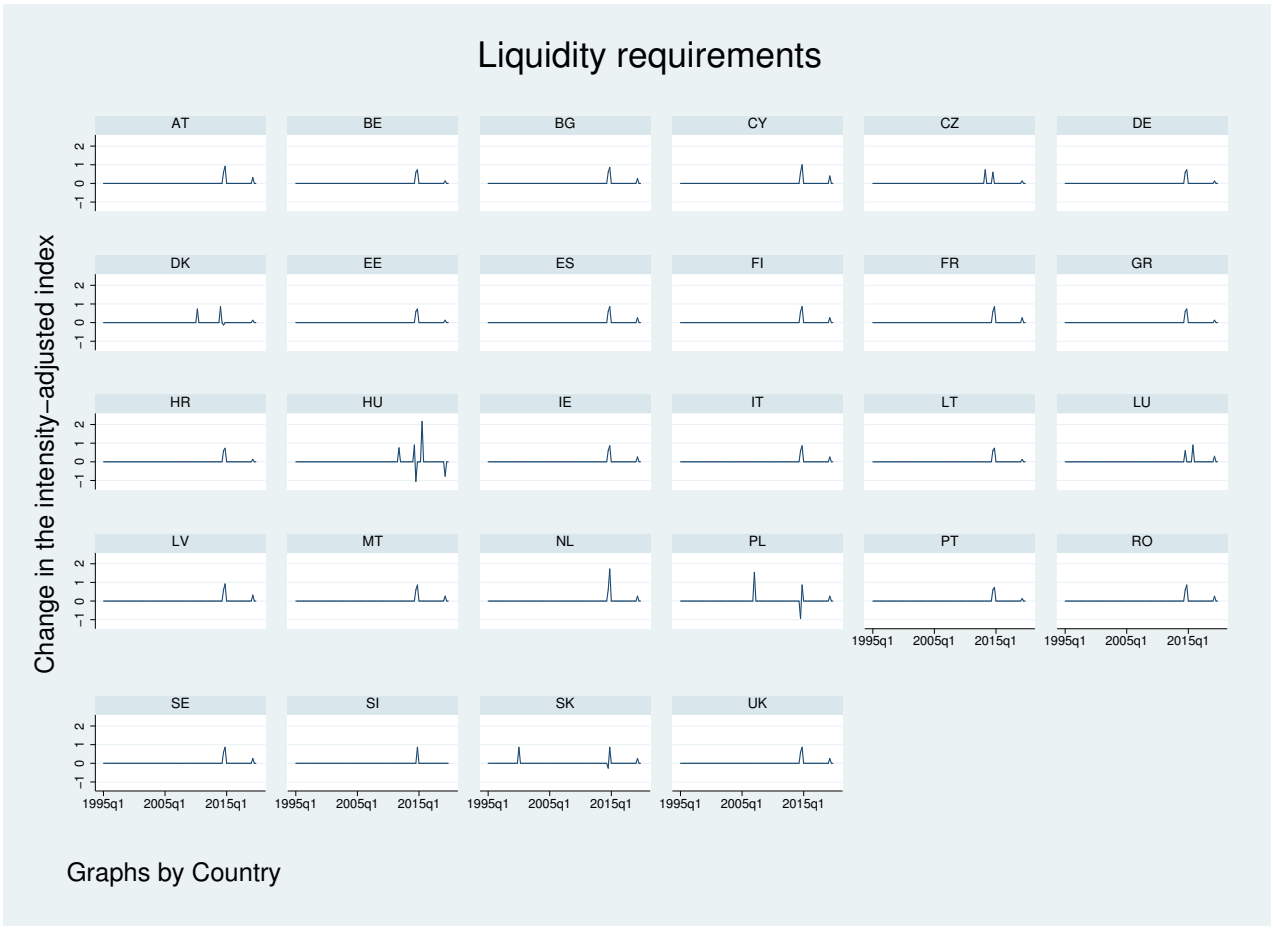

Figure A.7: This figure shows the change in the intensity-adjusted index for liquidity requirements across countries. The flat lines show that there were no policy announcements or that we could not construct an intensity-adjusted index for these announcements.

	MaPPED	Updated MaPPED	Intensity index Ann	Intensity index Enf
Borrower-based instruments				
LTV limit	76	97	42	48
DSTI limit	31	62	25	26
DTI limit	2	14	8	8
LTI limit	1	5	3	3
Maturity and amortization restrictions	29	43	13	13
Limits on interest rates on loans	8	-	-	-
Limits on the volume of personal loans	38	-	-	-
Other income requirements for loan eligibility	6	-	-	-
Other restrictions on lending standards	46	-	-	-
Risk weights				
Risk weights on loans backed by residential property	86	95	21	24
Risk weights on loans backed by commercial property	55	-	-	-
Other sectoral risk weights	16	-	-	-
Capital buffers				
Countercyclical capital buffer (CCyB)	13	69	69	69
Systemic risk buffer (SRB)	17	46	21	29
Capital conservation buffer (CCB)	18	78	78	78
Buffers for GSII	5	23	7	18
Buffers for OSII	10	93	60	70
Profit distribution restrictions	17	-	-	-
Other capital requirements targeting most important institutions	12	-	-	-
Other capital surcharges and own funds requirements	20	-	-	-
Minimum capital requirements				
Capital adequacy ratio (CAR)	167	167	145	145
Common Equity Tier 1 capital ratio (CET1)	37	36	36	36
Tier 1 capital ratio	39	40	40	40
Core Tier 1 capital ratio	9	9	9	9
Leverage ratio's	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	-	-	-
Liquidity requirements and limits on currency and maturity mismatch				
Loan-to deposit (LTD) limits	6	-	-	-
Short-term liquidity coverage ratios incl. LCR	102	191	31	133
Liquidity ratios and deposit coverage ratios	26	-	-	-
Limits on FX mismatches	36	-	-	-
Other stable funding requirements incl. NSFR	15	71	68	68
Other liquidity requirements	35	-	-	-
Limits on large exposures and concentration				
Single client exposure limits	193	-	-	-
Intragroup exposure limits	55	-	-	-
Limits on qualified holdings outside the financial-sector	104	-	-	-
Funding concentration limits	5	-	-	-
Sector and market segment exposure limits	38	-	-	-
Other exposure and concentration limits	24	-	-	-
Loan-loss provisioning				
Loan classification rules	56	-	-	-
Capital treatment of loan loss reserve	21	-	-	-
Minimum specific provisioning	44	-	-	-
General provisioning	26	-	-	-
Levy/tax on financial institutions and activities	45	-	-	-
Other measures				
Limits on deposit rates	7	-	-	-
Crisis management tools	57	-	-	-
Structural measures	5	-	-	-
Margin requirements	19	-	-	-
Debt resolution policies	45	-	-	-
Changes in regulatory framework	16	-	-	-
Other regulatory restrictions on financial activities	8	-	-	-
Other	42	-	-	-

Table A.5: Number of observations per (sub)category.

	MaPPED	Updated MaPPED	Intensity index Ann	Intensity index Enf
Borrower-based instruments				
LTV limit	21	22	14	15
DSTI limit	19	19	8	9
DTI limit	3	3	1	1
LTI limit	4	4	2	2
Maturity and amortization restrictions	11	19	9	9
Limits on interest rates on loans	5	-	-	-
Limits on the volume of personal loans	1	-	-	-
Other income requirements for loan eligibility	5	-	-	-
Other restrictions on lending standards	13	-	-	-
Risk weights				
Risk weights on loans backed by residential property	28	28	13	16
Risk weights on loans backed by commercial property	25	-	-	-
Other sectoral risk weights	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	28	28
Buffers for GSII	2	7	4	4
Buffers for OSII	5	20	19	19
Profit distribution restrictions	9	-	-	-
Other capital requirements targeting most important institutions	7	-	-	-
Other capital surcharges and own funds requirements	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 ratio's	2	28	28	28
Limits on credit growth and volume				
Reserve requirements related to banks' liabilities	7	28	28	28
Asset-based reserve requirements	5	-	-	-
Liquidity requirements and limits on currency and maturity mismatch				
Loan-to deposit (LTD) limits	5	-	-	-
Short-term liquidity coverage ratios incl. LCR	28	28	28	28
Liquidity ratios and deposit coverage ratios	7	-	-	-
Limits on FX mismatches	6	-	-	-
Other stable funding requirements incl. NSFR	6	28	28	28
Other liquidity requirements	12	-	-	-
Limits on large exposures and concentration				
Single client exposure limits	28	-	-	-
Intragroup exposure limits	25	-	-	-
Limits on qualified holdings outside the financial-sector	27	-	-	-
Funding concentration limits	2	-	-	-
Sector and market segment exposure limits	15	-	-	-
Other exposure and concentration limits	6	-	-	-
Loan-loss provisioning				
Loan classification rules	18	-	-	-
Capital treatment of loan loss reserve	9	-	-	-
Minimum specific provisioning	12	-	-	-
General provisioning	9	-	-	-
Levy/tax on financial institutions and activities	17	-	-	-
Other measures				
Limits on deposit rates	3	-	-	-
Crisis management tools	2	-	-	-
Structural measures	4	-	-	-
Margin requirements	1	-	-	-
Debt resolution policies	1	-	-	-
Changes in regulatory framework	2	-	-	-
Other regulatory restrictions on financial activities	2	-	-	-
Other	15	-	-	-

Table A.6: 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 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
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)
Crisis dummy	Dummy for systemic banking crises	Laeven and Valencia (2020)

Table B.1: Data variables and their sources.

	Mean	Std. Dev.	Min	Max	N
Intensity-adjusted index for borrower-based macorprudential policy (LTV, D(S)TI and DTI limits)	0.01	0.12	-0.24	5.02	2,800
Intensity-adjusted index for borrower-based macorprudential policy (LTV, D(S)TI, DTI, and maturity limits)	0.01	0.14	-0.24	5.02	2,800
Intensity-adjusted index for LTV limits	0.00	0.11	-0.24	5.02	2,800
Credit to households	48.72	26.22	5.81	133.48	1,769
Credit to households for house purchase	31.38	18.07	1.53	70.52	1,778
Credit to households for consumption	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	1.92	5.14	-7.63	33.00	2,315
Systemic banking crisis dummy	0.13	0.34	0.00	1.00	2,800

Table B.2: Descriptive statistics on the key variables used in equation 1.