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A Stress Test Approach to the Calibration of Borrower-Based Measures: A Case Study of the Czech Republic

Jiří Gregor *

Abstract

This paper focuses on the calibration of borrower-based measures using a semi-structural modelling framework and defines two approaches to the setting of these measures. The first approach takes into account the magnitude of losses in the mortgage portfolio and the associated absorption potential of banks, while the second, preferred approach, considers both the benefits of regulation in terms of loss reduction and its costs manifested as foregone profits. This approach thus facilitates the optimization of the macroprudential strategy to minimize Type I error (no regulation) and Type II error (excessive regulation). The case of the Czech Republic serves as an illustrative example, demonstrating that borrower-based regulation appears unnecessary and costly during periods of low credit growth, specifically in the downward phase of the credit cycle. However, if any regulation is preferred with respect to other factors and circumstances that are not captured by the modelling framework, a purely loan-to-value regulation shows the best results in terms of cost-benefit analysis.

Abstrakt

Tento článek se zaměřuje na kalibraci nástrojů zaměřených na dlužníky s využitím semistrukturálního modelového rámce a definuje dva přístupy k nastavování těchto nástrojů. První přístup zohledňuje rozsah ztrát v hypotečním portfoliu a s tím související absorpční potenciál bank, zatím co druhý preferovanější přístup zohledňuje nejen přínosy regulace ve smyslu redukce ztrát, ale i její náklady v podobě ušlých zisků. Druhý přístup tak umožňuje optimalizovat makroobezřetnostní strategii tím, že minimalizuje tzv. chyby prvního (žádná regulace) a chyby druhého typu (nadměrná regulace). Na příkladu České republiky pak článek ilustruje, že regulace zaměřená na dlužníky je nákladá a jen málo přínosná v období nízkého růstu úvěrů, tedy v sestupné fázi úvěrového cyklu. Nicméně, pokud je regulace preferována s ohledem i na jiné faktory a okolnosti, které modelový rámec nezachycuje, tak nejlepších výsledků z pohledu analýzy nákladů a přínosů dosahuje regulace skrze poměr výše úvěru k hodnotě nemovitosti (LTV).

JEL Codes: C63, E58, G21, G28, R31.
Keywords: Borrower-based measures, macroprudential policy, mortgage lending, stress testing, systematic risk.

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1. Introduction

During the record rise in property prices in the last couple of years, the sustainability of households' debt has been highly contested by policymakers and researchers alike, and macroprudential policy has become a central topic in national discussions. This is also due to the fact that the majority of banking crises have been closely associated with the cyclical patterns of property prices (Crowe et al., 2013).

In a broader context, macroprudential policy seeks to address market failures, with particular attention to externalities that have the potential to give rise to systemic risk. The academic literature (Schoenmaker and Wierts, 2011; De Nicoló et al., 2014; Claessens, 2015) identifies three main types of externalities: fire sales, interconnectedness, and strategic complementarities. Fire sales may occur when the value of collateral falls below the outstanding principal, resulting in losses for lenders, especially in economic downturns. Interconnectedness can lead to financial contagion, where shocks propagate across institutions and markets, amplifying risks and undermining financial stability. Strategic complementarities can arise when banks adopt similar risk models and strategies. In many cases, banks' collective disregard for – or inadequate pricing of – risk, as well as their incorrect assessment of the phase of the financial cycle,[1] significantly contribute to the amplification of systemic risk.

Linked to the concept of strategic complementarity is the issue of information asymmetry in the relationship between banks and their clients, as highlighted in the work of Gorton and He (2008) and Claessens (2015). A lowering of credit standards diminishes banks' incentives to rigorously screen new clients, leading to the inclusion of riskier clients and a reduction in the overall quality of the mortgage portfolio. Furthermore, the increased availability of credit as a result of low interest rates and lenient credit standards boosts the demand for credit. In the lead-up to the peak of the credit cycle, households are influenced by two biases: first, regret aversion bias, which underscores the fear of missing out on the opportunity to invest in real estate during a seemingly favorable period, and second, "keeping up with the Joneses" bias, which suggests that real estate purchases are motivated by a desire to conform to a social group rather than a purely rational decision. Moreover, the financial accelerator mechanism further exacerbates pro-cyclicality in the real estate market (Almeida et al., 2006).

Additionally, research by Levina et al. (2019) has highlighted the potential consequences of unregulated mortgage lending, which can lead to more significant corrections in house prices and a heightened risk of widespread borrower default. To temper over-optimism and mitigate the acceptance of excessive risk that could endanger financial stability, macroprudential policy, by setting up a variety of capital requirements and limits on borrower-based measures, corrects for the misbehavior of market participants, particularly during the expansionary phase of the credit cycle.

International financial institutions such as the International Monetary Fund (IMF), European Systemic Risk Board (ESRB), and Bank for International Settlements (BIS) have advocated for the use of macroprudential tools that target borrowers. These tools aim to enhance the resilience of banks' mortgage portfolios to unexpected adverse shocks to the economy. In this paper, I focus exclusively on such tools, specifically on the loan-to-value ratio (LTV), debt-to-income ratio

[1] For instance, a loan in the same amount as the value of the collateral (LTV equals 100) may be sufficient at the beginning of the growth phase of the credit cycle when property prices start to rise but not at the end of the phase when property prices are about to fall. In an ideal world, banks would correctly estimate the phase of the cycle and adequately assess the level of risk accordingly, but in the real world, banks – in their pursuit of profit and in an effort to maintain or increase their market share – underestimate the risk.

(DTI), and debt service-to-income ratio (DSTI). Other macroprudential instruments fall outside the scope of this paper. Nevertheless, the Capital Requirements Directive (CRD) defines the approach for the setting of capital buffers.[2]

Despite the guidelines provided by BIS (2012) and the IMF (2014) that highlight the potential indicators for the appropriate timing of the implementation of borrower-based measures, there has not been a unified approach to the calibration of these macroprudential tools across countries. Debates are still ongoing regarding the timing of individual measures, their format, when to tighten or relax such measures, which measures are most effective in mitigating credit defaults and losses, the optimal levels of these measures in specific situations, whether to introduce them in isolation or in conjunction with other tools, and whether, when easing macroprudential policy, the measures should be entirely deactivated or merely adjusted to borderline values where they exert minimal influence on the market and restrict only exceedingly risky loans.

A number of studies have addressed one or more of these pertinent questions. For instance, Gross and Población (2017) conducted an efficiency comparison between DSTI and LTV caps using a micro-macro model, demonstrating that DSTI regulation yielded superior outcomes in terms of mortgage default rates, while LTV regulation more effectively reduced mortgage losses. Similarly, Górnicka and Valderrama (2020) examined the combined effects of LTV and DSTI limits on the probability of default (PD) and loss given default (LGD), presenting various potential outcomes. However, none of these studies employed detailed borrower-level characteristics to define loan-level PD and LGD.

The primary objective of this paper is to provide additional analytical insights into this matter, contributing to the ongoing discourse and facilitating more informed decision-making in the realm of macroprudential regulation. The paper focuses on the calibration of borrower-based measures through a household stress test approach, comparing portfolio risk indicators, including default rate, loss given default ratio, and expected losses across a five-year scenario with different LTV, DTI, and DSTI settings. Furthermore, the paper delineates two straightforward approaches for the calibration of borrower-based measures, discussing each approach separately, along with their respective advantages and drawbacks. The first approach assesses the optimal borrower-based measures by determining the maximum acceptable losses, either in absolute or relative terms. It selects a combination of borrower-based measures in a manner that ensures losses remain within this predefined limit. This results in multiple acceptable combinations of borrower-based measures, with a preference for the less restrictive options.

The second approach evaluates the borrower-based measures' settings based on a cost-benefit analysis. The approach compares the cost of the regulation in the form of foregone profits from mortgage transactions and the benefits of the regulation in the form of reduced potential losses. It must be emphasised that any regulation comes with significant non-zero costs in addition to the benefits mentioned above. Therefore, the regulator should take these costs into account when calibrating borrower-based measures and should not unnecessarily regulate the banking sector when the potential benefits of regulation tend to be low.

The Czech Republic introduced new borrower-based macroprudential measures alongside various capital requirements in the 2010s in response to the risks associated with the potential overvaluation of residential properties and the increasing likelihood of loan defaults. As of the end of 2022, the Czech National Bank (CNB) has actively maintained limits on the LTV, DTI, and

[2] For more details see Directive (EU) 2019/878.

DSTI ratios at 80%, 45%, and 8.5 times net annual income (90%, 50%, and 9.5 times net annual income respectively for applicants under 36 years). Based on the simulations performed, it appears that borrower-based regulation currently (data to May 2023) provides little added value and carries non-zero costs in the Czech environment. For the given parametric setting of the household stress test and the simulation approach, it turns out that the most stringent regulation under consideration (an LTV of 70%, a DSTI of 40% and a DTI of 7 times net annual income) could reduce banks' losses by CZK 4–14 billion over a five-year horizon based on the economic scenario. However, the costs of such regulation would reach CZK 14 billion over a five-year horizon (almost CZK 3 billion per year). Milder regulation naturally carries lower costs, but the potential benefits in terms of lower expected losses remain relatively small. To summarize, from a cost-benefit analysis perspective, borrower-based regulation seems unnecessary at present. However, if any regulation were to be adopted, regulation through an LTV ratio of 80% alone seems to be optimal.

The rest of the paper is organized as follows. Section 2 provides a brief literature review. Section 3 describes the mortgage loan market in the Czech Republic, introduces the regulation on borrower-based measures in the Czech Republic, and defines possible indicators that could be useful for the setting of borrower-based measures. Section 4 discusses the data used in the analysis. Section 5 explains the modelling framework. Section 6 focuses on the calibration of the borrower-based measures. Section 7 discusses the most pressing regulatory issues. Section 8 concludes.

2. Literature Review

Borrower-based measures have been used widely across countries since the 1990s. For instance, Hong Kong introduced LTV limits in 1991, Malaysia in 1995, and Colombia in 1999. After the turn of the century, numerous other countries, mostly in South Eastern Europe, defined LTV and DTI/DSTI limits but the main wave of introducing macroprudential borrower-based measures occured after the global financial crisis (GFC). At the end of 2022, the majority of EU Member States applied at least one borrower-based tool. LTV (20 countries) and DSTI (13 countries) ratios appear to be the most frequently used.[3] Globally, there has been a stronger tendency to regulate the mortgage market in developing countries compared to advanced economies. However, this ratio has relatively leveled off since the GFC (Claessens, 2015).

The empirical literature focuses mostly on the efficiency evaluation of the borrower-based measures in terms of the limitation of credit growth, growth in house prices, loan defaults, loan losses, and the curbing of lending in foreign currency. For instance, in estimating the efficiency of the borrower-based measures in 49 countries between 2000 and 2010, Lim et al. (2011) find that LTV and DTI ratios, among others, reduce the pro-cyclicality of credit growth. Similarly, using a panel of 119 countries, Cerutti et al. (2017) confirm that LTV and DTI limits have a significant negative effect on credit growth. Also, Alam et al. (2024) confirmed that DSTI and LTV regulation has a significant negative effect on household credit growth in a study conducted on a sample of 134 countries in the period from 1990 to 2016. Nevertheless, they show that the negative effect holds only for emerging markets and developing countries but not for advanced economies. In contrast, they find that LTV limits reduce household prices only in advanced economies. They also confirm the nonlinear effects of LTV regulation on household credit. Tighter regulation (more than or equal to a 10 pp decrease in LTV limits) has lower cumulative effects on credit growth and house prices than looser regulation (less than a 10 pp decrease in LTV limits).

[3] See the regularly updated ESRB overview of national macroprudential measures.

Using difference-in-differences analysis, Aastveit et al. (2020) found that the introduction of LTV limits and their subsequent tightening led to a decline in credit in Norway (the average value of debt and the number of loans decreased). Their results also suggest non-linearity in the relationship between LTV limits and mortgage loans. They confirm that LTV regulation leads to lower debt and lower house prices. Lower debt is then reflected in lower debt repayments, which increases households' financial surplus. On the other hand, LTV limits lead to depletion of households' liquid reserves due to down-payments. According to their results, the decline in liquid reserves may not be temporary but could be long-lasting. This makes households more vulnerable to adverse shocks such as a sharp rise in unemployment.

Lindner and Albacete (2017), who examine the impact of borrower-based measures on household credit and house prices in Austria, confirm non-linearity as well. They find that the effect of macroprudential measures depends on the starting level of LTV, DTI and DSTI limits. Using the general equilibrium framework, Greenwald (2018) finds that income-based macroprudential regulation dampens credit growth and house prices more than LTV or capital-based regulation. Similarly, using data from Ireland, Kelly et al. (2018) find that the LTI ratio is more binding than the LTV and debt service ratios. They stressed the importance of the starting level of borrower-based limits and the timing of the introduction of borrower-based measures.

Another strand of the empirical literature focuses on the impact of regulation on risk indicators such as leverage, probability of default (PD), default rates (DR) and loss rates (LR), among others. For instance, examining the efficiency of macroprudential measures in 48 countries in 2000–2010, Claessens et al. (2013) confirm that LTV and DTI caps reduce the growth of leverage, assets and the non-core to core liabilities ratio during boom times. Nier et al. (2019.) found a non-linear effect of the DSTI limit on the PD in Romania, with the PD increasing rapidly from a DSTI of 50%.

The closest to the approach presented in this paper is the paper by Gross and Población (2017) in which they use a micro-macro model to estimate the PD and LGD. Their approach enables them to simultaneously incorporate caps on the LTV and DSTI ratios, which allows them to assess the effectiveness of the measures. Based on their results, the DSTI limits seem to be more effective in the reduction of excessive risk than LTV limits, but both measures reduce the PD and LGD rate.[4] Jurča et al. (2020) build on the Gross and Población (2017) approach and further extend the model to include new endogenous credit creation. Their results show that a combination of income (DTI and DSTI) and property value (LTV) indicators appears to be the most effective in the reduction of systemic risk, as they are appropriately complementary and reduce the risk of regulatory evasion.

Górnicka and Valderrama (2020), who build the ability to repay on the Harrison and Mathew (2008) default model, also employ a comparable approach to the one used in this paper. They employ simulation techniques to model the PD and LGD. In contrast, the methodology in this paper diverges from theirs, as it leverages micro-level data at the individual loan level, enabling the utilization of the actual portfolio in the simulation. This approach enhances flexibility, allowing the seamless incorporation of non-standard shocks, such as the impact of COVID, tax policy changes, or energy price spikes, into the simulation with a notably high degree of accuracy.

Lastly, beyond its advantages, which undoubtedly include limiting the risk to financial stability, borrower-based regulation carries several disadvantages that should not be overlooked. For instance, individuals seeking to evade regulatory constraints may engage in incorrect property valuations or engage in perilous borrowing from non-bank entities not captured in the credit register (Crowe et al.,

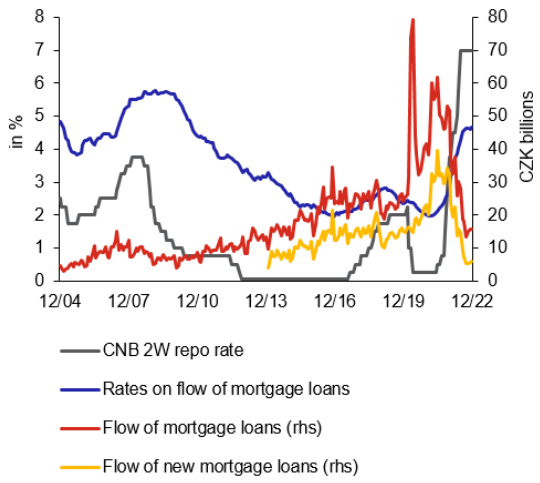
[4] In their paper, effectiveness in their paper is measured by the loss rate.

2013; Hodula et al., 2023). There are also negative impacts at the socio-economic level (Crowe et al., 2013). Regulation pushes less well-off households out of the credit market (lower income households or young families without assets) and thus increases income inequality (Malovaná et al., 2023).

3. Mortgage Market in the Czech Republic

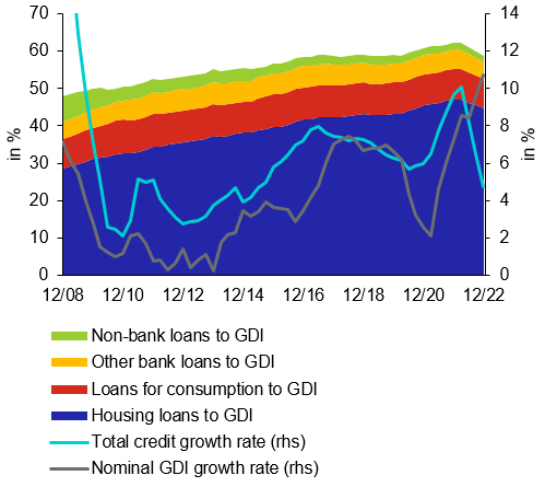
The mortgage market in the Czech Republic began to develop more strongly after the turn of the 21st century. The inflow of new mortgage loans accelerated slightly before 2008, but declining consumer sentiment, rising interest rates and a general tightening of bank lending standards after the GFC slowed the pace. With the exception of the fall in new mortgages in late 2018 and early 2019 due to the increase in monetary policy rates and the introduction of new macroprudential policy measures,[5] the flow of new mortgage loans had been growing since 2010 until the end of 2021, when the energy crisis in Europe, accompanied by high inflation, began to manifest itself, to which the CNB responded with a sharp increase in monetary policy rates (Figure 1 and Figure A1).

Figure 1: Rates and Flow of Mortgage Loans



Source: CNB
Note: The flow of mortgage loans includes new mortgage loans, refinanced loans, and other renegotiations of existing loans. The spike in the flow of new mortgage loans in 2020 lies in the sharp increase in other renegotiations of existing loans due to the COVID-19 pandemic (mostly as a result of the loan moratorium).

Figure 2: Household Indebtedness



Source: CNB

[5] In mid-2018, the CNB introduced two new borrower-based macroprudential instruments: the DTI and DSTI ratios. Both instruments were effective from October 2018 until the outbreak of the COVID crisis, when the established limits were abolished (the DTI in April and the DSTI in July 2021).

In line with the trends in the mortgage market, total household indebtedness has also increased (from 44% in 2008 to slightly below 62% in 2022). The growth in indebtedness has been strongly driven by developments in the housing credit market, where the share of housing loans in the total volume of loans to households rose from nearly 60% to almost 76% (Figure 2). However, the level of indebtedness remains low compared to Western countries such as Germany, France and the UK.[6]

As regards the structure of the mortgage market in the Czech Republic, banks and building societies provide most of the mortgage loans. Three large institutions hold a dominant position on the market, accounting for approximately 60% of new loan origination. In terms of mortgage lending, banks mainly provide fixed-rate loans, with the highest share of loans having a fixation period of 3-5 years (around 50%) in the long term. Variable-rate loans and loans with a fixation period of up to one year represent less than 4% of new loans.

3.1 Characteristics of Mortgage Loans and Borrowers

Examining the micro level of the mortgage market, in 2018–2021, a typical (median) borrower obtained a mortgage loan ranging from 5 to 5.8 times their net annual income, with monthly repayments amounting to 33-34% of their net monthly income. Younger clients (under 36 years of age) secured slightly higher mortgage loans compared to their older counterparts (36 years and older). However, the monthly loan repayment remained generally the same for both groups, attributable to differing maturities. Younger clients predominantly opted for a 30-year mortgage, while older clients favored a mortgage term of 23-25 years. Both age categories inclined toward fixed interest rates, with the typical mortgage loan having a fixed interest rate for 5-6 years. Furthermore, the typical loan demonstrated relatively robust collateralization, with a loan-to-value ratio hovering around 72%. Not surprisingly, the observed trend indicated that younger clients, lacking sufficient accumulated financial assets and alternative property ownership, secured mortgage loans with less collateral than their older counterparts. From the borrower's standpoint, banks predominantly extended mortgage loans to high-income households (relative to the total population), with the primary loan applicant averaging around 36 years old and possessing a university degree (see Table A1).

3.2 Macroprudential Tools

In the Czech Republic, the primary responsibility for financial stability lies with the CNB, which, among other things, seeks to increase the resilience of the financial system through macroprudential policy. In terms of mortgage lending, the CNB mainly uses capital and borrower-based instruments. The capital instruments applied include the countercyclical capital buffer, the systemic risk buffer, the capital buffer for other systemically important institutions, and the capital conservation buffer. However, the setting of capital buffers falls beyond the scope of this paper. For further information, I can refer to the CRD that defines the approach to capital buffer settings.[7] In addition to the overall capital requirements, the CNB may also use sectoral capital requirements linked to, for example, mortgage exposures. However, the CNB has not adopted this measure so far.

The CNB introduced borrower-based measures relatively recently. In 2015, the CNB implemented a limit on LTV, and in 2018 the CNB introduced limits on the DTI and DSTI ratios. Table 1 summarizes the changes in the setting of the individual limits on the LTV, DTI and DSTI ratios.

[6] The share of households with a mortgage loan also confirms the low level of indebtedness as it hovers slightly above 16% (Figure A2). However, this value stems from the household consumption survey, which is not designed for this purpose. Thus, the resulting value may be lower than in reality.

[7] See Directive (EU) 2019/878.

Until the end of 2020, the CNB introduced and changed the limits on the individual measures in the form of recommendations only and the limits were not legally binding for individual banks. However, the CNB has set limits on the measures in accordance with Act No 6/1993 Coll. on the Czech National Bank since 2021 and compliance with them is thus legally binding. In order to increase the affordability of home ownership for young households, the law defines more lenient limits for applicants under the age of 36 who take out a mortgage loan with the purpose of home ownership (Table 1, last column).[8] At the end of 2022, the CNB used three borrower-based measures – the LTV, DTI and DSTI ratios.

Table 1: Limits on Borrower-Based Measures

Date of effect	June 2015	October 2016	April 2017	October 2018	April 2020	July 2020	April 2022
LTV (%)	90 (100)	85 (95)	80 (90)	80 (90)	90	90	80/90* (100)
DTI (net annual income)				9			8.5/9.5*
DSTI (%)				45	50		45/50*

Note: * denotes the limit for applicants under 36 years. The hard limits are in parentheses. The white areas indicate that no limits apply for that period. The colors represent volume exemptions of 5% (yellow), 10% (orange), and 15% (green).

Before delving into the impact of borrower-based measures in the Czech Republic, I should make two noteworthy observations. Firstly, the introduction of the DTI and DSTI ratios in 2018 coincided with a negative media campaign, generating concerns among the public regarding the affordability of mortgage loans. Consequently, there was a pronounced frontloading of mortgage loans prior to the imposition of the limits, followed by a substantial decline after their implementation (see Figure 1). The situation returned to normal during 2019. Secondly, the onset of the COVID-19 pandemic prompted a relaxation of monetary and macroprudential policies. However, this policy shift, coupled with limited consumption opportunities and fiscal support for households, such as the abolition of property tax, a reduction in income tax, and other financial incentives, resulted in a substantial surge in interest in property acquisition, leading to record growth in new lending.

In addition, it is crucial to highlight that there was a gradual response from banks to the initial implementation or tightening of limits on borrower-based measures. In the initial quarter featuring stricter limits on the LTV, DTI, and DSTI ratios, banks encountered challenges in adhering to these limits (see Figure 3). However, in accordance with Act No. 6/1993 Coll. on the Czech National Bank, the effective date for the introduction or tightening of borrower-based measures was deferred by 4 months from the announcement. This postponement afforded banks ample time to modify their business models and adjust their risk pricing models.

Now to the effects of limits on borrower-based measures. LTV limits have rapidly reduced the share of loans with LTVs above 80%. Since the end of 2017, this share has been below 15% of the total volume of mortgage loans. This has significantly increased banks' resilience to potential default and losses. Despite the easing of the LTV limit from 2020 onwards, banks voluntarily continued their prudent behavior and the share of loans with LTVs above 80% decreased slightly in 2020 and 2021. Looking at the distribution of loans by LTV, there is a clear shift away from very risky loans with LTVs equal to 100%. Each successive tightening from 2016 to 2017 was followed by a gradual

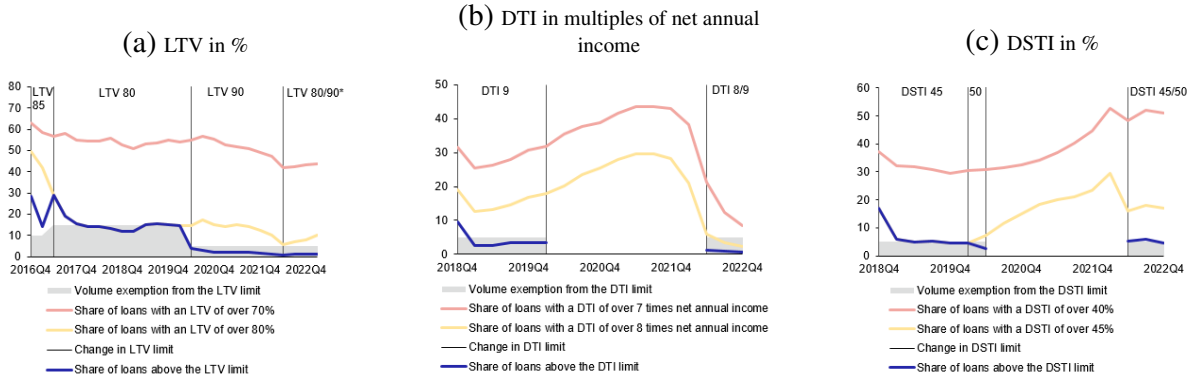
[8] In general, macroprudential regulation in the form of limits on borrower-based measures can also be differentiated by borrower characteristics, property type, and region, among others.

leftward shift in the distribution pulling the LTV down to 80% (Figure A3). However, in the case of loosening, there is essentially no change in the distribution and banks thus voluntarily maintain the 80% LTV threshold as the default in differentiating risky loans (Figure A4). In the context of macroprudential policy and the reduction of risks to financial stability, I can definitely speak about the positive and lasting effect of LTV limits on mortgage loans.

In contrast to LTV limits, the limitations imposed by DTI and DSTI ratios exhibit a pronounced constraining effect. In both instances, there was a substantial reduction in the proportion of loans with the introduction in 2018 of a DTI limit exceeding 9 times net annual income and a DSTI limit of over 45% until the first half of 2020. However, subsequent to the lifting of the limits, the volume of loans surpassing the DTI and DSTI thresholds experienced a resurgence (see Figure 3b and Figure 3c). Furthermore, the limits have a significant impact on the distribution of loans based on the DTI and DSTI limits. Following the imposition of the limits, the distribution of the share of loans based on the DTI and DSTI limits was truncated from the right at 9 times net annual income and 45%, respectively (see Figure A5 and Figure A7). In the case of the DSTI ratio, not only is the distribution truncated, but there is also a shift in the share of loans towards lower bands, leading to an overall change in the shape of the distribution. This suggests that both banks and loan applicants optimize their strategies after the introduction of the limits to facilitate mortgage loan realization.

Although the relaxation of the DTI limits resulted in a gradual return to the shape of the distribution prior to the introduction of the limits, the value of 9 remains prominent in the distribution (see Figure A6). Conversely, for the DSTI ratio, the distribution undergoes a permanent change, with a noticeable break at 45% and 50% persisting even a year after the relaxation of the limit (see Figure A8).

Figure 3: Share of Loans Above the Given LTV, DTI and DSTI Limits



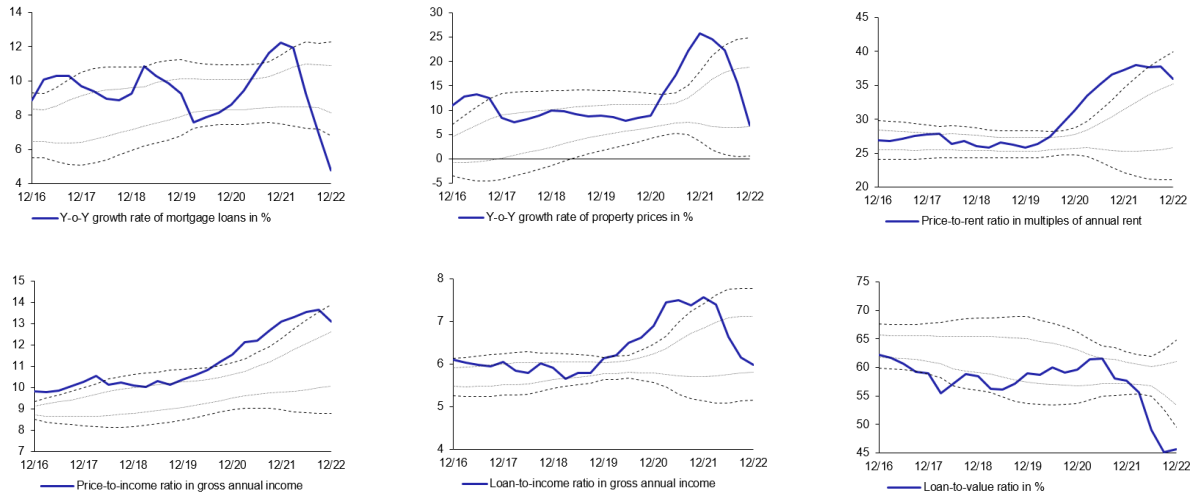
Source: CNB

3.3 Indicators Signaling the Need to Implement Borrower-Based Measures

The literature outlines several possible indicators that may signal the need for the implementation of borrower-based measures such as the credit-to-GDP gap, the financial cycle indicator, the household credit growth rate, the property price growth rate, the price-to-rent ratio, the price-to-income ratio, the loan-to-income ratio, and the loan-to-value ratio, among others (BIS, 2012; IMF, 2014). Figure 4 and Figure 5 show the individual indicators for the Czech Republic. While figure 4 includes naive bounds in the form of rolling deviations from the average value of the indicator over the last 20 quarters, the crossing of which signals a potentially increased (or decreased) risk for the

financial stability of the household sector and a possible need for regulation (or deregulation), figure 5 indicates an increased risk of financial instability when the credit-to-GDP ratio and the deviation of property prices from their fundamental values turn positive and when the financial cycle indicator is moving towards one.[9]

Figure 4: Mortgage Market Risk Indicators



Source: CNB
Note: The dashed black lines show spreads of one and two standard deviations from the average over the last 20 quarters.

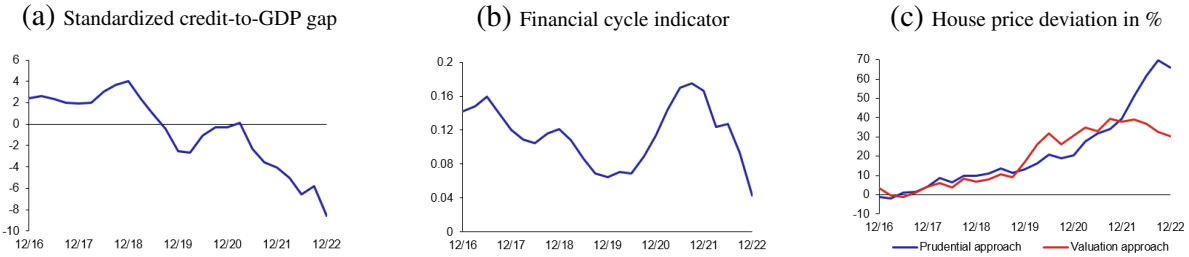
Three of the indicators in Figure 4 exhibit indications of heightened risk during 2017, a trend corroborated by the credit-to-GDP ratio and partially supported by the financial cycle indicator in Figure 5. In response, the CNB tightened the LTV limits and, in 2018, introduced DTI and DSTI limits. Faced with considerable market uncertainty at the onset of the COVID-19 pandemic, the CNB opted to relax the LTV limits and abolish the DTI and DSTI limits. The combination of accumulated savings, coupled with loose monetary and macroprudential policies, triggered a substantial surge in interest in property acquisition and loans to finance these properties. This effect was further magnified by an exceptionally expansionary fiscal policy, including measures such as the abolition of property tax and a reduction in income tax. As a result, the risk indicators pointed to a subsequent episode of increased risk emerging from 2020 to 2022 (see Figure 4).[10] Despite the robust inflow of new loans and the upswing in residential property prices, the LTV ratio indicates that the new loans were adequately secured, minimizing the risk of substantial credit losses resulting from potential defaults. Consequently, it is imperative to underscore the high resilience of the mortgage portfolio, which experienced only marginal changes despite the flow of riskier loans.

An additional valuable indicator is the deviation of house prices from the fundamentals, as proposed by Koetter and Poghosyan (2010). Their research emphasizes that signals of financial instability are more accurately identified through deviations from the fundamentals than though the price level or price changes per se. Thus, Figure 5 illustrates deviations of house prices from their fundamental

[9] The financial cycle indicator is based on the methodology by Plašil et al. (2014).
[10] Loan-to-income, price-to-income, and price-to-rent ratios signaled escalating risk starting in mid-2020. Growth indicators, including house price growth and mortgage loan growth, exhibited a delayed response in 2021. Contrary to expectations, the credit-to-GDP gap, often regarded as a key systemic risk indicator (Drehmann et al., 2010; IMF, 2014), did not suggest heightened risk.

values, computed using the methodology outlined by Plašil and Andrle (2019). The figure highlights an escalating risk since 2017, differing from the indicators mentioned above wherein risk exhibited a temporary decline in 2018 and 2019. This trend signifies the disproportionately robust growth in residential prices in recent years.

Figure 5: Main Mortgage Market Risk Indicators

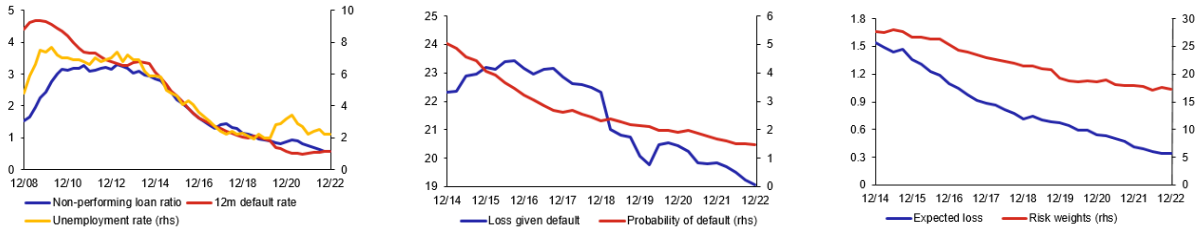


Source: CNB
Note: The value of the financial cycle indicator ranges from 0 to 1.

3.4 Ex-Post Risk Indicators

In its short history, the mortgage market in the Czech Republic has encountered a single episode of heightened risk, albeit without marked upheaval. The spillovers from the GFC triggered a sharp increase in non-performing loans, which peaked in 2009 and 2010 and continued at elevated levels until 2014. Subsequently, there was a gradual decline in non-performing loan ratios, default rates, and expected losses. In 2022, the ex-post risk indicators reached record lows. Thus, the mortgage market presents itself as remarkably stable. The record low unemployment rate contributes significantly to this development. The low risk of job loss and the still high number of vacancies helps to minimize the risk of loss of income for the borrower.

Figure 6: Ex-Post Risk Indicators and Unemployment Rate



Source: CNB
Note: Values on both axes for all graphs are in percentages. Loss given default, probability of default, risk weights and expected loss are calculated as weighted averages for IRB banks in the Czech Republic for performing retail exposures secured by non-SME real estate.

4. Data for the Analysis

The primary and most important source of data is a unique dataset based on the CNB Survey on consumer loans secured by residential property, encompassing comprehensive information on newly granted mortgage loans by individual banks. The survey helps the CNB to monitor the compliance of banks with Act No. 6/1993 Coll., on the Czech National Bank, and with the recommendations on the management of risks associated with the provision of retail loans secured by residential property. The survey data includes detailed information on borrowers and loans, such as level of income, source of income, age, volume of other debt, loan interest rate, loan volume, loan collateral, interest rate fixation period, loan maturity, among other things. However, all borrower and loan information is collected at the time of mortgage origination and cannot be monitored over time.

Data is collected semi-annually, transitioning to a quarterly basis since 2023, encompassing all new and refinanced consumer loans secured by residential property granted to households (hereinafter referred to as mortgage loans). However, the stress test only uses data on new loans because there is no identifying cue to pair refinanced loans with new loans. All mortgage lenders regularly participate in the survey. The CNB conducted its first round of the survey in the second half of 2015, but the first round is considered a trial version. Hence, the stress test relies on clean data starting from January 1, 2016. Table 2 provides an overview of the number of new mortgage loans from January 2016 to May 2023 by year of origination. Table A2 and Table A3 show descriptive statistics of the survey data and the share of mortgage loans granted based on categorical variables.

Table 2: Number of Mortgage Loans in the Dataset

Period	2016	2017	2018	2019	2020	2021	2022	2023*
Number of observations (loans granted)	90,217	94,306	91,862	73,157	82,062	114,636	50,339	14,595

Source: CNB
Note: The data for 2023 marked with an * cover the period from January to May.

To simulate the behavior of indebted households in the stress test, I use data from the European Union Statistics on Income and Living Conditions (EU-SILC) survey, the Household Budget Survey (HBS), and the Household Finance and Consumption Survey (HFCS) for the Czech Republic. The data are available on an annual basis and at a biennial frequency for the HFCS. Data include information on household income, expenditure, and wealth. Employing this data, I construct variables for necessary expenses, housing costs, the average propensity to save, and the liquid assets of households. The process of variable creation entails selecting a set of variables that are consistent across both the CNB Survey dataset and one of the aforementioned databases. Then, using a simple WLS estimation method, I estimate the parameters that can be used to define the variables in the CNB survey dataset.[11]

Furthermore, I utilize data from the Labour Force Survey (LFS) to define the unemployment rate by education. The general unemployment rate is re-weighted based on the estimated unemployment rate by education, ensuring alignment with the educational composition of the overall mortgage portfolio (see Figure A9). This methodology allows for the appropriate reflection of any shocks to the unemployment rate in the stress test simulations.

[11] Appendix B contains detailed information about the estimation of necessary expenses, housing costs, the average propensity to save, and the liquid assets of households.

Lastly, to adjust the mortgage portfolio over time, I use macro-financial data at the aggregate level, which are available from the public database of the CNB and the Czech Statistical Office (CZSO). To simulate future developments, I use the output of the official CNB g3+ forecasting model and related satellite models. The CNB g3+ model is a dynamic stochastic general equilibrium (DSGE) model of a small open economy based on the New Keynesian tradition (Brázdik et al., 2020). However, the g3+ model does not include the financial sector. Thus, I use additional satellite models for the estimation of mortgage interest rates, residential property prices and housing loans.[12]

5. Modeling Framework

The modeling framework relies on a micro-macro model, with the balance sheet simulator being a key element of the model. Figure A10 shows the overall structure. Parameters estimated on peripheral models of housing costs, necessary expenditures, savings, liquid assets and the unemployment rate enter the balance sheet simulator using key common variables.[13] The macro modules, whether in the form of historical data or future projections, allow me to recalculate the variables such as net income, house prices, and interest rates in the balance sheet simulator over time.

Employing the micro-macro model, I compute portfolio risk indicators (PD, LGD, and EL) utilizing the financial margin concept with household liquid assets, similarly as in Meriküll and Room (2020). The micro-macro model operates on the stock of mortgage loans, progressively incorporating new mortgage loans while removing repaid or defaulted loans. However, the micro-level data pertaining to the stock of mortgage loans is unavailable in the Czech Republic. Thus, I employ flow micro-level data (new mortgage loans) to construct the mortgage loan stock, akin to the methodology employed by Levina et al. (2019).

5.1 Composition of the Mortgage Portfolio

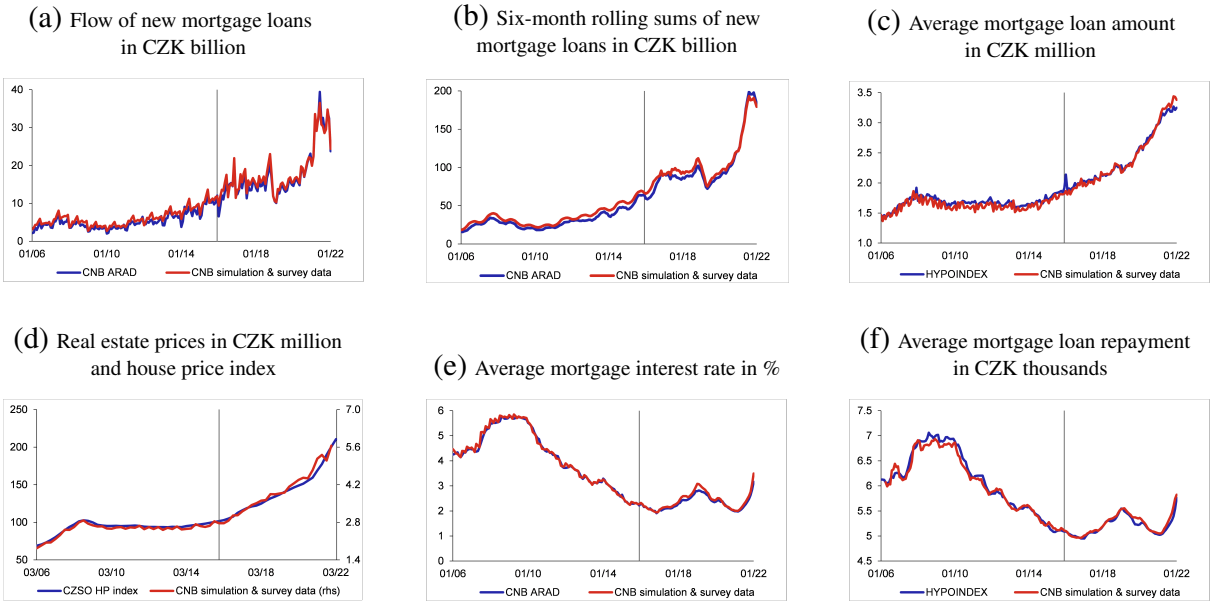
The construction of the mortgage portfolio relies on a unique dataset compiled from the CNB regulatory survey of mortgage lenders, representing the flow of mortgage loans from 2016 onward. However, given that the available data only spans from 2016, a backward simulation becomes necessary to model the flow of mortgage loans since 2005. This simulation follows a straightforward principle, wherein the mortgage loan data for 2016 is taken as a starting point. The values of the individual variables are then recalculated based on the dynamics of the macro-financial variables, such as house prices, net incomes, and collateral values. For example, loans from 2016 are considered for 2015, and the number of loans is randomly re-weighted to align with the actual number of loans originating in that year. Subsequently, variables for house prices, net income, collateral values, etc., are adjusted based on year-on-year growth in macro-financial variables. A similar approach is applied to a forward-looking simulation based on a predefined macroeconomic scenario.

To validate the accuracy of the backward simulation, a comparison is conducted between the simulated flow of new mortgage loans and their six-month rolling sums with aggregate values from the CNB's publicly available database. Likewise, individual values from the simulation, such as the average mortgage loan amount, property price, interest rate, and monthly payment, are compared with publicly available data from the CNB, CZSO, and Hypoindex.cz (see Figure 7).

[12] For details about the satellite models see Plašil (2021).
[13] For details see Appendix B.

The comparison reveals a consistent alignment between the volume of simulated loans and selected characteristics when compared to the publicly available data.

Figure 7: Comparison of Simulated Data with Observed Values



Source: CNB, Hypoindex.cz, CZSO
Note: The average mortgage loan payment relates to a mortgage loan of CZK 1 million with a maturity of 20 years. The vertical line separates the values from the simulation (pre-2016) and the values obtained from the CNB survey (post-2016).

Similar to the backward simulation, the simulation of the future flow of new mortgage loans based on a defined macro-financial scenario requires an estimate of the number of loans granted in each quarter. Once the number of loans is estimated, the adjustment of individual characteristics follows the same principle observed in the backward simulation. In order to reflect the dynamics of macroeconomic and financial conditions, the characteristics are linked to the evolution of selected variables from the stress scenario. Thus, variables such as the amount of individual mortgage loans, the value of their collateral, the interest rate, borrowers' income, among others, evolve in line with the prediction of house prices, interest rates, and wages, among others. Nevertheless, the simulation assumes that mortgage applicants hold the same preferences regarding the length of the loan maturity and the length of the interest rate fixation as when they took out the loan. The simulation of new loans over the tested horizon also assumes compliance with the caps on the LTV, DTI, and DSTI ratios, which is the key aspect for calibration.[14]

I construct the overall mortgage portfolio when credit flows are available (from 2005 until the end of the tested horizon). This portfolio develops sequentially on a quarterly basis, with new mortgage loans added each quarter, the gradual simulation of existing mortgage loan repayments and the removal of defaulted loans. The information contained in the mortgage portfolio is adjusted over time depending on macroeconomic developments, and in the case of forecast development, aligns with a defined macroeconomic scenario, i.e. wages are adjusted for wage growth, individual household expenditure for inflation and energy prices, and property values for house prices. The

[14] Section 6 describes in detail the effect of LTV, DTI and DSTI regulation on the number and distribution of new loans.

variables associated with the loan itself, such as the outstanding principal, maturity, collateral value, DTI ratio, DSTI ratio, and LTV ratio, are recalibrated each quarter. However, it must be stressed that the interest rate and therefore the amount of the repayment only changes when the loan is refixed and, in the case of floating rate loans, which are at a minimum, the amount of the repayment changes on a quarterly basis. The period of fixation is assumed to stay constant over the entire loan repayment term. Thus, if a client has a loan agreed for 30 years with a rate fixed for five years, it is assumed that the rate will be refixed every five years. It is also assumed that the client will be able to increase the existing unpaid principal of the loan when the rate is refixed.

5.2 Stress Test

An essential element of stress testing is the formulation of a macroeconomic scenario that determines the type of risk to be tested and the level of simulated stress (Dent et al., 2016). The adverse (stressed) macroeconomic scenario generally reflects the most significant risks, the materialization of which would have significant impacts on the household sector and the overall financial system. The paper focuses primarily on the credit risk of mortgage loans. However, to test the robustness of the estimates, I use several different scenarios.[15]

The stress test uses the concept of financial margin, including households' liquid assets as in the papers by Meriküll and Room (2020) and Giordana and Ziegelmeyer (2020). The liquid assets essentially mean savings that households may use to cover their liabilities in the event of adverse financial conditions, such as cash, funds in current, savings and term accounts, investment funds, stocks, and other securities. The financial margin (FM) is calculated for each quarter and is defined as the net income (NI) left to the household after deducting loans repayments (LR), housing costs (HC), and necessary expenses (NE):[16]

$$FM_{i,t} = NI_{i,t} - LR_{i,t} - HC_{i,t} - NE_{i,t}, \tag{1}$$

Each component of the financial margin may be subject to an adverse shock depending on the macro-financial situation or macro-financial scenario. NI reflects the wage growth dynamics and depends on the likelihood of losing employment, which is given by the estimated unemployment rate.[17] If the head of the household loses their job, they lose their regular income and receive only the state-guaranteed unemployment benefit of 45-65% of their income depending on the length of unemployment. Thus, there is a significant shock to household income in the case of job loss in the stress test. However, the test assumes that the duration of unemployment does not exceed 6 months.[18] LR changes only when the mortgage loan is refixed and is thus subject to an interest rate shock, but this is dampened by fixed interest rate contracts.[19] HC and NE increase in line with the inflation rate.

[15] Details of the scenario are discussed in Section 6.

[16] Appendix B contains detailed information about the HC and NE estimations.

[17] The unemployment rate enters the stress test by randomly selecting the households in the portfolio that lose their jobs so that the unemployment in the portfolio over the period corresponds to the re-weighted unemployment rate. Because the education level of the population with a mortgage loan exceeds the education level of the population as a whole, households with a mortgage loan face a relatively lower probability of losing their jobs than households in the economy as a whole. Figure A9 show the re-weighted unemployment rate.

[18] For indebted households that have a high incentive to find a new job to pay off their debts, this seems like a reasonable argument.

[19] As mentioned in Section 3, the vast majority of mortgage loans involve interest rate fixation of 3 or more years. Thus, the interest rate shock in the stress test tends to be suppressed to a large extent. In addition to mortgage

The computation of the financial margin represents the initial phase in the household stress test. This approach further acknowledges that households possess liquid assets (*LA*) in diverse forms, a crucial consideration, especially in instances of a negative financial margin. The amount of household liquid assets is estimated when a mortgage loan is acquired and its value is a function of the number of economically active persons (*EA*), age (*AGE*), education (*E*), household income category (*IC*), region (*R*), and a dummy for mortgage loans (*M*).[20] As demonstrated by Aastveit et al. (2020), the LTV limit may reduce the liquid reserves of households. Hence, the estimated liquid assets (*LA*) take into account the expenditure associated with the down payment (*DP*). However, the underlying assumption is that only households with LTVs above 70% use their liquid assets for the down payment, with the probability of using liquid assets for the down payment increasing linearly with the LTV ratio. Conversely, households with LTVs below 70% rely on additional collateral or fund the down payment from the sale of another property.

$$LA_{i,acquisition} = \begin{cases} f(X), & \text{if } LTV_{i,acquisition} \leq 70\% \mid LTV_{i,acquisition} \geq 100\% \\ \phi(f(X) - DP_i), & \text{if } LTV_{i,acquisition} > 70\% \ \wedge \ LTV_{i,acquisition} < 100\% \end{cases} \tag{2}$$

where $f(X)$ is a linear function of the above variables (*EA*, *AGE*, *E*, *IC*, *R*, *M*)[21] and ϕ represents the probability that a household uses its liquid assets for the down-payment.

Households' liquid assets are further adjusted for positive or negative savings (*S*) according to the value of *FM*, *NI*, average propensity to save (*aps*)[22], and the rate of minimum unnecessary consumption (θ)[23]:

$$LA_{i,t} = LA_{i,t-1} + S_{i,t}, \tag{3}$$

where

$$S_{i,t} = \begin{cases} aps_{i,t} \times NI_{i,t}, & \text{if } FM_{i,t} \geq NI_{i,t} \times (\theta + aps_{i,t}) \\ FM_{i,t} - \theta NI_{i,t}, & \text{if } FM_{i,t} < NI_{i,t} \times (\theta + aps_{i,t}) \ \wedge \ FM_{i,t} > \theta NI_{i,t} \\ 0, & \text{if } FM_{i,t} \geq 0 \ \wedge \ FM_{i,t} \leq \theta NI_{i,t} \\ FM_{i,t}, & \text{if } FM_{i,t} < 0 \end{cases}$$

If the value of *LA* falls below zero within a given quarter, indicating a negative *FM* and the depletion of all liquid assets by the household, the loan is categorized as a non-performing loan. The stress

repayments, *LR* includes repayments on other loans. However, detailed information on the borrower's other loans, such as maturity, interest rate and length of fixation, is not available. Thus, I use the simplifying assumption that borrowers with additional debt are more prone to indebtedness and their additional loan repayments are permanent in nature.

[20] Details of the estimation of *LA* are included in Appendix B.

[21] Details of the estimation are in Appendix B

[22] $aps = f(EA, D, AGE, IC, C, E, M)$ and maximum *aps* equal to 0.5 and minimum *aps* equal to 0. Appendix B contains details on the calculation of *aps*.

[23] θ represents the part of unnecessary expenditure that is preferred over savings. The default setting of the beta parameter is 20%.

test postulates a lenient stance from banks, presuming that they would facilitate loan restructuring for clients encountering non-performing loans. Consequently, in cases of negative liquid assets during the stress test, the loan undergoes restructuring, involving an adjustment of the maturity to the maximum allowable duration (30 years for clients under 40 years, and $70-AGE$ years for clients aged 40 and over). If the FM remains negative in the subsequent quarter, and the restructuring fails to mitigate the household's financial circumstances, the loan is classified as a defaulted loan and the PD is set at one:

$$PD_{i,t} = 1 \quad if \quad LA_{i,t-1} < 0 \wedge FM_{i,t} < 0, \quad otherwise \quad PD_{i,t} = 0. \tag{4}$$

Subsequently, one can determine the expected loss on the loan (ELL) for a loan in default ($PD = 1$). The calculation of the expected loss for a defaulted loan depends on factors such as the outstanding principal (P), the value of outstanding repayments coupled with any penalty interest (RP), the expected value of collateral (EC), and the expected recovery cost (ERC).

$$ELL_{i,t} = max(P_{i,t} + RP_{i,t} - EC_{i,t} + ERC_{i,t}; 0), \tag{5}$$

where

$$RP_{i,t} = repayment_{i,t} \times (1 + PR_{i,t}),\ EC_{i,t} = \frac{FDR \times PP_{i,t+n}}{1+DR},\ ERC_{i,t} = \frac{RCR \times PP_{i,t+n}}{1+DR},$$

where PR is the penalty rate, FDR indicates the foreclosure discount rate, which is a random variable with beta distribution $FDR \sim \beta(a,b)$.[24] PP denotes the expected value of the property at the date of sale of the property, with the assumption that the value of the property at the date of sale must be less than or equal to the value of the property at the date of default ($PP_{t+n} \leq PP_t$). DR represents the discount rate, which is determined by the CNB's 2W repo rate, and n indicates the length of the recovery process.[25] RCR indicates recovery cost ratio, which is a random variable with beta distribution $RCR \sim \beta(a,b)$.[26]

Equation 5 indicates that the minimum value of the expected loss equals zero. These are cases where the expected value of the collateral exceeds the total debt of the borrower and the recovery costs. The remaining value from the realisation of the collateral after settlement of the debt belongs to the borrower.

Defining PD and ELL at the loan level allows me to define portfolio indicators such as default rate (DR), loss given default (LGD) ratio and portfolio expected losses (EL):

[24] The FDR indicates the rate of discount to the market price at foreclosure. The mean FDR is based on CNB estimates and is equal to 68% with a degree of uncertainty given by a standard deviation of 12.5%.

[25] The length of the recovery process is set at 1 to 12 quarters in the stress test for simplicity, with the probability of the specific length determined by data from supervisory stress tests conducted by the CNB every two years

[26] The mean value of the beta distribution belongs to the interval (0.05 to 0.16) depending on the length of the recovery process (from 0.05 for 1 quarter to 0.16 for 12 quarters) and the measure of uncertainty expressed by the standard deviation is 0.05. This setting is based on data from supervisory stress tests conducted by the CNB every two years.

$$DR_t = \frac{\sum_{i=1}^{p}(PD_{i,t+k} \times EAD_{i,t+k})}{\sum_{i=1}^{p} P_{i,t}}, \tag{6}$$

$$LGD_t = \frac{\sum_{i=1}^{p}(PD_{i,t} \times ELL_{i,t})}{\sum_{i=1}^{p}(PD_{i,t} \times EAD_{i,t})}, \tag{7}$$

$$EL_t = PD_t \times LGD_t \times EAD_t, \tag{8}$$

where $EAD_{i,t} = P_{i,t} + RP_{i,t}$.

Portfolio indicators show banks' mortgage exposure risk. These indicators serve as metrics of the present condition of the portfolio as well as its condition under the most likely or most adverse future developments. Consequently, these indicators function as informative variables in the stress test, signaling alterations in portfolio risk. Their values assume a pivotal role in calibrating the borrower-based measures (see more in Section 6).

Finally, to quantify the costs and benefits associated with borrower-based regulation, this paper incorporates an estimation of potential costs to banks in terms of foregone profits and potential benefits in the form of diminished loan losses. The costs of regulation are derived from the difference in loan volumes with and without regulation, multiplied by the spread between the mortgage interest rate (*MIR*) and the five-year interest rate swap rate (*IRS*):

$$C = \sum_{t=1}^{T} \Delta TE_t \times (MIR_t - IRS_t), \tag{9}$$

where Δ represents the difference in total mortgage loan exposure (TE) under a given borrower-based regulation and no regulation. The sum over time shows the length of the period over which the cost-benefit analysis is performed. In this paper, the length of the period is set to 20 quarters.[27]

The advantages of regulation founded on loss reduction stem from the difference in expected losses determined through the conducted simulation:

$$B = \sum_{t=1}^{T} \Delta EL_t, \tag{10}$$

where Δ represents the difference in expected losses under a specific borrower-based regulation compared to the scenario without regulation.

A simplified rule for introducing borrower-based regulation could involve comparing the benefits and costs under a baseline scenario. If the benefits associated with a specific combination of LTV, DTI and DSTI ratios surpass the potential costs ($B \geq C$), then the regulation could be implemented.

[27] See Section 6 for more details.

5.3 Limitation of the Stress Test

Similar to Barasinska et al. (2019) and Górnicka and Valderrama (2020), the framework omits the consideration of strategic default.[28] Additionally, the stress test does not incorporate the potential financial contagion stemming from other portfolios, such as corporate loans or unsecured consumer loans, which may have adverse consequences, particularly in times of crisis.[29] Consequently, the values of the portfolio indicators obtained from the stress test should be viewed as a conservative estimate, representing a lower bound for these indicators when assessing the future performance of the portfolio.

Moreover, the simulation conducted using the household stress test does not account for the evolution of other household loans, including additional mortgage loans or unsecured consumer loans. The framework only assumes persistent household debt. Households that had existing loans when obtaining their mortgage are deemed permanently indebted, rendering them more susceptible to debt. These households continually repay their other loans over time, with these repayments entering the calculation of the financial margin. Conversely, households with no existing debts, for whom the mortgage loan is their first debt, are not anticipated to accumulate additional debt. The repayments considered in the financial margin calculation for such households only include mortgage loan repayments.

6. Calibration of Borrower-Based Measures

The calibration of borrower-based measures relies on the household stress test framework. A crucial step in stress testing involves formulating a macroeconomic scenario. The paper considers several different five-year macroeconomic scenarios, including the baseline (most probable) scenario that reflects the most likely economic developments in the Czech Republic.[30] In addition to the baseline scenario, the paper evaluates two adverse scenarios. The first, denoted as a typical adverse scenario, exemplifies the most common type and magnitude of the economic shock examined by the CNB. It constitutes a deflationary adverse shock, leading to a rise in the unemployment rate to 9%, accompanied by an approximate 12% decline in house prices. The second adverse scenario is purely hypothetical and intensifies the shock strength of the first scenario. In this scenario, the unemployment rate surges beyond 17%, and house prices experience a year-on-year decline of 27%.[31] Table 3 compares the developments in key variables for the household stress test across the baseline, typical adverse, and most adverse scenarios.

[28] Strategic default depends on the development of real estate prices. If the property price falls below the level of the housing loan, it is rational to default (Górnicka and Valderrama, 2020). For the Czech Republic and most other EU countries, strategic default incentives tend to be limited because of full recourse or close to full recourse legal environments. Therefore, not including strategic defaults in the model has a rational basis.

[29] However, when a client defaults on an unsecured loan, it does not automatically translate to a default on the mortgage. In such cases, banks are not obliged to categorize it as such (see Article 178 of Regulation (EU) No 575/2013 (CRR)).

[30] For this purpose, the paper uses the official macroeconomic forecast of the Czech National Bank for the first two years, assuming the constant development in the given variables for the subsequent three years.

[31] In the simulations, several other types of adverse scenarios were tested (e.g., inflation shock) and the strength of the shock (ranging between the baseline scenario and the aforementioned very adverse scenario). However, the results of these simulations did not affect the conclusions of this paper.

Table 3: Macroeconomic Scenarios

	Unemployment rate (in %)			Wage growth (y-o-y change in %)			Mortgage int. rate (in %)			Property price growth (y-o-y change in %)			Inflation (in %)		
	BS	TADV	VADV	BS	TADV	VADV	BS	TADV	VADV	BS	TADV	VADV	BS	TADV	VADV
1st year	2.7	2.7	3.2	8.0	8.0	7.7	5.9	5.9	5.8	-2.1	-2.8	-2.3	10.8	10.8	9.7
2nd year	3.0	3.0	7.3	7.2	5.0	2.6	5.1	5.1	4.8	3.4	-2.7	-6.9	2.6	2.6	1.9
3rd year	3.0	4.9	11.0	7.0	-2.7	1.1	4.6	4.2	3.3	3.2	-11.8	-27.1	2.1	-2.2	0.6
4th year	3.1	8.8	14.5	6.5	-0.4	-2.2	4.6	3.2	2.1	3.0	-3.4	-18.4	2.3	-0.4	-0.3
5th year	3.1	8.7	17.4	6.5	1.6	0.6	4.6	3.2	2.1	3.0	3.4	-3.1	2.3	0.2	0.2

Note: The table shows the annual average. BS = Baseline scenario, TADV = Typical adverse scenario, VADV = Very adverse scenario.

6.1 Simulation Approach

The simulation of new mortgage loans on a defined horizon relies on the joint probability distribution of mortgage loans by LTV and DTI/DSTI. The simulation allows for four possible settings for the LTV (none, 70%, 80%, and 90%), DTI (none, 7, 8, and 9 times net annual income) and DSTI (none, 40%, 45%, and 50%) ratios. For the DSTI ratio, the distribution of loans also depends on the level of mortgage interest rates at the aggregate level.[32] Higher interest rates lead to a more skewed distribution of mortgage loans based on the DSTI ratio, while lower interest rates flatten the distribution of mortgage loans (Figure 10). For simplicity, however, the distribution does not change with a continuous shift in mortgage rates, but changes only discretely by mortgage rate category. Overall, there are five categories of mortgage rates: up to 2%, 2-3%, 3-4%, 4-5%, and over 5%.

The simulation of the flow of new mortgage loans assumes that banks grant new loans at the margin of the borrower-based regulation, ensuring a prudent simulation approach that considers the highest possible risk. Thus, the volume of new loans granted in each quarter must not exceed the specified limits on borrower-based measures by more than 5% of the reference loan volume.[33] Nevertheless, the simulation of new loans rarely adheres to the 5% volume exemption for both DTI and DSTI limits simultaneously, as these measures are not equivalent. Their equivalence would necessitate a complete adjustment of the DSTI limit through maturity and interest rates, a scenario inconsistent with reality. Therefore, the simulation considers the distribution of loans at the margin of the LTV limit and at the margin of the more stringent of the DTI/DSTI limits. The choice of the tighter limit assumes a loan maturity of 30 years and compares the DTI and DSTI limits considering the average mortgage interest rate (see Figure A11 in Appendix A for illustration).

Figures 8, 9, and 10 provide the rationale for mortgage lending at the margin of limits on borrower-based measures. For the LTV limit, with a 90% limit in place and a 5% volume exemption specifying the share of loans that may exceed the limit, banks lend right at the margin (Figure 8, black vertical line). The red distribution plots suggest that the limits were being exceeded in 2018-2020. However, the CNB had set the lending volume exemption at 15% during this period (Figure A12 in Appendix A). Thus, the 80% LTV limit with a 15% volume exemption in 2018–2020 nicely corresponds to the later setting of a 90% LTV limit with a 5% volume exemption. In both cases, however, the crucial point remains that banks operate at the very limit of the LTV.

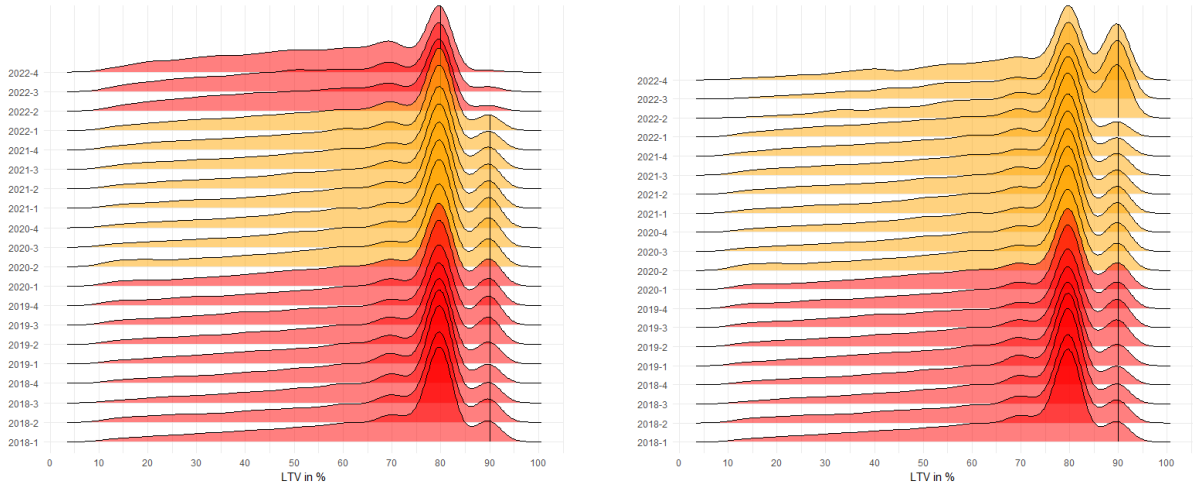
[32] For simplicity, the maturity of mortgage loans is assumed to be 30 years, which corresponds to the median maturity from the Survey of Consumer Loans Secured by Residential Real Estate (see Table A1).

[33] The reference loan volume is the total loan volume granted in the previous quarter.

Figure 8: LTV Density Distribution

(a) Loans without age exemption (valid from 2022 Q2)

(b) Loans with age exemption (valid from 2022 Q2)



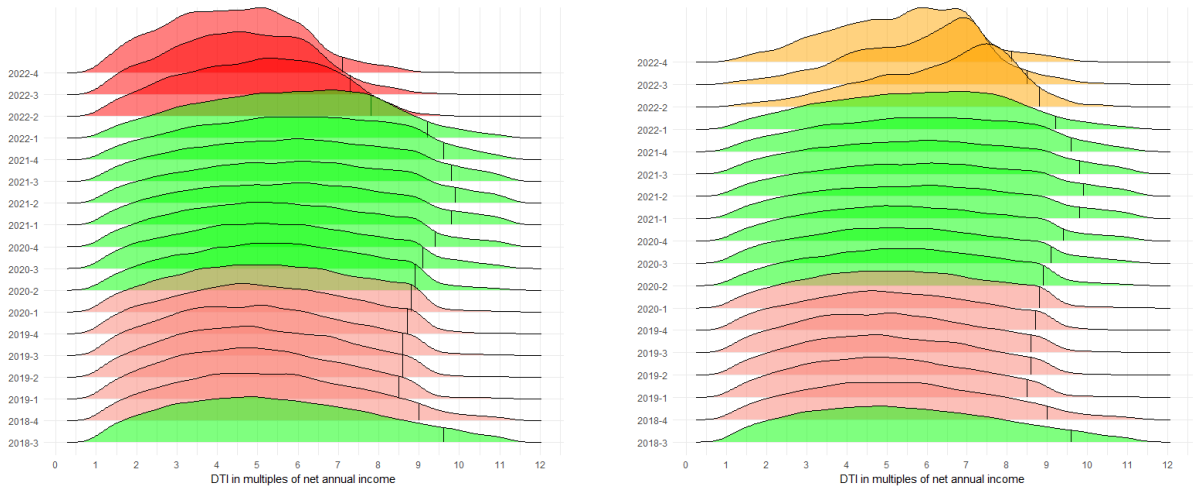
Source: CNB

Note: The red distributions indicate a tighter LTV limit of 80%, while the orange distributions show a more relaxed LTV limit of 90%. For 2022 Q2, Q3 and Q4, different limits apply to clients aged under 36 (age exemption - LTV of 90%) and over 36 (no age exemption - LTV of 80%). The black vertical line indicates the 95th percentile of the distribution.

Figure 9: DTI Density Distribution

(a) Loans without age exemption (valid from 2022 Q2)

(b) Loans with age exemption (valid from 2022 Q2)

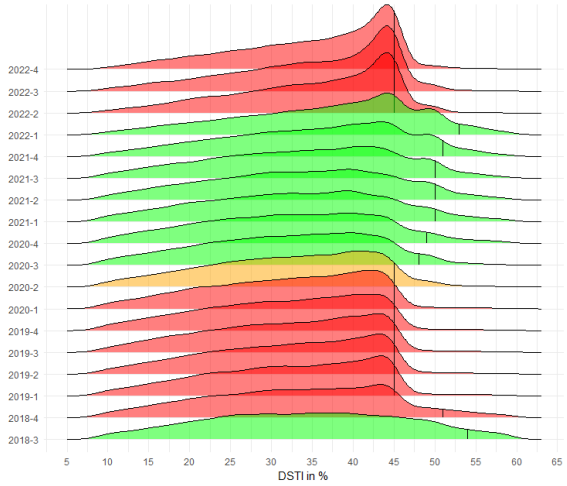


Source: CNB

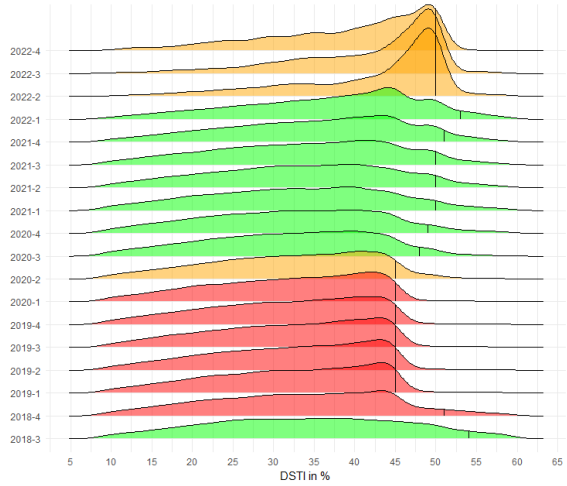
Note: The red distributions indicate a tighter DTI limit of 8.5, salmon a slightly tighter DTI limit of 9, orange a more relaxed DTI limit of 9.5 times net annual income, and green indicates that no limit was in force at the time. For 2022 Q2, Q3 and Q4, different limits apply to clients aged under 36 (age exemption - DTI of 8.5 times net annual income) and over 36 (no age exemption - DTI of 9.5 times net annual income). The black vertical line indicates the 95th percentile of the distribution.

Figure 10: DSTI Density Distribution

(a) Loans without age exemption (valid from 2022 Q2)



(b) Loans with age exemption (valid from 2022 Q2)



Source: CNB
Note: The red distributions indicate a tighter DSTI limit of 45%, orange a more relaxed DSTI limit of 50%, and green indicates that no limit was in force at the time. For 2022 Q2, Q3 and Q4, different limits apply to clients aged under 36 (age exemption - DSTI of 50%) and over 36 (no age exemption - DSTI of 45%). The black vertical line indicates the 95th percentile of the distribution.

In the context of the DTI and DSTI ratios, banks extend mortgage loans with regard to the DSTI ratio rather than the DTI ratio. Even when the DTI ratio appears to be more restrictive than the DSTI ratio, as observed from 2018 to 2021, banks offer loans at the margin of the DSTI regulation rather than adhering to the DTI regulation (see Figure 9 and 10). Under the DSTI regulation, the 95th percentile of the loan distribution consistently remains at the threshold of the imposed limit,[34] aligning with the volume exemption. In contrast, under DTI regulation, the loan distribution appears to shift toward the left side (lower values of DTI).[35] Considering variations in the LTV, DTI, DSTI settings, and mortgage interest rates,[36] there are 112 distinct joint distributions for new mortgage loans. Guided by the defined limits on borrower-based measures, the simulation selects an appropriate probability distribution of new mortgage loans in each quarter. According to this distribution, loans are simulated, with the number of loans corresponding to the defined macroeconomic scenario.

The simulation also re-verifies compliance with the LTV, DTI, and DSTI limits, considering the 5% volume exemption. If the volume of over-limit loans surpasses the volume exemption, individual over-limit loans are randomly eliminated until the volume exemption is satisfied. To illustrate the simulation process, Figure A13 in Appendix A shows the shared probability distribution for loans to be simulated in 2023 Q1.

[34] Except for the initial quarter following the introduction of the regulation in 2018, when banks lacked experience with DTI and DSTI limits and failed to implement the limits into their internal processes in a timely manner.
[35] This observation is reflected in the simulation, where new loans could be simulated based on a joint probability distribution by the LTV and DSTI ratios, disregarding the DTI ratio. From a DTI perspective, it would then be a matter of verifying that the newly simulated loans do not exceed the specified volume exemption. However, to maintain the validity of all measures, the simulation of new loans relies on a joint probability distribution based on the LTV ratio and the more restrictive of the DTI/DSTI indicators.
[36] The preference for the more restrictive of the DTI/DSTI measures is illustrated in simplified form in Table A5 in Appendix A.

Lastly, the macroeconomic scenario typically overlooks the establishment of borrower-based measures. Thus, I adjust the macroeconomic scenario to account for the second-round effect, which assumes a restrictive form and impacts the number of loans granted.[37] The empirical literature supports the varied effects of settings of borrower-based measures on credit growth (Malovaná et al., 2022; Claessens et al., 2013; Kuttner and Shim, 2016). Additionally, a substantial body of empirical evidence aligns with the notion that DTI/DSTI limits exert a more pronounced impact on reducing credit growth compared to LTV limits (Claessens et al., 2013; Kuttner and Shim, 2016; Lindner and Albacete, 2017; Cerutti et al., 2017). The literature also suggests a non-linear relationship between credit growth and borrower-based regulation (Kelly et al., 2018; Alam et al., 2024).[38] Appendix C describes the adjustment of the macroeconomic scenario for second-round effects, incorporating insights derived from the aforementioned empirical literature.

6.2 Simulation Results

The simulation is performed on a random sample of 5% of the data k times over the tested horizon.[39] It monitors the evolution of new loans and the entire mortgage portfolio and compares the results of the output risk variables at different LTV, DSTI and DTI settings. Table 4 shows the effect of each measure individually and in various combinations, all contingent on the macroeconomic scenario.

Table 4: Simulation Results

	Baseline scenario			Typical adverse scenario			Very adverse scenario		
Regulation (LTV-DSTI-DTI)	12M DR (in %)	LGD (in %)	Sum of EL (in CZK billions)	12M DR (in %)	LGD (in %)	Sum of EL (in CZK billions)	12M DR (in %)	LGD (in %)	Sum of EL (in CZK billions)
0-0-0	0.8	17.3	15.1	1.5	19.2	25.0	2.5	27.1	65.1
90-0-0	0.8	17.0	14.6	1.4	18.6	24.2	2.5	25.8	63.2
80-0-0	0.8	16.3	13.5	1.4	18.0	21.6	2.5	25.4	59.7
0-50-0	0.8	17.4	14.8	1.5	18.3	23.9	2.5	26.4	62.5
0-45-0	0.8	17.2	14.6	1.4	18.0	22.6	2.5	25.9	61.1
0-0-9	0.8	17.0	14.7	1.4	18.8	23.6	2.5	27.0	63.1
0-0-8	0.8	16.7	13.9	1.4	18.4	23.3	2.5	26.3	62.8
90-50-0	0.8	16.9	14.0	1.4	18.6	23.6	2.5	26.5	62.7
80-50-0	0.8	15.5	13.0	1.4	17.3	21.4	2.5	25.2	58.5
90-0-9	0.8	16.8	14.3	1.4	18.5	22.8	2.5	26.5	62.5
80-0-9	0.7	15.3	12.7	1.4	17.6	21.4	2.5	24.9	57.9
90-50-9	0.8	16.5	13.8	1.4	18.0	22.2	2.5	26.2	61.9
80-45-8	0.7	14.4	12.0	1.4	17.2	20.2	2.4	24.5	55.9
70-40-7	0.7	14.1	10.6	1.3	16.7	18.5	2.3	24.0	51.4

Note: Table shows the five-year average 12-month default rate (12M DR), five-year average loss given default (LGD), and the sum of expected losses (EL) over the five-year scenario.

The results show that over a five-year period, the regulatory impact on default rates is generally more subdued in the baseline scenario and in both adverse scenarios. This is attributed, in part, to the limited number of loans affected by the regulations, given the absence of a credit boom in either scenario.[40] As borrower-based measures solely influence new lending, their effectiveness

[37] The simulation disregards the potential frontloading of loans in the period directly preceding the introduction or tightening of borrower-based measures.

[38] The initial introduction of limits on borrower-based measures exerts a stronger effect than, for example, tightening under already relatively tight credit conditions. In other words, tightening the LTV limit by, for example, 10 percentage points would not have the same linear effect as a tightening of 20 percentage points.

[39] In the primary setting, k is equal to 100.

[40] On average, 55,000 loans are granted annually in the baseline scenario, 41 in the typical adverse scenario, and 32 in the very adverse scenario. The average number of loans granted in 2016-2020 was 86,000.

diminishes significantly when there is a low inflow of new loans.[41] The most stringent regulations, characterized by an LTV of 70%, a DSTI of 40%, and a DTI of 7 times net annual income, exhibit the highest reduction in default rates. However, such settings considerably restrict the issuance of new mortgage loans, and borrower-based measures - not even just one - have not been employed at this level in the Czech environment.[42] This setting, therefore, represents a rather theoretical lower limit of borrower-based regulation. Alternative configurations of borrower-based measures' settings show less pronounced efficacy, reducing the default rates on a five-year average by 0-0.1 percentage points depending on the scenario.[43]

In terms of expected losses, the difference between no regulation and the strictest regulation ranges from CZK 4 billion to almost CZK 14 billion depending on the scenario. The LTV regulation, in particular, shows relatively favorable results in reducing expected losses. While complementing the LTV regulation with DSTI or DTI limits enhances the results, their marginal benefit tends to be lower. When comparing the simulation results with the 80% LTV setting without income limits and the 80% LTV setting combined with a DSTI of 45% and/or a DTI of 8, the losses over the five-year horizon decrease by CZK 0.2-1.7 billion based on the scenario, which does not significantly affect the banking sector.

6.3 Calibration

The key question remains as to how to best calibrate the measures in order to prevent excessive risk-taking without unduly constraining credit creation. In other words, the regulator needs to optimize the macroprudential strategy to minimize Type I error, which is no intervention, and Type II error, which is excessive intervention (Crowe et al., 2013).

The paper outlines two possible approaches to calibrate borrower-based measures based on the performed simulations. The first approach, labelled as the acceptable loss approach, defines the maximum levels of acceptable losses that the banking sector can absorb without significant problems. The approach is very intuitive, relatively straightforward and allows a certain reserve to be set. Maximum values (caps) can be set both on a relative indicator such as LGD or on an absolute one such as expected losses. Expert judgement tends to be used in the setting of limits and may change over time depending on the underlying macro-financial and institutional conditions. For example, in absolute terms, limits may correspond to the value of losses that would be absorbed by the countercyclical capital buffer allocated to the housing portfolio. In the Czech environment, this is currently around CZK 6 billion per year. Therefore, the limit could be set at CZK 5 billion, with CZK 1 billion serving as a reserve in case of an unexpected stronger shock (see Figure 11).

Under the baseline scenario, where the CZK 5 billion limit is in place, borrower-based regulation would be considered unnecessary. Nevertheless, given the prudential approach to setting

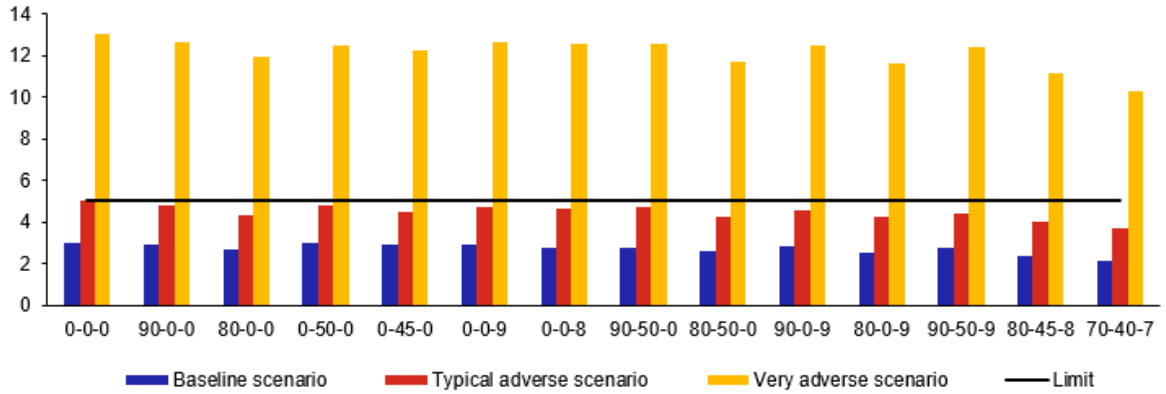
[41] Additionally, the simulations examined a typical adverse scenario wherein the initial two years witnessed rapid credit expansion similar to that observed in the Czech Republic during 2020-2021. In this scenario, the differences are more evident, specifically in terms of losses, which surpass even the outcomes from the very adverse scenario, with the difference in losses over the five-year horizon between no regulation and the most stringent regulation (70-40-7) reaching up to CZK 17 billion.

[42] Depending on the underlying macro-financial conditions, the potential reduction in new lending could reach 30-45%.

[43] As the increase in the default rate is gradual, the differences are relatively small on average. However, they start to widen considerably in the last two years of the scenario, reaching a difference of up to 0.5 pp for the 12M default rate depending on the scenario.

borrower-based measures, regulators should contemplate simulation outcomes derived from a typical adverse scenario—unlikely but still plausible. In light of this scenario, it appears that in the absence of borrower-based regulation, expected losses would reach a predetermined limit, justifying the implementation of regulation to marginally reduce these losses. However, opting for the strictest regulation might not be imperative. Instead, a move toward the regulation that closely aligns with the limit would suffice. A plausible consideration is a single borrower-based regulation – an LTV of 90%.

Figure 11: Annual Expected Losses by Borrower-Based Regulation and Scenario



Note: Losses are in CZK billion. The x-axis represents the setting of borrower-based measures in the form of LTV-DSTI-DTI. The limit equals CZK 5 billion.

The second approach, labelled as the cost-benefit approach, evaluates the settings of borrower-based measures based on a comparison of the costs and benefits of regulation. The benefits of regulation are measured as a reduction in mortgage loan losses under the regulation compared to a situation without borrower-based regulation over a five-year scenario, and the costs of borrower-based regulation correspond to foregone profits from unrealized mortgage business over a five-year scenario.

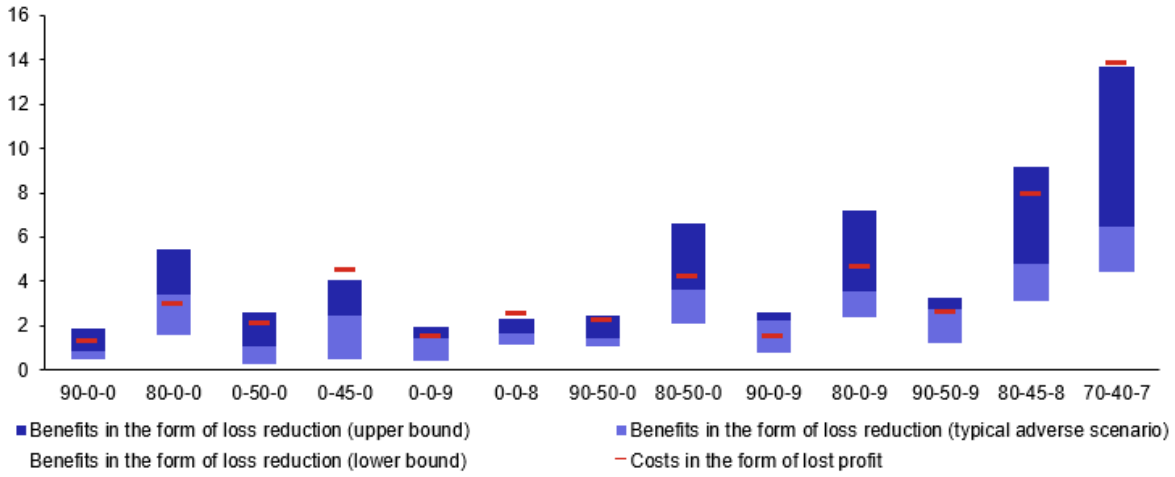
Figure 12 compares the most likely costs of regulation (red line – based on the baseline scenario) with the potential benefits of regulation under the baseline (lower bound), typical adverse (column splitting point) and very adverse (upper bound) scenarios.[44] A rule of thumb for regulation setting would be that if the benefits of the regulation outweigh the costs, then the regulation should be implemented. Regulation could also be considered if the costs exceed the benefits in the form of a lower bound, but are still within the splitting point. Regulation whose costs are above the splitting point appears to be too costly in terms of cost-benefit analysis and should not be considered. According to this approach, no regulation is recommended or, if any, then regulation through the LTV seems to show the best results. Firstly, it is not so costly and secondly, its potential for loss reduction is relatively strong.

The splitting point and upper bound depends on the type of adverse scenario. Therefore, I recommend setting a typical adverse scenario in the form of a realistic scenario that may occur. For example, using GDP-at-risk modelling, set the scenario for GDP at the 5th percentile of the baseline scenario and define the other variables accordingly based on the type of shock. The upper

[44] For example, the expected losses under no regulation amount to CZK 15.1, 25 and 65.1 billion depending on the type of scenario (see Table 4. In contrast, the expected losses under the most stringent regulation (70-40-7) are CZK 10.6, 18.5 and 51.4 billion. The difference between the situation with and without regulation is thus CZK 4.4 billion (lower bound), CZK 6.5 billion (column splitting point), and CZK 13.7 billion (upper bound).

bound modelled under a very adverse scenario should indicate some extreme limit one can reach with loss modelling. For example, after the global financial crisis, house prices in Latvia, Lithuania and Estonia fell by more than 30% and unemployment rates in those countries approached 20%. Therefore, the scenario could be formulated based on this historical experience.

Figure 12: Benefits and Costs of Borrower-Based Regulation



Note: Costs and benefits are in CZK billion. The x-axis represents the setting of borrower-based measures in the form of LTV-DSTI-DTI. Costs in the form of lost profits are modelled under the baseline scenario.

7. Discussion

It is evident that there is no simple guide to setting borrower-based measures, and a number of aspects, such as current macro-financial developments, risk tolerance, banking market structure, loan portfolio quality, among others, must be considered. The paper outlines two possible approaches to the calibration of borrower-based measures using the household stress test structure, with the second approach being preferable. The second approach reflects both the costs and benefits of borrower-based regulation based on the most likely economic developments (baseline scenario) and at the same time the potential costs in the less likely event of an adverse economic development. The approach thus meets the prudential stance expected of regulators. However, this approach should only form part of the assessment of the appropriate setting of borrower-based measures, as it depends to a large extent on the setting of the default parameters of the stress test and is thus somewhat limited. The generally recommended indicators presented in Section 3 should not be overlooked, and their values should be considered.

From a cyclical perspective, the simulations suggest that borrower-based regulation has real effects only during credit expansions followed by a sharp adverse economic shock. During credit constraints, the flow of new credit is relatively low and the difference between the situation with and without regulation is minimal and negligible in terms of credit losses.[45] Given that any regulation entails non-zero costs, the regulator should evaluate properly whether it is necessary to regulate the market with borrower-based measures even in the credit restriction phase.

Another issue that arises with borrower-based regulation is whether it is reasonable to combine the borrower-based measures. The simulation clearly indicates that the combination of value based

[45] In the simulation, the difference in losses amounted to at most CZK 0.9 billion per year on average under the baseline scenario, and CZK 1.3 billion per year on average under the typical adverse scenario.

(LTV) and income based (DTI/DSTI) measures reduces expected losses more strongly. Thus, I concur with the paper by Jurča et al. (2020). However, such regulation appears to be often more costly in terms of foregone profits for banks. It therefore depends on the objectives of the regulator and the underlying macro-financial conditions. It is not possible to be clear which option adds more value in the end. For example, the simulations carried out for the Czech Republic show that for similarly costly regulation options: single LTV regulation at 80% (CZK 3.1 billion) versus a combination of an LTV of 90%, a DSTI of 50% and a DTI of 9 times net annual income (CZK 2.7 billion), regulation using LTV only achieves better results in terms of expected loss reduction.

The question whether to regulate the market under both DTI and DSTI becomes even more challenging. The simulation results for the measures in terms of potential loss reduction appear to be in favor of DSTI, but are difficult to compare because the interest rate plays an important role. The advantage of DTI regulation is that it works more or less as an automatic stabilizer. During a credit boom, it dampens demand, and conversely, when prices and credit are falling (or stagnating), the restrictive effect on demand is reduced. Thus, an appropriately set DTI regulation can be long-lasting and, in general, one would only need to consider re-calibration in the event of structural shifts. However, the downside of DTI regulation lies in neglecting the risk of insufficient solvency for older generations of borrowers. For example, older clients aged 50+ may safely meet the DTI, but as they are constrained by their economic activity, they have limited maturity on their loans and hence their debt service ratio (DSTI) rises as their maturity falls, and can reach relatively high levels of DSTI (significantly above 50%).[46]

The advantage of DSTI regulation lies in the fact that it reduces the solvency risk of borrowers, which is the most common cause of credit default. However, a major disadvantage of DSTI is that it is undoubtedly cyclical in nature and would need to be linked to the level of interest rates. Cyclical policy instruments in general always tend to be more challenging to calibrate and even more so when they are forward-looking. The risk of an incorrect anticipation of the cycle exists at all times. Taking all these considerations into account, DTI regulation appears to be easier and carries a lower risk of Type II error and should be preferred over DSTI regulation. In extreme cases, it could then be complemented by DSTI regulation. However, it should be stressed that even DTI regulation itself carries a non-zero cost and the regulator should strongly consider its potential implementation.

There is also the question of whether to switch off the borrower-based measures when easing macroprudential policy, or just move their limits to predefined threshold values that should not fundamentally affect market developments (highly relaxed limits, such as an LTV of 90%, a DSTI of 50%, and a DTI of 9 times net annual income). From a regulatory point of view, the benefits of potential regulation at the threshold level in the form of credit loss limitations appear to be low, while at the same time having a non-zero cost in terms of foregone profits. Thus, a complete switch-off option seems preferable. However, the regulator may also consider other factors such as communication and signalling implications. The advantage of switching off the limits is that it sends a clear signal to the market that the sector is doing well and gives more freedom to the banking sector. On the other hand, leaving the limit in the marginal bands shows banks and potential loan applicants that the mortgage market is closely monitored and the scope for high-risk behaviour is thus minimal. Moreover, there is a risk of potential implementation delay in the reintroduction of borrower-based measures[47] and of frontloading before their reintroduction.

[46] The consequence of this shortcoming may be partly offset by the premise that older borrowers hold higher financial reserves and are thus able to use these reserves in case of difficulties in repaying loans.

[47] Once limits on borrower-based measures are tightened or reintroduced, banks in the Czech Republic have four months by law before limits come into effect. Thus, the time delay in recognizing the flow of riskier loans and in the subsequent implementation of borrower-based regulation could be up to three quarters in the extreme case.

However, this issue represents a problem only for a period of very strong credit expansion, the main prerequisite for which would be very low interest rates on new loans. Assuming a natural market evolution (loan volumes at long-run equilibrium), the time delay in the re-introduction of borrower-based limits and frontloading does not pose a risk to the stability of the mortgage portfolio.

From a structural perspective, regulation through borrower-based measures would make sense if the regulator wanted to improve the quality of banks' mortgage portfolios. In that case, the instruments should preferably be set at a constant level over a longer period. For example, if the average LTV of banks' mortgage portfolios is in the range of 80% upwards, regulation through the LTV would make sense and the average LTV could fall to about 50% over a five–ten year horizon, resulting in a significant improvement in the quality of mortgage portfolios and thus increasing the resilience of the sector as a whole.

Lastly, as recommended by the IMF (2014), the central bank should also define the maximum level of LTV and DSTI for the downward phase of the cycle, but this concept should be accompanied by minimum levels of those measures. Thus, it seems appropriate to define the macroprudential space for LTV, DSTI, and DTI regulation, for instance, an LTV from 70% to 100%, a DSTI from 40% to 50%, and a DTI from 7 to 9 times net annual income. Most importantly, by defining the macroprudential space for borrower-based measures, the regulator would anchor the expectations of the market, especially households, for whom saving for a down payment might not be easy. Moreover, the regulator should give banks room to evaluate special loan applications since they have more information about clients. Therefore, speed limits, such as volume exemptions (e.g., 5-15% of loan volumes), are considered necessary.

8. Conclusion

Using microeconomic data and the household stress test methodology, the paper assesses the timing, format, and necessity of introducing, tightening, or relaxing borrower-based measures. The simulations, conducted in the Czech Republic over a five-year horizon, explore various combinations of LTV, DTI, and DSTI limits. The paper employs two approaches to select the appropriate calibration. The first approach involves determining the optimal setting for borrower-based measures by selecting the maximum level of acceptable losses, either in absolute or relative terms. Subsequently, a combination of borrower-based measures is chosen through simulation to ensure that losses remain within the predefined limit. This results in multiple acceptable combinations of borrower-based measures, with a preference for the less restrictive ones. The second, and more preferable, approach evaluates the settings of borrower-based measures through a cost-benefit analysis. This involves comparing the cost of regulation, measured as foregone profits from mortgage transactions, with the benefits of the regulation in terms of potential loss reduction. This approach offers an optimization of the macroprudential strategy, aiming to minimize both Type I error (no intervention) and Type II error (excessive intervention).

The simulation results for the Czech Republic confirm the findings of the paper by Jurča et al. (2020) that a combination of value-based (LTV) and income-based (DTI/DSTI) measures significantly reduces the default rate and losses in the mortgage portfolio. However, in the current macro-financial environment (analysis based on data until May 2023) and taking into account not only the potential benefits in the form of reduced default rates and potential losses on the mortgage portfolio but also the costs of regulation, it appears that regulation through borrower-based

measures is unnecessary. If any borrower-based regulation should be chosen, then regulation through LTV only appears to be the most effective from the cost-benefit analysis perspective.

References

AASTVEIT, K. A., R. JUELSRUD, AND E. GETZ WOLD (2020): "Mortgage Regulation and Financial Vulnerability at the Household Level." Norges Bank Working Paper No. 6/20.

ALAM, Z., A. ALTER, J. EISEMAN, G. GELOS, H. KANG, M. NARITA, E. NIER, AND N. WANG (2024): "Digging Deeper–Evidence on the Effects of Macroprudential Policies from a New Database." *Journal of Money, Credit and Banking.*

ALMEIDA, H., M. CAMPELLO, AND C. LIU (2006): "The Financial Accelerator: Evidence from International Housing Markets." *Review of Finance,* 10(3):321–352.

BARASINSKA, N., P. HAENLE, A. KOBAN, AND A. SCHMIDT (2019): "Stress Testing the German Mortgage Market." Deutsche Bundesbank Discussion Paper No. 17/2019.

BIS (2012): "Operationalising the Selection and Application of Macroprudential Instruments." CGFS Paper No. 48, Bank for International Settlements.

BRÁZDIK, F., T. HLÉDIK, Z. HUMPLOVÁ, I. MARTONOSI, K. MUSIL, J. RYŠÁNEK, T. ŠESTOŘÁD, J. TONNER, S. TVRZ, AND J. ŽÁČEK (2020): "The G3+ Model: An Upgrade of the Czech National Bank's Core Forecasting Framework." CNB Working Paper No. 7/2020.

CERUTTI, E., S. CLAESSENS, AND L. LAEVEN (2017): "The Use and Effectiveness of Macroprudential Policies: New Evidence." *Journal of Financial Stability,* 28:203–224.

CLAESSENS, S. (2015): "An Overview of Macroprudential Policy Tools." *Annual Review of Financial Economics,* 7:397–422.

CLAESSENS, S., S. R. GHOSH, AND R. MIHET (2013): "Macro-Prudential Policies to Mitigate Financial System Vulnerabilities." *Journal of International Money and Finance,* 39:153–185.

CROWE, C., G. DELL'ARICCIA, D. IGAN, AND P. RABANAL (2013): "How to Deal with Real Estate Booms: Lessons from Country Experiences." *Journal of Financial Stability,* 9(3): 300–319.

DE NICOLÓ, M. G., G. FAVARA, AND M. L. RATNOVSKI (2014): "Externalities and Macroprudential Policy." *Journal of Financial Perspectives,* 2(1).

DENT, K., B. WESTWOOD, AND M. SEGOVIANO BASURTO (2016): "Stress Testing of Banks: An Introduction." *Bank of England Quarterly Bulletin,* 130–143.

DREHMANN, M., C. E. BORIO, L. GAMBACORTA, G. JIMENEZ, AND C. TRUCHARTE (2010): "Countercyclical Capital Buffers: Exploring Options." BIS Working Paper No. 317.

DYBCZAK, K., P. TÓTH, AND D. VOŇKA (2014): "Effects of Price Shocks on Consumer Demand: Estimating the QUAIDS Demand System on Czech Household Budget Survey Data." *Czech Journal of Economics and Finance,* 64(6):476–500.

GIORDANA, G. AND M. ZIEGELMEYER (2020): "Stress Testing Household Balance Sheets in Luxembourg." *The Quarterly Review of Economics and Finance,* 76:115–138.

GORTON, G. B. AND P. HE (2008): "Bank Credit Cycles." *The Review of Economic Studies,* 75 (4):1181–1214.

GREENWALD, D. (2018): "The Mortgage Credit Channel of Macroeconomic Transmission." MIT Sloan Research Paper No. 5184-16.

GROSS, M. AND J. POBLACIÓN (2017): "Assessing the Efficacy of Borrower-Based Macroprudential Policy Using an Integrated Micro-Macro Model for European Households." *Economic Modelling,* 61:510–528.

GÓRNICKA, L. AND L. VALDERRAMA (2020): "Stress Testing and Calibration of Macroprudential Policy Tools." IMF Working Paper No. 20/165.

HARRISON, I. AND C. MATHEW (2008): "Project Tui: A Structural Approach to the Understanding and Measurement of Residential Mortgage Lending Risk." Reserve Bank of New Zealand.

HODULA, M., M. MELECKÝ, L. PFEIFER, AND M. SZABO (2023): "Cooling the Mortgage Loan Market: The Effect of Borrower-Based Limits on New Mortgage Lending." *Journal of International Money and Finance,* 132:102808.

IMF (2014): "Staff Guidance Note on Macroprudential Policy-Detailed Guidance on Instruments." IMF Policy Paper, International Monetary Fund.

JURČA, P., J. KLACSO, E. TEREANU, M. FORLETTA, AND M. GROSS (2020): "The Effectiveness of Borrower-Based Macroprudential Measures: A Quantitative Analysis for Slovakia." IMF Working Paper No. 20/134.

KELLY, R., F. MCCANN, AND C. O'TOOLE (2018): "Credit Conditions, Macroprudential Policy and House Prices." *Journal of Housing Economics,* 41:153–167.

KOETTER, M. AND T. POGHOSYAN (2010): "Real Estate Prices and Bank Stability." *Journal of Banking & Finance,* 34(6):1129–1138.

KUTTNER, K. N. AND I. SHIM (2016): "Can Non-Interest Rate Policies Stabilize Housing Markets? Evidence from a Panel of 57 Economies." *Journal of Financial Stability,* 26: 31–44.

LEVINA, I., R. STURROCK, A. VARADI, AND G. WALLIS (2019): "Modelling the Distribution of Mortgage Debt." Bank of England Working Paper No. 808.

LIM, C. H., A. COSTA, F. COLUMBA, P. KONGSAMUT, A. OTANI, M. SAIYID, T. WEZEL, AND X. WU (2011): "Macroprudential Policy: What Instruments and How to Use Them? Lessons from Country Experiences." IMF Working Paper No. 11/238.

LINDNER, P. AND N. ALBACETE (2017): "Simulating Impacts of Borrower Based Macroprudential Policies on Mortgages and the Real Estate Sector in Austria–Evidence from the Household Finance and Consumption Survey 2014." Financial Stability Report 33, Oesterreichische Nationalbank.

MALOVANÁ, S., M. HODULA, Z. GRIC, AND J. BAJZÍK (2022): "Borrower-Based Macroprudential Measures and Credit Growth: How Biased is the Existing Literature?" *Journal of Economic Surveys.*

MALOVANÁ, S., J. JANKŮ, AND M. HODULA (2023): "Macroprudential Policy and Income Inequality: The Trade-Off Between Crisis Prevention and Credit Redistribution." CNB Working Paper No. 3/2023.

MERIKÜLL, J. AND T. ROOM (2020): "Stress Tests of the Household Sector Using Microdata from Survey and Administrative Sources." *International Journal of Central Banking,* 62.

NIER, E., R. POPA, M. SHAMLOO, AND L. VOINEA (2019.): "Debt Service and Default: Calibrating Macroprudential Policy Using Micro Data." IMF Working Paper No. 19/182.

PLAŠIL, M. (2021): "Designing Macro-Financial Scenarios: The New CNB Framework and Satellite Models for Property Prices and Credit." CNB Research and Policy Notes No. 1/2021.

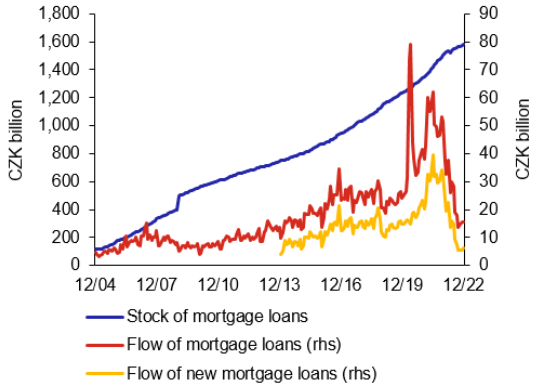
PLAŠIL, M. AND M. ANDRLE (2019): "Assessing House Price Sustainability." Thematic Article on Financial Stability, Czech National Bank.

PLAŠIL, M., J. SEIDLER, P. HLAVÁČ, AND T. KONEČNÝ (2014): "An Indicator of the Financial Cycle in the Czech Economy." Financial Stability Report 2013/2014, Czech National Bank.

SCHOENMAKER, D. AND P. WIERTS (2011): "Macroprudential Policy: The Need for a Coherent Policy Framework." Duisenburg School of Finance Policy Paper No. 13.

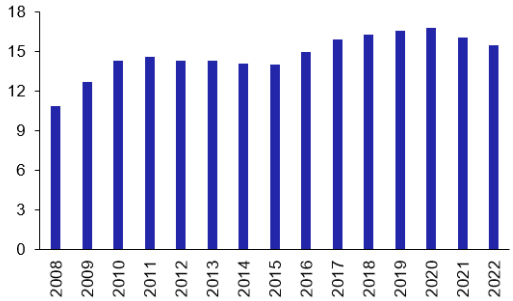
Appendix A: Figures and Tables

Figure A1: Stock and Flow of Mortgage Loans



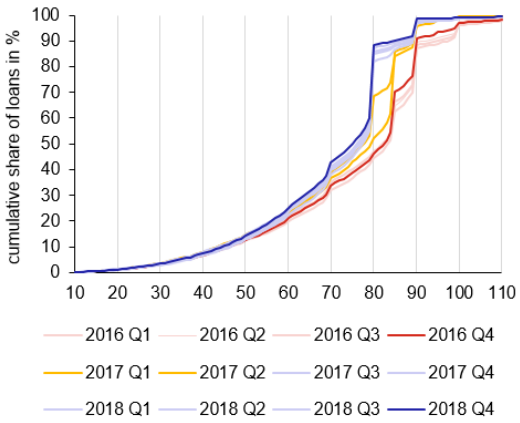
Source: CNB
Note: The hike in the stock of loans in 2008 reflects the change in methodology. New mortgage loans includes genuinely new mortgage loans, refinanced loans, and other renegotiations of existing loans. The spike in the flow of new mortgage loans in 2020 lies in the sharp increase of other renegotiations of existing loans due to the COVID-19 pandemic (mostly as a result of the loan moratorium).

Figure A2: Share of Households with a Mortgage Loan in the Czech Republic



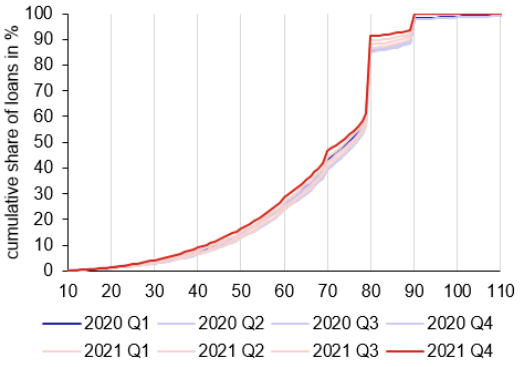
Source: CZSO
Note: This is the percentage share of households with a mortgage loan on a house or flat that is owned, privately owned or owned by a cooperative in terms of the legal reason for its use. This excludes households living in rented accommodation, with relatives and friends, etc.

Figure A3: LTV Tightening



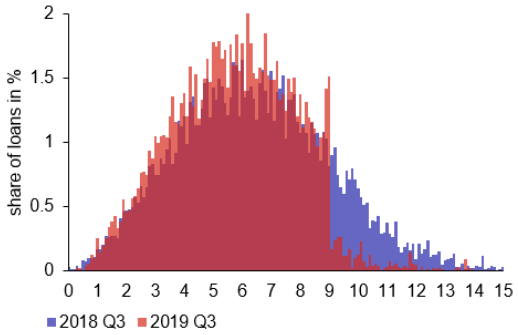
Source: CNB

Figure A4: LTV Easing



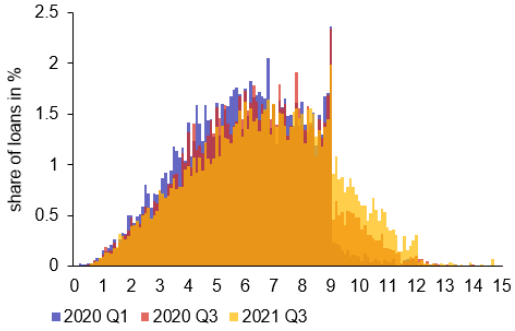
Source: CNB

Figure A5: Introduction of DTI Limit



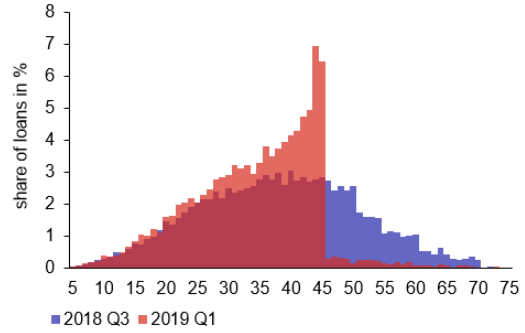
Source: CNB

Figure A6: Abolition of DTI Limit



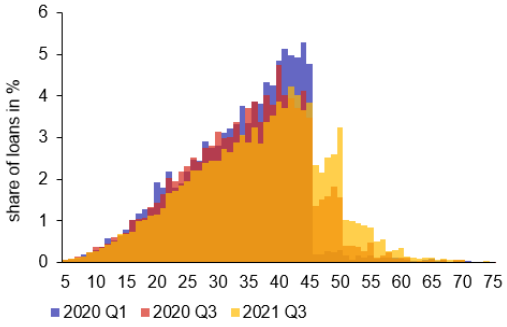
Source: CNB

Figure A7: Introduction of DSTI Limit



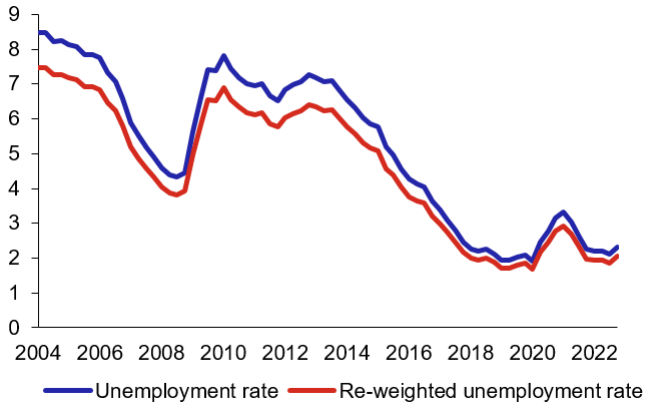
Source: CNB

Figure A8: Abolition of DSTI Limit



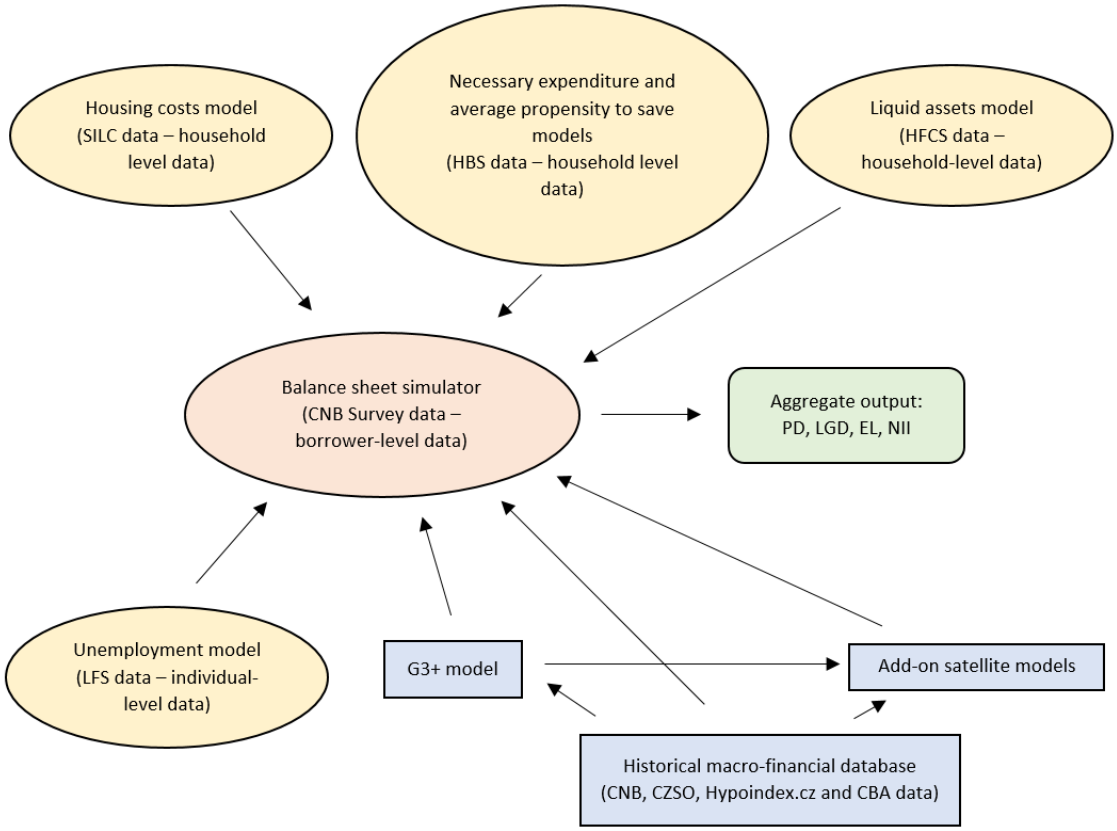
Source: CNB

Figure A9: Re-Weighted Unemployment Rate in %



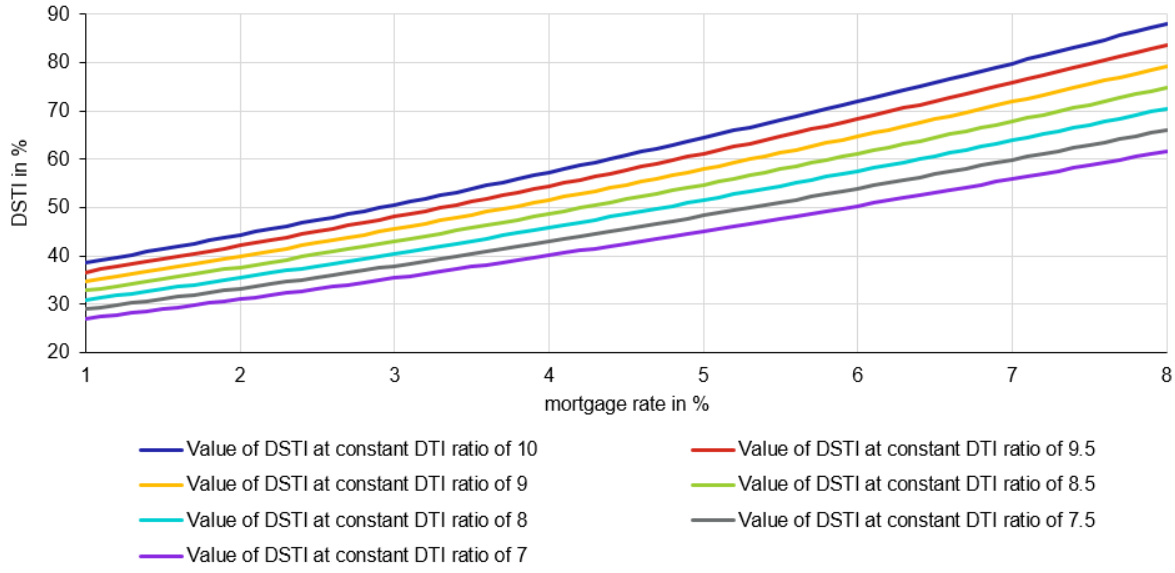
Note: The re-weighted unemployment rate (red line) corresponds to the educational structure of the mortgage portfolio.

Figure A10: Structure of the Modelling Framework



Note: The outputs from the individual micro-level models (orange) are linked into the balance sheet simulator using key common variables for each data set. The details are described in Appendix B.

Figure A11: DSTI and DTI Equivalent at Different Mortgage Rates



Source: CNB
Note: The loan maturity is assumed to be 30 years.

Figure A12: LTV Density Distribution with a 15% Volume Exemption

(a) Loans without age exemption (valid from 2022 Q2)

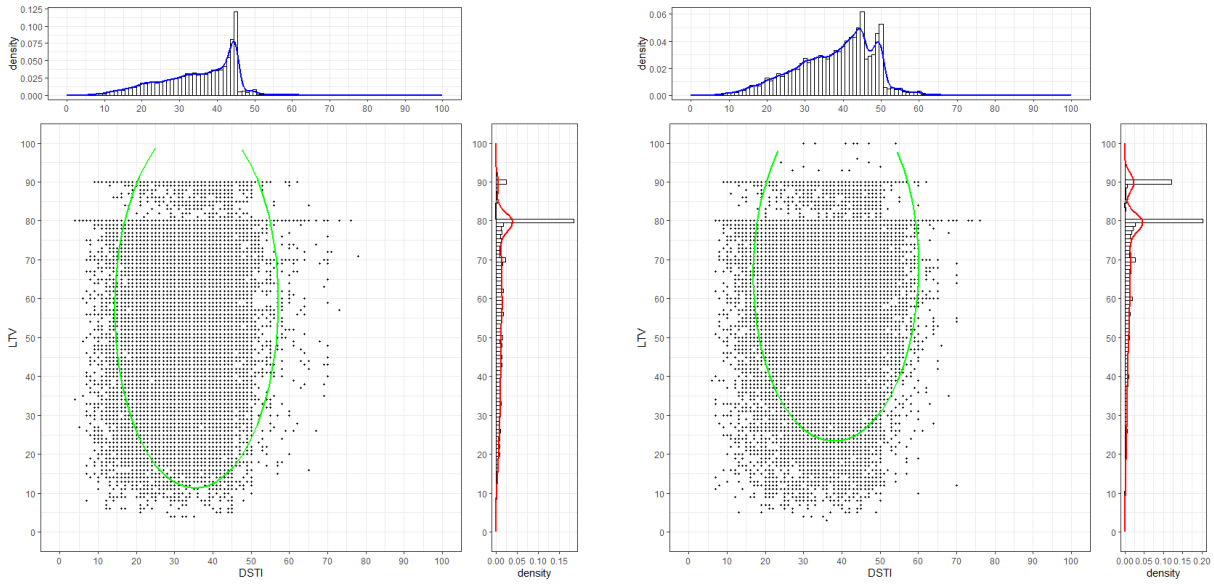
(b) Loans with age exemption (valid from 2022 Q2)

Source: CNB
Note: The red distributions indicate a tighter LTV limit of 80%, while the orange distributions show a more relaxed LTV limit of 90%. For 2022 Q2 and Q3, different limits apply to clients aged under 36 (age exemption - LTV of 90%) and over 36 (no age exemption - LTV of 80%). The black vertical line indicates the 85th percentile of the distribution.

Figure A13: Joint Probability Distribution

(a) Joint probability distribution of mortgage loans with 80% LTV limit and 45% DSTI limit

(b) Joint probability distribution of mortgage loans with 90% LTV limit and 50% DSTI limit



Source: CNB
Note: The green ellipse indicates a 95% data ellipse. The distribution for both charts A and B is based on the assumption that mortgage interest rates are 6% at the aggregate level.

Table A1: Median Values of Mortgage Loan and Borrower Characteristics

	All applicants					Applicants under 36 years					Applicants 36 years and over				
	2018	2019	2020	2021	2022	2018	2019	2020	2021	2022	2018	2019	2020	2021	2022
loan amount (CZK thousands)	1,808	1,935	2,250	2,789	2,890	1,992	2,025	2,500	3,000	3,000	1,660	1,750	2,000	2,500	2,600
loan collateral (CZK thousands)	3,060	3,303	3,800	4,600	4,950	3,000	3,290	3,800	4,600	4,800	3,120	3,400	3,800	4,690	5,000
property price (CZK thousands)	2,380	2,500	3,000	3,600	3,850	2,300	2,470	2,990	3,520	3,790	2,499	2,600	3,000	3,690	3,900
interest rate (%)	2.54	2.69	2.19	2.29	3.74	2.54	2.69	2.19	2.29	3.74	2.52	2.69	2.19	2.29	3.79
fixation (months)	60	71	83	60	72	60	82	83	60	72	60	60	72	60	72
maturity (months)	347	348	357	357	358	360	360	360	360	360	277	282	300	300	310
net annual income (CZK thousands)	464	510	557	613	674	415	461	504	552	612	532	579	626	694	757
age	35	35	35	36	36	29	30	30	30	30	42	43	43	43	43
additional debt (CZK thousands)	40	63	136	56	100	12	20	65	20	29	111	151	250	142	309
DTI (net annual income)	5.2	5.0	5.4	5.8	5.8	5.8	5.6	6.0	6.6	6.4	4.5	4.3	4.7	5.0	5.1
DSTI (%)	34	33	33	34	38	35	33	33	35	39	34	33	33	34	37
LTV (%)	74	72	73	70	69	79	78	78	77	73	69	67	68	65	64

Source: CNB

Table A2: Descriptive Statistics

	Mean	Sd	Min	Pctile[25]	Median	Pctile[75]	Max
loan amount (CZK thousands)	3,177	2,610	150	1,600	2,560	4,000	174,500
loan collateral (CZK thousands)	4,949	4,203	1	2,500	4,000	6,150	191,000
property price (CZK thousands)	4,139	3,539	7	2,000	3,300	5,200	177,500
interest rate (%)	2.3	0.6	0.5	2.0	2.2	2.5	6.4
fixation (months)	73	27	1	59	60	84	360
maturity (months)	309	68	13	275	346	359	360
monthly repayment (CZK thousands)	13.8	11.7	0.4	7.1	11.2	17.2	689.5
net annual income of client(s) (CZK thousands)	962	1,560	21	471	661	980	92,118
net annual income of main client (CZK thousands)	671	892	0	355	490	741	87,360
age of main client	38	8	18	31	37	44	82
additional debt (CZK thousands)	1,306	2,676	0	50	335	1,516	87,640
DTI (net annual income)	5.7	2.5	0.1	3.8	5.5	7.4	20.0
DSTI (%)	36	11	1	27	36	44	95
LTV (%)	70	18	3	60	78	80	145

Source: CNB

Table A3: Share of Mortgage Loans by Categorical Variables

loan category	mortgage loan 85.2%	bridge loan 14.8%			
loan determination	own housing 70.5%	for rent 5.3%	another property 8.7%	other 15.5%	
loan purpose	acquisition of real estate 67.1%	reconstruction 9.3%	construction 15.1%	non-purpose loan 1.5%	other purpose 7%
number of borrowers	1 54%	2 44.8%	3 1%	4+ 0.3%	
number of dependents	0 45.9%	1 23.6%	2 18.9%	3 9.4%	4+ 2.3%
source of income	employee 82.8%	self-employed 17.2%			
non-standard repayment process	Yes 2.7%	No 97.3%			
loan broker	Yes 66.6%	No 33.4%			
number of properties used as collateral	1 83.4%	2+ 16.6%			
first-time buyer	Yes 62.9%	No 37.1%			
borrower education	primary 0.6%	secondary 10.7%	secondary with diploma 44.1%	university 44.2%	not detected 0.3%
granting banks	Bank 1 21.7%	Bank 2 21.7%	Bank 3 16.3%	Bank 4 6.3%	others combined 34.1%
location of purchased property	Capital City of Prague 13.6%	Brno (city) 3.9%	Ostrava (city) 2.5%	Prague-East 2.4%	others combined 77.7%

Source: CNB

Table A4: Median Values of Variables Entering the Stress Test for SILC Households

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
monthly housing expenses (CZK thousands)	4.2	4.5	4.6	4.8	4.9	5.1	5.0	5.0	5.0	5.0	5.0	5.1	5.2	5.2
net annual income (CZK thousands)	365.7	400.6	406.4	411.2	421.7	423.6	450.9	460.2	480.5	489.6	526.5	572.1	607.4	604.9
number of economically active persons	2	2	2	2	2	2	2	2	2	2	2	2	2	2
number of children	1	1	1	1	1	1	1	1	1	1	1	1	1	1
age of the main member	39	40	40	39	39	39	40	41	41	42	42	42	43	43

Source: CZSO – SILC

Note: The values in the table apply to households with a mortgage loan and a head of household aged 15 to 70.

Table A5: The Choice of Distribution of Mortgage Loans According to the Stricter of the DTI/DSTI Limits

	Mortgage interest rates at the aggregate level					
	under 2%	2-3%	3-4%	4-5%	over 5%	over 6%
Any DTI limit and no DSTI limit	DTI	DTI	DTI	DTI	DTI	DTI
DTI of 7 times net annual income and DSTI of 50%	DTI	DTI	DTI	DTI	DTI	DSTI
DTI of 7 times net annual income and DSTI of 45%	DTI	DTI	DTI	DTI	DSTI	DSTI
DTI of 7 times net annual income and DSTI of 40%	DTI	DTI	DTI	DSTI	DSTI	DSTI
DTI of 8 times net annual income and DSTI of 50%	DTI	DTI	DTI	DTI	DSTI	DSTI
DTI of 8 times net annual income and DSTI of 45%	DTI	DTI	DTI	DSTI	DSTI	DSTI
DTI of 8 times net annual income and DSTI of 40%	DTI	DTI	DSTI	DSTI	DSTI	DSTI
DTI of 9 times net annual income and DSTI of 50%	DTI	DTI	DTI	DSTI	DSTI	DSTI
DTI of 9 times net annual income and DSTI of 45%	DTI	DTI	DSTI	DSTI	DSTI	DSTI
DTI of 9 times net annual income and DSTI of 40%	DTI	DSTI	DSTI	DSTI	DSTI	DSTI
No DTI limit and any DSTI limit	DSTI	DSTI	DSTI	DSTI	DSTI	DSTI

Note: The table shows only a simplified selection of the stricter limit by interest rate range for illustration purposes. However, the simulation defines the exact value of the DTI and DSTI with respect to interest rates. In both the simulation and the table, the selection of the more stringent of the DTI/DSTI parameters is assumed with a fixed maturity of 30 years.

Appendix B: Supplementary Models to the Household Stress Test

In addition to its fundamental model framework, the household stress test employs several additional models to estimate necessary expenditure (*NE*), housing costs (*HC*), the average propensity to save (*aps*), and liquid assets (*LA*). The variations in individual estimates arise from different data sources. HBS data is utilized for *NE* and *aps*, EU-SILC data for *HC*, and HFCS data for *LA*. Irrespective of the data source, outliers are removed by retaining data within the 1-99th percentile range, and for *NE* and *HC*, adjustments are made for inflation, converting them to constant prices. The estimation process involves the application of a simple weighted least squares (WLS) method, where the weight corresponds to the household's weight in the population:

$$Y = \alpha + \beta X + \varepsilon, \tag{B1}$$

where X includes the vector of explanatory variables. The choice of explanatory variables (household characteristics) tends to be restricted by the requirement of matching the variables in each data source with the variables in the CNB survey data. The set of possible variables is thus limited to the following: number of economically active persons, number of dependants, household income category (5 income quintiles), region of permanent residence, age of the head of the household, level of education of the head of household, dummy for having a mortgage. Table B1 shows the overview of used variables in the estimation of individual models.

Y denotes *NE*, *HC*, *aps*, and *LA*. The definition of *NE* relies on an estimation of the elasticity of demand (Dybczak et al., 2014), determining that *NE* includes expenditure on food, alcoholic and non-alcoholic beverages, cigarettes, and health. *HC* encompasses costs for rent, electricity, gas, central heating, water, fuels, maintenance, property tax, and other housing-related services, explicitly defined in the EU-SILC database. *aps* represents the ratio of monthly savings to net monthly income, where monthly savings are the amount of income a household retains after subtracting total monthly consumption and monthly payments on debts or other obligations. Finally, *LA* covers the stock of all liquid assets, such as assets in current, savings, and fixed-term accounts, building societies, mutual and similar funds, government or corporate bonds/debentures or notes, stocks, endowment life insurance, and other financial assets (e.g., cash savings).

Table B1: Explanatory Variables in Supplementary Household Stress Test Models

Explanatory variables	NE equation	HC equation	aps equation	LA equation
number of economically active persons	YES	YES	YES	YES
number of dependants	YES	YES	YES	NO
household income category	YES	YES	YES	YES
region of permanent residence	YES	YES	YES	YES
age of the head of the household	YES	YES	YES	YES
level of education of the head of household	YES	NO	YES	YES
dummy for having a mortgage	NO	YES	YES	YES

Note: In general, NO means that the variable was included in the estimation but removed after it was found to be insignificant.

Using parameters α and β from Eq. B1, I define *NE*, *HC*, *aps* and *LA* for the households in the CNB survey database. The variables are further adjusted in time on an annual basis using general inflation for *NE* and *HC*, and the dynamics of household financial assets at the aggregate level for *LA*.

Appendix C: Adjustment of the Macroeconomic Scenario for the Second-Round Effect

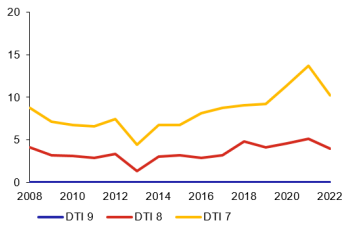
The second-round effect of borrower-based regulation involves adjusting the number of new mortgage loans. To make this adjustment, the concept of maximum accessibility of a household to an average mortgage loan is employed. This concept assumes that banks establish their internal lending limits, even in an unregulated environment. From the available data, it appears that the limit on the DTI ratio is set at 12 times net annual income, the limit on the DSTI ratio at 60% of net monthly income, and the LTV limit is 95% of the value of the collateral. Given these internal limits, the calculation determines how many households qualify for the average mortgage loan. Subsequently, the introduction of borrower-based regulation is assumed, and the percentage change in the number of households eligible for a mortgage loan is computed.

I use SILC data to determine the maximum credit accessibility in relation to the DTI and DSTI ratios. Specifically, I examine the income distribution of households and exclude those whose ratio of average mortgage loan repayment to net monthly income falls below 60%. This calculation takes into account average mortgage interest rates and the age structure of households, where older households have a shorter mortgage loan maturity capped at 30 years. Subsequently, I assess the change in the number of households eligible for a mortgage loan if DSTI regulatory values of 50%, 45%, and 40% are implemented. The computation of maximum accessibility in terms of DTI follows a similar process, concentrating on the total debt-to-income ratio and considering only the mortgage loan as a debt for simplicity (essentially an LTI calculation).

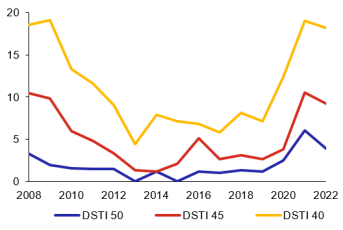
The calculation of maximum credit accessibility in relation to the LTV ratio relies on estimating the maximum down payment. This down payment encompasses all the liquid assets of the household and simultaneously considers the value of the real estate owned by the household, as property can serve as additional collateral for the mortgage loan. Using data from HFCS, I determine the number of households that can access a mortgage loan based on the distribution of the maximum down payment. Subsequently, I calculate the percentage difference in credit availability for households in response to LTV limit adjustments.[48]

Figure C1: Hypothetical Percentage Cut in the Number of New Mortgage Loans by the DTI, DSTI and LTV Ratios

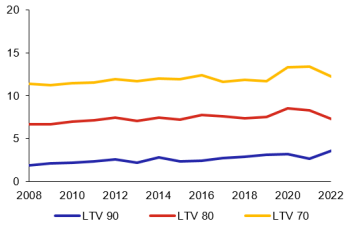
(a) DTI in multiples of net annual income



(b) DSTI in %



(c) LTV in %



[48] In calculating the maximum mortgage loan attainability for a household, I incorporate the assumption that households can partially adapt to regulation. Thus, accessibility calculations presume that, in the event of regulation, a household that would otherwise be unable to access a loan can reduce its required loan by 10%.

Figure C1 illustrates how various borrower-based measures affect the percentage reduction in the number of new mortgage loans. The chart demonstrates that the effect of LTV regulation on the number of loans remains relatively constant over time. Significant variability exists for DSTI regulation, influenced, among other factors, by the dependence of the indicator on interest rates. Consequently, DSTI regulation becomes more stringent as interest rates rise, limiting the availability of credit to a larger share of households, all else being equal.

The situation becomes more complex when simultaneous regulation by multiple measures is considered. In the case of DTI and DSTI regulation, I select the stricter of the two measures based on the prevailing level of interest rates. However, when DSTI or DTI regulation is coupled with LTV regulation, the joint effect of these measures must be taken into account. Utilizing available mortgage loan data from the CNB Survey, I estimate the probability that a household surpasses both the DTI/DSTI and LTV limits simultaneously and adjust the percentage reduction in new loans accordingly.

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