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THE SLOVAK REPUBLIC

SELECTED ISSUES PAPER

June 2021

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INTERNATIONAL MONETARY FUND

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June 7, 2021

Approved By
European Department

Prepared by Mariano Spector and Laura Valderrama

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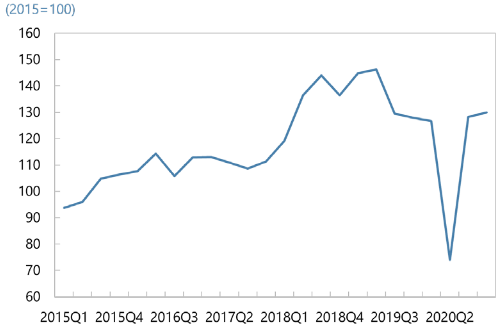
THE SLOVAK AUTO SECTOR DURING THE PANDEMIC AND BEYOND: MODEL BASED EVIDENCE [1]

The Slovak auto industry is deeply integrated in regional and global value chains. While this has brought tremendous benefits, it has also made the sector susceptible to foreign shocks as exemplified by the disruptions it experienced during the COVID-19 pandemic. Going forward, the industry will need to adapt to mega trends such as potential reconfigurations of supply chains and changes in preferences and technology. This paper uses a general equilibrium global trade model to: (i) quantify the impact of the pandemic-induced labor supply shock on the auto industry in Slovakia; (ii) disentangle the spillovers of the COVID-19 shock to the Slovak auto sector through cross-border and domestic production chains; and (iii) shed light on the Slovak auto sector's exposure to potential changes in the post-COVID global economy, namely higher trade costs with select partners.

A. Introduction

1. **The Slovak auto industry is deeply integrated in regional and global value chains.** While this integration has brought significant benefits, it has exposed the industry to foreign shocks. Such exposure became particularly salient during the COVID-19 pandemic. During the first wave of the pandemic, widespread factory shutdowns led to a historic contraction in car production. The high degree of integration of the Slovak auto industry within complex industrial value chains meant that its production was affected not only by car factory shutdowns but also by containment measures implemented up and down the value chain, both domestically and abroad.[2] Understanding the relative contribution of domestic lockdowns versus spillovers from lockdowns in trading partners will be important for policy-making going forward, should the current pandemic or future shocks require similar containment measures or trigger disruptions to the supply of key inputs.

Industrial Production: Manufacture of Transport Equipment
(2015=100)



Source: Haver

2. **More broadly, the COVID-19 pandemic may lead to long-lasting changes in the global economy, some signs of which predated the crisis.** In particular, a possible trend towards "deglobalization" and renationalization of production (see, for example, Chapter 1 of the April 2021 WEO) could have outsize effects on vehicle manufacturing compared to other industrial processes, since the European automotive supply chain is one of the most complex across sectors (Figure 1).

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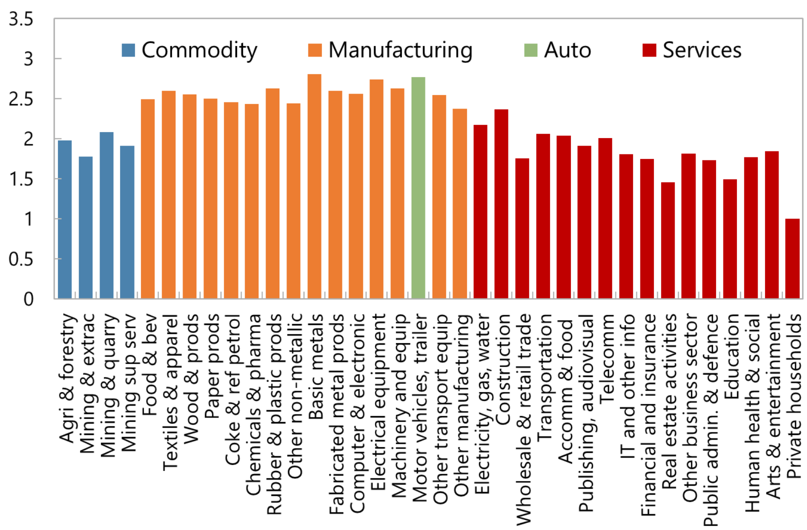
[1] Prepared by Mariano Spector, drawing on the forthcoming working paper by Boranova et al. (2021). We thank Barthelemy Bonadio and Andrei Levchenko for sharing the codes of their model and for useful discussions and advice.

[2] Banerjee and Zeman (2021) provide a comprehensive analysis of the evolution of the motor vehicles sector in the Slovak Republic, its integration with global production chains, and backward and forward linkages. See also IMF Staff Report 2019.

Such changes could have important macroeconomic consequences in the case of Slovakia: the car manufacturing sector directly accounts for 4.0 percent of total gross value added, 3.9 percent of jobs, and about a quarter of Slovakia's gross exports.[3] In no other country in Europe is the auto sector as dominant in terms of value added of and employment in manufacturing (Figure 2).

Figure 1. Cross-Sector Comparison of European Supply Chain Lengths

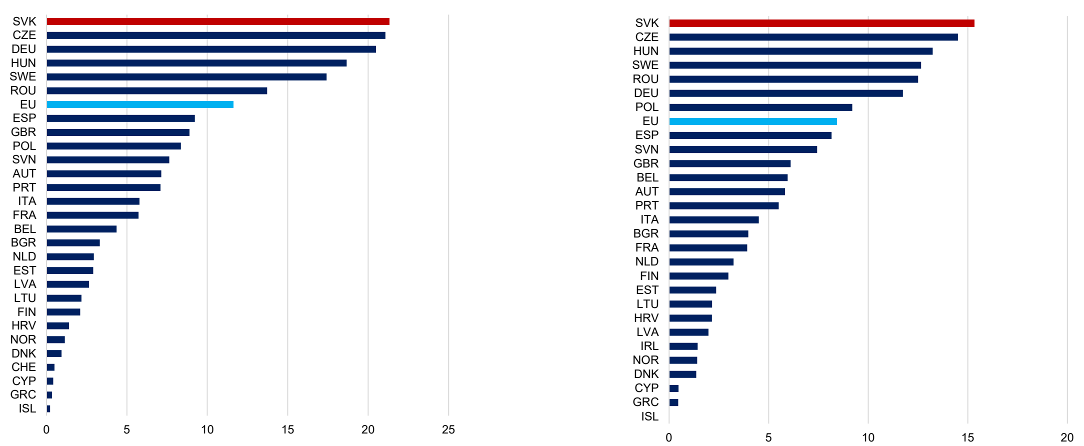


Source: OECD Inter-Country Input-Output Tables and IMF staff calculations.
Note: This chart uses a measure of supply chain length based on Fally (2012) which captures the number of production stages.

Figure 2. The Auto Industry Across European Countries

(Percent of Total Manufacturing)

Panel A. Gross Value Added | Panel B. Employment



Sources: Eurostat; Haver Analytics; and IMF staff calculations.

[3] Data for direct value added and jobs corresponds to 2019, while the data for gross exports corresponds to 2018 (source: Eurostat). Throughout this paper, we proxy car manufacturing by sector C29 in the European classification system NACE Rev. 2.

3. In order to shed some light on these questions, this paper employs a general equilibrium global trade model, following Bonadio et al. (2020), Huo, Levchenko and Pandalai-Nayar (2020), and Boranova et al. (forthcoming). The framework uses a static multi-country, multi-sector, multi-factor model in which countries trade both intermediate and final goods. Each sector uses labor, capital, and intermediate inputs that can come from any sector and country in the world. In the calibration, we have 64 countries from all continents and 33 economic sectors, and the main data source are the 2015 OECD Inter-country Input-Output tables.

4. The paper provides a quantification of the impact of the pandemic-induced labor supply shock on the auto industry in Slovakia. It disentangles the spillovers of the COVID-19 shock to the Slovak auto sector through cross-border and domestic production chains. Finally, it provides an illustrative simulation of how the Slovak auto sector might fare if trade costs with select partners were to sharply rise in the post-COVID global economy.

B. The Impact of the Pandemic

5. This paper follows closely Bonadio et al. (2021) and Boranova et al. (forthcoming) in modelling containment measures imposed during the COVID-19 pandemic as a labor supply shock, whose intensity depends on: (i) the stringency of the government response (captured by the Oxford Government Response Tracker; the value is set to the maximum stringency up to April 2020 to capture the peak of the first wave of the pandemic) and (ii) how amenable each sector is to working from home (captured by Dingel and Neiman (2020)'s work-from-home intensity index).[4] The contraction of the gross value added of the car industry during the peak of the first wave of the pandemic is decomposed between the direct effect of containment measures in the Slovak car industry and the indirect effect of measures in other sectors of the Slovak economy and in foreign countries.

6. The model predicts that, at the peak of the first wave, gross value added in the Slovak car industry falls by 31.1 percent due to the labor supply shock. If we look instead at value added in the whole economy, we find that the labor supply shock leads to a contraction of 27.5 percent.[5] The stronger effect on the auto sector than in the rest of the economy is largely explained by the fact that most tasks involved in car production cannot be done remotely.

7. Although the Slovak car industry is deeply integrated in regional and global value chains, the model indicates that most of the drop in value added was due to domestic containment measures (Figure 3): 69 percent of the decline is explained by the direct effect of restrictions, while 16 percent is due to restrictions in other domestic sectors, of which services

[4] The model does not include any "preference" shock against travelling during the pandemic nor nominal rigidities. Therefore, the pandemic shock is modeled purely as a supply shock, although demand is endogenously affected through income effects.

[5] Note that the labor supply shock is calibrated to the peak intensity of the containment measures, so it is not intended to match the GDP contraction in any given quarter.

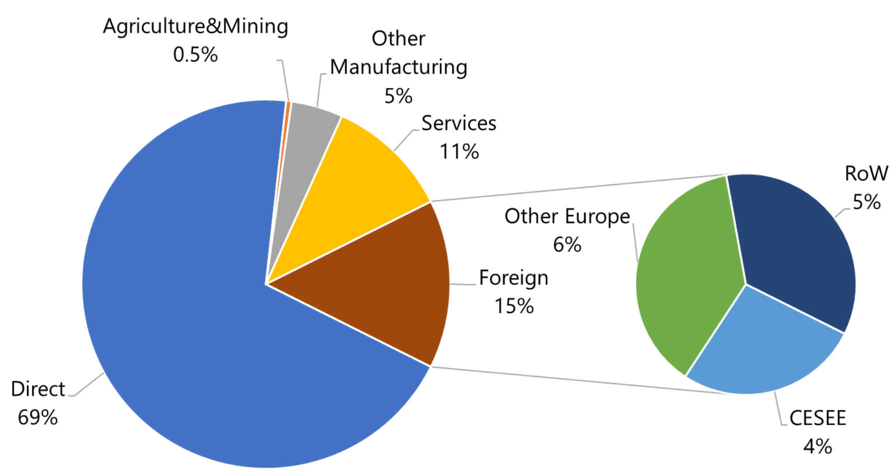
account for the lion's share. The remaining 15 percent is explained by containment measures implemented by trading partners.

8. The geographical distribution of the countries with the largest spillovers on the Slovak auto sector confirms the dominant influence of regional trading partners. Almost two thirds of the spillovers from abroad come from shocks to other European countries, reflecting the role of Slovakia as a producer relying mostly on inputs from within the European region. Outside of Europe, the main shock comes from China, accounting for 1.6 percent of the total contraction; meanwhile, the US accounts for only 0.5 percent of the total.

9. These results suggest that the reintroduction of strict lockdowns domestically to contain new waves of the virus would have a severe impact on the auto industry even if the rest of the world remained largely open. However, international spillovers, particularly those from Europe, are also important.

10. If we repeat the same exercise for other European countries, we find that on average only 11 percent of the shock to the auto industry comes from abroad. This is slightly lower than the 15 percent obtained for Slovakia, probably due to the higher degree of openness and integration into global value chains of the Slovak auto sector.

Figure 3. Change in Slovak Auto Sector GVA by Source of Shock



Sources: IMF staff calcualtions.

C. Reorganization of Supply Chains

11. There has recently been considerable speculation that the pandemic might lead to supply chain renationalization as a way to protect against similar shocks in the future. This exacerbates pre-existing concerns regarding global trade tensions, Brexit and potential de-globalization. To quantify the exposure of the Slovak car industry, the same model is employed to compute the change in auto industry value added in a highly stylized counterfactual scenario. In particular, this paper examines the potential impact of a complete shutdown of trade between the EU and China, and between the EU and Great Britain.[6] These scenarios are chosen as an illustrative tool of the channels through which the Slovak auto industry is exposed to disruptions in the patterns of international trade, rather than due to the realism of the shock. In each case, we alternatively consider a complete shutdown of trade, and a shutdown only in trade of intermediate goods and services.

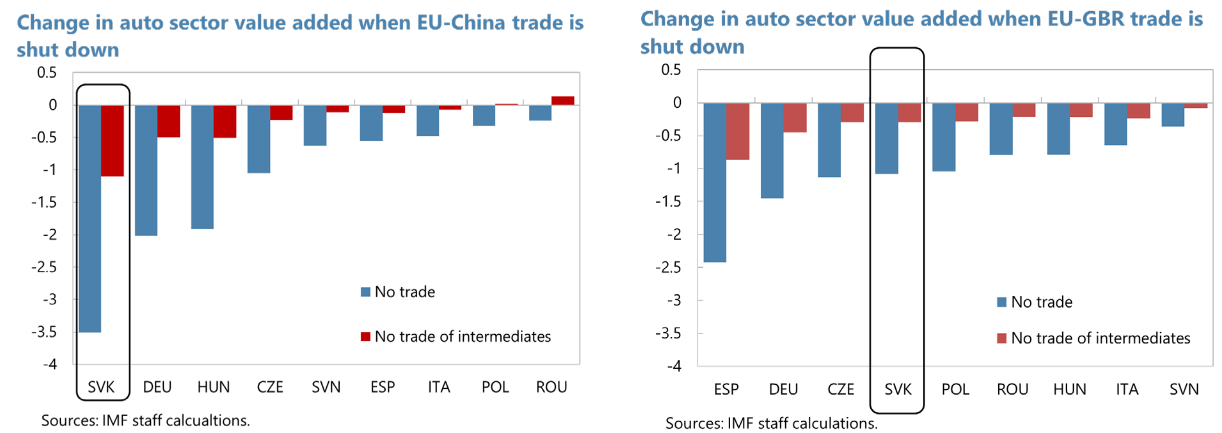
12. The Slovak auto sector has a sizeable exposure to trade with China. China's role as a destination for the value added of the Slovak auto sector has grown significantly over time, as documented by Banerjee and Zeman (2021). Suppliers, however, remain largely from within the region. In the event of a complete shutdown of trade between the EU and China, Slovakia's auto sector value added would contract by 3.5 percent, the highest across all EU countries (Figure 4).

13. If only trade of intermediates were shut down, there would be a sizeable, but much smaller, contraction of 1.1 percent of auto sector value added. The large difference between the two scenarios reflects that China is a much more important destination for final goods than for intermediates produced by the Slovak auto industry. Other Central and Eastern European (CEE) countries, which also have large auto sectors integrated in global value chains, are also significantly exposed to trade tensions with China, but their exposure is significantly lower than that of the Slovak Republic. The reason for this is simple: China accounts for a larger fraction of Slovak auto exports (both final and intermediate) than for the exports of most other European countries.

14. Meanwhile, the exposure of the Slovak auto sector to trade with Great Britain is far smaller, albeit non-negligible. In the event of a total shutdown of trade between the EU and Great Britain, Slovak auto sector value added would contract by 1.1 percent, and by 0.3 percent when only trade of intermediate goods and services is interrupted (Figure 4). This exposure is similar to that of other CEE countries like Poland and the Czech Republic, and smaller than that of countries like Spain and Germany, for whom Great Britain is a more important export destination.

[6] In these scenarios, there are no labor supply shocks, only a reconfiguration of trade patterns (modeled as an infinitely large increase in iceberg trade costs). The labor supply shock discussed before is intended to capture the short-run impact of the pandemic, while the change in trade structure is interpreted as a long-term shock.

Figure 4. Exposure to Changes in Trade Patterns



D. Conclusion

15. The auto sector is macro-critical in the Slovak Republic and is characterized by long and elaborate supply chains. Using a multi-sector and multi-country general equilibrium model, this paper presents a quantitative assessment of how the pandemic-related labor supply shocks—related to lockdowns imposed in different sectors and countries—would impact the Slovak auto sector via global value chains. Our results suggest that these labor supply shocks would have a significant adverse impact on the Slovak auto sector. While labor supply disruptions within the Slovak car sector itself account for the vast majority of the decline in value added, about 30 percent of output drop could be attributed to the effects of disruptions in supply chains within and across borders. Of those, one half come from outside Slovakia's borders.

16. Second, we exploit the model to shed light on the exposure of the Slovak auto sector to potential reorganization of the auto supply chains. Simulations suggests that, in a highly stylized scenario in which trade costs are high enough to preclude the EU's trade with select trading partners, the Slovak (and EU's) auto sector would be significantly worse off. These findings present yet another piece of evidence supportive of the call to resist protectionist tendencies that could undermine productivity and growth in the post-COVID world.

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Annex I. Model Setup

This annex provides more details on the setup of the general equilibrium model. The world economy consists of N countries (labelled by n and m), and there are J sectors (indexed by j and i) in each country. Each country n is populated by a representative household. The household consumes the final good available in country n and supplies labor and capital to firms. International trade is subject to iceberg trade costs τ_{mnj} to ship good j from country m to country n (the first subscript denotes the source or exporter, and the second denotes the destination or importer).

Households. There is a continuum of workers in a representative household who gain utility from the common consumption bundle. The household's utility maximization problem is

$$\max_{F_n,\{H_{nj}\}} U(F_n - \frac{\psi}{1+\psi}\sum_j \xi_{nj} H_{nj}^{1+\frac{1}{\psi}})$$

Subject to

$$P_n F_n \equiv \sum_{m,j} P_{mnj} F_{mnj} = \sum_j W_{nj} H_{nj} + \sum_j R_{nj} K_{nj}$$

On the supply side, H_{nj} is the total labor hours supplied to sector j, and K_{nj} is the amount of installed capital, which is assumed to be exogenous:

$$K_{nj} = \bar{K}_{nj}$$

Each unit of labor supply collects a sector-specific wage W_{nj}, and capital is rented at the sector-specific price R_{nj}. ξ_{nj} is a (negative) preference shock on the labor supply of sector j. This preference shock is used to capture the pandemic-induced containment measures. ψ is the Frisch elasticity that governs the responsiveness of labor supply. This type of preference gives an especially simple isoelastic labor supply curve that only depends on the real wage:

$$H_{nj} = \left(\frac{W_{nj}}{\xi_{nj} P_n}\right)^{\psi} \tag{1}$$

On the demand side, F_n is the consumption of final goods with corresponding aggregate consumer price index P_n, F_{mnj} is the final use in n of sector j goods coming from country m and P_{mnj} is the corresponding price. The final use F_n in the economy is a Cobb-Douglas aggregate across sectoral final composites, where each sectoral final composite aggregates up country-specific absorptions:

$$F_n = \prod_{j=1}^{J} (F_{nj})^{\omega_{nj}}, F_{nj} = \left[\sum_m \vartheta_{mnj}^{\frac{1}{\rho}} F_{mnj}^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}} \tag{2}$$

The corresponding price indices can be also expressed by the following CES aggregations:

$$P_n = \prod_{j=1}^{J} \left(\frac{P_{nj}}{\omega_{nj}}\right)^{\omega_{nj}}, P_{nj} = \left[\sum_m \vartheta_{mnj} P_{mnj}^{1-\rho}\right]^{\frac{1}{1-\rho}} \tag{3}$$

The final expenditure share of a particular good from country m and sector j that is imported by country n is given by

$$\frac{P_{mnj}F_{mnj}}{\sum_{k,l}P_{knl}F_{knl}} \equiv \pi^{f}_{mnj} = \omega_{nj}\frac{\vartheta_{mnj}P^{1-\rho}_{mnj}}{\sum_{k}\vartheta_{knj}P^{1-\rho}_{knj}} = \omega_{nj}\pi^{c}_{mnj} \tag{4}$$

Firms. A representative firm in country n and sector j operates a Cobb-Douglas production function

$$Y_{nj} = Z_{nj}\left(K^{\alpha_j}_{nj}H^{1-\alpha_j}_{nj}\right)^{\eta_j}X^{1-\eta_j}_{nj} \tag{5}$$

Where the TFP is denoted by Z_{nj}, K_{nj} and H_{nj} are the corresponding capital and labor supply from the household, and X_{nj} is the intermediate input usage that aggregates inputs from all potential countries and sectors:

$$X_{nj} = \left(\sum_{i}\sum_{m}\mu^{\frac{1}{\varepsilon}}_{mi,nj}X^{\frac{\varepsilon-1}{\varepsilon}}_{mi,nj}\right)^{\frac{\varepsilon}{\varepsilon-1}} \tag{6}$$

where $X_{mi,nj}$ is the usage of inputs coming from sector i in country m in production of sector j in country n, and $\mu_{mi,nj}$ is the intermediate taste shifter. Similar to the final good price index, we can derive the price index of this intermediate input bundle:

$$P^{x}_{nj} = \left(\sum_{i}\sum_{m}\mu_{mi,nj}P^{1-\varepsilon}_{mi,nj}\right)^{\frac{1}{1-\varepsilon}} \tag{7}$$

where $P_{mi,nj}$ be the price paid in country n, sector j for inputs from country m, sector i.

Let P_{nj} denote the price of output produced by sector j in country n. No arbitrage in shipping implies:

$$P_{mi,nj} = P_{mni} = \tau_{mni}P_{mi} \tag{8}$$

The cost minimization decision implies that the payments to primary factors and intermediate inputs are:

$$R_{nj}K_{nj} = \alpha_j\eta_jP_{nj}Y_{nj} \tag{9}$$

$$W_{nj}H_{nj} = (1-\alpha_j)\eta_jP_{nj}Y_{nj} \tag{10}$$

$$P_{mi,nj}X_{mi,nj} = \pi^{x}_{mi,nj}(1-\eta_j)P_{nj}Y_{nj} \tag{11}$$

where $\pi^{x}_{mi,nj}$ is the share of intermediates from country m, sector i in total intermediate spending by country n, sector j, given by:

$$\frac{P_{mi,nj}X_{mi,nj}}{\sum_{k,l}P_{ki,nl}X_{ki,nl}} \equiv \pi^{x}_{mi,nj} = \frac{\mu_{mi,nj}(\tau_{mni}P_{mi})^{1-\varepsilon}}{\sum_{k,l}\mu_{kl,nj}(\tau_{knl}P_{kl})^{1-\varepsilon}} \tag{12}$$

Equilibrium conditions. An equilibrium in this economy is a set of goods and factor prices $\{P_{nj}, W_{nj}, R_{nj}\}$, factor allocations $\{K_{nj}, H_{nj}\}$, and goods allocation $\{Y_{nj}\},\{F_{mnj}, X_{mi,nj}\}$ for all countries and sectors such that given all exogenous realization of labor supply shocks $\{\xi_{nj}\}$:

(i) households maximize utility by satisfying (1)-(4).

(ii) firms maximize profits through (5)-(12).

(iii) all markets clear.

More specifically, market clearing conditions for sectoral goods should satisfy:

$$P_{nj} Y_{nj} = \underbrace{\sum_{m} \sum_{i} \eta_i P_{mi} Y_{mi} \omega_{mj} \pi^{c}_{nmj}}_{final\ use} + \underbrace{\sum_{m} \sum_{i} (1-\eta_i) P_{mi} Y_{mi} \pi^{x}_{nj,mi}}_{\text{intermediate use}} \tag{13}$$

On the other hand, the labor supply should meet the corresponding labor demand from representative firms in each country and sector:

$$H_{nj} = \left(\frac{W_{nj}}{\xi_{nj} P_n}\right)^{\psi} = \frac{(1-\alpha_j)\eta_j P_{nj} Y_{nj}}{W_{nj}} \tag{14}$$

Here we want to highlight another important feature of this framework: like other quantitative models in the international trade literature, the model equilibrium nominal sectoral output $P_{nj} Y_{nj}$ can be solved up to a normalization with information on only the value-added shares η_i and the final and intermediate demand systems $\omega_{mj} \pi^{c}_{nmj}$ and $\pi^{x}_{nj,mi}$. Given this nice property, we can compute the equilibrium changes of the variables of interest that only requires the calibration of a limited number of parameters. This greatly reduces the burden of computation as the number of countries and sectors increase and makes this framework more tractable to match the data.

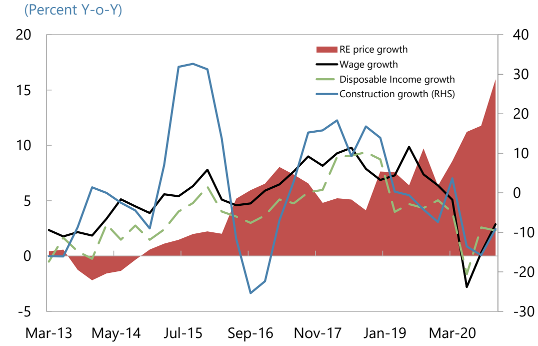
MACROPRUDENTIAL POLICY CALIBRATION IN SLOVAKIA[1]

The Slovak banking sector has coped well with the COVID-19 pandemic so far, but vulnerabilities associated with the housing market have accumulated. Notwithstanding the proactive tightening of regulatory limits before the pandemic, mortgage credit and real estate prices continue to grow, and housing loans account for an increasing share in banks' private sector loan portfolio. We develop a modeling framework that quantifies the effectiveness of different macroprudential policy instruments in reducing mortgage losses, in case of a severe downside scenario including a house price correction. We show that different regulatory limits can achieve a similar reduction in default risk, but loan-to-value (LTV) restrictions can be particularly effective in addressing systemic risk in housing loans relative to other borrower-based tools in terms of decreasing bank losses. We calibrate the level of minimum risk weights on IRB banks and the sectoral systemic risk buffer (SyRB) on mortgage exposures, which would absorb mortgage losses under stressed conditions.

A. The Context

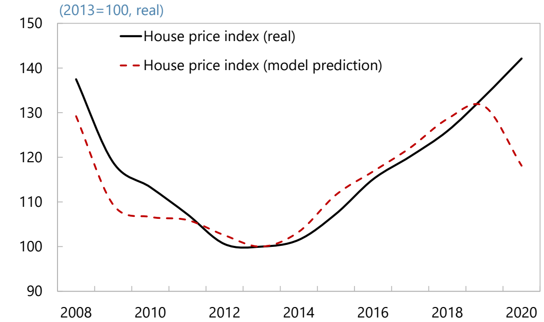
1. Real estate prices in Slovakia have continued growing at a brisk pace through the pandemic. House prices rose by 16 percent in 2020, significantly outpacing growth in wages and household disposable income. Several factors likely contributed to this phenomenon. Demand for housing remained strong, as mortgage rates declined to under 1 percent in 2020, fueled by the decrease in long-term yields and fierce banking system competition. Supply constraints, including land-use restrictions in urban areas and the 9 percent contraction in domestic construction, contributed to fewer houses being built despite rising demand.

Real Estate Price Growth, Demand and Supply Drivers
(Percent Y-o-Y)



Sources: Haver Analytics and IMF staff calculations

House price index and the model prediction
(2013=100, real)



Sources: Eurostat; National Bank of Slovakia and IMF staff estimates.

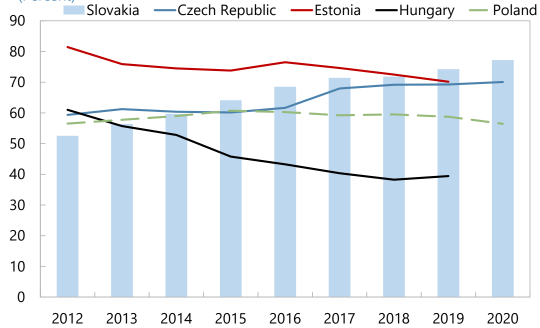
2. With the significant GDP decline in 2020, a gap has emerged between actual and model-predicted residential real estate prices.[2] A regression-based assessment of fundamental drivers of real estate prices across a panel of Central, Eastern

[1] Prepared by Laura Valderrama (EUR). The author thanks Marek Ličák, Pavol Jurča, Ján Klasco, and colleagues at the National Bank of Slovakia for sharing the data and for insightful comments and remarks, and Lucyna Górnicka, Peter Harvan, and Erlend Nier for very fruitful discussions.

[2] The rise in house prices in Slovakia mirrors trends in global asset prices supported by accommodative financial conditions

and Southeastern economies (CESEE) suggests house prices may have deviated from model-predicted values by around 20 percent in 2020.[3] Though the extent of house price misalignment is difficult to gauge given the unique nature of the COVID-19 shock, this estimate is consistent with house price gaps assessments by the NBS and rating agencies (NBS, 2020, and Moody's, 2021).

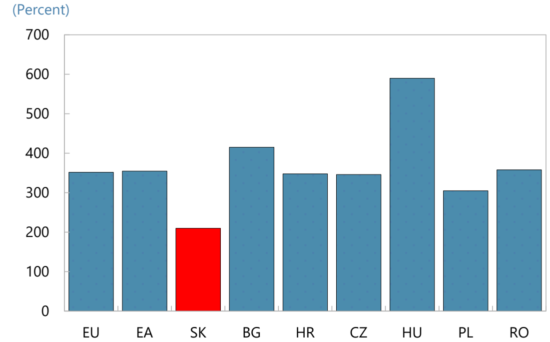
Household Debt to Disposable Income
(Percent)



Source: Haver Analytics and IMF staff calculations

3. **Strong housing demand has contributed to a sustained increase in household indebtedness.** The ratio of debt to household disposable income has risen significantly from about 50 percent in 2012 to 77 percent in 2020, outpacing growth in peer countries in the CESEE region. While household indebtedness is not high compared to other advanced economies in Europe, a high share of mortgages sensitive to interest rate changes and low financial asset-to-debt ratio are a source of vulnerability. At the same time, the high share of refinancing of mortgage loans – the share of refinancing in new mortgage production exceeded 50 percent in 2021 – allows households to lock in low lending rates in the prevailing low interest rate environment.

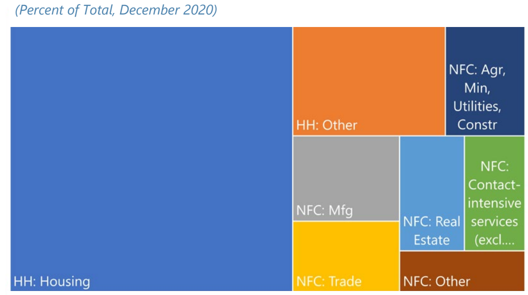
Household Financial Assets to Liability Ratio in 2020
(Percent)



Sources: Haver Analytics and IMF staff calculations

4. **Taken together, these indicators point to a build-up of systemic risk associated with mortgage exposures in the Slovak banking system.** The level of systemic risk could pose a threat to financial stability as the importance of the housing market on banks' balance sheets continues to rise. Housing loans account for more than a third of banks' total assets, the highest share in the euro area, where the average hovers at around 13.2 percent.[4] The protracted expansion of banks' exposures to mortgage lending to Slovak households and the intense competition in housing loans has increased the share of household mortgages in the domestic portfolio from 43.6 to 49.1 percent over the past five years.

Credit to Households and Non-Financial Corporates
(Percent of Total, December 2020)



Sources: National Bank of Slovakia; EBA Interactive Dashboard, Q42020; and IMF staff calculations.

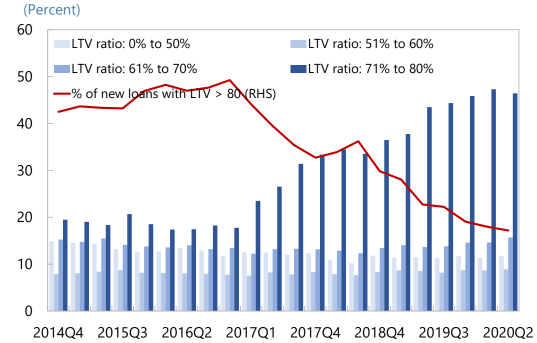
[3] House price growth is regressed on one-year lag of affordability (detrended housing prices/GDP per capita), GDP per capita growth, employment rates growth, and changes in construction costs. The estimation is conducted using a panel approach for CESEE countries over 2006-2020. A key driver of the hosing price gap is the recent decline in GDP, which may not fully capture long-term income effects or households' debt servicing capacity.

[4] National Bank of Slovakia (2021), "Financial Stability Report", May.

B. The Policy Response

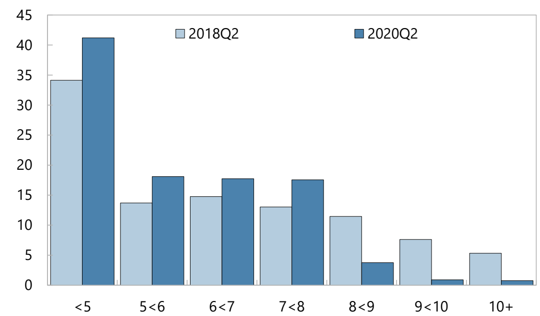
5. The NBS has used proactively a range of macroprudential measures. In December 2016, it tightened regulatory tools for housing loans introducing a debt-service-to-income (DSTI) limit of 80 percent, including a 2-percentage point stressed interest rate and a deduction of a subsistence amount from net income. It also tightened loan-to-value (LTV) limits with the share of new loans over an LTV of 80 percent capped at 40 percent of total production. A 30-year maturity limit for housing loans was also introduced in 2014.[5] To address potential regulatory leakages, the standards for housing loans were extended to consumer loans in 2018, and regulatory limits on DSTI and maximum maturity of 8 years became applicable to consumer loans too. In July 2018, the NBS also introduced a limit on debt-to-income (DTI) ratio of 8[6]. It also tightened the LTV limit, with the maximum share of new loans exceeding an LTV of 80 percent set at 20 percent and the maximum LTV at 90 percent. The DSTI ratio was tightened from 80 percent to 60 percent in January 2020 with phase-in arrangements through July 2020.[7]

New Lending by LTV Ratio
(Percent)



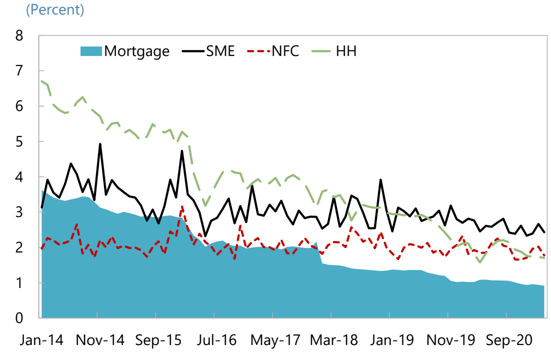
Sources: National Bank of Slovakia; and IMF staff calculations.

New Lending by DTI Ratio
(Percent)



Sources: National Bank of Slovakia; and IMF staff calculations.

Lending rates on new loans
(Percent)



Sources: Haver Analytics and IMF staff calculations

6. During the pandemic, the countercyclical capital buffer (CCyB) was lowered from 1.5 percent to 1.0 percent. The NBS reduced the CCyB buffer effective in August 2020 as a response to the coronavirus crisis to help banks absorb loan-loss provisions and support lending to the real economy. The tightening of DSTI from 80 to 60 percent became binding in July 2020 as planned and announced prior to the pandemic with the decision published in December 2019.

7. The use of macroprudential measures has been instrumental in containing risks in the mortgage portfolio. The macroprudential policy

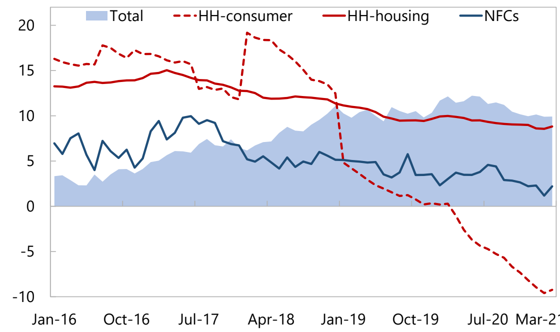
[5] Banks are allowed to exceed the maturity limit for ten percent of new loans but in practice have made limited use of this option.

[6] Five percent of new loans can exceed the DTI limit of 8.

[7] Exemptions included five percent of new loans granted with DSTI up to 70 percent; and an additional five percent of new consumer loans granted below 70 percent provided their maturity does not exceed five years.

measure to contain the rise in high LTV mortgages was effective to bring down the share of new mortgages with LTV ratios exceeding 80 percent from 50 percent in 2017 to 17 percent in 2020. Similarly, restrictions on DTI have succeeded in decreasing the share of new mortgages with ratios exceeding 8 from 24 percent in 2018 to 5 percent in 2020.

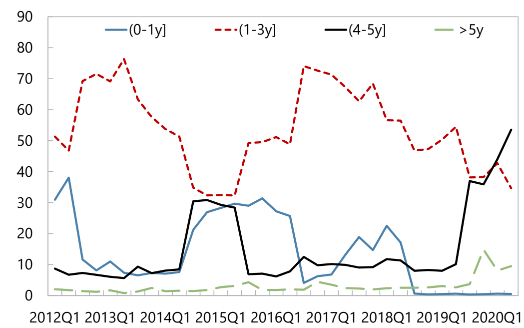
Private Sector Credit Growth
(Year-on-year percent change)



Sources: Haver Analytics; and IMF staff calculations.

8. **Despite swift policy action, mortgage lending has remained brisk and the issuance of new mortgages is concentrated just below regulatory thresholds.** In the year up to March 2021, housing loans grew by 9.2 percent while corporate lending growth slowed to 3.1 percent and consumer credit contracted by 5.9 percent.[8] Banks seem to have responded to the tighter LTV and DTI limits by increasingly issuing mortgages just below regulatory thresholds. The share of mortgages with an LTV between 70 and 80 percent (respectively with a DTI between 6 and 8) rose from 18 to 46 percent (respectively from 28 to 35 percent) between 2017 and 2020. This could lead to potential under-collateralization and financial distress if house prices drop sharply, disposable income contracts stretching households' repayment capacity, or interest rates rise.

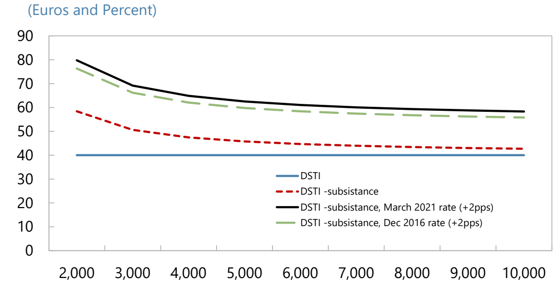
Time to repricing of mortgage loans by vintage
(Percent)



Sources: Haver and IMF staff calculations

9. **Newer borrowers are likely to be more vulnerable than older borrowers, which, together with their large share in banks' portfolio, warrants a vintage assessment of mortgage risk.** An interest rate hike would lead to greater financial stress for recent borrowers. In a tail risk scenario, for an average household with a 22-year mortgage and a DTI of 7, a 300 basis points increase in mortgage rates – arguably a sizable increase from the current interest rate of 0.92 percent to the level prevailing in 2013 - would increase the DSTI ratio from 40 percent to 60 percent.[9] However, NBS regulatory DSTI is stricter than that of peer countries, particularly in an ultra-low interest rate environment, and for low income households. First, debt service includes a stressed interest hike of 200 basis points. Second, disposable income is defined as net income minus the minimum subsistence amount for

DSTI NBS regulatory definition by income level
(Euros and Percent)



Sources: IMF staff calculations
Note: This chart shows the comparison between a standard DSTI regulatory ratio of 60 percent computed as debt service payments over net income (blue line), and the RBNZ DSTI stricter definition calculated as debt service payments with a 2pp increase in lending rates over net income minus subsistance consumption for a household of two adults and two children. Crucially the definition is stricter for lower income households (household net income in the x axis in euros) and lower interest rates. The dotted green line shows the DSTI schedule at the mortgage rates prevailing in Dec 2016 when the limit was implemented whereas the black line shows the DSTI schedule at current mortgage rates.

[8] While consumer credit started decelerating in January 2019, the pandemic has reinforced this trend. Factors underlining the consumer credit contraction include lower demand related to the general decline in consumption during the pandemic, some consolidation of debts into housing loans, and binding regulatory limits.

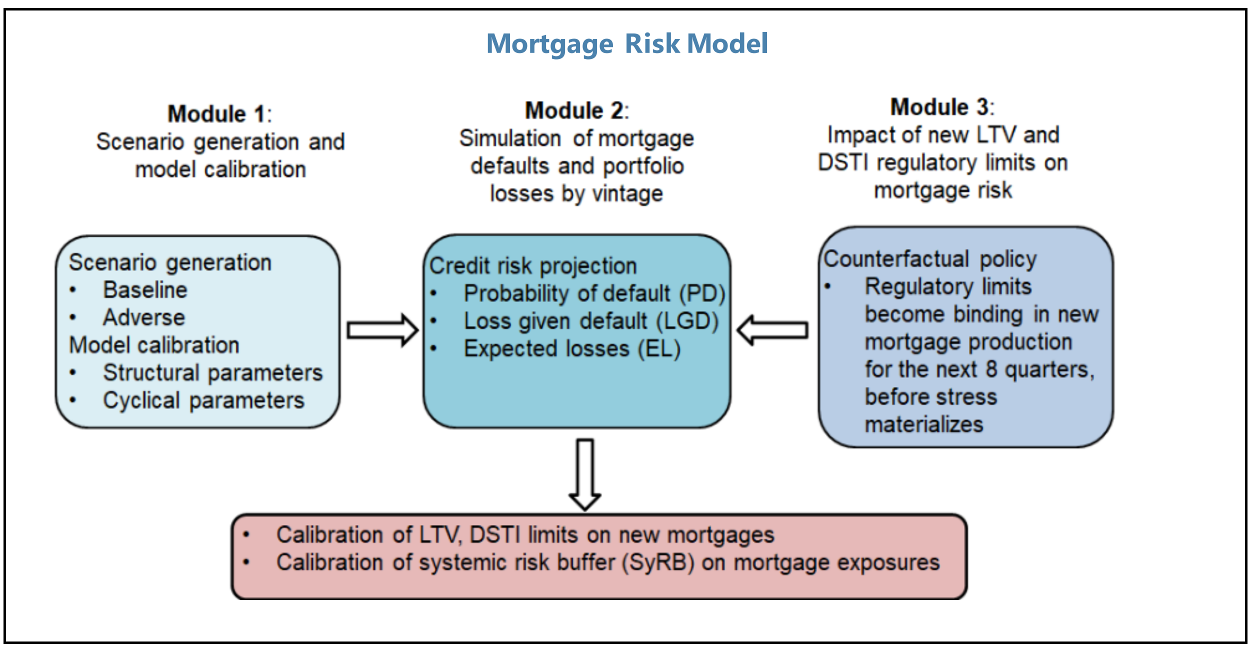
[9] In Slovakia, the average maturity of new housing loans issued in 2020 was around 22½ years, with around 54percent of loans between 20 and 30 years. However, the time to repricing is shorter at around 4¼ years with one third of new issuances having a remaining time to re-setting period between 2 and 3 years.

the entire household, which should provide some buffers.[10] More broadly, new borrowers tend to be more vulnerable than earlier borrowers as they have repaid less principal, they have less home equity value, and their affordability risk is assessed at lower interest rates. Recent mortgages represent a large fraction of the total outstanding mortgage portfolio in the banking sector. Mortgages issued or refinanced in the past two years account for 60 percent of the total outstanding mortgage loans as of 2020:Q3.[11]

C. The Model

10. **We present a modeling framework that could inform the calibration of a wide range of macroprudential policy tools.** In addition to regulatory limits (LTV, DSTI, DTI), we discuss the calibration of sectoral capital requirements, such as a sectoral systemic risk buffers (SyRB) or minimum risk weights on mortgage exposures. The main benefit of regulatory limits is that they increase the resilience of the borrower to an asset, income, or interest rate shock. Capital-based measures, on the other hand, increase the resilience of the lenders, reducing negative feedback effects on the economy from a credit crunch or the sale of distressed debt at fire sales prices. While the NBS has been active in implementing regulatory limits on mortgage loans, the flexibility on the use of SyRB to target systemic risk under the recent Capital Requirement Directive (CRD) V presents an opportunity to expand the toolkit with targeted capital requirements.

11. **The key elements of the modelling exercise, which are described in greater detail in Annex I, are as follows:**



[10] For a household formed by two adults and two children and net income of EUR 2,000, a DSTI ratio of 40 percent in peer countries is equivalent to 80 percent under NBS DSTI definition.

[11] The large production is partly driven by the high share of refinancing loans which increased from 50 percent in 2019 to 55 percent in 2021 (NBS, 2021).

- **We use a structural model to project credit risk by *vintage buckets*, which we then aggregate to assess risk at the portfolio level under the baseline forecast.** The vintage-based approach not only allows for a more accurate assessment of risks (as discussed above) but it is also crucial for the calibration of macroprudential measures since borrower-based measures are applied to the production of new mortgages, whereas sectoral capital buffers are applied to the outstanding portfolio. Using a detailed supervisory dataset covering all issuances of housing loans 1999;Q1-2020;Q2 by risk characteristics (namely, DSTI, LTV and DTI buckets at origination), we trace the evolution of the banking sector mortgage portfolio taking into account repayments of principals, new issuances, changes in real estate prices and lending rates, and the evolution of household income, to project the loss rate of the outstanding portfolio (namely probability of default, loss given default and expected losses) up until 2023 under the baseline forecast as reported in the April 2021 IMF World Economic Outlook. [12]

- **We then quantify the risk stemming from housing loans under stressed conditions.** This follows recent EBA guidance, which encourages macroprudential authorities to measure credit risk of systemic exposures taking into consideration forward-looking indicators including losses under adverse macroeconomic developments, given the pre-emptive nature of macroprudential buffers (EBA, 2020). To calibrate the adverse scenario we use a structural model to project corporate insolvency risk in Slovakia due to the COVID-19 shock after accounting for fiscal, monetary, and financial policy support.[13] The correction in house prices is calibrated using the overvaluation model discussed above. The shock to disposable income is estimated using a VAR approach, and the interest rate shock is calibrated to bring mortgage rates to historical levels prevailing just before macroprudential policy was activated in Slovakia in 2014.

- **Finally, we examine the impact of alternative settings of borrower- and capital-based measures on projected credit risk under the baseline and stressed scenarios.** The counterfactual policy simulations quantify the extent to which the preemptive tightening of different measures could reduce expected losses should an adverse scenario materialize. They also shed light on the relative effectiveness of alternative combinations of macroprudential limits. We consider a tightening of the current LTV limit (80 percent with 20 percent speed limit with a maximum of 90 percent) by 5 percentage point increments to 70 with no exemptions, and

Variable	Baseline (cumulative change 2021-2023)	Adverse (cumulative change 2021-23)
Household disposable income	+4.31 percent	-3.78 percent
House price level	-10 percent	-25 percent
Unemployment rate	+2.6 percentage points	+5.74 percentage points
Average mortgage rate	+120 basis points	+300 basis points

[12] The baseline scenario includes income and lending rate projections consistent with WEO forecasts as of April 2021. For ease of comparison with NBS stress test results, the scenario includes projections for unemployment based on NBS baseline scenario (FSR, November 2020). To benchmark baseline results against Slovak banks' credit risk projections for mortgage exposures booked under IRB, the house price shock is consistent with a downturn scenario as prescribed by Basel for the calculation of capital requirements for IRB exposures.

[13] See Slovakia staff report (2021), Box 2: "The corporate sector", June; and Ebeke et al (2021).

a decrease in the current DSTI limit (60 percent with 5 percent speed limit with a maximum of 70 percent) to hard limits between 40 and 60 percent.

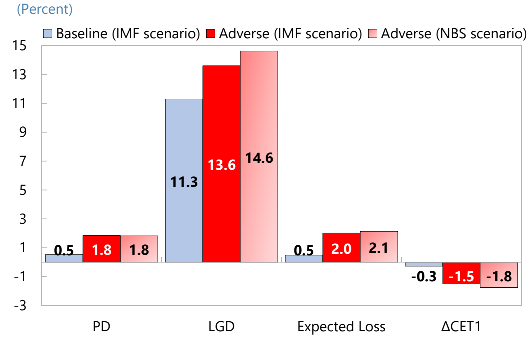
12. Using the new flexibility allowed under the EU Capital Requirements Directive (CRD V) we calibrate the sectoral SyRB buffer applied to mortgage exposures. By contrast with CRD IV that restricted the application of the SyRB to the mitigation of structural systemic risks of a long-term nature, CRD V increased the flexibility of the instrument to target specific systemic risks that are inherent in banks' exposures at a sectoral level (EBA, 2020). Here we calibrate the SyRB on all retail exposures in Slovakia secured by residential property. For this, we first assess the losses of the stress scenario on the mortgage stock, including new issuance, and then compute the additional capital buffer that would be required to absorb the losses under stress given the current risk weights of mortgage exposures in Slovakia.

13. While the modelling framework quantifies the relative benefits of alternative calibrations of macroprudential measures, the findings are subject to several caveats. First, the model captures the benefits of macroprudential measures in terms of improving banking sector resilience from the mortgage portfolio, abstracting from other policy objectives, such as, for example, balancing welfare gains from home ownership or expanded access to credit vs financial stability risks. Second, the analysis draws on detailed, yet aggregated, mortgage loan data by vintage and risk bucket using supervisory data. While regulatory reporting is updated at a high frequency and the segmentation facilitates policy evaluation as it is based on the same risk buckets used for macroprudential policy interventions, it does not reflect individual borrower heterogeneity such as differential consumption patterns. Finally, the modeling framework is not designed to capture regulatory leakages from the migration of housing loans to consumer loans that may be used to top-up constrained mortgages as a result of macroprudential policy enforcement.

D. Stress Test Results

14. Stress test results suggest that the average default rate of the aggregate mortgage portfolio would reach 1.8 percent in 2021-24 depleting 150 basis points of banks' total CET1 capital. The average loss given default (LGD) would reach 13.6 percent, and the annualized loss rate of the portfolio 2 percent of mortgage exposures. This compares against a default rate of ½ percent under the IMF baseline scenario. This estimate ranges between the 0.33 and 0.88 percent probability of default (PD) on mortgage exposures reported by Slovak IRB banks as of 2020;Q4.[14] The impact of default risk on banks' capital position is through two channels: first, an income channel, as defaulted loans do not accrue interest income; second, a provisioning channel, as defaulted loans migrate to the Stage 3

Stress Test Results on Mortgage Portfolio
(Percent)



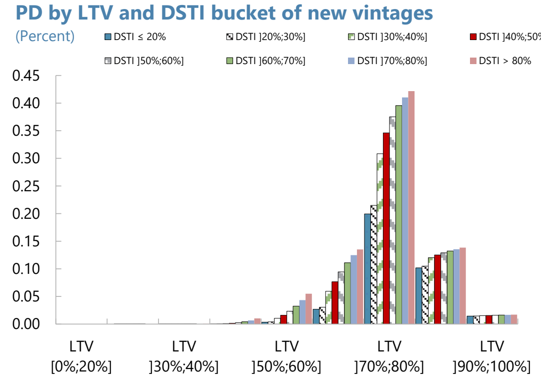
Source: IMF staff estimates

[14] The adjusted PD on retail exposures secured on real estate property reported by Slovak IRB banks ranges between 0.33 percent (median) and 0.88 percent (weighted average). See EBA (2021).

category under IFRS 9 with the coverage ratio increasing from the current 0.4 percent in Stage 1 to 66.7 percent for IRB banks as of end 2020. The impact on risk-weighted assets is muted as Slovak IRB banks use through-the-cycle risk weights with minimal variability of risk weights across the cycle. Results would be similar under the scenarios published in NBS (2021) where unemployment increases by 4.8 percentage points, disposable income decreases by 10 percent and there is a 30 percent correction in real estate prices.

15. For new vintages, default rates are concentrated in mortgages issued with LTV between 70 and 80 percent, and DSTI between 60 and 70 percent. Under stressed conditions, the default rate of new mortgages reaches 4.7 percent, relative to 1.8 percent for the outstanding portfolio. This is because the Point-in-Time (PiT) LTV and DSTI ratios are higher than for earlier vintages, even if the risk profile at origination is better given the tightening of lending standards prompted by NBS macroprudential interventions. Default rates in the 70 to 80 percent LTV bucket, and 60 to 70 percent DSTI reach 0.4 percent. The reason is twofold. First, there is a material production at origination concentrated in these buckets. Second, even if higher buckets are riskier, they were mainly issued in earlier vintages which have been partly amortized and benefited from positive income growth, lower refinancing rates, and higher real estate prices.

PD by LTV and DSTI bucket of new vintages



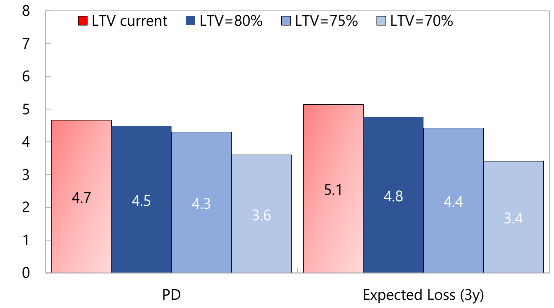
Source: IMF staff estimates

E. Counterfactual Macroprudential Policy Simulations

16. In line with the pre-emptive nature of macroprudential policy, we assume that borrower-based measures are tightened before the adverse scenario materializes. Given the lag between announcement and implementation in Slovakia, we assume that policies are tightened eight quarters before the stress test scenario begins. The tightening of regulatory limits changes the distribution of LTV, DSTI, and DTI ratios of the new mortgage production. The next step is to forecast the distribution of new flows using information on the growth rate of issuance over the last four quarters and the repayment profile of outstanding mortgages. We assume that under current NBS macroprudential policy, mortgage loans will have similar risk characteristics at origination as the average flow during the last four quarters. A tightening of regulatory limits reduces the relative mass of loans with LTVs, DSTIs, or DTIs above the limits to zero. There is "bunching" of new loans below regulatory limits consistent with the empirical distribution observed in mortgage flows in Slovakia during earlier policy interventions.

17. Further tightening of LTV and DSTI limits could reduce future default rates under the stress scenario by 23 percent. Different combinations of macroprudential limits could have a similar impact on expected losses in the adverse scenario. A LTV limit of 70 percent could reduce the default rate of new mortgages by 23 percent. A similar result would be achieved with a DSTI ratio of 45 percent. However, a greater reduction in losses can be accomplished with further LTV tightening as it operates through two channels: (i) it decreases financial stress of stretched households; and (ii) it reduces loss given default for banks. By contrast, DSTI or DTI limits operate only through the financial stress channel.

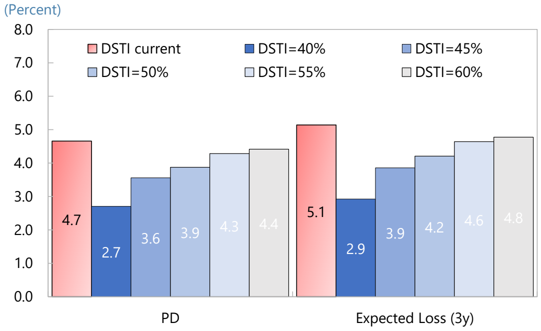
Counterfactual Macroprudential Policy Scenario: Credit risk of new vintages under IMF stress scenario
(Percent)



Souce: IMF staff estimates

18. LTV tightening could have further benefits in terms of allocative efficiency as it is applied only to mortgage exposures. Even if different regulatory limits can be calibrated to achieve the same loss reduction, they are likely to have a differential impact on allocative efficiency and house price sustainability. For instance, a tightening of LTV ratios may be preferable to a tightening of DSTI limits as the former applies only to mortgage loans whereas the latter is applied to all retail lending (including consumer loans) to address potential regulatory leakages (such as consumer loans being used by borrowers to top up housing loans).[15] To the extent that consumer lending is used to finance housing loans, a combined strategy including debt serviceability constraints on household loans used to finance mortgage credit could be more effective,[16] accounting for the potential efficiency costs from restricting credit access to otherwise creditworthy borrowers. As explained by the NBS in the May 2021 FSR, there is some evidence that the recent tightening of regulatory limits on DSTI and DTI ratios could have contributed to the contraction of consumer credit observed in 2019-2020. Furthermore, tightening LTV ratios could help moderate house price growth if the marginal borrower is credit constrained as it dampens expectations of banks and investors over future house price increases (Bloor and Lu, 2019).[17]

Counterfactual Macroprudential Policy Scenario: Credit risk of new vintages under IMF stress scenario
(Percent)



Source: IMF staff estimates

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[15] The assessment of potential of leakages from the migration of housing loans outside the scope of the macroprudential tool as a result of tightening of LTV limits is outside the scope of the paper.

[16] See Jurča et al. (2020) for an analysis of the relative effectiveness of LTV and DSTI limits on the probability of default using Slovak household surveys.

[17] For a related discussion, see also Andrle and Plasil (2019).

19. A sectoral SyRB of 2.7 percent on retail housing loans could absorb expected losses under stressed conditions.[18] Given the current mortgage exposure at EUR 33.8 billion, estimated risk weights on IRB and standardized (STA) mortgage exposures by Slovak banks, and the losses realized over 1 year under the IMF stress scenario, a capital buffer of 2.7 percent on retail exposures secured by residential property would be able to absorb the estimated EUR 190 million losses under stressed conditions. To the extent that the relative importance of housing loans in terms of RWAs varies across significant institutions (SIs) and less significant institutions (LSIs), the application of the sectoral buffer could potentially result in an increase in the variability of capital requirements that could be mitigated by linking the SyRB to the risk profile of the exposure.[19]

20. A macroprudential risk weight floor of 20 percent for IRB mortgage exposures, could cover all expected losses under an adverse scenario. The four largest banks in Slovakia book their retail mortgage exposures under the IRB approach which uses internal credit risk parameters (PD, LGD), effective maturity (which in Slovakia is low given the large share of loans repricing at 3-4 years), correlation, and exposure at default. IRB exposures account for three quarters of total mortgage loans. The remaining banks use a standardized model that relies on Basel risk weights for mortgage loans, at an average of 37 percent risk density. Increasing the risk weights on IRB exposures from the current 14 percent risk weights to 20 percent would increase the resilience of the system to stressed conditions, under the assumption that the current microprudential risk weights do not capture macroprudential losses from a system-wide event. By contrast with the sectoral SyRB buffer, minimum macroprudential risk weights would apply to IRB banks mortgage exposures.

F. Policy Implications

21. The proactive use of macroprudential policy measures in Slovakia has successfully limited the buildup of systemic risk during a prolonged period of rapid financial deepening of housing loans. However, persistently rapid mortgage growth, fueled by fierce competition and declining interest rates, growing household indebtedness, significant banks' exposures to mortgage loans and rising housing prices require continued vigilance.

22. We develop a modelling framework that quantifies the impact of alternative calibration of regulatory limits on the capacity of the banking system to absorb losses under stressed conditions. According to this framework, a tightening of LTV and DSTI ratios could reduce the default rate of mortgage loans by 23 percent, with additional benefits achieved by LTV limits. While an LTV limit of 70 percent could reduce the default rate to the same extent as a DSTI ratio of 45 percent, bank losses could be further reduced by LTV restrictions through a decrease in loss given default on defaulted exposures.[20] Additional benefits of LTV ratios come from their targeted

[18] This figure is marginally lower than the NBS estimate of the sectoral SyRB needed to cover stressed losses incurred by banks.

[19] The differentiation of macroprudential risk weights by risk bucket is applied in Belgium and New Zealand.

[20] This finding is, however, contingent on the modeling framework, which does not measure the potential migration of housing loans to the consumer portfolio to top up LTV-constrained mortgages.

nature to housing loans relative to DSTI or DTI limits, which apply to all retail exposures to address potential regulatory leakages. Given the different pace in credit growth and banks' balance sheets of mortgage loans relative to other retail loans, a more targeted tool may be desirable, taking into account the overall riskiness of the retail portfolio to prevent the migration of financial activity outside the scope of application of the macroprudential tool.

23. **The NBS could explore the option of complementing borrower-based tools with targeted capital-based measures on mortgage exposures.** The modelling framework also provided estimates of the calibration of targeted capital-based measures on mortgages exposures that would be able to fully cover the losses under stressed conditions. A sectoral SyRB of 2.7 percent on retail housing loans could absorb expected losses under stressed conditions. A similar loss absorption capacity could be achieved by setting a regulatory risk weight floor on IRB mortgage exposures to around 20 percent. Risk weights could be set by LTV risk bucket given the differential impact on bank losses from loans with diverse risk characteristics as shown in the paper. The NBS could explore applying the sectoral systemic risk buffer (SyRB) to target systemic risks from mortgage loans under the new CRD V European directive. However, the implementation of such measures should be based on a thorough cost-benefit analysis including criteria of banking system resilience, allocative efficiency, and house price sustainability, and taking into account possible overlaps with existing measures, including the CCyB buffer.

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Annex I. A Structural Model to Measure Mortgage Risk

The Model: Projecting Credit Risk, Probability of Default and Loss Given Default

1. **We use a structural model by risk and vintage buckets to define the loss event.** The modeling approach follows Gornicka and Valderrama (2020), which is itself based on Harrison and Mathew (2008). A borrower defaults if she fails the two insolvency tests in the Slovak insolvency regime: (i) 'the cash-flow test' which indicates that the borrower cannot pay the debt as it comes due and the bank can open insolvency proceedings; and (ii) 'the balance sheet test' whereby a borrower becomes insolvent if the value of her assets fall below the value of liabilities. This assumption implies that a borrower in financial distress could avoid default, as long as she has positive home equity that be extracted to refinance the loan or repay the debt.[1] This approach differs from Jurca et al (2020) who assume default if a borrower does not have sufficient cash to repay debt net of subsistence consumption.[2]

2. **We project credit risk by vintage and aggregate risk at the portfolio level.** This is required because borrower-based measures are applied to the new production of mortgages, whereas sectoral capital buffers are applied to the outstanding portfolio. The volume of earlier vintages changes over time as borrowers repay the principal and refinance their mortgages at lower lending rates. Crucially, the risk characteristics of mortgages also transition over time due to the full and partial repayment of principal, the dynamics of real estate prices, the evolution of household income, and changes to interest rates. Following Bloor and Lu (2019), the stock of outstanding mortgages at time *t* satisfies:

$$Stock_{b,t} = Stock_{b,t-1} - Payments_{b,t} - Transitions_{b,t} + Flows_{b,t} \tag{1}$$

where *b* captures the risk bucket (LTV, DSTI, DTI). Solving the system recursively and taking into account the maturity of mortgage loans in Slovakia, we trace the migration of mortgage loans (payment, transitions, and flows) from 1999Q1 to 2020Q2. We then aggregate risk at the vintage/risk bucket level to project the loss rate of the outstanding portfolio.

3. The probability that a borrower i gets into financial distress in period t is driven by:

$$\Pr\left(FD_{i,t}\right) = \Phi\left(DSTI_{i,t-1}\right)\cdot D_i + \beta_1 \cdot \Delta DSTI_{i,t-1}{}^{\gamma} + \Phi\left(DSTI_{i,t-1}\right)\cdot\left(\beta_2 \cdot U_{t-1} + \beta_3 \cdot \Delta U^{\alpha}_{t-1}\right) \tag{2}$$

which is a function of: (1) the borrower's affordability risk measured by the debt service-to-income ratio (*DSTI*) in the previous period; (2) the change in the debt servicing capacity since the last period (*ΔDSTI*); (3) the likelihood of being unemployed measured by the unemployment rate (*U*) in the previous period, and the change in the unemployment rate (*ΔU*), which are a function of the current

[1] By contrast, the model does not consider "strategic defaults", i.e. a situation where the borrower decides to stop repayments once the value of the underlying collateral falls below the value of the loan. Incentives to do so might exist in the case of non-recourse loans, which is not the case in Slovakia.

[2] Their analysis is also based on projecting credit risk for mortgage flows rather than for the outstanding portfolio.

DSTI ratio of the borrower; and (4) a demographic factor (*D*) which captures shocks to household composition.

4. A default occurs when the borrower is in distress *and* cannot repay the loan to the bank early by selling the collateral at market price $\tilde{\boldsymbol{P}}$ net of transaction costs C[3]:

$$\tilde{P}_{i,t} - C < NPV\left(L_{i,t}, r_t^{type,M}, r_t^f, T_{s,t}\right) \qquad (3)$$

where the net present value of the loan (NPV) at time *t* consists of two elements: (1) the outstanding loan amount $L_{i,t}$, and (2) the penalty for early prepayment, which is assumed to equal the discounted value of future interest payments. This is a function of $r_t^{type,M}$ which stands for the current interest rate of the mortgage (that differs from the rate at issuance depending on the type of the mortgage and its resetting schedule M); $T_{s,t}$ which denotes the remaining maturity at time *t* of a loan issued at time *s*, and r_t^f is the 10-year Slovak sovereign yield used to discount the value of future interest payments at time *t*. The amortization schedule (for each period *j* over its remaining lifetime) is proxied by a linear amortization scheme.

5. Conditional on defaulting, a bank's loss given default (LGD) on a mortgage is driven by the discounted sale price of the collateral:

$$LGD_{i,t} = \max\left\{0, NPV\left(L_{i,t}, r_t^{type,M}, r_t^f, T_{s,t}\right)\right\} - (1-\delta)\cdot\frac{\tilde{P}_{i,t+n}}{\left(1 + r_t^f + spread\right)^n} \qquad (4)$$

where δ denotes the foreclosure discount at which the bank sells the repossessed collateral at time *t+n*, where *n* denotes the time needed to realize the proceeds of the sale, and *spread* is the risk-adjusted spread used to discount the value of the house. From the perspective of affordability risk, the price of collateral affects the likelihood of financial distress as well as the loss given default for the bank.

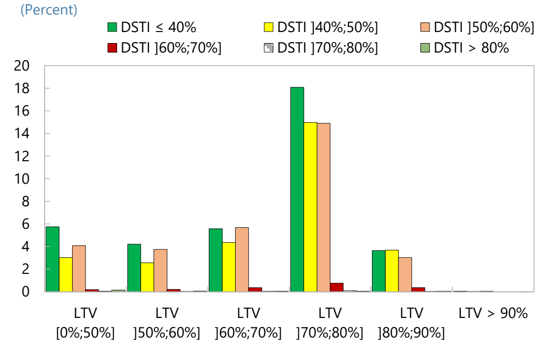
6. We simulate probability of default (PD) and LGD for each LTV-vintage bucket of mortgages using Monte Carlo simulation techniques. In practice, we divide the portfolio of mortgages into buckets based on their key credit quality indicators and perform simulations for each bucket separately. We consider buckets by quarter of mortgage origination, and by the LTV ("*vintage-LTV buckets*"). The vintage of the mortgage matters, as it allows us to calculate the impact of interest shocks on affordability risk, the remaining time to maturity, the outstanding value of the loan and the market value of collateral. For a given vintage-LTV bucket of mortgages, a number *N* of borrowers *already in financial distress* is considered. For each of the *N* borrowers a house price draw is generated from a distribution with a mean equal to the average house price level in the tail risk scenario. For each of the house price draws, the model determines whether condition (3) is satisfied (i.e. if the borrower defaults) and—if so—the LGD in equation (4). In the next step, the bucket-specific PD is calculated as the total number of defaults divided by the number of draws, *N*, and multiplied by the bucket-specific probability of financial distress from equation (2). To reduce noise,

[3] The transaction cost is likely to increase during a crisis, given the high stock of foreclosed properties.

this simulation process is repeated *K* times for each bucket. The final bucket-specific PDs and LGDs are calculated as the averages across *K* iterations. In the applications presented we set *N=2000* and *K=10,000*. In the final step, the ultimate outputs, i.e. portfolio-wide PD, LGD, and the loss rate are calculated by combining separately estimated outputs for the vintage-LTV buckets and weighting them by the share in the total portfolio.

7. We use a comprehensive supervisory dataset covering all issuances of housing loans in Slovakia starting in 1999Q1 which were still outstanding in 2020Q2. The rich dataset provides volumes of issuance at origination, outstanding amounts as of 2020:Q2, repricing schedules by vintage and remaining time to next refixation period, maturity profile, and lending rates by type of mortgage. Also, it provides loan risk characteristics by DSTI, LTV, and DTI bucket at origination by vintage, as well as the time series of matrices including LTV-DTI and LTV-DSTI starting in 2017Q1. The granularity of reporting is very high with 8 buckets for DSTI, 12 buckets for LTV, and 10 buckets for DTI. Repricing schedules are reporting for 6-time buckets. As the data captures the risk profile at origination, we need to compute risk characteristics Point-in-Time (PiT) to capture the law of motion of house prices, interest rates, and income growth (see Part II of Annex I). For housing loans issued in 2020;Q2, the largest concentration is in the [70-80] LTV / [50-60] DSTI bucket. Overall, 20 percent of mortgages are issued with LTV greater than 70 percent and DSTI exceeding 50 percent.

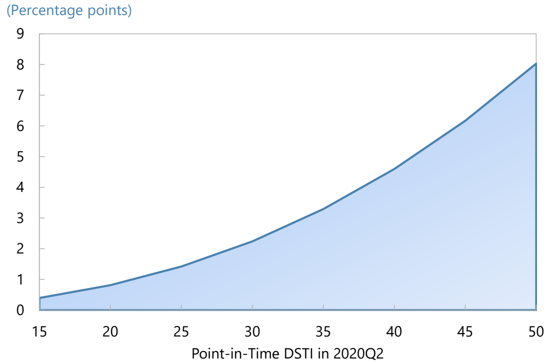
Risk profile of new housing loans by bucket, Q2 2020
(Percent)



Sources: National Bank of Slovakia and IMF staff calculations

8. The model is calibrated using historical loan losses on mortgage exposures in Slovakia during 2008-2010 and matching predicted values to IRB banks' 1-year default probability under baseline conditions. During 2008-2010, real estate prices contracted by 23 percent, unemployment rose by 4.5 percentage points and annual disposable income growth slowed down from 11 to 0 percent. At the same time, lending rates declined by 60 basis points providing some relief to stretched households. We generate a rate of financial distress in equation (2) from the increase in NPLs in mortgage loans from 2.2 to 3.7 percent and using the experience of the UK real estate crisis in the 1990s to back out the share of distressed households. We allocate the share of financial stress due to the rise in unemployment (80 percent) and the change to mortgage rates (20 percent). We distribute the aggregate stressed sales by DSTI bucket to match that a 50 percent increase in the debt servicing ratio for a typical mortgage issued in 2020;Q2 generates an increase in financial distress by 6 percentage points following Harrison and Mathew (2008). Further details of the calibration are found in Valderrama et al (forthcoming).

Increase in Pr(FD) given 50% in interest rate by DSTI bucket
(Percentage points)



9. From Origination to Point-in-Time (PiT) Risk Parameters

We calculate the Point-in-Time (PiT) risk parameters of loans issued from 1999;Q1 through 2020;Q2 as of 2020;Q2 using information on the risk characteristics of the loans, and data provided by NBS on household disposable income, interest rates at origination, and real estate prices. We denote the time of issuance as *s*, the current period as *t*, and the maturity of the loan as *T*.

First, we compute the PiT LTV ratio by backing out the outstanding principal of the loan net of repayments at time t and repricing the mortgage collateral:

$$LTV_{s,t}^{PiT} = \frac{\left(LTV_s^{Orig} \cdot P_s\right) \cdot \left(\frac{T-t}{T-s}\right)}{P_t} \tag{5}$$

Then, we compute the income PiT using information extracting income at origination from DSTI and lending rates at origination i_s^{Orig}, and quarterly income growth g:

$$Income_s = \frac{\left(\frac{1}{T} + i_s^{Orig}\right) \cdot \left(LTV_s^{Orig} \cdot P_s\right)}{DSTI_t} \tag{6}$$

$$Income_t = Income_s \cdot (1+g)^{t-s} \tag{7}$$

This allows us to compute DSTI and DTI PiT as:

$$DSTI_{s,t}^{PiT} = \frac{\left(LTV_s^{Orig} \cdot P_s\right) \cdot \left(\frac{1}{T-s} + i_{s,t}^{s+k}\right)}{Income_t} \tag{8}$$

$$DTI_{s,t}^{PiT} = \frac{\left(LTV_s^{Orig} \cdot P_s\right) \cdot \left(\frac{T-t}{T-s}\right)}{Income_t} \tag{9}$$

where $i_{s,t}^{s+k}$ is the lending rate as of *t* of a mortgage issued in *s* and with the last re-setting period of interest rate in *s*+*k*. During the stress testing horizon at time *t*+*j*, we compute the shock to DSTI as:

$$\Delta DSTI_{s,t+j}^{PiT} = \frac{\left(LTV_s^{Orig} \cdot P_s\right) \cdot \left(\frac{1}{T-s} + i_{s,t+j}^{s+\lambda}\right)}{Income_t \cdot \left(1 + shock_j\right)} \tag{10}$$

where $i_{s,t+j}^{s+\lambda}$ is the lending rate as of *t*+*j* of a mortgage issued in *s* and with the last re-setting period of interest rate in $s+\lambda$.