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SELECTED ISSUES

June 28, 2023

Approved By
European Department

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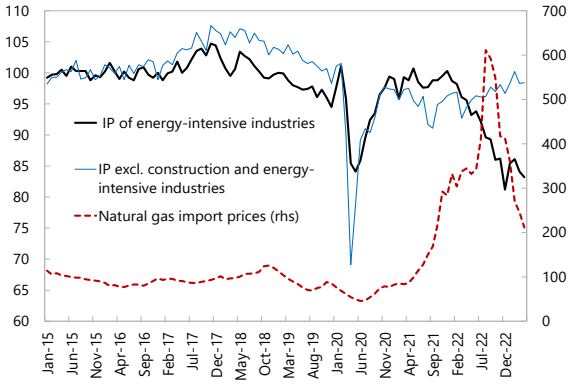
IMPACT OF HIGH ENERGY PRICES ON GERMANY'S POTENTIAL OUPUT[1]

The surge in energy prices since Russia's invasion of Ukraine has reduced the energy-intensive sector's production in Germany, although the non-energy intensive sector's production has held up thanks in part to firms' efforts to improve energy efficiency. Energy prices are expected to remain elevated in the foreseeable future, compared to pre-war levels, adversely affecting firms' productivity and thus lowering Germany's potential output. Economic modeling suggests that this effect could be around 1¼ percent of GDP in staff's baseline, with some uncertainty around this estimate, given uncertainties about the ultimate magnitude of the energy price shock and the degree to which increased energy efficiency can mitigate it. Policies can promote effective adjustment to the shock by increasing productivity and maintaining strong price incentives to conserve energy and invest in renewable energy production.

A. Introduction

1. The surge in energy prices since Russia's invasion of Ukraine has led to a contraction in the energy-intensive sector's production, while the non-energy intensive sector's industrial production has remained resilient. At their peak in 2022, Germany's natural gas import prices reached nearly tenfold their 2021 average, before falling to below threefold the 2021 average as of April 2023. In response to the surge in gas prices, production of energy-intensive industries[2] declined almost 20 percent from pre-war levels between late 2021 and late 2022 (Figure 1). Meanwhile, production of other industries saw limited declines during 2022, followed by a gradual increase in 2023 as pandemic-induced supply disruptions started easing and external demand recovered.

Figure 1. Gas Price and Industrial Production
(2015=100, seasonally adjusted)



Sources: Destatis and Haver Analytics.

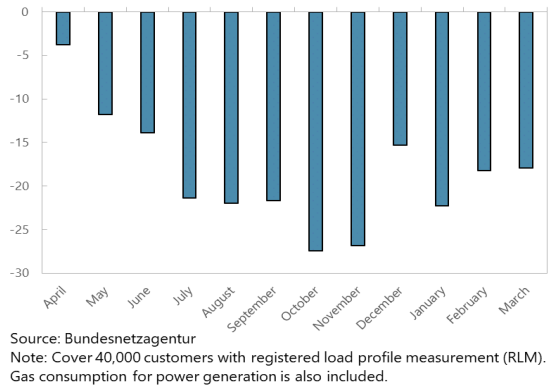
2. Amid the surge in gas prices, German industries have considerably reduced gas consumption by substituting gas with other types of energy or improving their energy efficiency. During the second half of 2022, German industries' gas consumption was on average

[1] Prepared by Yushu Chen, Ting Lan, Aiko Mineshima, and Jing Zhou (all EUR).

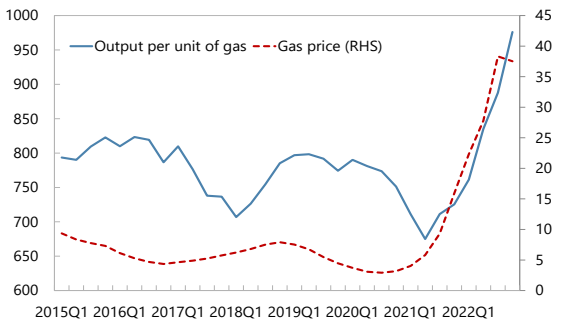
[2] Energy-intensive industries include: (i) manufacture of chemical products; (ii) metal production and processing; (iii) manufacture of glassware, ceramics, stone, and earth processing, (iv) manufacture of paper, cardboard, and goods made from them; and (v) coking plant and petroleum processing. These industries constituted 13.2 percent of industrial production in 2015 (the base year for the current IP data), and 3.1 percent of GDP in 2020 (the latest available data point).

22 percent below their 2018–22 levels (Figure 2, top left). Their gas intensity—measured by output per unit of gas—improved by around 25 percent since 2021 (Figure 2, top right), of which about two-thirds was driven by efficiency gains within sectors and one-third from shifts in production from energy-intensive sectors to other sectors (Figure 2, bottom left). This is consistent with survey results that show more than half of manufacturing firms planned to invest in energy efficiency measures (Figure 3, bottom), plans supported by rises in public spending on clean energy R&D and in the number of new clean energy start-ups (Figure 2, bottom right). Survey evidence by the Ifo Institute for Economic Research shows that 75 percent of German firms were able to save natural gas without reducing production.

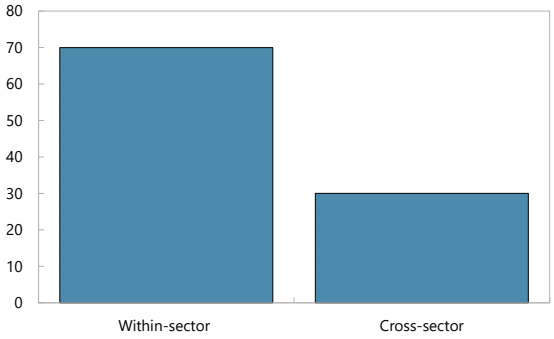
Figure 2. German Industries' Gas Consumption and Gas Efficiency



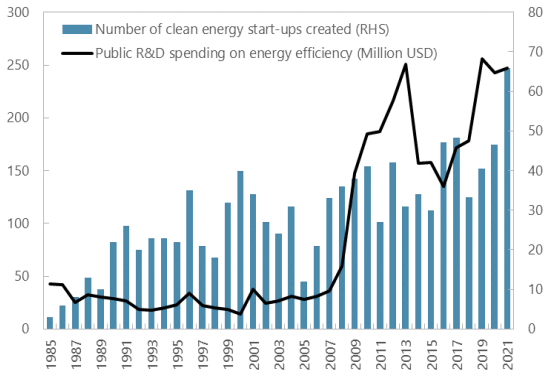
Source: Bundesnetzagentur
Note: Cover 40,000 customers with registered load profile measurement (RLM). Gas consumption for power generation is also included.



Sources: Eurostat and EIA.



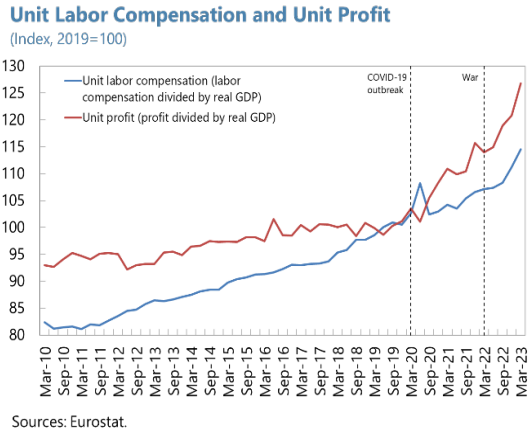
Sources: Eurostat.



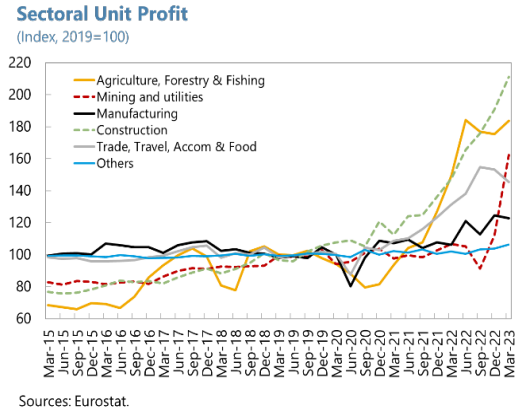
3. Despite high energy prices, corporate profits have remained resilient. Unit profit per real output has exceeded the historical trend and increased by almost 20 percent in the last two years (Figure 3, left), and the average profit share between 2022Q1 and 2023Q1 was 2 percentage points higher than the 2019 average. On the contrary, after a temporary spike during the 2020Q2 lockdown during the COVID-19 pandemic, unit labor cost has not surpassed its trend despite high inflation, although with an uptick in late-2022. The increase in unit profit was concentrated in

agriculture, construction, manufacturing, utilities, and contact-intensive service sectors (Figure 3, right). A survey conducted by DIHK suggests that facing higher energy costs, three-quarters of manufacturing firms in Germany planned to pass high production costs onto end-users (Figure 3, bottom). And some companies have taken advantage of their pricing power to increase their sales prices more than was indicated by the development of purchase prices.[3] For the utility sector its unique market structure allowed for windfall profit gains; due to the inframarginal pricing in the electricity market, where electricity prices are determined by the marginal cost of production (which was driven by fossil-fuel-based electricity producers in 2022), electricity producers that use renewable sources experienced virtually no increases in their marginal costs but much higher revenues. For contact-intensive sectors such as food and travel, the post-pandemic pent-up demand provided them with pricing power and led to increases in profit margin. Similarly, the construction sector enjoyed larger pricing powers, aided by buoyant demand for housing. Agriculture and manufacturing, which produce a larger share of tradable goods than the other sectors, have benefited from rising global prices (e.g., the food shortage caused by Ukraine grain exports disruptions).

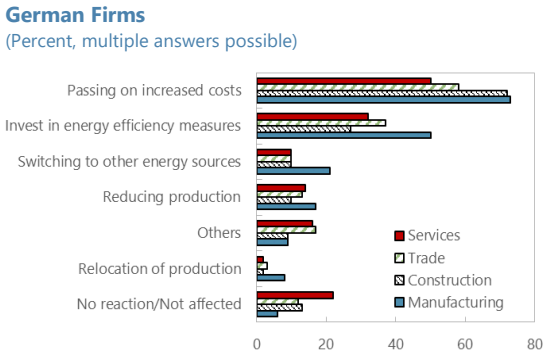
Figure 3. Corporate Labor Compensation and Profit



Sources: Eurostat.



Sources: Eurostat.



Source: DIHK Economic Survey Fall 2022
Question asked: How do you react to the high electricity, gas and fuel prices?

[3] See, for instance, German Companies in Trade, Construction, and Agriculture Used Inflation to Increase Profits.

4. Against this background, we analyze the possible effects of the energy price shock on Germany's potential output over the medium term. We do this using a closed-economy, directed technical change model. The rest of this chapter discusses this model's set-up and results. It then concludes with a discussion of possible policy responses.

B. Analytical Approach

5. We analyze the impact of energy price shocks on potential *growth* and *output* with a closed-economy, directed technical change model.[4] The directed technical change model, initially proposed by Acemoglu (2002), considers that technological progress is shaped by deliberate choices made by firms, rather than considering it as exogenously given. In this model, firms allocate resources towards technologies that complement specific factors, and the relative profitability of different types of technologies determines the direction of technical changes. There are two competing factors that shape the relative profitability of different types of innovation. The first factor is the price effect, which incentivizes the development of technologies used in the production of more expensive goods or those that rely on more expensive inputs for production. The second factor is the market size effect, which encourages the development of technologies that have a larger market share, particularly those utilizing the more abundant factor. These two effects are in competition with each other, as the price effect favors technological advancements benefiting scarce factors, while the market size effect drives innovations complementing the abundant factor. The relative strengths of these effects are determined by the elasticity of substitution between the factors. When the elasticity of substitution is low, scarce factors command higher prices, leading to a relatively more dominant price effect. Our analysis reveals that there is a relatively low elasticity of substitution between energy and labor-capital inputs. This suggests that when energy prices increase, the price effect becomes dominant in influencing firms' production decisions. In response, firms tend to prioritize and direct their technical changes towards enhancing energy efficiency.

Firms' Optimization Problem for Technology and Inputs

6. Assuming that energy is a key input for production with its own productivity parameter (energy efficiency), the firm's production function can be written as follows:

$$y_t \equiv F(A_t k_t^{\alpha} l_t^{1-\alpha}, A_{et} e_t) = \left[(1-\gamma)(A_t k_t^{\alpha} l_t^{1-\alpha})^{\frac{\epsilon-1}{\epsilon}} + \gamma(A_{et} e_t)^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}},$$

where ϵ is the elasticity of substitution between capital (k_t) / labor (l_t) and energy (e_t), A_t is capital-labor productivity, A_{et} is energy productivity, and γ is the share parameter in the CES production

[4] The model draws inspiration from the work of Acemoglu (2002), Acemoglu, Aghion, Bursztyn & Hémous (2012), and Hassler, Krusell, and Olovsson (2021).

function. We employ a Bayesian estimation approach to jointly estimate ϵ and the shock variances. The posterior estimate of ϵ for Germany is 0.03.[5] With a relatively low elasticity of substitution, the price effect will be dominant, implying that higher energy prices will incentivize firms to raise energy efficiency.

At each period t, a fixed amount of R&D investment is allocated to enhance the efficiency of the capital/labor bundle and energy efficiency, where firms choose efficiency growth A_{t+1}/A_t and $A_{e,t+1}/A_{et}$ subject to the technology constraint:

$$G\left(A_{t+1}/A_t, A_{e,t+1}/A_{et}\right) = 0,$$

where G is strictly increasing in both arguments. Thus, the choice to select a high level of one of the input-saving technologies comes at the expense of the other.[6] Once a firm chooses the allocation of R&D investment, it takes the technology levels for A_t and A_{et} as given and chooses levels for k_t, l_t, and e_t. Under the baseline scenario where energy prices are assumed to be 20 percent higher than the pre-pandemic levels in 2028, our simulation results indicate that Germany's energy efficiency by thenis higher by 6 percentage points compared with the counterfactual of a no-shock scenario.

Consumers' Optimization Problem

7. A representative household is assumed to maximize its utility subject to resource and budget constraints. The household derives utility from a stream of consumption units, c_t. It owns a depletable energy resource R, and it supplies one unit of labor l inelastically each period. The problem for the households is to maximize

$$U = \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma} - 1}{1-\sigma}$$

subject to the resource constraint,

$$\sum_{t=0}^{\infty} e_t = R_0$$

as well as the budget constraint

$$c_t + k_{t+1} = w_t l_t + r_t k_t + p_t e_t$$

[5] The size of the elasticity of substitution is comparable to that for the euro area of 0.04 by Lan et al. (2023) and that for the U.S. of 0.02 by Hassler et al. (2021). There is a typical degree of uncertainty around the estimated parameter.

[6] In our analysis, we assume that the G function exhibits constant returns to scale and is quasi-concave and twice differentiable.

Aggregation

At the aggregate, the economy's planning problem can be written as

$$\max_{\{c_t,k_{t+1},l_t,e_t,A_{t+1},A_{e,t+1}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma}-1}{1-\sigma}$$

subject to the budget constraint,

$$c_t + k_{t+1} = F(A_t k_t^{\alpha} l_t^{1-\alpha}, A_{et} e_t) + (1-\delta)k_t$$

and subject to the technology constraint

$$G\left(A_{t+1}/A_t, A_{e,t+1}/A_{et}\right) = 0,$$

for all t, and with the resource constraint

$$\sum_{t=0}^{\infty} e_t \leq R_0$$

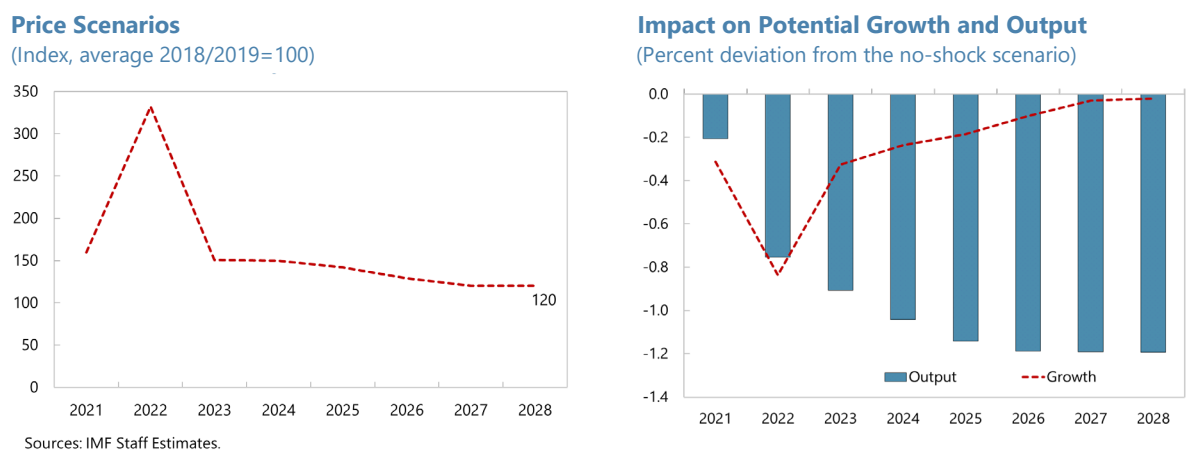
C. Impact of Higher Energy Prices

8. With the model calibrated for Germany, we simulate the impact of higher energy prices on Germany's potential *growth* and potential *output*. The model allows technology to respond endogenously to changes in the economic environment and thus save on expensive inputs. With a relatively low calibrated elasticity of substitution between energy and capital-labor inputs, compared with the typical size of the elasticity of substitution between capital and labor, energy price shocks prompt a shift in investment from enhancing capital-labor productivity to enhancing energy efficiency. This leads to both less capital-labor productivity and more energy efficiency relative to the balanced growth path. In the short to medium term, such energy efficiency gains cannot fully offset the adverse price effect and the transitional cost of shifting investment from capital-labor productivity to energy productivity. This in turn lowers potential *growth* and *output* compared with a no-energy shock scenario. Over the long run, however, the economy is expected to adjust and return to the balanced growth path, but the temporary deviation from the balanced path will lead to a permanent output loss.

9. Energy prices that are 20 percent above the 2018–19 average are estimated to reduce Germany's potential output by 1.2 percent in the medium term. In the scenario where energy prices in Germany (i.e., the consumption share-weighted average of coal, oil, and natural gas prices) are assumed to stay 20 percent above pre-pandemic levels (based on futures prices as of June

2023),[7] the growth of energy efficiency takes off while the growth of capital-labor productivity falls, leading to a decrease in potential growth and output. The largest adverse impact is estimated to have taken place in 2022, when energy prices rose by 232 percent from the 2018–19 average, while the annual incremental impact diminishes over time (Figure 4). By 2028, potential *output* is estimated to be lower by 1.2 percent compared to the no-shock scenario. Meanwhile, the adverse impact on potential growth diminishes to well below 0.1 percentage points by 2028.

Figure 4. Baseline Energy Price Path and Impact on Potential Growth and Output

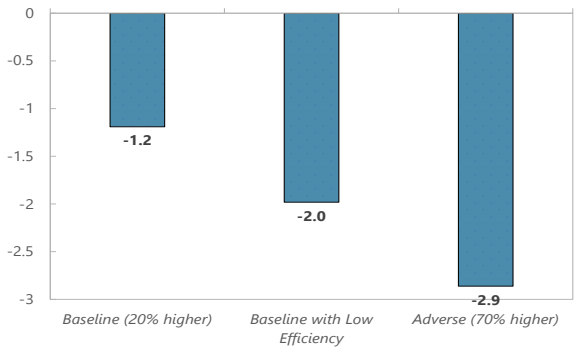


Source: IMF staff

10. Output losses become larger if energy efficiency is less responsive to energy price changes or if price shocks are greater.[8] When energy prices increase, the directed technical change mitigates the negative economic consequences of high energy prices. However, the effectiveness of this cushioning effect depends on the degree to which energy efficiency responds to changes in energy price. In an alternative scenario where energy efficiency is less responsive to the high energy price shock—i.e., an energy efficiency gain of only around 4 percentage points by 2028, instead of 6 percentage points assumed under the baseline—the level of potential output is estimated to be

Figure 5. Impact of Higher Energy Prices on Potential Output

(Percent deviations from the no-shocks scenario in 2028)



Sources: IMF Staff Estimates

[7] The weight of each energy product is calculated with data on German industries' energy consumption from Eurostat's Energy Balances database.

[8] Our approach has limitations in capturing the multi-sector input-output effects and the potential re-allocation of production across sectors and across countries. These factors could influence the overall impact of higher energy prices on the economy.

2 percentage points lower than that in the non-shock scenario (Figure 5, middle bar). Furthermore, the impact on potential output also depends on the size of energy price shocks. In an adverse scenario where energy prices are assumed to be 70 percent higher than the pre-pandemic level—around the peak of five-year future energy prices, which was observed in the fall of 2022—the estimated reduction in potential output is 2.9 percentage points (Figure 5, right bar).

D. Conclusion and Policy Discussion

11. Permanently higher energy prices could reduce Germany's potential output, but some of the impact is expected to be offset by firms' endogenous response to improving energy efficiency. Under the scenario in which energy prices are above the 2018–19 average by 20 percent, the energy price shock could reduce Germany's potential *output* by around 1.2 percent and potential *growth* by 0.1 percentage points over the medium term, compared to the non-shock scenario. The adverse impact becomes larger if firms' energy efficiency response to price increases is low and/or energy prices turn out to be higher.

12. Policy recommendations. Some decline in Germany's potential output level as a result of higher energy prices is likely unavoidable. However, good policies can help mitigate this loss and avoid exacerbating it. Specifically, it is important to note the following:

- **Price signals are important.** Increased energy efficiency is key to mitigating the adverse effects of the energy price shock. Suppressing price signals by—for example, subsidizing energy prices—could delay improvements in energy efficiency (and the climate transition).
- **Boosting labor and capital productivity remains critical.** Higher labor and capital productivity can help offset output losses from higher energy prices. Government policy can help boost productivity by fostering innovation and human capital development, as discussed in more detail in the 2023 and previous year's Article IV reports.
- **Government interventions can help direct the transition to cleaner energy.** It is important that Germany respond to the energy shock in ways that also support the green transition, given Germany's goals to significantly reduce its CO2 emissions. This can be achieved by continuing to gradually increase carbon pricing while also increasing public investment in renewable energy infrastructure and energy efficiency.

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"Many industrial companies in Germany cut Gas consumption without curbing production." Ifo Institute. Many Industrial Companies in Germany Cut Gas Consumption without Curbing Production | Press release | ifo Institute.

BORROWER-BASED MACROPRUDENTIAL INSTRUMENTS IN GERMANY[1]

Germany's macroprudential policy toolkit is well-developed, but its key missing piece is a set of instruments related to a borrower's income. In addition, existing powers to adopt LTV limits have not yet been deployed. Against this background, this paper advances the discussion of borrower-based macroprudential policy in Germany by explaining how borrower-based measures could strengthen financial stability, macroeconomic stability, and consumer protection; explaining how potential concerns about these instruments could be addressed; offering approaches to initial calibrations of instruments for further analysis; and hinting at their likely effects based on other countries' experiences. The paper also uses a microsimulation model to show that activating borrower-based measures could provide as much capital to the banking system as the capital buffer requirements that were activated in 2022.

A. Introduction

1. This paper considers residential real estate vulnerabilities in Germany, the toolkit of borrower-based measures, and their settings. Relative to previous work by the Bundesbank, ESRB, and IMF, this paper provides additional discussion and new quantifications of the policy advice. Recent developments in property markets and macroprudential policy, policy advice for addressing vulnerabilities in commercial real estate markets, and the authorities' views on the current state of macroprudential policy are all covered instead in the accompanying staff report (IMF, 2023a). The remainder of this section explains the structure of this paper.

2. Section B discusses why income-based macroprudential instruments are needed in Germany. Germany's macroprudential toolkit contains risk weights, bank capital buffers, and borrower-based measures in the form of loan-to-value (LTV) ratio limits and amortization requirements, though powers to deploy LTV limits and amortization requirements have not yet been used. The existing borrower-based measures are described in Box 1. However, Germany's toolkit is missing income-related borrower-based measures, like limits on the debt service-to-income ratio. Germany's Financial Stability Committee, IMF staff, and the ESRB have recommended that income-related measures be added to the toolkit. Section B revisits and elaborates on their arguments. Legislation has been drafted and will be presented to parliament when the political environment is opportune.

3. Sections C and D explain, in staff's view, why borrower-based macroprudential measures should be activated in Germany in future as the economy recovers. The IMF and the

[1] Prepared by Galen Sher (EUR), with thanks to Yushu Chen, Marizielle Evio, and Santiago Previde for excellent research support. The author thanks Saioa Armendariz, Oya Celasun, Pragyan Deb, Kevin Fletcher, Karina Garcia, Andre Geis, Heedon Kang, Jaunius Karmelavičius, Roland Meeks, Adil Mohommad, Marco Pani, Narayanan Raman, Laura Valderrama, and seminar participants at BaFin, the Bundesbank and Federal Ministry of Finance for helpful comments.

ESRB have recommended that borrower-based measures be activated in Germany. Section C revisits the arguments that support this recommendation. Section D critically reviews some potential concerns associated with their activation and explains how some can be addressed or where further work is needed.

4. In Section E, we use a simulation to quantify how much less banks' capital would decline, under a one-year housing market stress scenario starting in 2022Q2, if LTV and DSTI limits had been imposed in 2015. The financial stability benefits of residential borrower-based measures are most evident in a housing market stress scenario (i.e., a scenario in which house prices decline rapidly) because falling house prices make it more likely that borrowers default by being pushed into negative equity and because falling house prices reduce the amount that banks can recover from defaulted mortgages through the foreclosure process. Therefore, the stress scenario in this study incorporates a significant housing market price decline. We find that the benefits of these LTV and DSTI limits would be to prevent losses in CET1 bank capital under the stress scenario of almost 6 percent, or €26 billion. This is similar to the €23 billion that was locked in through the introduction of CCyB and SSRB capital buffers in 2022. These estimates are subject to significant model and scenario uncertainty, but their effectiveness supports the view that borrower-based measures can bolster financial stability and play a helpful role alongside capital-based measures in the macroprudential policy mix.

5. Section F presents simple and intuitive approaches to calibrating borrower-based measures in Germany. These approaches fill a gap in the literature. However, they are only a first step for policy design in Germany and require further analysis and refinement.

6. In Section G, we summarize evidence of the effects of borrower-based measures in advanced economies like Germany. We also offer case studies of advanced economies' experiences with these measures.

B. The Case for Adding Income-Related Macroprudential Instruments to the Toolkit

7. Income-related macroprudential instruments restrict the ability of banks to lend large sums to homebuyers relative to their incomes. Specifically, they restrict the amount of a bank's new lending (i.e., the number of new loans or their total value) over a specific period (e.g., three months) that can exceed specific thresholds linked to the borrower's income. The thresholds could be specified in terms of the debt service-to-income (DSTI) ratio, which is the ratio of (typically monthly) interest and principal repayments on the new mortgage and all other debts of the borrower relative to her income, the debt-to-income (DTI) ratio, which is the value of the mortgage loan and the outstanding balances of all other debts of the borrower relative to her income, or the loan-to-income (LTI) ratio, which is the value of only the mortgage loan relative to the income of the borrower. For example, in Austria, only 10 percent of a bank's newly issued loans over a six-month period are allowed to exceed a 40 percent DSTI ratio.

8. Income-related macroprudential instruments are the key missing piece in Germany's otherwise well-developed toolkit. Currently, the macroprudential toolkit contains, among other measures, the ability to vary risk weights for certain types of lending, a countercyclical capital buffer (CCyB), a sectoral systemic risk buffer (SSRB), capital buffers for systemically important financial institutions, restrictions on the amount of a bank's new lending that can exceed specific thresholds on loan-to-value (LTV) ratios, and minimum amortization rates (see Box 1). Along with LTV and amortization requirements (and maturity limits for interest-only loans), income-related macroprudential instruments are known as "borrower-based measures", while risk weights, the CCyB and SSRB are known as "lender-based measures" or "capital-based measures".

9. Borrower-based tools are needed as a complement to lender-based tools, for at least five reasons: (i) they can target some risky lending practices in ways that capital measures cannot, thus resulting in fewer spillovers to other types of lending, with the potential side-effect of achieving the same banking sector resilience with lower levels of capital overall;[2] (ii) bank capital might not be fully usable in a crisis, given overlapping requirements including the leverage ratio and MREL (IMF, 2022b); (iii) higher bank capital requirements tend to have a limited effect on credit growth when this is accompanied by increasing asset prices (IMF, 2013); (iv) excessive leverage by borrowers can fuel unsustainable construction activity, real estate prices, and/or consumption during a boom that then reverses during a downturn,[3] amplifying economic volatility, even if borrowers do not default on loans (i.e., this is an economic stability motivation, rather than a financial stability motivation); and (v) consumers need to be protected from overindebtedness, even if banks could withstand the associated credit losses (i.e., this is a consumer protection motivation, rather than a financial stability motivation).[4]

10. Furthermore, the authority to set limits on DSTI/DTI/LTI ratios would substantially complement the existing authority to impose limits on LTV ratios or amortization requirements:

- Unlike LTV caps, DSTI/DTI/LTI caps do not relax as house prices rise, and they in fact bind more tightly when house prices grow faster than incomes, which can therefore guard against

[2] For example, limiting the quantity of high-LTV lending need not affect interest rates paid by lower-LTV borrowers, whereas even the relatively targeted SSRB on residential real estate could affect interest rates paid by both high- and low-LTV borrowers. While it is in principle possible to target an SSRB at a specific segment of the mortgage market, like high-LTV loans, such an SSRB would need to show that the targeted segment itself is systemic, which can be difficult in practice (IMF, 2022b). Furthermore, an SSRB targeted at a specific segment of the mortgage market might not be effective at limiting credit supply to that segment, because it might not be effective in raising a bank's cost of financing such lending (ECB, 2022).

[3] Construction accounted for 5.4 percent of nominal gross value added, on average, between 2018 and 2022.

[4] In Germany, legislation on borrower-based measures is aimed primarily at preserving financial stability and does not include consumer protection as one of the goals of borrower-based measures (Box 1).

situations where house prices and credit feed off each other. It also makes them effective in preventing credit from fueling even greater house price overvaluations.[5]

- DSTI/DTI/LTI caps make it less likely that a borrower is forced into default in the first place, while LTV caps make it more likely that the bank is able to recover the lost loan repayments by selling the underlying residential property (and thus less likely that the borrower is left with unpaid debt after foreclosure).

- DSTI/DTI/LTI caps should be in the toolkit because, if LTV caps or amortization requirements are someday activated, then DSTI/DTI/LTI caps can prevent associated leakages. For example, DSTI/DTI/LTI caps can prevent some of the incentive for banks to provide a mortgage borrower with additional unsecured credit to circumvent the LTV cap. It can also prevent banks from replacing high-LTV loans with high-DSTI/DTI/LTI loans in response to LTV caps. Furthermore, DSTI/DTI/LTI caps can prevent banks from increasing DSTI ratios even further on already high-DSTI loans in response to faster minimum amortization rates.

11. It is important to complete the macroprudential toolkit in Germany, not least because Germany is part of a currency union. Since monetary policy is centralized in the euro area, systemic risk can build up more in some euro area countries than others, which calls for compensating national macroprudential policy actions (IMF, 2013). Relatedly, Germany needs income-based tools to avoid becoming a source of regulatory arbitrage in Europe. For example, if another European country imposes income-related borrower-based measures but Germany does not, then German banks could potentially lend cross-border (i.e., not through local branches or subsidiaries) into that country, without being restricted by the borrower-based measures of that country. The country that imposes borrower-based measures could ask Germany, through the ESRB's so-called "reciprocity mechanism," to impose similar measures on German banks doing cross-border lending into that country. Germany would then need the income-related borrower-based tools to comply with such a request.

C. The Case for Activating Borrower-Based Measures in Germany as the Economy Recovers

12. There are financial stability, macroeconomic stability, and consumer protection arguments for activating borrower-based measures in Germany as the economy recovers. The financial stability argument is discussed in the remaining paragraphs of this section. However, there are also macroeconomic stability and consumer protection arguments for borrower-based measures, even if they may not be within the mandate of financial stability authorities (see footnote 4). From a macroeconomic stability perspective, borrower-based measures could limit the amplification of housing market booms and busts and associated cyclicality in consumption and construction activity, even if defaults remain low. In Germany, the correlation

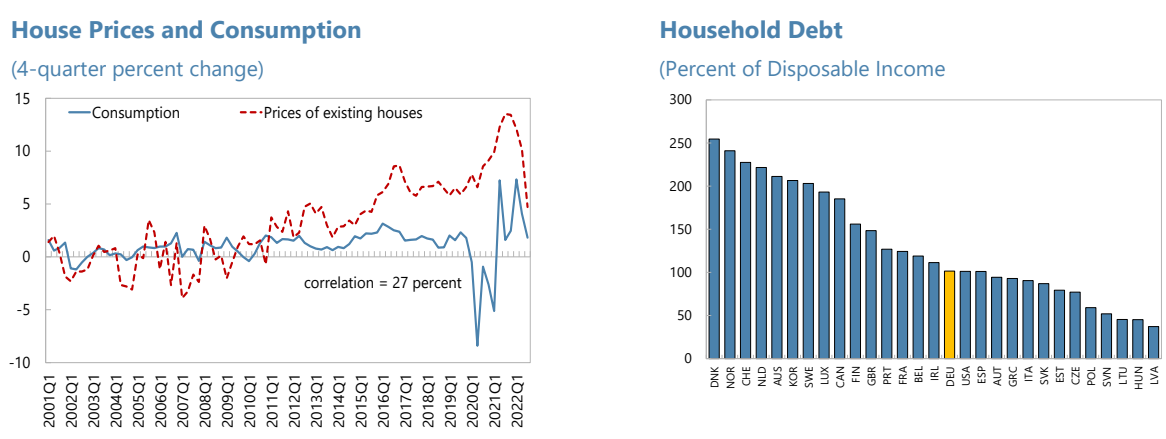
[5] Indeed, higher credit demand in response to falling mortgage rates between 2010 and 2016 has been found to be the main factor driving up property prices at that time (Bundesbank, 2020).

between the growth rates of house prices and consumption is 27 percent (Figure 1, top-left chart).[6] Since Germany has full-recourse mortgage lending, this could make consumption extra sensitive to house prices in a downturn, because borrowers might cut back their consumption extensively to avoid default. From a consumer protection perspective, there is little reason to think that a loan with both a high LTV and a high DSTI is appropriate for the borrower. If the borrower is unable to continue servicing the mortgage, it can cause hardship, even if the bank is able to recover its losses by foreclosing on the underlying house.

13. The market for residential real estate is important to financial stability in Germany. Mortgages make up 70 percent of household liabilities and 50 percent of domestic bank loans. Household debt is 100 percent of income (Figure 1, top-right chart). Mortgage credit growth accelerated between the global financial crisis and 2021Q3, and credit growth decelerated but remained positive in 2022 (Figure 1, bottom-left chart). The Basel credit gap stood at 5 percent of GDP in 2022Q2. Credit losses on residential real estate loans in a downside macroeconomic scenario are driven by high-LTV mortgages (Barasinska et al., 2019).

14. House prices could fall further, given that they still appear to be overvalued in Germany. The Bundesbank estimates that house prices in cities were overvalued by 25–40 percent in 2022, depending on the location and methodology (Bundesbank, 2023). House prices are some 20 and 40 percent above historical average price-to-income and price-to-rent ratios, respectively (Figure 1, bottom-right chart). According to these two metrics, tightening monetary policy in 2022 and 2023 helped to reduce some of the overvaluation in house prices, with house prices falling 9 percent between 2022Q2 and 2023Q1, but most of the overvaluation remains. The literature shows that structurally higher LTV caps reduce house price volatility (see Section G below).

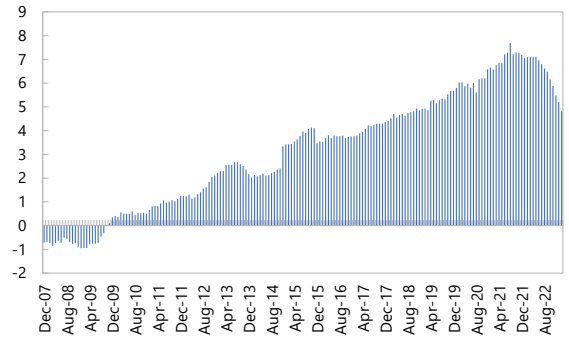
Figure 1. Residential Real Estate and Financial and Macroeconomic Stability



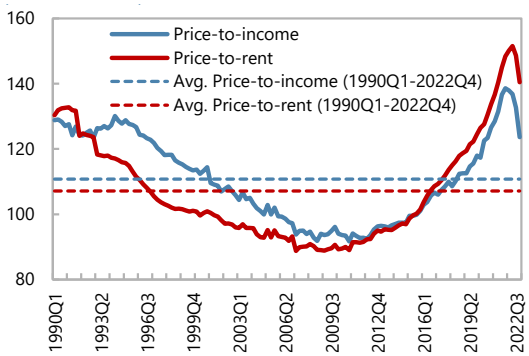
[6] Hamburg, Hoffman and Keller (2005) find that a one euro increase in asset wealth in Germany leads to an 4–5 euro cents increase in consumption, which is within the range of similar estimates provided for Australia, the UK, and US in Paiella (2009) Table 1. So far, evidence is lacking on the contribution of full-recourse mortgage lending to the sensitivity of consumption to house prices in downturns. However, Guerrieri and Iacoviello (2017) found that consumption responds stronger to declines in housing wealth than to increases.

Figure 1. Residential Real Estate and Financial and Macroeconomic Stability (Concluded)

Housing Loans
(Yearly growth in stock)



House Price Valuation
(Index, 2015=100)



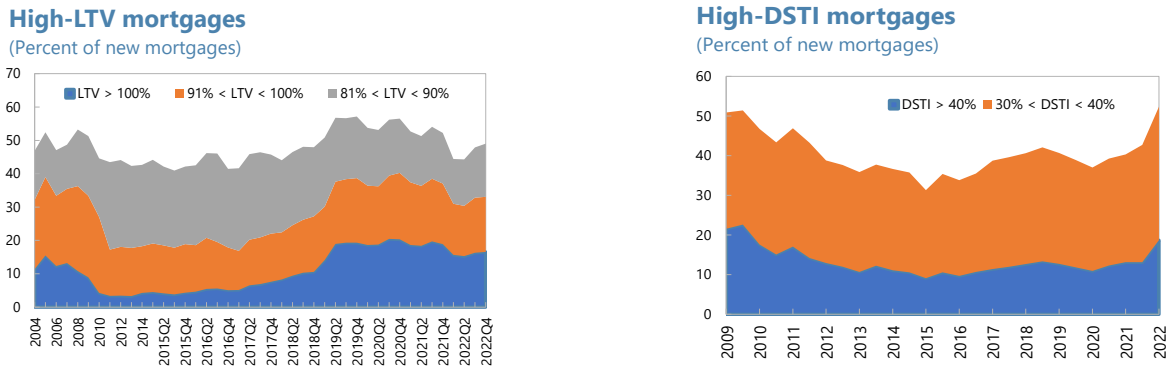
Sources: Federal Statistical Office; Bundesbank; and OECD.

15. Large segments of new mortgage lending with loose lending standards have persisted since at least 2018. The lack of common definitions of concepts like LTV, DSTI, and LTI ratios and the lack of representative data on lending standards have made it difficult to compare lending standards over time and across countries. Nevertheless, the available data sources point to loose lending standards. Publicly available data from Europace show that over the past two decades, almost half of new mortgages have been issued with an LTV ratio above 80 percent (Figure 2, left chart).[7] After 2018, more loans began to be issued at LTVs above 100 percent, presumably to help the borrower cover taxes and transaction costs, which effectively means that part of the loan is unsecured. Data from another provider, published in Bundesbank (2022), show that over the past decade, more than 10 percent of loans have been issued at DSTI ratios above 40 percent (Figure 2, right chart). A BaFin survey in the summer of 2022 found that 15 percent of new borrowers spend more than 50 percent of their net income on the loan installments (BaFin, 2023). Tightening monetary policy in 2022 and 2023 caused euro area banks to perceive higher risks and thus tighten their lending standards. This tightening is evident in a slight reduction of high-LTV lending, but it is undermined by an increase in variable-rate and high-DSTI lending. Official, representative data on lending standards called WIFSta (*Wohnimmobilienfinanzierungsstatistik*) are being collected from 2023Q1 onwards and will help to reduce data uncertainties. High-LTV and high-DSTI lending can be profitable for banks if the loans are priced correctly, but individual banks do not necessarily internalize the systemic risk that such lending generates, in the form of more-overvalued property

[7] These data are based on mortgage lending values, which produce higher LTV ratios than if they were based on market values. The differences are explained in paragraph 22.

prices, over indebtedness increasing the credit risk on loans to other banks, or a higher income sensitivity of aggregate consumption (Mian and Sufi, 2010).

Figure 2. Structurally Loose Lending Standards in Germany



Sources: Europace, Bundesbank Financial Stability Review 2022.
Notes: LTV = loan-to-value ratio. DSTI = debt service-to-income ratio.

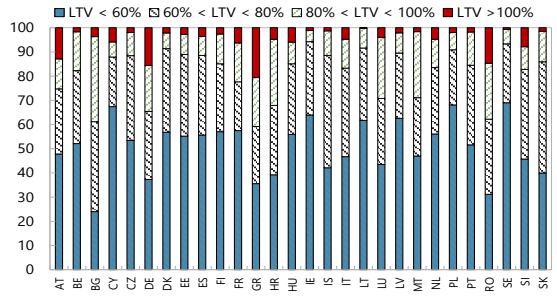
16. These loose lending standards are evident in cross-country comparisons as well. New lending at high LTV and high LTI ratios is high in Germany relative to peer countries, although comparability is somewhat hampered by differences in data definitions. In 2022Q1, Germany had the second-highest share of new loans with LTV ratios above 100 percent among EU countries (Figure 3). In 2018, Germany had the sixth-highest share of new loans with LTV ratios above 80 percent and the fourth-highest share of new loans with LTI ratios above 5 (Lang et al., 2020). Note that the high share of high-LTI loans means that one cannot take comfort in arguments that German homebuyers tend to be high-income and therefore creditworthy (see paragraph 23).

17. Mortgage insurance is uncommon in Germany and there is no regulatory requirement to obtain mortgage insurance. Mortgage insurance is provided by private companies in the life insurance sector. It usually covers mortality risk, and in some cases morbidity and unemployment risk. The authorities estimate that residual debt insurance (*Restschuldversicherungen*) covered €12.7 billion as at end-2021. BaFin (2017) estimated the total sum insured to be €13.3 billion in 2015, which amounts to 1.1 percent of mortgage loans[8] or 0.4 percent of GDP. However, the latter amount might understate the size of the mortgage insurance market because it excludes without-profit policies and supplementary casualty or unemployment insurance. BCBS (2013) estimated the coverage of mortgage insurance to be 10–25 percent of loans.

[8] According to the Bundesbank's January 2016 Monthly Report, the total volume of mortgage loans extended by German banks to German residents in September 2015 was €1,245 billion.

Figure 3. Comparatively Loose Lending Standards on New Mortgages in Germany

LTVs of New Mortgages in 2021Q1
(Percent of new loans)



Source: EBA (2022).

18. Borrower-based measures could thus bolster financial stability in Germany and better align Germany's safeguards with those of peer countries. From a cyclical perspective, now is not the ideal time to activate borrower-based measures, as the real estate market is entering a downturn in response to higher interest rates and lender-based measures were recently tightened. However, a new upward cycle in house prices and mortgage lending could begin within the next few years. Timely implementation of borrower-based measures during that cycle could help lessen financial stability risks associated with that cycle and other future cycles, while also improving macroeconomic stability and consumer protection. Recognizing these benefits, many other peer countries have introduced borrower-based measures (Table 1).

19. Early activation of borrower-based measures is essential. Borrower-based measures only affect new lending and therefore take years to alter the composition of outstanding mortgage loans in a way that could materially strengthen financial stability.[9] Early activation is especially important when introducing these measures for the first time, given that (i) measures may need to be phased in gradually to reduce disruptions; and (ii) some learning-by-doing may be needed to optimize the calibration. Early activation of measures during the next upturn requires that legislation to strengthen Germany's toolkit be passed soon, as it will take some after the legislation's passage to put its provisions into place, given the need to adopt implementing regulations, establish monitoring mechanisms, and consult on these processes.

D. Concerns with Activating Borrower-Based Measures and How to Address Them

20. Below we discuss several potential concerns about instituting borrower-based measures in Germany, as well as counterarguments and ways to address these concerns. These

[9] For an analysis of this in the German context, see Barasinska, Ludwig, and Vogel (2021).

"potential concerns" are not meant to reflect views of IMF staff or the authorities but rather concerns that opponents of borrower-based measures have at times raised or that they might potentially raise.

21. ***Potential Concern #1: Germany has already activated the CCyB and SSRB, and these are sufficient to preserve financial stability.*** There are at least three responses to this concern:

- *First, despite these capital buffers, Germany's banks do not have extremely high capital when compared to banks in peer countries.* Germany's bank capitalization is at the 38th percentile of the distribution across G7 and advanced European countries. Therefore, there is no evidence that Germany's capital requirements are excessive, especially relative to its real estate vulnerabilities. In fact, actual bank capital levels in Germany are lower than in other countries with high shares of high-LTV loans (FR, NL, LT, LV, BE) or in countries with LTV caps (AT, NL, FI, DK, IE, NO, PT).

- *Second, it is important to consider Germany's macroprudential policy mix overall.* As noted earlier (paragraph 9), the question is not whether borrower-based measures should be added to the existing capital requirements, but whether there is a better mix of capital requirements and borrower-based measures. For example, have the latest capital requirements increased interest rates on corporate loans (CCyB) or on relatively safe low-LTV or low-DSTI mortgages (CCyB and SSRB)? Have they diverted mortgage lending activity from banks to NBFIs? These could be the unintended consequences of relying entirely on bank capital-based measures to preserve financial stability.

- *Third, borrower-based measures would provide macroeconomic stability and consumer protection benefits that the CCyB and SSRB do not provide.*

22. ***Potential Concern #2: Germany has typically used the conservative "mortgage lending value" concept when calculating LTVs, so that Germany's lending standards would stand out less in cross-country comparisons if market values were used instead.*** New (*WIFSta*) data will provide LTV ratios on a market value basis, facilitating comparisons, but until then, data based on the mortgage lending value are more typical. The mortgage lending value (*Beleihungswert*) is a value determined by appraisers following a methodology that tries to avoid cyclical fluctuations in property values,[10] and is generally considered to produce more conservative (i.e., lower) valuations than the market (and therefore higher LTV ratios). However, DSTI and LTI ratios are high in Germany as well, and these do not depend on the mortgage lending value. Furthermore, other countries also use a conservative valuation standard in national regulations on LTV ratios, namely Austria, Czechia, Germany, Hungary, Luxembourg, Poland, Slovenia and Spain (RICS, 2018). Notably, Austria, Czechia, Poland and Slovenia have activated caps on LTV ratios, despite having such a standard.

23. ***Potential Concern #3: Mortgage borrowers in Germany tend to be high-net worth individuals, who therefore have low risk.*** There do not seem to be data on the net worth of new

[10] The methodology is outlined in the Ordinance on the Determination of the Mortgage Lending Value (*Beleihungswertermittlungsverordnung*).

mortgage borrowers in order to validate this claim, but it is true that households with an outstanding mortgage report higher net worth (median: €218,400) than all German households (median: €70,800) (Bundesbank, 2019).[11] It should be noted that, in principle, high-net worth individuals can, in principle, be riskier than low-net worth individuals if they have higher leverage, so this needs to be checked. On this point, it is useful to note that DSTI and LTI ratios are high in Germany as well, which means that these high-net worth individuals do not have high income (relative to the amounts that they borrow). Cases in which high-LTV and high-DSTI borrowers are low-risk because they have high net worth are thus likely to be limited. Such cases could be accommodated by allowing "speed limits" in the regulation, and high-net worth individuals can accommodate LTV requirements by pledging additional collateral or selling assets to fund higher downpayments.

24. ***Potential Concern #4: Germany has full recourse lending, which limits default risk.*** Full recourse lending reduces defaults but does not eliminate them, as defaults are often not strategic but instead driven by the borrower's income or liquidity difficulties. Indeed, many countries with full-recourse lending have experienced real estate-fueled financial crises (e.g., Nordic crisis in early 1990s, Spain crisis in early 2010s). Furthermore, even with full recourse lending, a housing market crash could still increase banks' required provisions and risk-weighted assets materially (see Section E). Finally, it is exactly in a country with full recourse lending where the consumer protection argument is strongest.

25. ***Potential Concern #5: Borrower-based measures could make housing less affordable or disproportionately impact younger or lower-income borrowers.*** Indeed, Biesenbeek et al. (2022) estimated that homeownership among first-time buyers declined 6 percent in the Netherlands due to LTV limits imposed there. However, at least for LTV limits, this effect is likely to be temporary, because buyers have to wait longer to accumulate the larger down-payment. Moreover, the net impact of borrower-based measures on affordability is uncertain, because they can also be expected to reduce house prices (e.g., Armstrong, Skilling and Yao, 2019), which can to some extent improve affordability. Furthermore, younger and lower-income borrowers benefit most from the consumer protection element of borrower-based measures. Nevertheless, borrower-based measures should be designed carefully to limit their impact on vulnerable groups. For example, looser restrictions can be applied to first-time homebuyers, given that they tend to have lower credit risk (Kelly et al., 2015; Nier et al., 2019), and speed limits and *de minimis* exemptions can provide additional flexibility. Conversely, tighter restrictions can be placed on more speculative behavior, like purchases of second homes or buy-to-let activity.

[11] This difference between the net worth of mortgage-holders and all households in Germany is bigger than that in the euro area. In the euro area, the median net worth of mortgage-holders is €156,600 and the median net worth of all households is €99,500.

Table 1.Germany: Active Macroprudential Instruments for Residential Mortgage Loans in G7 and Selected European Countries, as of February 2023

	Austria	Belgium	Canada	Cyprus	Czechia	Denmark	Estonia	Finland	France	Iceland	Ireland	Latvia	Lithuania	Netherlands	Norway	Poland	Portugal	Slovakia	Slovenia	Sweden	Switzerland	United Kingdom	United States
Borrower-based measures																							
LTV	90% (20% speed limit)	80% for BTL (with 10% allowed up to 90%); 90% for FTB (with 35% allowed up to 100% and 5% allowed over 100%); 90% for SSB (with 20% allowed up to 100%);	95% for owner-occupied with government guarantee up to CAD 500,000 (90% above CAD 500,000); 80% for others	80% for FTB; 50% for construction of luxury properties; 70% for others	90% for those under age 36; 80% for others	95% /1	90% if guaranteed by KredEx (15% speed limit); 85% for others (15% speed limit)	95% for FTB; 85% for others	-	85% for FTB; 80% for others	90% for FTB (15% speed limit); 70% for BTL (10% speed limit); 80% for others	95% for mortgages under state guarantee; 70% for BTL; 90% for others	70% for indebted SSB; 85% for others /2	100%	60% for second homes in Oslo; 85% for others	90% for insured or overcollateralized mortgages; 80% for others	90% for own and permanent residence; 80% for others	80% (with 20% allowed up to 90%)	80% for FTB; 70% for others	85%	25% for investment properties; 90% for others	-	96.5% for FHA loans; 70-95% for FNMA-conforming loans; guidelines require insurance for mortgages above 90% LTV
DSTI or stressed DSTI	40% (10% speed limit)	50%	39% stressed GDS and 44% stressed TDS for loans with government guarantee;	80%	50% for those under age 36; 45% for others	-	50% stressed DSTI	-	35%	40% stressed DSTI for FTB; 35% for others (5% speed limit)	none	40% (10% speed limit)	40% unstressed; 50% stressed DSTI (with 5% allowed up to 60%)	13-36%, depending on income and interest rate	-	-	50% (with 10% allowed up to 60%)	60% (with 5% allowed up to 70%)	-	-	-	-	31-45% for FHA loans; 36-50% for FNMA eligibility
LTI	-	-	-	-	-	LTIs above 4 require stress testing	-	-	-	-	3.5 for FTBs (20% speed limit); 3.5 for SSBs (20% speed limit)	-	-	-	-	-	-	-	-	-	-	4.5 times (with 15% speed limit)	-
Capital-based measures																							
CCyB	0%	0%	none	0% /3	0.5% /3	2.5%	1% /3	0%	0% /3	2%	0.5% /3	0%	0% /3	0% /3	2%	0%	0%	1% /3	0% /3	1% /3	0%	1% /3	0%

Source: ESRB Macroprudential Measures Database; IMF Macroprudential Policy Survey; Bank for International Settlements; Swiss Financial Market Supervisory Authority; Bank of England; US Federal National Mortgage Association; US Code of Federal Regulations Title 12 Part 208 (Regulation H) Appendix C; US Department of Housing and Urban Development.

Notes:

1/ Furthermore, since 2018, Denmark has had a supervisory benchmark where less than 25% of lending with an interest rate fixation period of up to two years may exceed an LTV of 75%.

2/ An indebted SSB is one who has a previous mortgage loan with a current LTV of at least 50%.

3/ Set to tighten in 2023.

Some of these measures are not legally binding. BTL = buy-to-let; FTB = first-time homebuyer; SSB = second-and-subsequent-time homebuyer; GDS = gross debt service ratio; TDS = total debt service ratio. Australia, Greece, Italy, Japan and Spain had few active measures and are therefore not shown to save space.

E. Microsimulation Evidence of Activating Borrower-Based Measures in Germany

26. This section quantifies the benefits of imposing borrower-based measures by analyzing a stress scenario in which house prices decline rapidly (a housing market "crash" scenario). We ask how much less banks' capital would decline, under a one-year housing market crash scenario starting in 2022Q2, if LTV and DSTI limits had been imposed (and fully phased-in) in 2015. The approach is to simulate the outstanding stock of German residential mortgages as at 2022Q2, with and without borrower-based measures. We then apply the same housing market crash scenario to each portfolio of loans and compare the impact on bank capital in each case. The outcomes under the housing market crash scenario are measured relative to those under a reference, business-as-usual scenario.

27. The outstanding stock of German residential mortgages is simulated as follows:

- The simulation starts in 1980. We randomly draw 1,000 newly issued loans each quarter between 1982Q2 and 2022Q2.[12] Therefore, the loan book grows in the beginning, but after about 20 years, the loan book stabilizes because the number of new loans being issued roughly offsets the number of maturing loans. Therefore, mortgage credit growth is exogenous in this model (i.e., unaffected by the macroeconomic scenario), and this model does not try to describe the behavior of overall mortgage credit in Germany.

- For each new loan, we give it some characteristics, like an outstanding principal balance, maturity, fixed vs. variable rate status, and liquid assets of the borrower. These characteristics are drawn with replacement from all three waves of the ECB's Household Finance and Consumption Survey (HFCS), so the distribution from which they are drawn is constant over time. We preserve the joint distribution of loan characteristics, like, for example, higher principal balances and shorter maturities for borrowers with more liquid assets.[13] Outliers are removed from this distribution by filtering out wave—households with the largest 1 percent of loan balances (both in euros and relative to the loan maturity), and those with the largest or smallest half a percent of loan maturities, liquid assets, or financial wealth. The median loan maturity is 10 years, and the range of maturities is 2–40 years. About 14 percent of loans are variable-rate.

- Each new loan gets an LTV and DSTI ratio drawn from the distributions of Europace and Interhyp data,[14] respectively (Figure 2). Given a lack of information, we assume a uniform distribution of

[12] This procedure results in 161,000 loans issued over 161 quarters. The large number of loans means that the simulation results do not change much from one simulation to the next, as evidenced by the small standard errors in Table 3.

[13] The correlation between the natural logarithm of the loan balance and the natural logarithm of liquid assets is 14 percent. The correlation between the loan maturity in years and the natural logarithm of liquid assets is -13 percent. These correlations are calculated across households, after averaging across the five implicates/imputations for each household, and after removing outliers.

[14] The Interhyp data are used as published in Bundesbank (2022).

- LTV and DSTI ratios within each bucket, which implies no "bunching" of LTV or DSTI ratios within buckets. We adjust LTVs down by 7.5 ppts to convert mortgage lending values to market values, because Barasinska et al. (2019) estimate that an LTV of 80 percent based on the mortgage lending value corresponds to an LTV of 70–75 percent based on the market value.

- We assume that every loan is fully amortizing,[15] repayable in monthly instalments, issued at national-aggregate interest rates, and collateralized by a house whose price follows national house prices.

- We trace each loan's characteristics (e.g., principal outstanding, interest rate, LTV, DSTI) over time as it is amortized, and as house prices and interest rates evolve.

28. Each loan's creditworthiness at each point in time is summarized by its expected loss, which is defined as the product of the loan's probability of default (PD) and loss given default (LGD). In turn, the PD and LGD are modeled by extending the work of Valderrama (2022), Górnicka and Valderrama (2020), and Harrison and Mathew (2008). The specific equations for PD and LGD are given in Annex I.

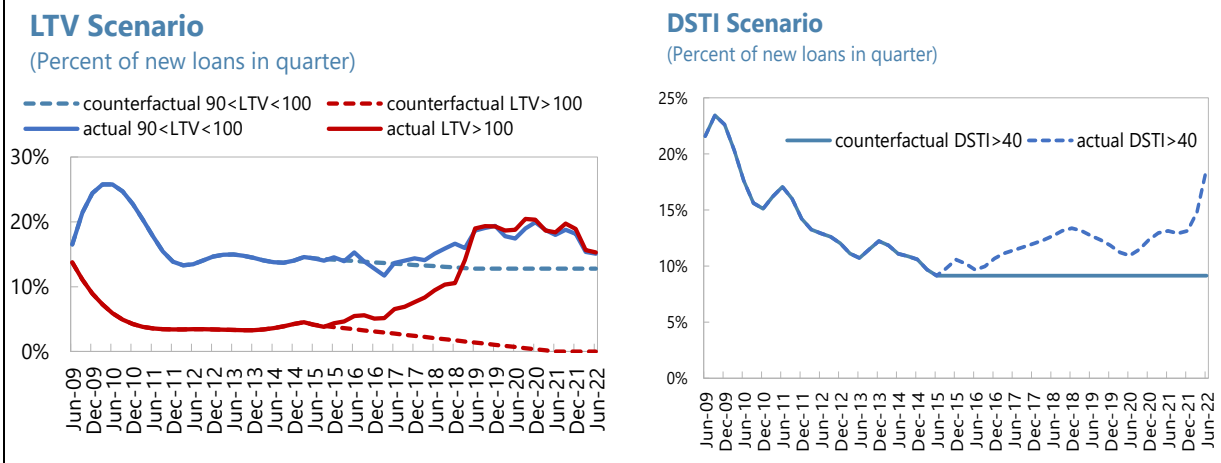
29. We then repeat the previous simulation of new loans (paragraphs 27–28), but we suppose instead that LTV and DSTI limits were imposed in 2015. The same loans are issued in terms of their outstanding balance, maturity and interest rate, but their LTV and DSTI ratios are drawn from distributions with lower LTV and DSTI ratios. Again, given the lack of information on the distributions of LTV or DSTI ratios within buckets, we assume that they are uniformly distributed within buckets, which means no "bunching" of LTV or DSTI ratios.[16] We calibrate these counterfactual distributions of LTV and DSTI ratios as follows. After 2015Q2, LTVs between 90 and 100 percent (of the mortgage lending value[17]) reduce to 10 percent of new lending over 2 years and LTVs above 100 percent phase out over 2 years. New lending at DSTIs above 40 percent drops from 10 percent to 5 percent over 2 years and then stays there. Figure 4 shows how the actual data for high-LTV and high-DSTI lending compare to the counterfactual policy experiment. These scenarios are realistic from a policy perspective: they amount to imposing borrower-based measures with speed limits.

[15] Fully amortizing means that the outstanding principal balance of each loan decreases over the life of the loan and reaches zero with the last monthly repayment. Each monthly repayment contributes first to the interest due and then the remaining part of the monthly repayment is applied to the outstanding principal balance. The formula for the outstanding principal balance of a fixed-rate loan, issued at (monthly) interest rate r, with original maturity of T months and remaining maturity of τ months, is $(1-(1+r)^{-\tau})/(1-(1+r)^{-T})$.

[16] In other contexts, LTV and DSTI ratios have been found to bunch up just below the LTV and DSTI limits. If bunching were to occur, it could increase losses in the housing market crash scenario with the LTV and DSTI limits imposed, which could reduce the estimated benefits of these borrower-based measures, but we expect that such reductions would not be material.

[17] Recall that the LTVs are drawn from Europace data, which use the mortgage lending value.

Figure 4. Counterfactual Policy Experiment with LTV and DSTI Limits



Sources: Bundesbank and IMF staff calculations.

Notes: LTVs in the left chart are expressed in terms of the mortgage lending value.

30. The same housing market crash scenario and reference scenario are applied to each of the two portfolios of loans. The scenarios run for 4 quarters, from 2022Q3 to 2023Q2 inclusive. The stress scenario captures a housing market crash that is accompanied by tighter monetary policy and rising inflation. To capture the housing market crash, nominal house prices fall 40 percent, which is the upper bound of overvaluation estimates and therefore could represent an overcorrection of house prices that would subsequently be reversed. Falling house prices increase PDs through the probability of negative equity and increase LGDs by lowering the foreclosure value of the home that collateralized the mortgage. Unemployment increases 2.2 percentage points, which is a three-standard deviation increase (Table 2). Rising unemployment lifts PDs by increasing the chance that the borrower faces insufficient income to continue servicing the loan. Mortgage rates increase 4.3 percentage points, which is twice the increase observed so far in the latest monetary policy tightening cycle. Higher mortgage rates increase the monthly debt servicing payments and DSTI on variable-rate loans. The model does not explicitly feature non-interest expenses. Therefore, to capture rising living costs caused by higher inflation, nominal disposable income is reduced by 4.3 percent; this increases the DSTI ratio on fixed- and variable-rate loans. Liquid assets fall 5 percent, reflecting monetary tightening. Risk-free rates increase 2 percentage points at all maturities. In this model, higher risk-free rates reduce household financial stress, because they reduce the household's prepayment penalty. Outcomes under the housing market crash scenario are compared to those under a reference scenario. In the reference scenario, house prices increase by a cumulative 3.3 percent over the scenario horizon (in line with average historical growth rates), (registered) unemployment is stable at the 2022Q2 level of 5.1 percent, mortgage rates are stable, nominal disposable income increases 4.5 percent (in line with a benign inflation environment), liquid assets are stable and risk-free rates stable. Both scenarios assume for

convenience that there is no new lending, so that existing loans run off. Therefore, there is no difference in credit growth between the two scenarios.

Table 2. Germany: Reference Scenario and Housing Market Crash Scenario

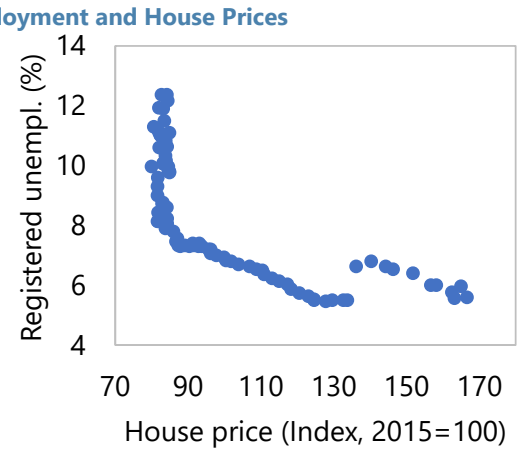
	unemployment (percent)	house prices (index)	risk free rate (cumulative change, ppts)	mortgage rate (cumulative change, ppts)	disposable income (cumulative change, percent)	liquid assets (index)
Reference scenario						
2022Q2	5.10	1.00	0.00	0.00	0.00	1.00
2022Q3	5.10	1.01	0.03	0.00	1.24	1.00
2022Q4	5.10	1.02	0.05	0.00	2.49	1.00
2023Q1	5.10	1.02	0.08	0.00	3.45	1.00
2023Q2	5.10	1.03	0.10	0.00	4.41	1.00
Stress scenario						
2022Q2	5.10	1.00	0.00	0.00	0.00	1.00
2022Q3	5.59	0.88	0.50	1.08	-1.09	0.99
2022Q4	6.12	0.77	1.00	2.15	-2.19	0.98
2023Q1	6.70	0.68	1.50	3.23	-3.28	0.96
2023Q2	7.34	0.60	2.00	4.30	-4.38	0.95

31. The relative responses of house prices and employment are within the range of responses in the recent data and the available literature. The relative response of house prices and unemployment in the stress scenario considered here (relative to the reference scenario) is consistent with that in the first year of the 2018 EU-wide banking sector stress test. Specifically, in the first year of that scenario, house prices fall 13.6 percent more in the first year in the adverse scenario than in the baseline, while the unemployment rate is 0.9 percentage points higher. If we multiply these two number by a factor of three, we get similar responses of house prices and unemployment as in the scenario above. However, the increase in unemployment is stronger than the fall in house prices from the perspective of recent historical data. Specifically, the 40 percent fall in house prices would decrease the house price index from 160 to 96, which corresponds to a 1.4 percentage point rise in the unemployment rate (Figure 4).[18] The stronger response of unemployment than house prices is designed to capture the fact that the discretionary expansions of Kurzarbeit eligibility and generosity during the COVID-19 pandemic might not repeat themselves in future. Nevertheless, the response of unemployment relative to house prices is weaker in the

[18] This calculation is based on the registered unemployment rate as published by the Federal Employment Agency, but the increase in unemployment is similar (1.6 percentage points) using the unemployment rates from the labor force survey published by the Federal Statistical Office.

stress scenario considered here than in Barasinska et al. (2019) or the 2023 EU-wide banking sector stress tests.

Figure 5. Unemployment and House Prices in Germany



Sources: Federal Statistical Office and Federal Employment Agency.
Notes: Unemployment is the registered unemployment rate in percent of the labor force. The chart shows quarterly data from 2000Q1 to 2022Q4.

32. Borrower-based measures preserve almost 6 percent of CET1 capital, or €26 billion (Table 3). Expected credit losses are €21 billion higher, or 4.9 percent of the CET1 of the banking system, without the LTV/DSTI limits.[19] This amount is roughly the increase in provisions that banks would have to make in the stress scenario (over and above any increase in provisions in the reference scenario). However, by improving the creditworthiness of the mortgage market, borrower-based measures also prevent risk-weighted assets from increasing as much in the stress scenario. The prevention of increasing risk-weighted assets preserves a further 1 percent of CET1 capital. Together, these amount to 5.9 percent of CET1 capital (4.9 percent plus 1 percent), or €26 billion. This shows the financial stability benefits provided by the borrower-based measures. However, the simulation results also point to the consumer protection benefits of the measures. For example, most of the €21 billion in losses originate among loans with LTVs between 70 and 100 percent (of market value) in 2022Q2, even though these make up a small share of the portfolio (Figure 6, left chart). Similarly, most of the loss prevention of borrower-based measures occurs within the high-LTV buckets. For example, 7 percent of losses are prevented in the 80–90 percent LTV bucket and 24 percent of losses in the 90–100 percent LTV bucket (Figure 6, right chart).

[19] Loss rates (in the stress scenario in excess of the reference scenario) are aggregated across loans using loan balance-weighted averages, and are then accumulated over the four periods of the scenario horizon. To convert these losses from a fraction of loan balances to euros (row (1) in Table 3), the aggregate loss rate is multiplied by the stock of residential mortgage loans (€1,731bn) in the banking system. To estimate the increase in RWAs (row (4) of Table 3), we calculate the four-quarter change in the aggregate risk weight (in the stress scenario in excess of the reference scenario), which is a loan balance-weighted average across loans, and then multiply by the share of residential real estate in IRB RWAs (assumed 20 percent) and the share of IRB RWAs in RWAs (assumed 50 percent).

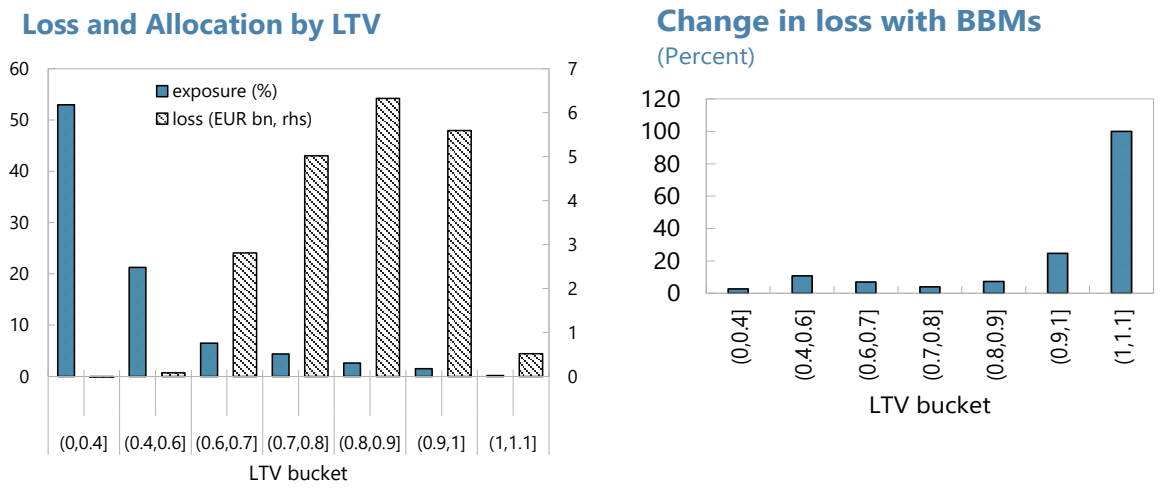
Table 3. Germany: Results of the Housing Market Crash Scenario

		without BBMs	with BBMs	difference
(1)	loss (€ bn)	51.7	30.4	-21.3
		(0.33)	*(0.44)*	*(0.43)*
(2)	loss (% CET1)	11.9	7.0	-4.9
		(0.08)	*(0.1)*	*(0.1)*
(3)	loss (% RWA)	1.9	1.1	-0.8
		(0.01)	*(0.02)*	*(0.02)*
(4)	% increase RWA	3.2	2.2	-1.0
		(0.03)	*(0.02)*	*(0.02)*
=(2)+(4)	% change CET1	15.1	9.2	-5.9
		(0.1)	*(0.12)*	*(0.1)*

Sources: IMF staff calculations.
Notes: Results are cumulative over the 4-quarter scenario horizon and show the losses in the stress scenario in excess of the reference scenario. BBMs = borrower-based measures. Rows (2) and (3) assume CET1 capital of €433 bn and RWAs of €2,706 bn in the banking system. Standard errors are shown under each estimate in parentheses, in the same units as the estimate above. In turn, standard errors are estimated as the standard deviation across ten replications of the experiment, using the same risk parameters from Table 4 in each case. The small standard errors suggest that sampling uncertainty has a negligible effect on the estimates here, due to the large sample of loans taken. However, the standard errors here do not capture model or scenario uncertainty, which are likely to be substantial. Annex I quantifies some of the model uncertainty coming from parameter estimation.

33. The benefits of borrower-based measures could be larger than simulated here, and this simulation says nothing about costs. As explained in paragraph 28, the benefits of borrower-based measures could be understated here owing to limitations of the data on PDs used. Moreover, borrower-based measures in this simulation are introduced in 2015, and the policy is allowed to run for seven years before the housing market crash begins in 2022. However, the benefits of borrower-based measures would be larger if they were allowed more time to change the composition of the mortgage market before the housing market crash—this point underscores the importance of early activation of borrower-based measures. This simulation also does not capture the possibility that borrower-based measures limit house price overvaluation in the first place, which could limit the size of the housing market crash. Similarly, this simulation does not investigate the possibility that borrower-based measures could limit household leverage, thus limiting the contraction in consumption in response to the housing market crash. Finally, while this simulation illustrates the potential benefits of borrower-based measures in Germany, it does not investigate the costs of these measures. From a financial stability perspective, a key cost could be foregone bank profits. When comparing borrower-based measures to lender-based macroprudential measures, it is important to compare the costs as well as the benefits.

Figure 6. Loss and Loss Prevention by LTV Bucket



Sources: IMF staff calculations.

Notes: BBMs = borrower-based measures. In the left panel, the blue bars show the allocation of all mortgage loans into LTV buckets, as a percent of the value of all mortgage loans outstanding. The dashed white bars show the losses in the housing market crash scenario, in euros, by LTV bucket. The right panel shows the value of BBMs by LTV bucket using a difference-in-difference calculation. Specifically, for each LTV bucket, the bar shows the extra loss in the stress scenario (in excess of the reference scenario) without BBMs, over and above the same loss that occurs with BBMs. For example, the bar on the far right shows that without BBMs, the loss would be 100 percent higher than, or in other words double the level of, the loss with BBMs.

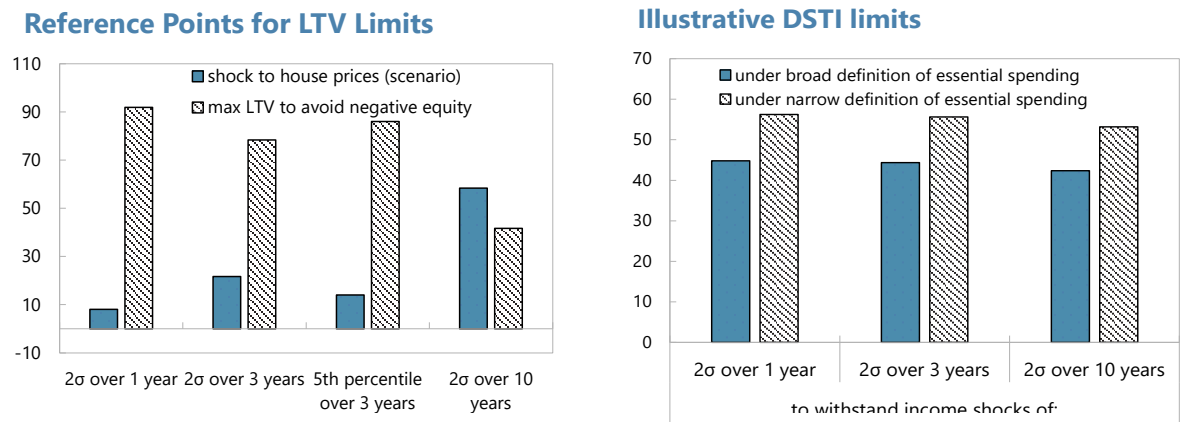
F. Illustrative Approach to Calibrating Borrower-Based Measures in Germany

34. This section illustrates approaches to calibrating borrower-based measures in the German context. The literature provides little guidance of how these instruments can be calibrated. Therefore, this section shows that simple rules can be applied to create initial calibrations of borrower-based measures for further consideration. A microsimulation approach, like the one demonstrated in Section E, could be used to analyze the implications of these calibrations.

35. To start calibrating LTV limits, one could ask what maximum LTV would protect a borrower from negative equity in the event of a housing market crash. For example, a 2-standard deviation drop in the prices of existing German houses over one year amounts to a drop of 8 percent. Therefore, in order for a homebuyer to be protected from this scenario, she should make a down-payment of at least 8 percent, which means borrowing at most 92 percent of the market value of the property (i.e., a maximum LTV of 92 percent). The 8 percent shock and the 92 percent LTV are shown in the first solid blue and shaded white bars in the left chart in Figure 7. This assumes that we care about protecting the borrower over a one-year horizon. Over a longer horizon, larger shocks are possible. For example, a 2-standard deviation shock over three years is 22 percent, and to protect a borrower from this scenario, the borrower should have a maximum LTV of 78 percent. This shock and LTV limit are shown in the second solid blue and shaded white bars in the left chart in Figure 7. Alternatively, instead of using standard deviations to calibrate the shock,

one could use estimates of the entire distribution of house prices changes, conditional on the state of the economy. In 2022, the 5th percentile of this distribution of three-year changes was a 14 percent drop in house prices (IMF, 2022a). To protect a borrower from this scenario requires a maximum LTV of 86 percent.

Figure 7. Example Calibrations of Borrower-Based Measures in Germany



Sources: IMF staff calculations.
Notes: σ = standard deviation, which refers to house price fluctuations in the left chart and household income in the right chart.

36. Similarly, one can calculate the maximum DSTI ratios for a fixed-rate mortgage that would allow a homebuyer to continue buying essential items even in the event of an unexpected drop in her income. Since it is difficult to know what types of expenditures are essential, we consider both a broad definition (which includes food, transport and communication, medical, education and financial services expenditures, as well as income that is saved, e.g., for retirement), and a narrow definition, which drops savings. These two types of essential spending amount to 54 percent and 42 percent respectively, on average between 2021Q3 and 2022Q3, which therefore leaves at most 46 and 58 percent, respectively, for debt-servicing and non-essential spending. Playing a smaller role in the calculation is the size of unexpected falls in income, which reflects the risk of such events as job loss, illness, or the loss of a spouse. A 2-standard deviation fall in household income amounts to 3.5 percent over 1 year, 4.6 percent over 3 years and 9.5 percent over 10 years (the typical mortgage rate fixation period in Germany). Therefore, in order to have at least 54 percent of income available for essential spending, even under these three scenarios for falling incomes, a household should spend no more than 45, 44, and 42 percent, respectively, on debt servicing (the three solid blue bars in the right chart in Figure 7). Similarly, in order to have at least 42 percent of income available for essential spending, even under these three scenarios for falling incomes, a household should spend no more than 56, 56 and 53 percent, respectively, on debt servicing (the three shaded white bars in the right chart in Figure 7).

G. International Experience with Borrower-Based Measures

37. The evidence from advanced economies tentatively suggests that activating borrower-based measures for the first time could reduce house prices, household credit, and inflation, with no clear effect on output. Most of the recent papers adopt methods (like methods of moments, propensity score matching, or narrative approaches) that aim to address endogeneity, because borrower-based measures may be introduced or tightened in anticipation of a rise in credit or house prices. Some of the papers control for the effects of other policies, like monetary policy or amortization requirements, that are often adjusted at the same time as LTV or DSTI caps. More evidence is available on LTV caps. The following outcome variables are considered in the literature:

- *Credit and house prices*. There is mixed evidence on the effects of borrower-based measures on credit and house prices. For example, the literature review by Gatt (2023) concludes that the evidence on a link between LTV caps and credit is 'suggestive.' Specifically, borrower-based measures seem to have weaker effects in advanced economies (AEs) and stronger effects when they are first introduced than when they are subsequently tightened. Cerutti et al. (2017) do not find evidence of an effect of LTV or DTI caps on aggregate credit growth or house price growth in AEs, but they do find that tighter DTI caps reduce *household* credit growth in AEs. IMF (2018) finds limited evidence in Sweden and Norway of any effects on credit. Alam et al. (2019) find that tighter LTV caps reduce household credit in AEs when the initial LTV cap is loose (at 100 percent or higher), but not when the initial LTV cap is tight. Mokas and Giuliodori (2021) find a drop in real household credit, and a statistically insignificant change in real house prices, in response to LTV caps in an EU sample. One potential reason for the ambiguity in the effects of borrower-based measures is that it is difficult to capture the complexity in their design and in their effects—they can have multiple thresholds and exemptions, are typically anticipated through consultations and phase-in periods, and can affect outcomes with significant and variable lags.[20]

- *Output and inflation*. Richter et al. (2019) do not find evidence for an effect of LTV caps on output in AEs. They find that tighter LTV caps reduce consumer prices in AEs temporarily, up to about two years, after which there is no statistically significant evidence of any effect.

38. Evidence also suggests that activating borrower-based measures tends to increase resilience. This resilience can take the form of lower volatility of house prices, lower rates of default on mortgages, and lower sensitivity of consumption to house prices (Verbruggen et al. 2015; IMF, 2023b). However, it is unclear to what extent this evidence on resilience applies to AEs because much of the evidence mixes AEs with EMs. The mechanisms by which borrower-based measures increase household resilience are intuitive. A tighter LTV cap means that a borrower must take a greater equity stake in the home, making it less likely that she exhausts her equity stake in the event of a fall in house prices. A tighter DSTI/DTI/LTI cap means that she is more likely to be able to afford

[20] Another reason for the ambiguity in the estimated effects is that borrower-based measures are still relatively new in many countries, meaning that limited evidence is so far available across housing market and economic cycles.

debt service payments (and regular consumption expenditures) even if her income unexpectedly falls.

39. Case studies suggest that borrower-based measures have their desired effects with limited or manageable side-effects.

- *Ireland* introduced LTV and LTI caps for residential mortgages in 2015, with financial stability and consumer protection motivations. Up to 2006, the share of loans with LTVs greater than 95 percent had grown up to 20 percent. The policy has separate limits for first-time buyers, second-and-subsequent buyers, and buy-to-let investors. It also has a speed limit. The policy initially had a sliding scale LTV limit for first-time buyers, so that cheaper properties face a looser limit, helping with affordability, but this was abolished later. After the introduction of the policy in 2015 and its tightening in 2018, house price growth slowed. CBI (2019) found that house prices may have been 13-25 percent higher in 2019 without the mortgage measures. New mortgages bunched below the LTV thresholds (IMF, 2022c). Acharya et al. (2020) found that the policy was successful in reducing credit-house price spirals. They also found that it tended to reallocate credit from cities to other areas and from low-income to high-income borrowers.

- *The Netherlands* introduced LTV and DSTI caps in January 2013, also with financial stability and consumer protection motivations. The LTV cap was introduced for financial stability reasons, while the DSTI cap had a consumer protection motivation. The LTV cap started at 106 percent in 2012 and was gradually reduced by 1 percentage point per year to 100 percent in 2018. In 2013, the DSTI cap was around 18.5 percent of gross income for low-income households and increased up to 46.5 percent for high-income households. By 2018, these DSTI caps had been tightened to 13-36 percent across the household income distribution. According to the Netherlands' financial stability reports, the average LTV on new loans fell from around 103 percent in 2011 to about 90 percent by 2018. Between 2014 and 2019, the share of new loans with an LTV above 90 percent declined from 75 to 66 percent for first-time buyers and from 55 to 47 percent for second-and-subsequent-time buyers (DNB, 2019). IMF (2023c) assessed that the LTV limits were successful in reducing household mortgage debt from 106 percent of GDP in 2012 to 93 percent in 2020. Nevertheless, house prices increased strongly—after bottoming out in 2013 after the global financial crisis, they increased 90 percent by 2022. Biesenbeek et al. (2022) estimated that homeownership among first-time buyers fell by 6 percent due to the LTV cap. The Netherlands has also taken other macroprudential measures, including limiting mortgage interest deductibility, placing restrictions on non-amortizing mortgages, and introducing a minimum risk weight on the residential mortgages of IRB banks (12 percent for that part of each loan with an LTV of up to 55 percent and 45 percent on the remaining part of the loan).

- *New Zealand* introduced LTV caps in 2013, to preserve financial stability. At the time, 21 percent of outstanding loans had LTVs above 80 percent. The policy had a speed limit, differentiated by city, and exempted newly constructed homes, to avoid discouraging housing supply. Adjusting the calibration of LTV caps and speed limits is done by discretion, with reference to indicators published in financial stability reports. By 2016, 11 percent of outstanding loans had LTVs above

80 percent. After the introduction of the policy in 2013 and its tightening in 2016, house price growth and household credit growth both slowed. However, the impact of LTV caps on house prices is unclear because policies to boost housing supply and monetary tightening from 2021 likely affected house prices. New Zealand removed LTV caps during COVID-19, but following a public consultation and impact assessment, re-introduced them at pre-pandemic settings in March 2021, and tightened them further in May and November. RBNZ (2021) assessed that re-introducing LTV caps would strengthen financial stability, both by strengthening bank and borrower balance sheets and by dampening the financial cycle, which would provide substantial medium-term real economic benefits in the form of higher resilience. It also found that re-introducing LTV caps would come with small short-term economic costs, by moderating house price inflation and hence consumption linked to housing wealth, and by restricting credit to households with low liquidity but high creditworthiness. RBNZ (2021) also judged that re-introducing LTV caps would reduce house price inflation by 1-4 percentage points, citing Armstrong et al. (2019) and other papers. The New Zealand policy clearly has a cyclical element, but it also seems to be aimed at reducing structural vulnerabilities.

- *Austria* introduced an LTV cap of 90 percent in 2022, to preserve financial stability. There is a 20 percent speed limit. At the same time, it introduced a DSTI cap of 40 percent and a maximum loan term of 35 years. These were introduced in June 2022 (to take effect in August 2022) in response to a recommendation in March 2022 by the Financial Market Stability Board of Austria, which follows its quantitative guidance issued in 2018 and its qualitative guidance in 2016. The introduction also follows recommendations by the ESRB, OECD and IMF. In 2021H1, half of new mortgage loans had LTVs above 90 percent, and 18 percent had DSTI above 40 percent.

- *Denmark* introduced an LTV cap of 95 percent in 2015. After these measures, the share of new borrowers with LTV above 95 percent declined markedly, while the share of borrowers with LTV between 80 and 90 percent declined slightly.

H. Conclusion

40. This paper explains how borrower-based measures could strengthen financial stability, macroeconomic stability, and consumer protection in Germany. It highlights potential concerns about these instruments, of which the most pertinent seem to be the overall regulatory burden (when combined with existing lender-based measures) and the impact on housing affordability. This paper explains some countervailing arguments, like the housing market risk-versus-resilience balance in Germany compared to peer countries and the ambiguous effects on housing affordability, and where more work is needed. The paper shows approaches to initial calibrations of LTV and DSTI limits in the German context, which produce plausible candidate limits that can be used as inputs in more detailed impact assessments. The paper reviews the evidence from advanced economies, which is still unsettled but suggests that borrower-based measures in Germany could be expected to dampen credit supply and house prices, without having much effect on GDP. An analysis with a microsimulation model shows that activating borrower-based measures (restricting lending at LTVs above 90 percent of the mortgage lending value or at DSTIs above 40 percent)

could preserve as much capital in the banking system as the capital buffer requirements that were activated in 2022, although these estimates are subject to significant uncertainty.

41. Therefore, income-related borrower-based measures should be added to complete the macroprudential toolkit. These would complement existing lender- and borrower-based macroprudential measures.

42. Borrower-based measures should be activated as the economy recovers, well in advance of the next housing market downturn. Given current weakness in property markets, now is not the ideal time to activate borrower-based measures. However, the economy is expected to recover over the next few years and with it, vulnerabilities will again build in the absence of activated borrower-based measures. One phased approach could be to start by introducing quantitative guidance on LTV limits, which are not legally binding. Further work should examine the merits of calibrating these measures on a cyclical basis, i.e., whether they should be tightened or loosened with the economic cycle, or calibrating them at levels that would be appropriate throughout the cycle.

Box 1. Germany's Existing Borrower-Based Measures

LTV limits and amortization requirements can be imposed for financial stability reasons. The authority for Germany's existing borrower-based measures is established in Section 48u of the German Banking Act (*Gesetz über das Kreditwesen*, KWG). The law gives BaFin powers to impose an LTV cap or an amortization requirement on new loans for the purchase (or construction) of residential real estate. The LTV cap is specified relative to the market value of the property, not the mortgage lending value. The law only allows these powers to be used to preserve financial stability or the functioning of the financial system, rather than other objectives like macroeconomic stability or consumer protection. The amortization requirement is defined as a maximum period of time within which a certain fraction of a loan must be repaid or, in the case of interest-only loans, a maximum loan term.

The LTV limit allows for exemptions and some differentiation between borrowers. The borrower-based measures have a speed limit, which is a proportion of new loans that are not subject to the measures, and a *de minimis limit*, which is an exemption for small loans. The law does not explicitly mention differentiated limits by type of borrower (e.g., first-time homebuyers, second-and-subsequent-time homebuyers, and buy-to-let investors), but the authorities have signaled that a differentiated application is within the margin of discretion, if warranted from a macroprudential risk perspective.

The borrower-based measures prevent leakages to NBFIs, but rely on reciprocation by other jurisdictions to prevent cross-border leakages:

- Leakages to NBFIs can be avoided because similar instruments exist for insurers and investment funds in the Insurance Supervision Law (paragraph 308b) and Capital Investment Code (paragraph 5 (8a)) respectively.
- The measures apply to lending by subsidiaries and branches of foreign banks in Germany, but not to cross-border lending by foreign banks into Germany. If these leakages were material, BaFin could request other authorities in the EU or EEA to activate similar borrower-based measures reciprocally, through the ESRB.

The borrower-based measures can be activated pre-emptively. IMF (2022b) (paragraph 86) recommended that the authorities adjust the relevant legislation to allow borrower-based measures to be activated pre-emptively, before a material deterioration in lending standards has been observed, to avoid any public misperceptions to the contrary. Since then, a joint working group of the Ministry of Finance, BaFin and the Bundesbank concluded that there were no such obstacles in the legislation. In any event, such concerns do not prevent borrower-based measures from being imposed in a non-legally binding form; for example, through quantitative guidance, or instructing banks not to lend towards taxes and transaction costs in a house purchase.

Other laws also place restrictions on mortgage lending standards, but they cover small fractions of activity. Mortgages to be funded by covered bonds (*Pfandbriefe*) cannot have an LTV more than 60 percent of the mortgage lending value, according to Section 14 of the Pfandbrief Act. However, only 13 percent of outstanding mortgages were funded by covered bonds as of September 2022. Mortgages extended by building societies (*Bausparkassen*) cannot have an LTV more than 80 percent of the mortgage lending value, according to Section 7 of the Building and Loan Associations Act (*Bausparkassengesetz*). However, only 10 percent of outstanding residential real estate loans were with building and loan associations as of September 2022./[1]

1/ The 13 percent share of outstanding mortgages funded by covered bonds is the ratio of €228 bn in Pfandbriefe to €1,758 bn in domestic home loans, according to the statistical annex of the Bundesbank's January 2023 Monthly Report. From the same source, the 10 percent of outstanding residential real estate loans that were with building and loan associations is calculated as €185 bn in building loans out of €1,758 bn in domestic home loans.

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Annex I. Technical Details of the Microsimulation

1. Each loan's creditworthiness at each point in time is summarized by its expected loss, which is defined as the product of the loan's probability of default (PD) and loss given default (LGD). In turn, the PD and LGD are modeled by extending the work of Valderrama (2022), Górnicka and Valderrama (2020), and Harrison and Mathew (2008). Specifically:

- The PD of a given loan on a given date t is modeled using a dual-trigger approach

$$PD_t = P(\text{distress})_t \cdot P(\text{equity} < 0)_t \,,$$

in which the borrower defaults if her income drops relative to her debt service payments and her equity in the home becomes negative (see, for example, Schelkle, 2018).

- The income-based trigger, called "the probability of distress", is modelled in the first equation in terms of the DSTI ratio and unemployment rate:

$$P(\text{distress})_t = \beta_1(\Delta DSTI_t)^2 + \Phi(DSTI_t)(D + \beta_2 u_t + \beta_3(\Delta u_t^+)^\alpha), \text{ restricted to } [0,1]$$

where $\Phi(x) = \max\{0, \min\{1.3x/0.33, 1.3\}\}$ for each x, Δ denotes the change over time, the superscript $+$ denotes the positive part of a number, and $\beta_1, D, \beta_2, \alpha$ are parameters to estimate.

- The second trigger, called "the probability of negative equity", depends on how likely it is for the house selling price, plus the borrower's liquid assets, to fall below the outstanding loan balance and the prepayment penalty:

$$P(\text{equity} < 0)_t = 1 - N((p_t(1-c) + la_t - L_t - pp_t)/\sigma)$$

where p_t is the house price, la_t is the household's liquid assets, L_t is the outstanding loan balance, pp_t is the prepayment penalty defined as the present value of future interest payments on the loan:

$$pp_t = r_0(T)L_t \sum_{j=1}^{12(T-t)} \left(1 - \frac{j}{T-t}\right)(1 + r_t(T-t))^{-j} \text{ for a fixed-rate loan, otherwise } 0,$$

$r_t(\tau)$ is the monthly mortgage rate at date t and maturity τ, T is the original contractual maturity of the loan, and c, σ are parameters to estimate. The expression for $P(\text{equity} < 0)_t$ above generalizes the deterministic expression in equation (2) of Valderrama (2022) to allow for a normally distributed shock with variance σ^2, which captures the possibility of some uncertainty. When $\sigma \to 0$, $P(\text{equity} < 0)_t$ approaches the expression in equation (2) of Valderrama (2022). Over the 1980–2022Q2 period, each house price (p_t) is assumed to follow the national house price index and each household's liquid assets (la_t) are assumed to follow the development of household deposits net of loans. Net financial wealth would arguably be a better indicator than liquid assets for defining negative equity, but data on net financial wealth in HFCS are

questionable because, in our analysis of the data, more than half of households with outstanding mortgage loans report negative net financial wealth.

- The LGD looks at the situation from the bank's perspective and compares the outstanding loan balance and future interest payments to the foreclosure value of the home:

$$LGD_t = \left[L_t + pp_t - \frac{(1-\delta_t)p_t}{(1+r_t(T-t)+s)^n}\right]/L_t, \text{ restricted to } [0,1]$$

where $\delta_t = \text{sigmoid}(\delta_0 + \delta_1 t)$ is the foreclosure discount, $s = 0.011$ is the spread that the bank uses for discounting from Valderrama (2022), $n = 1$ is the time taken to foreclose from Valderrama (2022), and $r_t(\tau)$ here is yearly rather than monthly. Parameter δ_1 allows the foreclosure discount to trend up or down over time and generalizes the fixed foreclosure discount parameter in Valderrama (2022) equation (4).

- To determine capital requirements, we compute the risk-weight associated with each loan as

$$12.5 \cdot 1.06 \cdot \left[LGD_t \cdot N\left(\frac{1}{\sqrt{0.85}}G(PD_t) + \sqrt{\frac{0.15}{0.85}}G(0.999)\right) - LGD_t PD_t\right],$$

where G is the inverse of the cumulative distribution function of the standard normal distribution. The formula is an application of that in Article 154 of the EU Capital Requirements Regulation with $R = 0.15$ as specified in Article 154(3) for residential real estate.

2. The parameters are estimated by nonlinear least squares to fit aggregate (weighted average) COREP data on PDs and LGDs.[1] These data are reported by EU banks on their German retail loans secured by real estate. Specifically, if we let the subscript i index individual loans, then we seek the constrained parameters $0 < D < 1, \beta_2 > 0, \beta_3 > 0, 0 < c < 1, \sigma > 0$ and unconstrained parameters $\beta_1, \delta_0, \delta_1$ to minimize

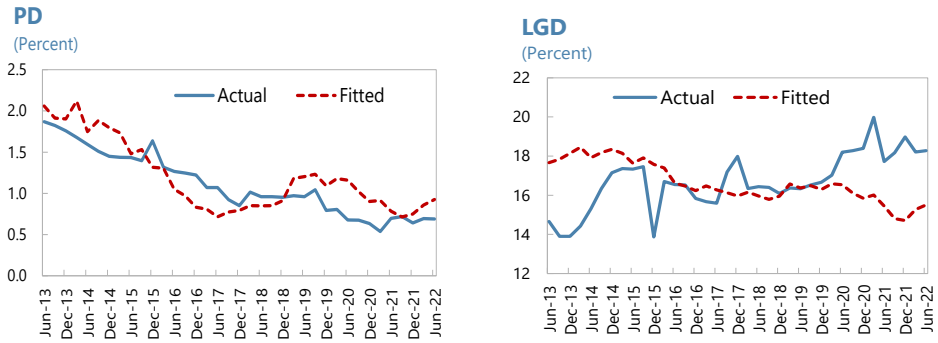
$$\sum_t u_t^2 + \frac{1}{2}\sum_t v_t^2$$

where $u_t = PD_t - \sum_i (L_{it}/\sum_i L_{it}) PD_{it}$, $v_t = LGD_t - \sum_i (L_{it}/\sum_i L_{it}) LGD_{it}$, and PD_t and LGD_t are from COREP. Estimation places more weight on PDs, because LGDs are known to be more influenced by the discretion of banks and supervisors. Given the non-differentiability of the objective function in places, minimization is by the Nelder-Mead algorithm. The model is able to fit PDs and LGDs reasonably well. Figure 8 shows the COREP data in solid blue and the cross-section weighted-

[1] The PDs are long-run average PDs, which are therefore insensitive to economic conditions. Furthermore, the LGDs are "downturn LGDs", which are LGDs that would prevail in an adverse scenario rather than central (i.e., business-as-usual scenario) expectations of LGDs. This definition means that these LGDs could be counter-cyclical, i.e. rising during good times, which justifies the introduction of the trend parameter δ_1 in the LGD model. Adjustments to PDs and LGDs were considered for this work, but given the lack of literature on this topic, it was left for future work.

average PD and LGD from the model in dashed red. In particular, the model-implied PDs match the data on average over time and they trend downward. The model achieves the upward trend in LGDs partly through its estimate of a trend increase in the foreclosure discount $\delta_1 > 0$, which shows the value of this extension to the model.[2] Nevertheless, the PDs are long-run averages and therefore cannot be expected to vary with unemployment. Therefore, standard errors are wide (Table 4) and it is no surprise that standard errors for β_1, β_3, and α are too numerically imprecise to estimate with the delta method. This insensitivity of PDs means that the losses in the stress scenario, and hence the benefits of borrower-based measures, might be understated here. Future work should seek more precise parameter estimates.

Figure 1. Fit of the PD and LGD Models



Sources: IMF staff calculations.

Table 1. Germany: Estimation Uncertainty of the Model Parameters

	Estimate	Standard error	t-statistic
D	0.168	1.312	0.13
β_1	1.017	n.a.	n.a.
β_2	0.014	1.325	0.01
β_3	0.075	n.a.	n.a.
α	2.080	n.a.	n.a.
c	0.045	1.003	0.04
δ_0	-3.894	4.236	-0.92
δ_1	0.106	0.119	0.89
σ	32,597	458,942	0.07

Sources: IMF staff calculations.
Notes: Parameter σ is denominated in euro units. "n.a." indicates that standard errors could not be determined through the delta method due to numerical imprecision.

[2] The other way that the model achieves the upward trend in LGDs is through a compositional shift. Specifically, new loans being issued after 2013 tend to have higher LTV and DSTI ratios than new loans issued previously (Figure 2), which tends to lift the average PD and LGD of the loan portfolio.