

# MACROPRUDENTIAL STRESS TESTING UNDER GREAT UNCERTAINTY

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First used as a crisis solution tool to identify and quantify capital shortfalls, stress testing gradually became a prevention tool, aimed at identifying vulnerabilities in the financial system. Because stress testing exercises accommodate a broad range of scenarios, they provide regulators with answers on questions with a high degree of uncertainty like the Covid crisis. Two types of stress testing exercises coexist: microprudential ones, which aim at identifying individual banks vulnerabilities, and macroprudential ones, which consider the banking sector as a whole. The latter incorporate banks dynamic adjustments, the interaction between banks and the real economy, and the interconnection with non-banks. New directions for macroprudential stress testing include the climate risk, and the modelling of interactions between individual institutions.

First used as a crisis solution tool to identify and quantify capital shortfalls and enhance market discipline, stress testing has gradually become a prevention tool, aimed at identifying vulnerabilities in the financial system. In 2020 a number of authorities, including the European Central Bank (ECB), relied on stress testing exercises to evaluate the impact of the coronavirus (Covid-19) outbreak on bank solvency and to inform the appropriate policy decisions. Stress tests are particularly suited to the current circumstances, which feature a high degree of uncertainty about future economic developments. This is because stress-testing exercises can provide policymakers with an understanding of how a range of different economic scenarios and policies may affect bank solvency.

To assess individual banks' capital adequacy, supervisory authorities rely on two complementary stress test perspectives: bottom-up and top-down, for which either banks or the authorities compute capital shortfalls. In contrast, the macroprudential approach assesses the resilience of the banking sector as a whole. It extends traditional stress testing at three levels: banks' dynamic adjustment to macrofinancial developments, the interaction between banks and the real economy and the interconnections between banks and non-bank financial institutions. Stress testing can be a multipurpose tool. For example, the ECB uses its macroprudential stress-testing framework to assess the impact of banking sector regulations and to inform the calibration of macroprudential policies such as capital buffers. New directions for macroprudential stress tests include the development of tools to account for climate risk and to tackle interactions between individual institutions within the financial sector.

## 1 The development of stress testing as a policy tool

Since the financial crisis, stress tests have become an important tool for central banks and banking supervisors and have been used for different policy purposes (de Guindos, 2019a).

During the financial crisis, stress tests were used mainly to identify and quantify capital shortfalls in the banking sector and enhance market discipline. This was achieved by publishing consistent and granular bank-level data and by requiring banks to fill capital shortfalls identified in the stress test if their capital ratios fell below a pre-defined pass/fail threshold.

The way stress tests are used has evolved since the crisis, both in Europe and globally. They have become a key part of the supervisory and financial stability toolkit to assess risk profiles and performance under adverse macroeconomic conditions.

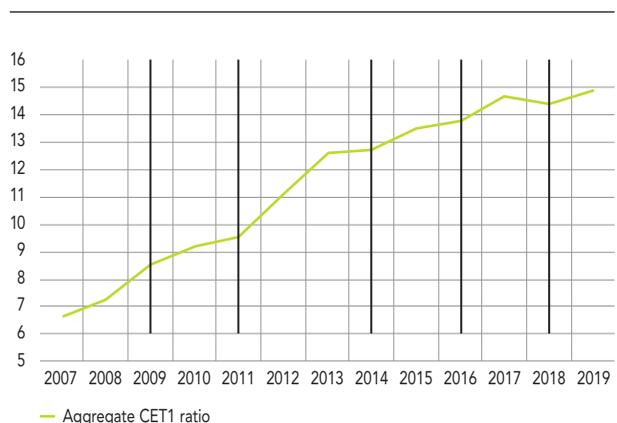
In recent years, stress tests have been used for crisis prevention purposes. The aim has been to identify vulnerabilities in the financial system and assess the resilience of the banking sector and individual banks to adverse macrofinancial shocks, thereby informing supervisory evaluations and macroprudential policy decisions and calibrations.

In Europe, the biennial EU-wide stress tests coordinated by the European Banking Authority (EBA) contribute significantly to the ECB's Supervisory Review and Evaluation Process (SREP).<sup>1</sup>

In other words, rather than finishing with a pass or fail assessment, stress tests now provide a starting point, both for discussions between banks and supervisors and for macroprudential policymakers.

Overall, the various European stress tests conducted since the crisis have been instrumental in improving the capitalisation, and therefore the resilience, of the euro area banking sector. The Common Equity Tier 1 (CET1) ratio of euro area significant institutions increased from less than 7% in 2007 to almost 15% in 2019 (see Chart 1). The enhanced resilience is also reflected in gradually higher

C1 Aggregate CET1 ratio of euro area significant institutions (%)



Sources: European Central Bank, S&P Global Market Intelligence.  
 Notes: Based on publicly available data for an unbalanced sample of significant institutions (2007-14) and on published supervisory statistics (2015-19).  
 Vertical lines indicate the EU-wide stress tests since 2009.  
 CET1: Common Equity Tier 1, EU: European Union.

levels of “stressed” CET1 ratios when comparing the results of the 2014, 2016 and 2018 stress tests.<sup>2</sup>

The EU-wide stress tests follow a constrained bottom-up approach, which involves significant input from the banks. Under this approach, banks generate their stress test projections using their own models. These projections are based on a macrofinancial scenario – provided by the European Systemic Risk Board (ESRB) – which is the same for all banks and on a predefined methodology provided by the EBA.

The constrained bottom-up approach has several advantages. In particular a bottom-up approach should also support banks’ own risk management capacity by requiring them to consider in-house how severe adverse circumstances may affect their solvency. It should strengthen their ability to detect vulnerabilities and encourage them to develop their own internal stress-testing models.

However, the constrained bottom-up approach also has some limitations. The static balance sheet assumption<sup>3</sup> limits the realism of the exercise as it does not account for how banks would respond under stressed situations. Certain constraints imposed by the stress test methodology may also make the outcome of the stress test less realistic. Furthermore, this approach also gives banks substantial scope to materially underestimate their vulnerability to adverse circumstances and thus to “game” the exercise.<sup>4</sup>

Consequently, European supervisors conduct a thorough quality assurance of banks’ bottom-up stress test results to ensure that the outcomes are credible. In particular, banks are presented with independent model-based estimates through a top-down model challenge. This process generally leads to individual banks revising their stress test outcomes before publication.

The extensive supervisory scrutiny, which also involves the top-down model challenge and has so far taken the form of a dialogue between supervisors and banks, plays an important role in disciplining banks and reducing the incentives for them to systematically underestimate their vulnerabilities.<sup>5</sup>

Notably, the European supervisory community is currently discussing the possibility of reforming the existing set-up of the EBA EU-wide stress test exercises with a view to overcoming some of the drawbacks mentioned above. In particular, the aim would be to make the stress tests more realistic and the quality assurance process more efficient, while preserving comparability and conservatism.

In the next section I will provide details on how stress testing has been used at the ECB to assess the vulnerability of the euro area banking sector during the Covid-19 crisis and to inform the necessary policy considerations in the challenging and highly uncertain situation that characterised the first half of 2020. I will highlight the benefits which stemmed from its use and the challenges that were faced during its implementation.

## 2 The 2020 ECB vulnerability analysis

In 2020, as a consequence of the outbreak of the Covid-19 pandemic, the planned EU-wide stress test was postponed until 2021. Due to this, the ECB – in cooperation with Single Supervisory Mechanism (SSM) national competent authorities (NCAs) – carried out a centralised top-down stress test of 86 banks under SSM direct supervision, encompassing about 80% of total assets in the euro area, to identify potential vulnerabilities within the banking sector at an early stage.<sup>6, 7</sup>

1 The ECB Banking Supervision takes into account both the qualitative results (quality and timeliness of banks’ submissions) and the quantitative results (capital depletion and banks’ resilience under the adverse scenario) when setting Pillar 2 capital requirements and Pillar 2 capital guidance during the SREP. In addition to the EBA exercise covering the largest euro area banks, the ECB conducts, in parallel, a stress test for the remaining significant institutions that it directly supervises.

2 The average final CET1 ratio under the adverse scenario in 2018 stood at 9.9%, up from 8.8% in the 2016 stress test (for 33 banks, on a fully loaded CET1 basis). The final average CET1 ratio in the adverse scenario in 2016 was higher at 9.1%, compared to 8.6% in the 2014 Comprehensive Assessment Stress Test (for 37 banks, on a transitional CET1 basis).

3 The static balance sheet assumption implies that banks maintain a constant balance sheet and the same business mix and model over the stress test horizon. Instead, the dynamic balance sheet assumption, which is generally applied in macroprudential stress tests, implies that

banks are allowed to adjust their balance sheets in response to the macroeconomic and financial developments over the stress test horizon.

4 For empirical evidence of the “gaming” behaviour of banks participating in the stress test, see Philippon et al. (2017); Niepmann and Stebunovs (2018); Quagliarillo (2019) and Kok et al. (2019).

5 In fact, recent empirical evidence suggests that the comprehensive intrusion associated with the ECB stress test quality assurance process has a disciplinary effect on banks’ risk-taking after the stress tests (see Kok et al., 2019). For related evidence in a US context, see Acharya et al. (2018) and Hirtle et al. (2019).

6 The methodology used in this exercise was compliant with the EBA methodology used in the EU-wide stress test. Accordingly, the static balance sheet assumption was applied.

7 Baudino (2020) provides an illustration of the use of stress-testing by different authorities during the Covid-19 crisis.

The exercise was carried out by exploiting supervisory data and relying on three scenarios: (i) the EBA 2020 stress test baseline scenario, which was defined before the Covid-19 outbreak and was used as a benchmark to better assess the impact of the coronavirus crisis; (ii) a Covid-19 central scenario; and (iii) a Covid-19 severe scenario outlined in the June 2020 Eurosystem staff macroeconomic projections. The two latter scenarios included, to a certain extent, the impact of the monetary, supervisory and fiscal relief measures taken in response to the coronavirus crisis.<sup>8</sup> Under the central scenario banks' aggregate CET1 ratio was depleted by approximately 1.9 percentage points to 12.6% while under the severe scenario it was depleted by 5.7 percentage points to 8.8% by end-2022. Overall, the results showed that the euro area banking sector can withstand the pandemic-induced stress and continue to fulfil its role of lending to the economy. However, if the severe scenario were to materialise, the depletion of bank capital could be significant for some banks.

This exercise allowed the ECB to publish a timely assessment of the banking sector as a whole. The results of the stress test were also used to inform the ECB's efforts to address the current crisis, both on the microprudential and macroprudential side. Furthermore, publication of the results reduced uncertainty and helped investors to maintain confidence in the soundness of the euro area banking sector and its ability to continue to support the real economy. It also provided banks with an indication as to the ECB's view on the likelihood of potential solvency risks and its expectations about the evolution of banks' main balance sheets and profit and loss items.

The unusual nature of the current crisis made the implementation of the 2020 ECB vulnerability analysis particularly challenging.

For the first time the ECB carried out and published the aggregate results of a granular top-down stress test conducted without the involvement of banks. While this approach ensured the timeliness of the exercise in these extraordinary circumstances and helped to free up bank resources, which are normally involved in the EU-wide stress tests, it meant that the ECB had to rely on a smaller set of information to conduct its analysis. The ECB could not exploit the data that are regularly submitted by banks in the course of EU-wide stress test and also could not interact with banks during the exercise. Furthermore, the design of the scenario was particularly complex due to the high uncertainty surrounding near-term economic developments. To mitigate this concern, the ECB relied on two Covid-19 scenarios in the analysis rather than the usual single adverse scenario.

A further element of complexity stemmed from the need to include policy responses in the analysis – this differs from the standard practice in stress tests. Such an approach was necessary as exceptional support measures across different policy domains were introduced very soon after the pandemic crisis started. These measures needed to be included to obtain a more realistic estimate of the impact of the Covid-19 outbreak. However, including them was not without practical challenges: it required making assumptions about the effectiveness of the measures, their possible extension and the potential situations that may arise upon withdrawal or expiration of these measures.

Having illustrated how the use of stress tests has changed over time and how the ECB has used this tool so far during the Covid-19 crisis, I will use the following section to focus in more detail on how comprehensive, system-wide exercises could inform macroprudential analysis by incorporating amplification effects caused by interbank contagion or feedback loops between the real economy and the financial sector.

### 3 Macprudential stress testing the banking sector at the ECB

Macroprudential stress tests build on supervisory exercises by providing a perspective on the banking sector as a whole, rather than focusing solely on the resilience of individual banks. This involves extending the standard stress-testing framework at three levels.

First, macroprudential stress tests account for banks' reactions to macroeconomic and financial developments. They enable relaxation of the static balance sheet assumption. This allows banks to adjust assets, liabilities and prices. Macroprudential stress tests also take account of possible interactions between banks' solvency and their funding costs.<sup>9</sup>

Second, macroprudential stress tests allow to take into account the interconnections between financial institutions and the related endogenous transmission channels of systemic risk, such as fire sales and contagion effects.

Finally, macroprudential stress tests can incorporate interactions between the financial sector and the real economy. In this respect, their results can not only provide information on the system-wide capital depletion under adverse scenarios but also insights into the sector's ability to withstand adverse developments without disrupting the flow of credit to the real economy.

In recent years the ECB has developed a large semi-structural macroprudential stress-testing model (Budnik, 2019; Budnik et al., 2019) which captures the joint dynamics of the 19 euro area economies and of the circa 100 largest individual euro area banks. The model is being further developed in collaboration with Eurosystem central banks.

In this model banks can endogenously adjust the size and composition of their balance sheets, modify their dividend policies and reset their interest rates on loans and deposits in response to economic conditions and depending on their individual characteristics (such as solvency, asset quality, profitability and balance sheet structure). In addition, the model features the two-side interdependency between the financial sector and the real economy and the related non-linear amplification mechanisms, as illustrated in Diagram 1.

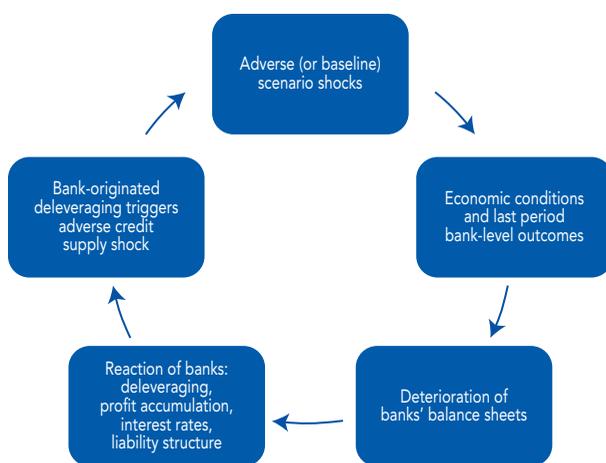
The model supports a biennial assessment of the resilience of the banking system from a macroprudential perspective, complementing the regular supervisory stress test. For instance, in 2018 the macroprudential stress test revealed a higher level of system-wide capital depletion in nominal amounts in the adverse scenario compared with the results obtained under the static balance sheet assumption. However, because of banks' deleveraging, CET1 ratios were on average higher in the macroprudential stress test. The loan growth of a significant proportion of banks in the adverse scenario appeared negative, especially in the case of credit to non-financial corporations.

In addition to results based on the original adverse scenario, the macroprudential stress test provided an estimate of second-round effects on economic output. The feedback loop between the real economy and the banking sector and the related amplification could deduct an additional 1.6% from euro area output. In the cross-country perspective illustrated in Chart 2, the amplification mechanism was more pronounced for those countries with banking systems that had relatively low levels of capitalisation at the beginning of the scenario horizon.

This macroprudential stress-testing framework can also be used to analyse the medium-term prospects of banking sector policies. It was recently used in combination with a "Growth-at-risk" approach to assess the macroeconomic costs and benefits of the finalisation of the Basel III framework in cooperation with the EBA (see EBA, 2019).

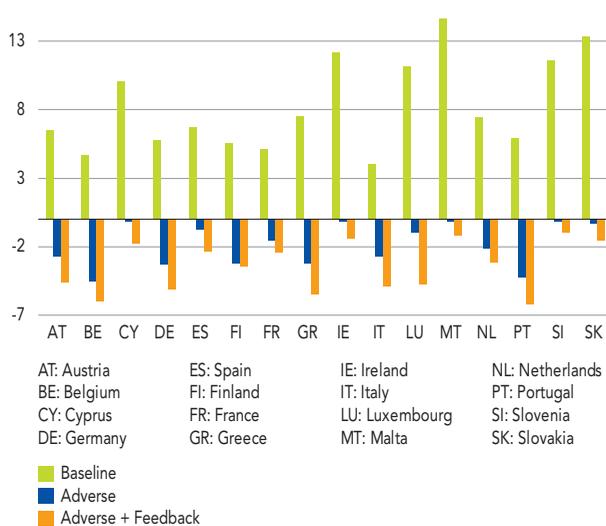
In this analysis, macroeconomic costs are measured in terms of lower expected Gross Domestic Product (GDP) growth under baseline conditions resulting from the introduction

**Diagram 1** The stylised representation of the real economy-financial sector amplification mechanism in the ECB macroprudential stress test model



Source: European Central Bank (ECB).

**C2** Cumulative Gross Domestic Product (GDP) growth in the 2018 scenarios: baseline, adverse and the adverse with feedback (% cumulative GDP growth)



Source: Budnik et al. (2019).

8 The Covid-19 central scenario was considered the most likely to materialise. It featured an unprecedented fall in euro area real Gross Domestic Product in 2020 and a rebound in 2021 and 2022 as medical solutions become available. The Covid-19 severe scenario represented a more adverse, but still

plausible development of the crisis, due to a strong resurgence of infections and an extension of strict containment measures until mid-2021. For further details see ECB (2020a).

9 On the relationship between banks' solvency and funding costs, see Arnaud et al. (2020).

of the Basel III finalisation package due to the possible transitory reduction in bank lending. The benefits are instead measured in terms of the expected reduction in the decrease of GDP growth under adverse conditions due to the improved capacity of the banking sector to grant credit to the real economy resulting from the introduction of the Basel III finalisation package.

The results of the analysis show that the implementation of the Basel reforms will result in modest transitional costs, which will fade over time. The long-term benefits will be substantial and will outweigh the modest transitory costs. The reforms would mitigate the severity of future economic downturns through a reduction in both the probability and intensity of future banking crises, leading to sizeable long-term net benefits.

This analytical framework can also support the calibration of macroprudential policies. For instance, it can assess the costs and benefits and the impact of timing of introducing macroprudential capital buffer requirements. In terms of the benefits, the framework can quantify how a better capitalised banking sector makes it possible to maintain a smooth provision of credit to the real economy over the cycle. This should be weighed against the (transitory) cost of introducing new requirements which, in turn, may vary over the cycle. When the new policy is phased in under normal conditions, banks are able to build up additional capital by retaining their profits, and do not need to reduce lending to improve capital ratios. However, the phase-in of a new capital policy at the beginning of a slowdown is likely to trigger a reduction in credit and put an additional drag on the economy. Bad timing aggravates the costs of macroprudential and regulatory interventions, and can limit their effectiveness.

The macroprudential stress test framework re-interpreted within the growth-at-risk approach to systemic risk can thus provide intuitive and consistent cost-benefit analyses of regulation and policies. An integrated model delivers comparable metrics, details transmission channels and allows policy makers to differentiate between short-term and medium-to-long term effects. Such a model is complex and resource intensive but it relies on a limited number of assumptions and does not rely on rare events that are very difficult to measure with precision such as systemic crises to deliver its impact assessment.

Furthermore, the ECB is in the process of adapting its macroprudential stress-testing framework so that climate-related risks can also be assessed. Climate change has the potential to affect many parts of an economy and,

consequently, the financial system. Macroprudential stress testing appears well suited to the analysis of risks such as extreme weather events, structural changes triggered by gradually increasing temperatures and the impact of remedial policy measures.

There are two dimensions to this work. The first is a pilot stress test focusing on the materiality of transition risks for banks' solvency and lending capacity, and their implications for the overall economy (de Guindos, 2019b). Such risks relate to either the belated introduction of environmental policies or the sudden phase-in of new technological solutions. The second relates to the more ambitious goal of assessing the importance of physical risks for the banking sector and investigating the interaction between transition risks and physical risks.

#### **4 Macroprudential stress testing: accounting for interactions between banks and non-banks**

While the ECB's stress-testing activities have mostly focused on the banking sector, it is important to look further than banks and consider the broader financial system. Understanding the reaction of the whole financial system to an adverse macrofinancial shock scenario is crucial for policymakers and financial market participants. This is of particular importance given the material growth of the non-bank financial sector in recent years and the potential risks from this part of the financial system.<sup>10</sup> There is a growing body of literature that studies interconnections between the different channels and layers of financial markets, with a strong case being made for the joint integration of stress tests.<sup>11</sup> System-wide stress-testing models aim to fulfil this demand and many central banks and academics are currently developing such models.

Currently, there are only a few documented system-wide stress test models with different types of agents. Finding complete and consistent data for mapping and analysing the financial network remains a key challenge. As a result, existing papers on system-wide stress testing mostly use simulated data or focus on aggregate data for financial entities (e.g. using one representative bank, one representative insurer, etc. as in Aikman et al., 2019).

Along these lines, ECB staff built a model to study relevant interactions in the euro area market-based financial system. The core of the model is a set of representative agents, namely banks, insurance companies, pension

funds, investment and hedge funds, and the central bank. These agents interact in asset, funding and derivatives markets, and endogenously reallocate portfolios according to their investment horizon, regulatory constraints and optimising behaviour.

The model was used recently to investigate the possible effects of large-scale euro area corporate bond rating downgrades amid the Covid-19 crisis (di lasio et al., 2020). In the simulations, these shocks affect market prices and risky assets are traded with a large discount. While banks' and insurance companies' reactions are still orderly, large outflows from investment funds amplify the system's response to shocks and explain most losses throughout the euro area financial system. This validates the ECB's view that the resilience of the non-bank financial sector – and the asset management industry in particular – needs to be enhanced in a way that reflects macroprudential perspectives.<sup>12</sup>

This approach with aggregated sectors doesn't capture important dynamics related to interconnectedness among individual entities and network effects. Thus ECB staff members are currently working with staff from the euro area national central banks to develop an analytical stress-testing framework that can capture the interactions between banks and non-bank financial institutions by using a range of granular datasets. This new framework is intended to allow staff at the ECB and National Competent Authorities (NCAs) to assess the impact of an adverse macrofinancial scenario on individual financial entities and on the financial system as a whole. The framework features direct and indirect contagion mechanisms, liquidity and solvency interactions, dynamic balance sheet developments and related reactions of the different financial institutions that may in turn lead to material amplification effects. The new framework should help reveal vulnerabilities in the non-bank financial sector and assess the potential for spillovers – most notably due to fire sales – between institutions and between sectors (e.g. between banks, investment funds and insurance corporations).

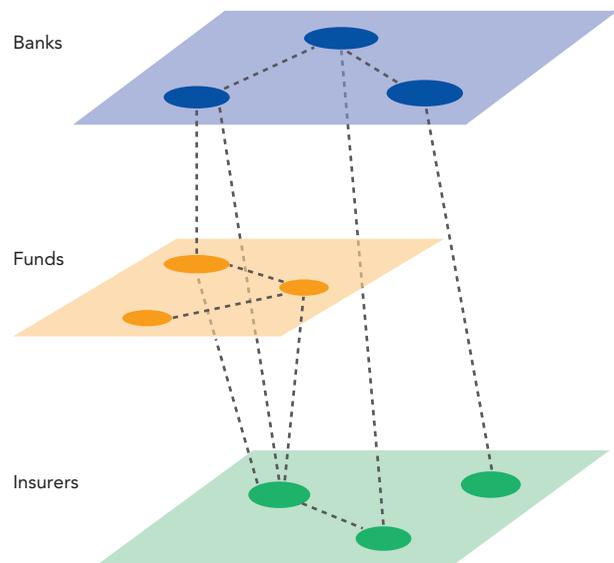
The perspective used in this ECB framework considers systematic risk, meaning that there is a common (macrofinancial) shock that would affect a large range of firms. Thus, this system-wide stress-testing model aims to assess the risk of a systemic event. This contrasts with the European supervisory authorities' stress tests, which in most cases concentrate on the solvency risk for individual entities, whereas work by the ECB focuses on the soundness of the financial system as a whole.

This ECB framework aims to reduce the scope for underestimating systemic risk on the basis of explicit and detailed modelling of contagion risk caused by the existence of relationships in the financial network (see Diagram 2).

In this framework, the scenario yields defaults in the non-financial part of the system combined with a redemption shock on investment funds.

The ECB framework considers mostly regulatory constraints for banks and funds (see also Cont and Schaaning, 2017), and other agents may perform specific operations in order to reach institution-specific targets. These targets may themselves evolve, reflecting strategic decisions. In the final step, a statistical distribution of results is obtained from the set of simulation outputs. In particular, the framework measures systemic risk, performing a posterior analysis of the different vectors of contagion and assessing the contribution of the different sectors.

**Diagram 2** Illustration of relationships within the financial network



Source: European Central Bank.

<sup>10</sup> See, for example, ECB (2020b).

<sup>11</sup> See, for example, Calimani et al. (2019); Chrétien et al. (2020);

Halaj (2018); Mirza et al. (2020) and Timmer (2018).

<sup>12</sup> See, for example, Pires (2019).

Given its complexity, the calibration of the model involves a large set of parameters. Therefore, the model is kept very modular in its implementation, making it easy to change key parameters or exclude certain mechanisms in order to perform sensitivity tests.

## Conclusion

Since the financial crisis, stress tests have become an increasingly important policy tool. Accordingly, they have been used by different authorities, including the ECB, also during the Covid-19 crisis.

Macroprudential stress tests can be used to assess the extent to which the financial sector can withstand adverse macrofinancial developments without reducing the extension of credit to the real economy. They therefore serve a broad financial stability purpose, making it possible to assess the resilience of the financial system as a whole. They can also be used to perform counterfactual impact assessments and thereby inform discussions on macroprudential policy and financial regulatory initiatives.

In this context, and with a view to supporting its macroprudential policy assessments, the ECB has developed its own macroprudential stress-testing frameworks focusing on both the time dimension of systemic risk (i.e. real-financial feedback loops) and the cross-section dimension of systemic risk (i.e. contagion effects due to interconnectedness). While significant analytical progress has been achieved in recent years, much remains to be done. Substantial resources are devoted to further developing such tools; especially with a view to confidently assessing climate-related financial stability risks and the interactions between banks and non-banks and with the real economy.

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