SYSTEMIC ANALYSIS FRAMEWORK FOR THE IMPACT OF ECONOMIC AND FINANCIAL RISKS

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Abstract

This paper presents the Banco de España's reference framework for the analysis of macroeconomic and financial risk, and the impact of the materialisation of this risk on financial stability and the real economy. The framework encompasses a broad set of empirical and theoretical models and methods, with the aim of capturing heterogeneity in the characteristics of different sources of risk. In particular, the paper describes how these models are used to identify the impact of endogenous sources of risk, such as the build-up of macro-financial imbalances over the cycle, and of exogenous shocks. Regarding the latter, the paper presents an application of the models to the main exogenous events that have occurred recently: the COVID-19 pandemic, including the fiscal, monetary and prudential measures adopted as a response to this shock; the Russian invasion of Ukraine; and the subsequent high inflation and economic uncertainty environment.

Keywords: financial markets, financial stability, macroeconomic forecasting models, macro-financial models, macro-financial risk, stress testing.

JEL classification: E17, E58, G10, G21, G28, G32, G50.

Resumen

Este documento presenta el marco de referencia del Banco de España para el análisis del impacto de la materialización de riesgos macroeconómicos y financieros sobre la actividad real y la estabilidad financiera. Este marco incluye un amplio conjunto de modelos y métodos, tanto empíricos como teóricos, con el fin de capturar la heterogeneidad de las diversas fuentes de riesgo y sus distintas características. En particular, se describe su aplicación para medir el impacto de riesgos, derivados tanto de fuentes endógenas (como la acumulación de desequilibrios macroeconómicos y financieros a lo largo del ciclo) como de fuentes exógenas. Respecto a estas últimas, se presenta la aplicación de estos modelos en el contexto de la irrupción de la pandemia de COVID-19 y de las medidas de política económica adoptadas en respuesta la crisis resultante, tanto en los ámbitos fiscal y monetario como en el prudencial. Igualmente, se presenta su aplicación en el contexto de la invasión rusa de Ucrania y de la intensificación de las tensiones inflacionarias y de incertidumbre económica.

Palabras clave: estabilidad financiera, mercados financieros, modelos macrofinancieros, modelos de previsión macroeconómica, riesgo macroeconómico, riesgo financiero, pruebas de resistencia.

Códigos JEL: E17, E58, G10, G21, G28, G32, G50.

Contents

1 Introduction

This paper aims to gather together the models and methods, both empirical and theoretical, that make up the Banco de España's reference framework for analysing the impact on real activity and financial stability of the materialisation of macroeconomic and financial risks.

Risks to economic activity and financial stability can originate from sources either endogenous or exogenous to the economic and financial system itself. On the one hand, risks from endogenous sources arise when macroeconomic and financial imbalances build up over the course of the cycle or in the structural dimension of the system. A clear example is the global financial crisis, where excessive growth in lending to the non-financial private sector, in house prices, in the current account balance and in the sectoral concentration of activity led to a significant build-up of risks that had very profound consequences when they materialised. On the other hand, the recent crisis episodes caused by the COVID-19 pandemic or the war in Ukraine are examples of exogenous factors that nevertheless generate macro-financial risks and have an unexpected impact on economic activity and financial stability.

The wide range of potential sources and characteristics of risk makes it necessary to properly capture this heterogeneity and accurately identify its impact. The changes over time in the characteristics of crises and the interactions between the real and financial sectors also call for a process of continuous learning about the emergence and impact of new and different types of risk that culminates in the development of new and enhanced methodologies.

Against this background, this paper presents the methodologies used by the Banco de España for assessing the risks arising from macro-financial imbalances and for measuring the economic impact of recent exogenous factors. In particular, it describes the application of several models for identifying and monitoring risks after the outbreak of the COVID-19 pandemic, the effects of the fiscal, monetary and prudential measures adopted in response to it, and the impact of the invasion of Ukraine by Russia and of the heightened inflationary pressures and economic uncertainty that ensued.

The remainder of this paper is structured as follows. Section 2 considers the application of theoretical models to identify the impact channels of macro-financial risks and to analyse the effects of various economic policies ahead of their implementation. Section 3 describes the most relevant empirical models. Section 4 describes the application of these models to assess the impact of the outbreak of the COVID-19 crisis and the war in Ukraine. Lastly, Section 5 presents the conclusions and development outlook.

2 Theoretical models

In the modern economic literature, the theoretical analysis of the macroeconomic impact of policies and shocks is based mainly on dynamic stochastic general equilibrium (DSGE) models, which allow the behaviour of the different economic agents to be considered in a consistent manner. Moreover, these models are able to reproduce the intertemporal consequences of economic agents' decisions, taken not in an environment of certainty but of risk.

These models necessarily involve a simplified representation of reality. A given model will have greater relative strengths or weaknesses when analysing certain issues depending of the degree of detail with which its various elements are modelled, particularly the transmission channels of shocks and monetary policy. It is therefore necessary to have different tools with which to address different questions. In this regard, partial equilibrium models for specific markets or agents that take all other macroeconomic conditions as exogenous are useful to obtain a more comprehensive overview of certain risk transmission channels, which can subsequently inform the development of new DSGE models.

Given the wide range of issues that may be analysed within its mandate, the Banco de España has developed a variety of DSGE models in recent years. These have incorporated different rigidities or imperfections in various markets (e.g. different types of financial frictions), changes in agents' preferences (habits, risk aversion, etc.) and the impact of technological change. The most salient examples are presented in the following subsections.

2.1 Models for analysing the impact of cyclical risks to activity

The BEMOD model, described in Andrés, Burriel and Estrada (2006), whose estimation is presented in Andrés, Hurtado, Ortega and Thomas (2010), is a large-scale DSGE model for Spain and the rest of the euro area that incorporates nominal frictions in price and wage-setting and a sectoral breakdown, inter alia, and which focuses on studying the effect of general productivity and demand shocks, trade flows or dual inflation[1] , among others. As this is a model that uses empirical estimations, it can also be used to assess experts' macroeconomic projections, by breaking them down in terms of the structural shocks[2] included in the model. BEMOD also enables different risk scenarios to be developed depending on the path these structural shocks follow.

The BEMOD model has recently been replaced for impact analysis purposes by the JoSE (joint Spain-euro area) model, which adds financial frictions and greater detail for

1 The term "dual inflation" refers to an uneven increase in the prices of various goods and services, particularly when it is higher for goods that are not internationally tradable.

2 The literature refers to DSGE model shocks as structural because they try to capture fundamental concepts (such as changes in consumer preferences, productivity or profit margins) rather than simply being the residuals of a reduced form equation.

the housing market. Both BEMOD and JoSE are general models that incorporate a wide range of transmission channels, often through simplified elements that make them easy to use, without stripping them of their microfounded nature or the analytical rigour this entails.

Models that are more detailed in certain aspects have been developed for specific tasks. For example, the FiMOD model in Stähler and Thomas (2012), which incorporates a wide range of taxes and forms of government spending, has been used to assess fiscal policy-related risks. Subsequently, Hurtado, Nuño and Thomas (2023) have researched the interaction between price stability and sovereign debt sustainability using a small-scale open economy model, where the government issues nominal debt and chooses the fiscal policy. In this model monetary policy is determined either (1) by discretionary choice, or (2) exogenously, due to the currency being pegged to a foreign currency or integrated into a monetary union. This latter situation yields the highest level of social well-being under the most relevant calibration.

The ELMo (Extended Learning Model), described in Aguilar and Vázquez (2018), considers a looser rational expectations assumption than most DSGE models,[3] and adds the assumption that agents learn over time. This allows it to assess, among other issues, the anchoring of inflation expectations and the risks associated with the transition, which requires agents to go through a learning process following the adoption of different monetary policy strategies, etc. before a new equilibrium for the economy as a whole can be reached.

2.2 Macro-financial models

To analyse the relationship between macroeconomic variables (such as GDP or inflation) and financial variables (such as lending, leverage or interest rate spreads) the models need to have channels through which these variables can affect one another.[4]

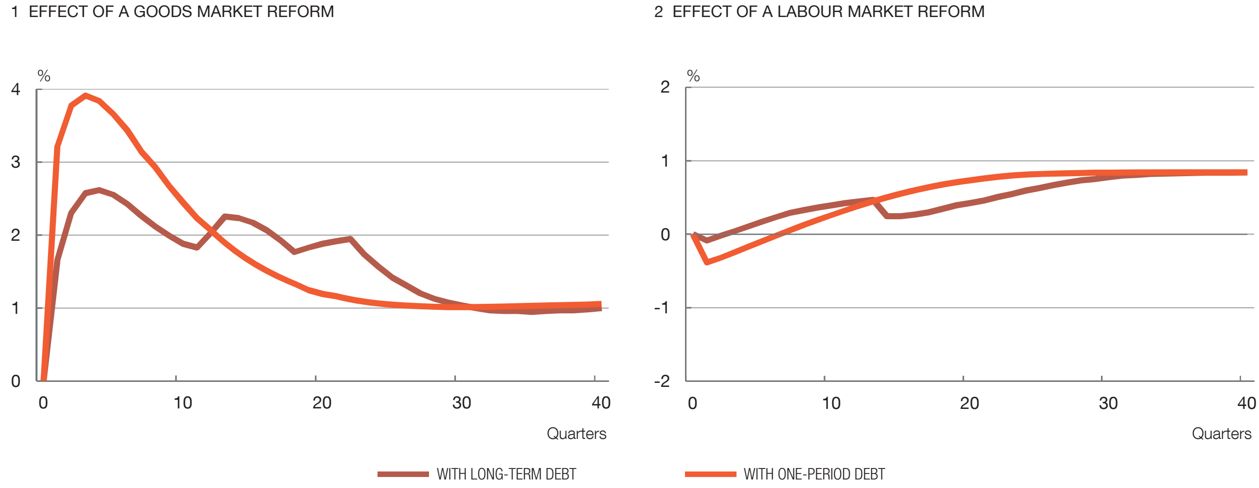
The effect of collateral constraints

One of the most common ways of introducing lending and financial multipliers into a DSGE model is through collateral constraints, i.e. limits on the amount of lending to agents that are determined by the value of the assets that can act as collateral or as a guarantee (e.g. a house or productive capital). These mechanisms magnify the economic cycle, since collateral prices are positively correlated with it (i.e. these assets have a higher market value during economic upswings), which in turn leads to endogenous changes in agents' indebtedness (i.e. the greater value of the collateral allows them to access credit more readily and under better conditions).

3 The assumption of rational expectations considers that economic agents' expectations for the future are shaped by their knowledge of how the economy works and their efficient use of all the available information.

4 For a general analysis of macro-financial models, see Cochrane (2017). There are many assumptions that can justify the development of models with a significant interaction between macroeconomic and financial variables (e.g. cyclical variations in risk aversion), that are not just limited to financial frictions in models such as Brunnermeier and Sannikov (2017).

Chart 1
IMPULSE-RESPONSE OF REAL GDP TO THE ADOPTION OF STRUCTURAL REFORMS (a)



SOURCE: Andrés, Arce and Thomas (2017).

a The chart shows the impact on real GDP of implementing structural reforms in the goods and labour markets using a macroeconomic model with credit restrictions, which depends on the existence of long-term debt capable of generating deleveraging episodes.

In this setting, Ortega, Rubio and Thomas (2011) use a model with collateral constraints to assess the effect on the size of the rental market of various hypothetical fiscal changes homogenising the treatment of house purchase and rental. Using these types of models allows them to incorporate the changes in agents' incentives introduced by the different regulatory forms considered.

In a subsequent article, Andrés, Arce and Thomas (2017) incorporate the existence of long-term debt in a DSGE model with collateral constraints, thus setting a limit on the pace at which agents may have to reduce their indebtedness.[5] The authors then analyse how a possible financial shock that brings about a deleveraging process may alter the effectiveness of structural reforms in the goods and labour markets.[6] Chart 1 shows how the estimation of the effects of these reforms vary in this model depending on whether there is only short-term debt or also long-term debt capable of generating episodes of gradual deleveraging. In this latter case, goods market reforms boost activity in the short term less than under the model that only envisages short-term debt, as part of the agents are over-indebted and slowly and steadily recovering from this situation. Throughout this deleveraging process, they are less responsive to the stimulus to activity provided by the goods market reform. Even so, the effect is positive, despite the deflationary effects of the reform. This channel does not

5 In this model, in the low periods of the financial cycle collateral loses value, the flow of new credit slows or stops and the contractual repayment of long-term debt implies a slow deleveraging process.

6 The reforms considered are those that lead to lower margins, both in terms of prices in the goods market and of wages in the labour market, and that aim to regain international competitiveness in costs and prices in periphery euro area countries. In the goods market, an example of such a reform is a decrease in retail income tax, while in the labour market, an example is an increase in wage flexibility.

apply in the case of labour market reforms, which have a more modest impact on economic activity in the short term, as the effects of these reforms are felt over a long time owing to the existence of other nominal rigidities, such as wage adjustments.

Arce, Hurtado and Thomas (2016) use a version of this model with two countries that form a monetary union and analyse the effect that deleveraging and the existence of a zero lower bound[7] on interest rates have on the international transmission of the impact of fiscal policy and structural reforms. Finally, Andrés, Arce, Fernández-Villaverde and Hurtado (2020) expand this analysis, using the same model, to explore dimensions such as the size of the region making the reforms or the optimal sequence of reforms during an interest rate lift-off from its lower bound.

The role of financial intermediaries

In the models cited above, the credit obtained by debtors comes directly from savers and the special role of banks as agents that intermediate between them is not analysed. Andrés, Arce and Thomas (2013) use a model with collateral constraints where banks operate under monopolistic competition to analyse the optimal monetary policy in the presence of endogenous interest rate spreads. For their part, Nuño and Thomas (2017) study the relationship between the cyclical fluctuations of GDP and of financial institutions' leverage, in a model where regulated banks and other financial intermediaries behave very differently over the course of the cycle owing to the different incentives created by their respective specific regulations.

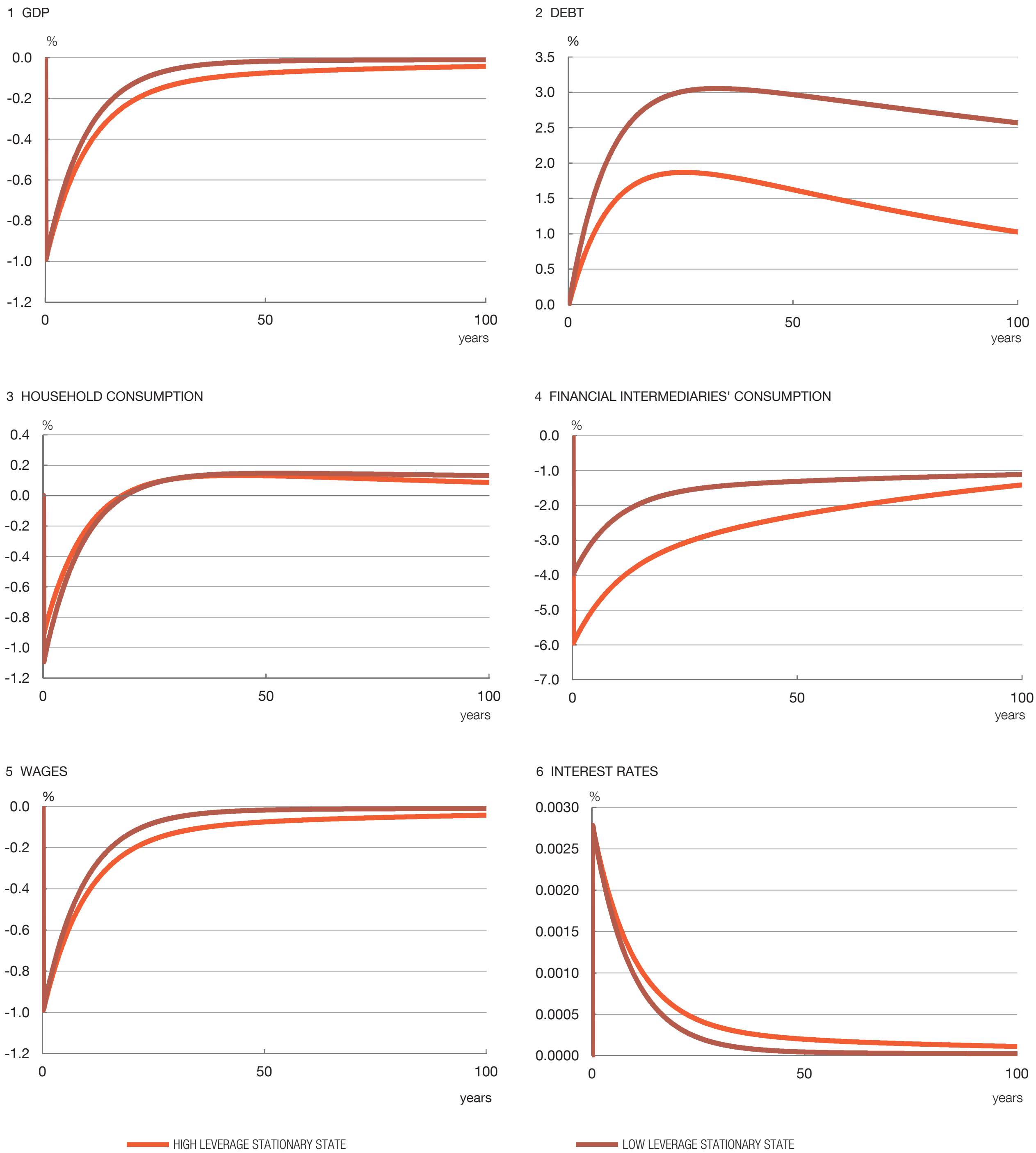
Similarly, Abbate and Thaler (2019) develop a DSGE model where agency problems distort bank's incentives and lead them to choose excessively risky investments. Using this model, they show that when real interest rates fall, the scale of these distortions increases and banks take on more risks. This has a negative impact on the efficiency of their investments and ultimately makes it optimal for the central bank to accept more volatility in inflation in exchange for reduced risk-taking. The rigorous microeconomic basis for DSGE models allows these types of effects to be captured through the incentives of financial intermediaries.

Aguilar, Fahr, Gerba and Hurtado (2019) use the 3D model developed by Clerc et al. (2015), also incorporating the possibility that debtors, including banks, may fail endogenously. This makes it possible to explore the effects of macroprudential policy (in this case, the setting of a capital requirement for the banking sector, which can evolve countercyclically) and to search for a specification that maximises the welfare of the economy by striking the right balance between the benefits of implementing these types of measures, in terms of reducing risk and volatility, and the costs, measured as the reduction in the economy's average size resulting from lower lending levels stemming from the adoption of the measures.

7 In the model, nominal interest rates cannot be negative. This approximates what is observed in the real world, where, although they can be slightly negative, in practice they cannot be strongly negative.

Chart 2

EFFECT OF A PRODUCTIVITY SHOCK IN A NON-LINEAR MODEL WITH HETEROGENEOUS AGENTS AND FINANCIAL INTERMEDIARIES (a)



SOURCE: Fernández-Villaverde, Hurtado and Nuño (2020).

a The chart depicts the impact of a negative productivity shock on a set of macro-financial variables, in terms of their percentage change. The results are shown for two different stochastic stationary states of the economy, one with high leverage and one with low leverage.

Presence of heterogeneous agents

These models may even include, in the more complex cases, a considerable range of agent types: consumers that save and others that borrow, banks intermediating between them, employers that accumulate capital and produce goods and services, retailers that set the prices of their products, exporters and importers that intermediate in international trade flows, etc. However, each category normally comprises a single representative agent that resolves an optimisation problem based only on the significant aggregate variables. The inclusion of heterogeneous agents has advantages, as it enables issues such as income distribution and inequality, wealth and firm size, among others, to be studied. At the same time, it allows for a better impact assessment of policies, whose effects may be different for agents at different points along the distribution, or may even vary at aggregate level when this heterogeneity is considered.

Kaplan, Moll and Violante (2018) analyse the effects of monetary policy in a neo-Keynesian model[8] with heterogeneous agents and find that the indirect effects of a change in interest rates, which operate through general equilibrium adjustments in the labour market, are more significant than its direct effect on households' intertemporal substitution decisions. Fernández-Villaverde, Hurtado and Nuño (2020) incorporate financial intermediaries into a non-linear DSGE model with heterogeneous agents, with which they illustrate the endogenous aggregate risk generated as a result of the interaction between the supply of bonds by these intermediaries and households' precautionary demand. This interaction causes a shift in the aggregate state of the economy, which switches between two different equilibriums with high and low leverage and time-varying levels of volatility and skewness of the distributions of variables such as output and interest rates. Chart 2 shows that the effects of a productivity shock in this model are also different depending on whether the economy is in the high or low-leverage region: when leverage is high, although the effect of the shock on debt is lower in percentage terms, its effects on the economy are more persistent, and variables such as GDP, wages and interest rates take longer to return to their initial levels prior to the shock.

8 This term refers to a set of macroeconomic models featuring imperfect competition and nominal rigidities, which make them particularly well suited for analysing the effects of monetary policy.

3 Empirical analysis

The empirical models used by the Banco de España to analyse the impact of the different aggregate risks can be divided into three main categories. The first of these comprises the macroeconomic forecasting models that seek to determine the most accurate expectations possible about the performance of economic activity. The second category covers macro-financial interaction models, which mainly aim to identify and analyse financial imbalances and the risk that they pose to economic growth. Lastly, there are financial market analysis models, which comprise a wide range of variables and markets and have different goals, but which generally seek to identify possible imbalances that might increase the probability or severity of financial crises.

3.1 Macroeconomic forecasting models

DSGE models such as those presented in Section 2 can be used for macroeconomic forecasting, but it is also common to use models with a less strict microeconomic foundation, which adapt in a more flexible manner to changes in the observed data. This is the case of the Quarterly Macroeconometric Model of the Banco de España (MTBE, by its Spanish abbreviation), a large-scale semi-structural macroeconometric model[9] specified as a large number of error correction mechanism equations[10] describing the aggregate behaviour of variables such as household consumption, private productive investment, residential investment, exports and imports of goods and services to and from the euro area and the rest of the world, employment and wages, etc. The model replicates the structure of the National Accounts in great detail and its behaviour, particularly in the short term, is mainly driven by demand channels. The first version of this model was detailed in Estrada, Fernández, Moral and Regil (2004) and, since then, it has been continuously developed in successive versions,[11] the current one being that set out in Arencibia, Hurtado, De Luis López and Ortega (2017).

The MTBE is used during the preparation of the medium-term forecasts for the Spanish economy to provide a neutral (non-judgemental) projection that can be used as a reference by the experts who prepare the forecasts and to determine the contributions of the different variables included in the model's equations. It is also used to generate counterfactual scenarios: simulations of economic policy measures, risk scenarios around the baseline forecasts, etc.

For example, in Delgado Téllez, Hernández de Cos, Hurtado and Pérez (2015), the MTBE is used to assess the impact on the Spanish economy of the extraordinary mechanisms

9 Contrary to what was discussed in a previous footnote on the use of structural shocks that try to capture fundamental economic shocks, this term indicates that in this case the model is at least partially specified as a set of reduced form equations fitted to the data based on statistical criteria and the shocks are the residuals of these equations, which do not always have any real significance.

10 An error correction model reflects a variable's changes not only as a function of their lags and of changes in explanatory variables, but also of the distance between these variables' level and their long-term equilibrium level.

11 Ortega, Burriel, Fernández, Ferraz and Hurtado (2007); Hurtado, Fernández, Ortega and Urtasun (2011); Hurtado, Manzano, Ortega and Urtasun (2014).

Chart 3
MACROECONOMIC PROJECTIONS FOR THE SPANISH ECONOMY (2021-2023) (a)

SOURCE: "Macroeconomic projections for the Spanish economy (2021-2023): the Banco de España's contribution to the Eurosystem's June 2021 joint forecasting exercise", Economic Bulletin - *Banco de España,* 2/2021.

a Scenarios generated in June 2021 based on simulations carried out using the quarterly macroeconometric model of the Banco de España. Three scenarios (baseline, benign and adverse scenarios) were prepared to assess the effects of different future paths of household consumption and saving, and toursim exports, inter alia. The benign scenario envisaged that the decline in the incidence of the pandemic observed at the time would continue, allowing the lifting of the remaining restrictions on economic activity to be brought forward. By contrast, the adverse scenario envisaged the possibility of fresh surges in case numbers, possibly linked to the appearance of more infectious variants of the virus that could be resistant to vaccines, requiring the re-establishment of restrictions on movement and on some economic activities that entail high levels of personal contact. The model allows full paths for the most significant macroeconomic variables to be generated from a baseline scenario and a small number of assumptions for each alternative scenario, in a general equilibrium environment that captures the relationships historically observed in the Spanish economy.

for paying general government suppliers which were approved after the 2012 crisis. More recently, during the COVID-19 crisis, the MTBE model was used to generate different alternative scenarios around the baseline forecast. Chart 3 shows the paths of different variables of interest under the scenarios constructed based on the MTBE model in the Banco de España's June 2021 macroeconomic projection exercise. The different scenarios for that exercise considered more or less favourable assumptions about the course of the COVID-19 pandemic, which translated into different paths for international tourist flows, household saving decisions, etc., which, via the model, resulted in different paths for GDP and GDP growth and for the other macroeconomic variables envisaged in the MTBE.

Meanwhile, the model developed by the National Institute of Economic and Social Research (the NiGEM model) is commonly used for international modelling. NiGEM is a global macroeconomic model that includes more than 60 countries and regions and country-level disaggregated models. This model not only produces baseline projections based on variables' actual observed levels, but also scenarios based on assumptions about specific shocks. It can also be used to carry out simulations of the impact of different economic policy actions, ranging from monetary and fiscal policy to changes in tariffs.

The above-mentioned models can provide a comprehensive distribution of possible future scenarios and their associated probability. However, this is not the main purpose for which they were created; rather, they are focused on providing a baseline forecast for economic activity. In order to provide a better quantification of downside risks to economic developments, recent years have also seen progress in the use of models specifically designed to capture these risks. This is the case of quantile regressions, which focus on a specific quantile (for example, observations in the lower 10% of the distribution) rather than on the baseline projection. Ganics and Rodríguez-Moreno (2022) use these types of models for GDP and house prices in the 27 euro area countries and analyse the financial stability implications of the resulting risk distribution. These models are discussed in further detail in Section 3.2.

This emphasis on capturing the behaviour of the entire distribution of possible results complicates the analysis, but recent efforts make it possible to combine these distribution analysis techniques with forecast models. Thus, Ganics and Odendahl (2021) show how to use the entropic tilting and soft conditioning techniques to incorporate distributional information from the European Central Bank's Survey of Professional Forecasters into the forecasts from a BVAR model, and how this improves the point and density forecasts prepared using the model.

3.2 Macro-financial interaction models

Models for identifying credit imbalances

The last global financial crisis brought home the risk posed by periods of excessive growth to financial and macroeconomic stability. The role of credit growth in the build-up of cyclical systemic risk and the fact that this growth tends to precede systemic crises have been clearly documented in the scientific literature (Drehmann, Borio and Tsatsaronis, 2011; Schularik and Taylor, 2012). Therefore, a proper and timely identification of credit imbalances is essential for implementing prudential policies that can prevent the build-up of systemic risks and mitigate the impact of their potential materialisation.

Against this background, the literature proposes a series of indicators of credit imbalances, most of which are based on statistical methods. One of the most widely used is the credit-to-GDP gap, defined as the excess credit as a share of GDP with respect to its long-term trend, obtained using a statistical filter (Drehmann, Borio, Gambacorta, Jiménez and Trucharte, 2010; Detken et al., 2014).[12] Other indicators proposed include transformations of macro-financial variables (Alessi and Detken, 2011; Babecký, Havránek, Mateju, Rusnák, Smídková and Vasícek, 2014), their aggregation through composite indicators (Lang, Izzo, Fahr and Ruzicka, 2019) and a variety of statistical methods ranging from adaptations of filter techniques to decision trees and other non-parametric methods (Alessi and Detken, 2018; Galán, 2019).

However, although several of these proposals have potential as early warning indicators of systemic crises, none of them distinguish sustainable and macroeconomically justified credit growth from unsustainable, excessive growth that can be a source of systemic risk. In this regard, Galán and Mencía (2021) propose two indicators of credit imbalances based on the estimation of two structural models linking credit levels to changes in macro-financial variables. In particular, they propose an unobserved components model (UCM) and a vector autoregressive error-correction (VEC) model that estimate long-term relationships between credit and GDP, interest rates and house prices.

The estimation of imbalances using the models proposed by Galán and Mencía (2021) is superior to that using statistical methods in terms of providing early warning signals of a build-up of cyclical systemic risk. In particular, the indicators based on these models have high predictive power for financial crises outside the sample and a high correlation with indicators of crisis severity, and are less biased when faced with abrupt changes in macro-financial conditions. All these properties are particularly useful to identify cyclical imbalances and implement macroprudential tools.

Growth-at-risk models

Although economic recessions do not always coincide with financial crises because the duration of financial and economic cycles varies, financial crises very often go hand in hand with sharp declines in economic growth (Claessens, Kose and Terrones, 2012; Aikman, Haldane and Nelson, 2015). Recently, Adrian, Boyarchenko and Giannone (2019) found that a tightening of financial conditions has significant negative effects on the left-hand tail of the GDP distribution, i.e. this tightening deteriorates growth at risk, defined as the economic growth that would be observed in a severely adverse scenario occurring with a given probability. The concept of growth at risk is very important because of its link to the probability of occurrence and severity of financial crises.

Against this backdrop, Galán (2020) extends the use of quantile regressions proposed by Adrian, Boyarchenko and Giannone (2019) to identify impacts on growth at risk, by adding additional control variables including macro-financial variables with the capacity

12 This is the benchmark indicator recommended by the Basel Committee on Banking Supervision and by European legislation (Bank for International Settlements, 2010; Regulation (EU) 575/2013 and Directive 2013/36/EU) for setting the value of the countercyclical capital buffer (CCyB).

to provide early warnings of systemic crises and variables that identify macroprudential measures. This study finds that the build-up of systemic risk and the materialisation of episodes of financial stress result in lower growth at risk and increase the skewness of the GDP growth distribution towards the left (more negative or less positive values). However, the time structure of these impacts differs. While the impact of financial stress is felt in the short term (i.e. horizons of around one year), cyclical financial imbalances affect growth at risk in the medium term (i.e. horizons of around three years).

Moreover, since the ultimate aim of macroprudential policy is to prevent and mitigate systemic crises, estimating the impact of macroprudential measures on the economy's growth rates under very adverse scenarios is very useful for quantifying the effects of such measures in terms of their ultimate aim. Galán (2020) identified positive and significant effects of macroprudential policy on growth at risk which reduce the skewness of the distribution towards the left tail. These benefits stand in contrast to the slightly negative effects on the median of the distribution, which may be linked to the cost of implementing these measures as the cycle smoothes, and which confirm prior results based on estimations of the conditional mean of GDP (Noss and Toffano, 2016; Kim and Mehrotra, 2018; Richter, Schularik and Shim, 2019; Bedayo, Estrada and Saurina, 2020).

Further, Galán (2020) finds that the impact of macroprudential policy on growth at risk depends on the position in the financial cycle, the direction of the macroprudential measures (tightening or easing), the type of macroprudential instrument used and the time elapsed since its implementation. In particular, Chart 4 shows that it takes around eight quarters for the positive effects on growth at risk of an increase in capital requirements during expansionary phases of the cycle to begin to show, while the tightening of borrower-based measures has faster and more persistent effects. Meanwhile, the release of capital during contractionary phases or events of financial stress has almost immediate positive effects, while easing credit standards has very limited effects. These findings suggest that capital measures should be taken well in advance of excessive expansion of the financial cycle, while limits on lending standards could be effective even at later stages of the cycle. Overall, the results confirm the benefits of using such measures countercyclically and of having sufficient macroprudential space, especially in terms of capital, to deal with financial stress shocks.

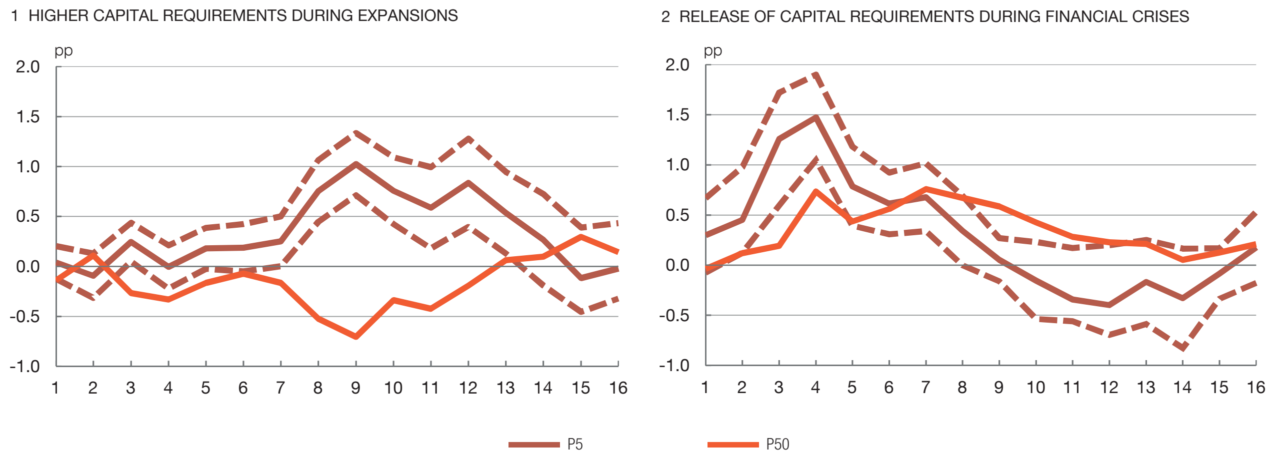
3.3 Financial market analysis

The tasks entrusted to the Banco de España require both a continuous and conjunctural analysis of financial markets and a monitoring of their structural development. In this respect, the Banco de España analyses the risks associated with changes in the valuations of the different financial assets, including equities and fixed-income securities, which are important because of the impact they may have on financial intermediaries' balance sheets, and thus on their capacity to channel funds between savers and other agents with funding needs.

Similarly, it also analyses the risks linked to specific money market conditions, which may have a significant impact on financial market conditions. The Banco de España also

Chart 4

IMPACT OF THE INCREASE AND RELEASE OF CAPITAL REQUIREMENTS ON THE 5TH AND 50TH PERCENTILES OF THE GDP GROWTH DISTRIBUTION AT HORIZONS FROM 1 TO 16 QUARTERS AHEAD (a)



SOURCE: Galán (2020).

a The solid lines depict the estimated impact in percentage points on the 5th and 50th percentiles of the conditional GDP growth distribution, respectively. The broken lines depict the 95% confidence bands obtained using bootstrapping.The estimation is calculated for a sample of 36 countries including advanced and emerging market economies for the period 1990-2016. Crisis periods are those identified as financial crises in Laeven and Valencia (2018). Expansionary periods are those where credit and house price growth exceed the 75th percentile of each country's historical distribution. Capital measures (provisioning and capital requirements, including buffers) are captured using a cumulative index that discriminates between activation/tightening of the measures and release/easing of the measures.

prepares systemic risk indicators to assess the vulnerabilities of the Spanish financial system. These indicators complement the risk analyses of different segments of the financial market, which are summarised here, providing signals of global risk in the system under analysis.

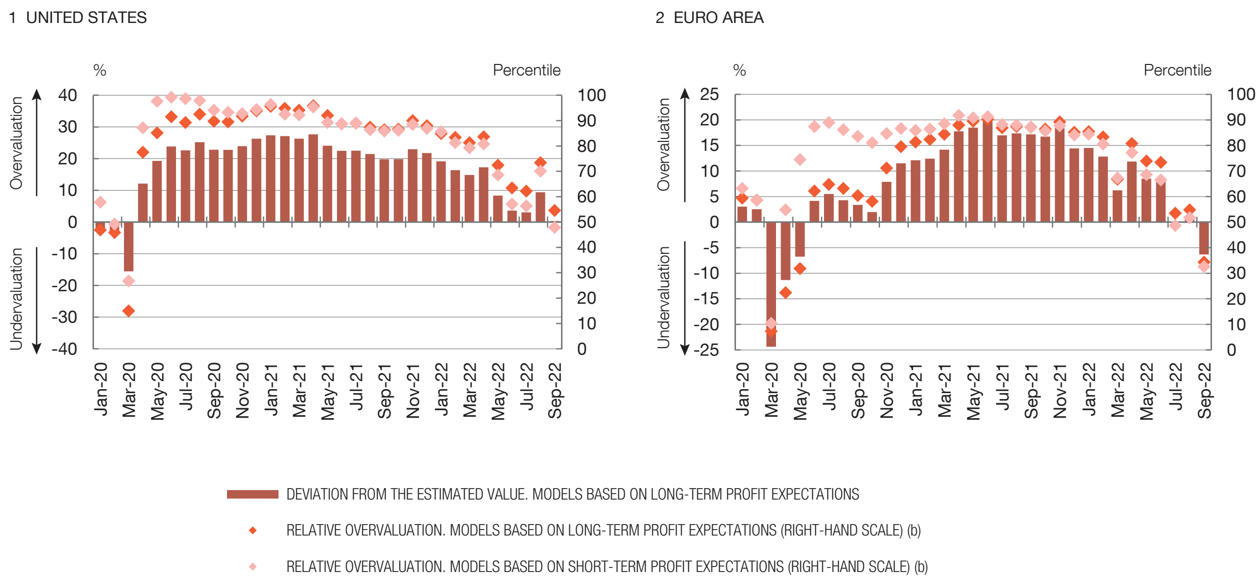
Stock overvaluation models

To assess the possible overvaluation of US and euro area firms' stocks, Gálvez and Roibás (2022) conduct an analysis based on dividend discount models. Specifically, in these models, share prices are expressed as a function of three variables: earnings per share expectations, which provide information on dividends and other expected payments to shareholders; the uncertainty surrounding these estimates, which represents the risk associated with variable-yield securities; and the term structure of interest rates, which provides information on expectations about the state of the economy and the opportunity cost of investing in fixed income.

The S&P 500 and the EURO STOXX[13] are used to measure changes in firms' share prices in the United States and the euro area, respectively. As regards the model's explanatory variables, earnings expectations are proxied by the weighted average of analysts' forecasts three fiscal years ahead, available from the Institutional Brokers' Estimate

13 The EURO STOXX is a subset of the STOXX Europe 600 index which includes 300 large, medium and small enterprises from 11 euro area countries: Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain.

Chart 5
STOCK OVERVALUATION MODEL (a)



SOURCES: Thomson Reuters Datastream and own calculations.

a The estimation sample includes monthly data from January 1990 to September 2022.
b The percentile of the historical distribution for the period 1990-2022 where the corresponding difference between the value observed and that estimated by the model lies is indicated for each date.

System (I/B/E/S), while the uncertainty surrounding these estimates is measured by these forecasts' coefficient of variation.[14] Lastly, the interest rate term structure is approximated through the difference in profitability between long and short-term government bonds (10, 20 or 30 years vs three months).

The estimated models have a good fit[15] and all the coefficients are statistically significant and have the expected sign, in line with results in previous papers, such as Campbell and Shiller (1988). Thus, an increase in earnings expectations leads to a rise in share prices, while an increase in risk or term spreads leads to a fall in the stock index. According to the estimated models, and under the additional assumption of long-term expectations, following the sharp stock market losses since early 2022, driven by the tightening of monetary policy, at end-2022 Q3 the S&P 500 was in line with its fundamentals, while the EURO STOXX was 6% below the predicted value (see Chart 5). In terms of its historical distribution, the difference between the observed value of the US index and that estimated by the model was somewhat above the 50th percentile, and only above the 30th percentile in the case of the euro area.

14 To measure uncertainty about analysts' expectations it is preferable to use the coefficient of variation rather than the standard deviation, since, as earnings grow over time, the latter has an undesirable upward trend that could skew estimates of overvaluation in recent periods upwards.

15 An R^2 of 93% for the US model and of 87% for the euro area model.

The time horizon of the earnings expectations included in these models plays a key role in the degree of overvaluation estimated in certain crisis periods. In particular, long-term expectations were more appropriate for capturing the flow of future payments to shareholders in a context such as the COVID-19 health crisis, where a sharp contraction in GDP and corporate profits was expected in the short term, but a significant recovery was expected over longer horizons. The results of the models presented here, which include longer-term earnings expectations, stand in contrast with the greater overvaluation suggested by other approaches based on short-term earnings expectations (12 or 18 months) for the first months of the pandemic.[16] This highlights the need to study the robustness of the findings regarding the overvaluation of financial assets to the assumptions used. This consideration is very much present in the frameworks used by the Banco de España to analyse this issue.

Monetary policy implementation, asset management and market intelligence

Owing to their market sensitivity, many of the models used by the Banco de España for asset and liquidity management, collateral analysis and money market transaction monitoring are confidential and cannot be fully detailed in this paper.

The models which focus on evaluating and monitoring fixed-income, credit, inflation and money markets and financial assets are used in a first stage of the analysis work, owing to the Banco de España's direct or indirect participation in them and their interest for monetary policy. Among these models, first there are those aimed at analysing inflation expectations and the probabilities of monetary policy movements based on bond and inflation derivatives market prices (futures, options, forwards and swaps). Here we mainly follow the models of Gimeno and Ibañez (2018), Gimeno and Ortega (2018) and Aguilar and Gimeno (2022).

Second, the models and indicators listed below are used to assess interest rate curves (slope, credit spreads and duration risk):

— Banco de España (2018) is used to decompose interest rates and slope determinants for the dollar and the euro.

— An indicator of corporate bond market fragmentation is also used, which is calculated via a panel data model that includes data on duration, credit quality, etc. for the main euro area countries.

— An indicator of duration risk for euro area sovereign bond issues by country and type of holder is also used (Cahill, Damico, Li and Sears, 2013; Esser, Lemke, Ken, Radde and Vladu 2019).

Third, the assessment of risk factors in fixed-income portfolios (public sector bonds and credit) used to support portfolio positioning and relative value and duration risk analysis is based in particular on:

16 See IMF (2020).

— A quantitative duration position model based on a binomial model with macroeconomic and financial variables.

— A synthetic relative value indicator based on a principal component analysis (PCA) and percentile thresholds for a bond universe.

— A market scoring index to support the tactical management of own portfolios, based on quantitative and qualitative variables (macroeconomic and political context, monetary policy expectations, analysts' consensus, technical and sentiment analysis, etc.).

Lastly, monitoring money markets is important in the context of transactions and liquidity management, collateral on monetary policy operations and the euro-denominated securities lending programme. This monitoring is generally conducted using indicators that, in many cases, are not public. Noteworthy among those most commonly used are:

— Indicators based on transaction data (secured and unsecured segments) reported to Money Market Statistical Reporting (MMSR) and on money market types, changes, volumes and spreads: €STR, EONIA, 3-month and 12-month EURIBOR, repo rates (general collateral analysis and special collateral analysis by jurisdiction).[17]

— Institutions' available collateral buffers: the ratio of the value of the pledged collateral after haircuts to the total outstanding credit in monetary policy refinancing operations.

— The volume of euro-denominated securities lending against cash and collateral; and the utilisation ratio for each reference subject to lending and valuation.

Following a more general approach, analyses and assessments related to liquidity, volatility, uncertainty and market sentiment are carried out for different product segments, sectors and regions. Volatility and liquidity in financial markets is mainly analysed using the following analytical models:

— Models for measuring implied volatility (VIX) for different assets and sectors (González-Pérez, 2021); and volatility spillovers between markets (Whaley, 1993; Carr and Madam, 1998; Demeterfi, Derman, Kamal and Zou, 1999; Britten-Jones and Neuberger, 2000; Diebold and Yilmaz, 2012).

— A global implied volatility index based on a dynamic factor model applied to several asset types and regions.

17 General collateral is defined as an asset pool (e.g. certain government bonds) with similar characteristics and associated with the same interest rate if they are used as collateral in a repo operation. Conversely, bonds considered special collateral are traded at a specific repo rate for that asset.

— A synthetic liquidity indicator for the European bond market based on market depth and efficiency, foreclosure costs, the bid-ask spread, the change in the traded volume, etc. (Sarr and Lybek, 2002; Amihud, 2002).

In addition, analytical tools based on text mining and dictionaries are used to analyse sentiment and uncertainty about markets, the economy and specific firms. These include most notably:

— A model based on a specific dictionary and on natural language processing to obtain a sentiment indicator for financial stability reports and related press news (Moreno and González, 2020).

— An analysis of economic sentiment and how it evolves over time, by subject (external sector, domestic economy, inflation, etc.), based on the minutes of the central banks of the euro area, the United States, Canada and Australia.

— The construction of indicators based on the Economic Policy Uncertainty (EPU) methodology (Baker, Bloom and Davis, 2016). Notable examples include an index of the number of economic news items mentioning words related to dovish, rather than hawkish, monetary policies, and a geopolitical risk index by region based on news relating to this risk and subject area.

Lastly, special attention is paid to analyses relating to the market performance of financial institutions as monetary policy and reserve management counterparties. In the analysis and study of events related to financial institutions the following models are notable:

— Impact analysis on the dates banks' quarterly results are published and for specific significant events (e.g. mergers): comparison of actual data with analysts' estimates, impact on debt yields and market value, and sentiment index for press presentations and conferences (Feldman, Govindaraj, Livnat and Segal, 2010; McKay, Doran, Peterson and Bliss, 2012; Neuhier, Scherbina and Schlusche, 2013).

— An indicator of listed financial institutions' sensitivity to interest rate changes.

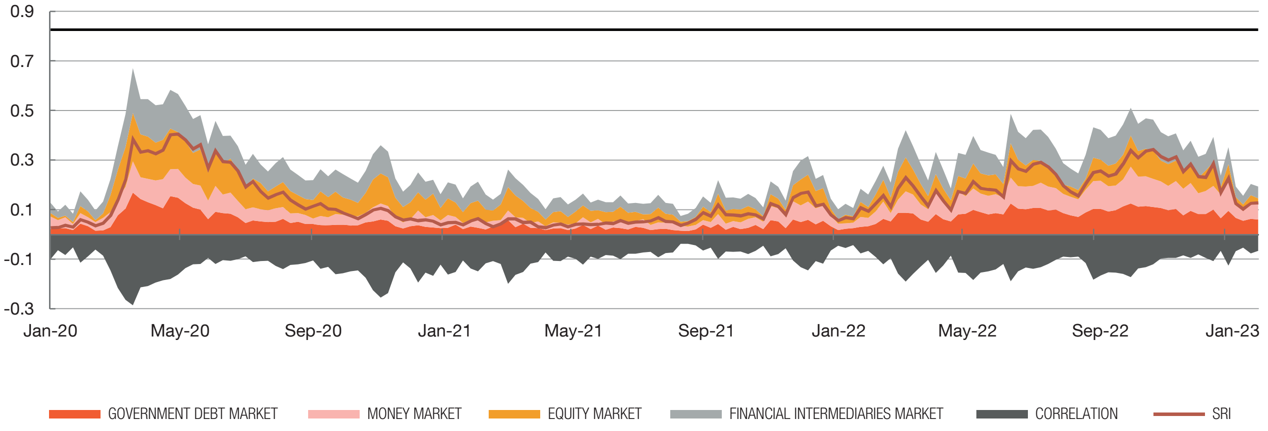
— A sentiment analysis drawn from analysts' reports on Spanish and other European banks, and their performance during the COVID-19 crisis (Banco de España, 2020).

Systemic risk indicators

The systemic risk indicator (SRI) is analysed on a weekly basis to monitor tensions (or the absence thereof) potentially extending across the entire financial system and with possible harmful effects on the real economy. This indicator uses the Composite Indicator of Systemic

Chart 6

SYSTEMIC RISK INDICATOR (a)



SOURCES: Datastream and Banco de España.

a The SRI aggregates 12 individual stress indicators (volatilities, interest rate spreads, maximum historical losses and others) for four segments of the Spanish financial system. The effect of cross-correlations is taken into account to calculate the SRI. Thus, the SRI is higher when market correlation is high and lower when it is low or negative. For a detailed explanation of this indicator, see Box 1.1 of the May 2013 *Financial Stability Report*. The black line represents the highest historical value of the SRI.

Stress (CISS) developed by the ECB[18], condensing the level of financial systemic risk in Spain in a single figure. The SRI aggregates 12 individual stress indicators (volatilities, interest rate spreads, maximum historical losses, etc.) from different segments of the Spanish financial system (the money, public debt, equity and bank funding markets). To calculate the SRI the effect of cross-correlations is taken into account. Thus, the SRI records higher values when the correlation between the four markets is high, particularly in situations with a high level of stress in the four markets simultaneously. Conversely, its value decreases when the correlation is lower or negative i.e. in situations where the stress level is high in some markets and low in others.[19]

In recent years, the most significant increase in the SRI occurred in the wake of the COVID-19 pandemic in 2020, reflecting the financial tensions arising primarily in the first two quarters following the onset of the health crisis (see Chart 6). Subsequently, after a quieter period in the financial markets, the outbreak of the war in Ukraine in February 2022 and heightened macroeconomic uncertainty have led to a fresh build-up of systemic risk. Although this build-up was smaller, it was more persistent, holding and even increasing during much of 2022, and then easing in the final stretch of the year and in early 2023. These two bouts of tension, linked to the onset of the COVID-19 pandemic and the war in Ukraine, have in any event involved smaller financial tensions than those recorded during the global financial crisis.

18 Hollo, Kremer and Lo Duca (2012).

19 For a detailed explanation of this indicator, see Box 1.1 of the May 2013 *Financial Stability Report*.

The Banco de España also uses an indicator named SRISK, which quantifies the systemic importance of individual banks and the banking sector overall, by assessing and aggregating the impact of an extreme negative market event on each bank.[20] This latent risk indicator provides an estimate of a bank's expected capital shortfall after a hypothetical severe crisis in equity markets entailing a correction of its market capitalisation. It thus constitutes a systemic risk metric, since the high cost of covering a capital shortfall for the banking sector could distort financial intermediation. Changes in the SRISK indicator since mid-2020 have pointed to a decrease in European banks' exposure to adverse systemic shocks, although the outbreak of war in Ukraine led to a slight rise in this indicator for the European Union as a whole, which fed through to Spanish banks to a lesser extent.

3.4 Stress tests

The Banco de España conducts stress testing exercises on Spanish banks at least annually by applying its Forward Looking Exercise on Spanish Banks (FLESB) tool. The aim is to assess the solvency and liquidity of deposit-taking institutions in the Spanish financial system. These exercises provide both aggregate results and the different heterogeneity measures of the degree of resilience across individual institutions.[21]

The FLESB is a top-down tool and its outcome depends on the macro-financial assumptions considered. The methodology within this framework uses a set of quantitative models developed in-house by the Banco de España which are applied to the granular information available about the banks thanks to regulatory and supervisory reporting.[22] This tool is very useful to measure the impact on the financial system of the materialisation of comprehensive macro-financial scenarios, but it can also be used to carry out sensitivity analyses to assess the isolated effect of certain variables of interest or the independent materialisation of different macro-financial risks identified[23] (e.g. a drop in house prices or an across-the-board interest rate rise).

In order for these exercises to be useful, it is very important that they be underpinned by macroeconomic scenarios that strike a balance between severity and plausibility. Baseline scenarios, in line with the macroeconomic projections, are by definition feasible and may be used to form expectations about institutions' solvency and liquidity under the economy's expected trajectory. By contrast, adverse scenarios do not reflect economic expectations, but are based on plausible hypothetical assumptions, and seek to measure banks' solvency and liquidity in the event that the risks identified around the baseline scenario materialise.

20 For details on the construction of this indicator, see Brownless and Engle (2017). The Banco de España has also used this indicator recently to establish that the capital buffers for systemically important institutions (SIIs) reduce the systemic risk perceived by the markets in relation to these institutions. For further details, see Broto, Fernández Lafuerza and Melnychik (2022)

21 The latest results of the FLESB can be found in Box 2.2 of the autumn 2022 *Financial Stability Report*.

22 A different approach for these exercises would be the bottom-up option, where the banks themselves make estimations, applying their own models and databases. The European stress test exercise coordinated by the EBA mainly uses this approach, although the bottom-up results are restricted by methodological guidelines and are verified by supervisory models developed by the ECB.

23 See the spring 2019 *Financial Stability Report* .

The post-2008 global financial crisis is a very useful historical experience for creating these scenarios, but it needs to be borne in mind that the economy's imbalances have evolved over time and past episodes will not necessarily be replicated in the face of a new crisis. Therefore, a new narrative is defined each year in line with the risks to financial stability identified at that time.

The FLESB's methodology uses a dynamic balance sheet approach to generate results for macroprudential supervision purposes.[24] Thus, for instance, in an adverse macroeconomic scenario in which GDP contracts and unemployment rises, a decrease in aggregate lending to the private sector, leading to some bank deleveraging, is to be expected. Reducing balance sheet size helps banks, *ceteris paribus*, to maintain their solvency levels, but scenarios with a greater contraction of aggregate lending tend to be associated with a worse overall macroeconomic situation. In turn this leads to a greater deterioration of bank earnings, for example, via losses due to new provisioning, and potentially to higher capital consumption in the numerator of the solvency ratio. The FLESB tool can be used to evaluate the impact on bank solvency of alternative scenarios involving different credit and economic activity growth trends, and can thus help to assess macro-financial risks and the different macroprudential policies adopted to temper them.[25]

As a more specific illustration of this framework, Section 4 describes the application of adverse scenarios linked to the COVID-19 crisis and the aggregate results obtained.

24 For other purposes, such as the performance of stress tests supporting the micro supervisory process, the framework can also use a static balance sheet approach.

25 The FLESB tool uses macroeconomic scenarios that include growth projections for different components of lending to the private sector, but in its current form it does not model the feedback between the changes in bank solvency and the real economy in a given year, which can amplify an initial macroeconomic shock. Some examples of the development of a feedback loop in stress test exercises include the ECB's *Banking euro area stress test model* (September 2020), a macroprudential stress exercise, and the Bank of Canada's *Framework for Risk Identification and Assessment* (November 2018).

4 Application of the framework for analysing the impact of macro-financial risks to recent crises

4.1 The COVID-19 crisis

Macroeconomic projections

In the setting of the COVID-19 crisis, the preparation of economic projections was tremendously hampered not only by the usual difficulties that this task entails, but also by new sources of uncertainty. The first and main source of uncertainty related to how the pandemic would unfold healthwise and to the scope of the measures that might need to be taken both on preventively, to prevent the emergence of fresh bouts of contagion, and to contain those that did arise. Also, the impact of these measures on the economy and the financial sector had to be analysed in the absence of valid historical references with which to compare the pandemic crisis.

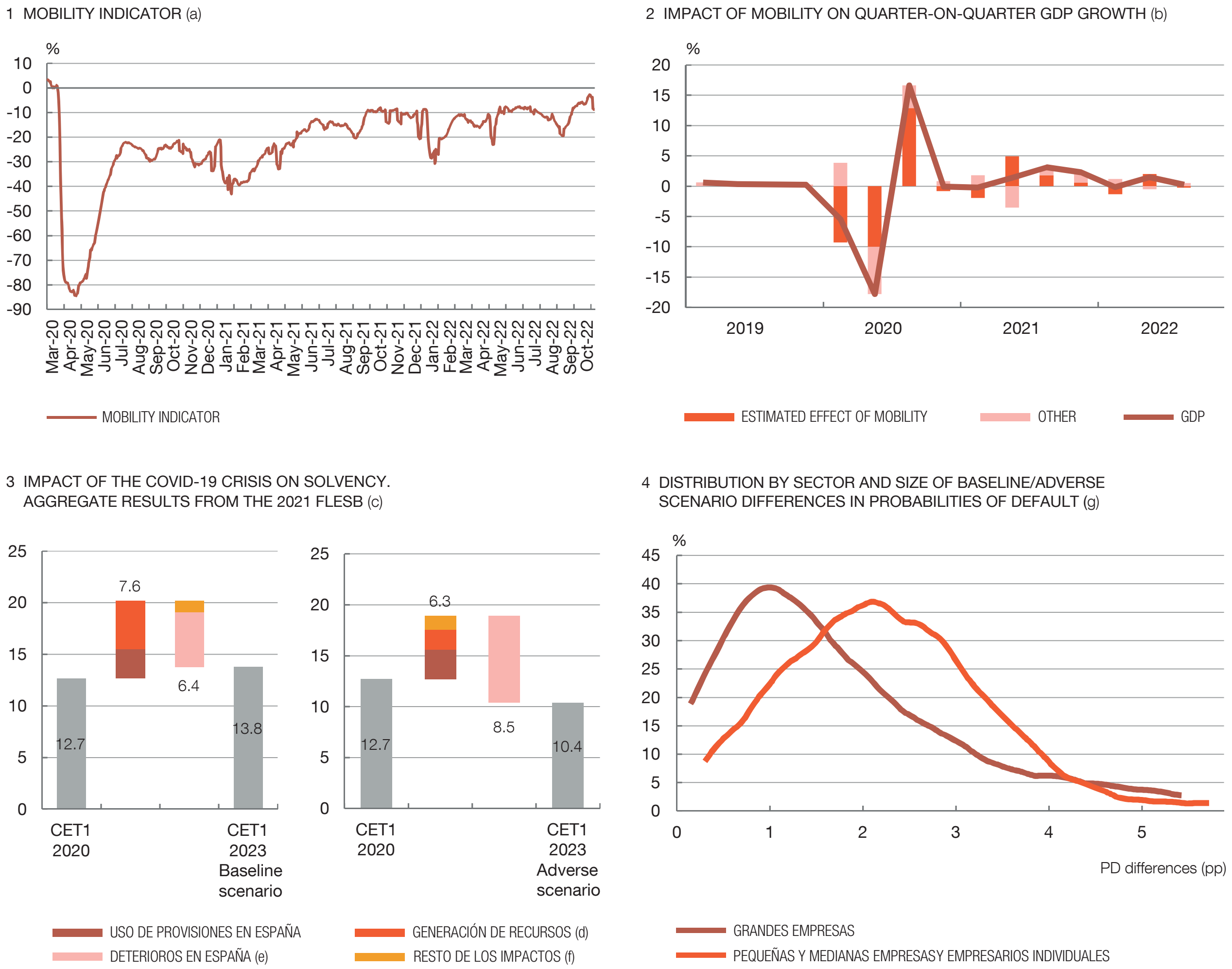
Prior to the publication of the macroeconomic projections, partial information is usually available on a set of monthly indicators that are used to calibrate short-term activity projections. This information provides sufficient anchoring when the economy functions smoothly, without big disruptions. However, as it was impossible to anticipate the shock associated with the outbreak and scale of the pandemic, this traditional approach was not as useful. The first signs of the crisis were only perceived when it had already started.

Against this backdrop, the search for alternative sources of information was supported by data processing improvements in recent years. For instance, the Banco de España now analyses numerous high-frequency indicators which provide significant information in real time. However, their use is not without difficulties. Specifically, the use of high-frequency (even daily) data requires making more complex calendar effect adjustments, since new seasonal, intraweek or intramonth effects emerge which do not appear in the monthly and quarterly data. Also, usually, the daily data time series are short and no full economic cycle is available for them.

Additionally, in constructing the scenarios linked to the onset of the pandemic, emphasis was placed on different aspects of the transmission mechanisms of the shocks associated with the health crisis, which it must be noted, are not the usual ones in the economic models. Accordingly, it became necessary to make alternative approximations, largely based on assumptions regarding the unfolding of the pandemic and the restrictions on movement, with these analysis starting from different degrees of regional and sectoral detail.

Different exercises were conducted to project activity for the projections published in December 2020 by the Banco de España. In an initial exercise, the measures implemented to curb the spread of infection were assessed against effective mobility and the latter, against economic activity (see Charts 7.1 and 7.2). To this end, indicators of restrictions at national and regional level were used, which were prepared on the basis of a database which analyses the frequency with which certain terms relating to the severity of the measures

Chart 7
HIGH-FREQUENCY INDICATORS AND IMPACT ON RISKS TO BANK SOLVENCY IN THE COVID-19 CRISIS



SOURCES: Banco de España and Google.

a Data from the Community Mobility Reports published by Google. Average of the retail and recreation, public transport and workplace indicators.
b Effects estimated in Ghirelli, Hurtado and Urtasun (2021).
c The net effect of the positive (negative) flows is indicated in the data label above (below) the corresponding bar. The initial and final CET1 ratios are presented as "fully-loaded". Other impacts include the change in RWAs between 2019 and 2022. A restriction on dividend distribution is considered and government measures are assumed to have an intermediate effect.
d This variable includes net operating income in Spain and net profit/loss attributable to business abroad. The aim is to compare the possible funds generated by the group as a whole with impairment losses in Spain, which are usually the focus of these exercises.
e This variable shows the projection over the three years of the exercise of gross losses due to credit portolio impairment for exposures in Spain and other losses (associated with the fixed income portfolio, management of foreclosed assets and the sovereign portfolio).
f This variable includes, among other effects, the change in RWAs between 2019 and 2022. A restriction on dividend distribution is considered and government measures (ICO-guaranteed loans) are assumed to have an intermediate effect.
g Probability of default (PD) is defined as the probability that an exposure will be classified from performing to non-performing within 12 months.This probability is estimated using a model that links the observed PD to macroeconomic variables and firms' financial ratios. The chart shows the density function of the difference (in pp) between the PD estimated for each sector under the adverse scenario and that estimated under the baseline scenario. The estimation is carried out bank by bank, but the chart depicts the average for each sector weighted by the number of borrowers. This density function is approximated using a kernel estimator, which makes it possible to obtain a non-parametric estimate, providing a continuous and smoothed representation of that function.

appear in the press. The results of this exercise therefore made it possible to translate the assumptions regarding the measures required to contain the pandemic into mobility and economic activity paths compatible with the assumptions.

An alternative approximation was based on evidence that the containment measures adopted in the face of the COVID-19 health crisis had markedly different effects across sectors of activity. The uneven effect of the pandemic at sectoral level became most clearly manifest in the labour market. The health crisis caused heavy job losses in the sectors most affected by the restrictions on mobility, such as those linked to tourism. In this connection, the monthly Social Security data on registrations and furlough schemes (ERTEs, by their Spanish abbreviation) was a reliable source for monitoring changes in activity in each sector. On the basis of this information, monthly effective employment ratios were calculated for each sector, estimated as the ratio of observed employment to the counterfactual employment that would have been observed in a hypothetical COVID-19-free situation. These ratios and scenarios regarding the course of the pandemic were used to calculate activity paths compatible with the assumptions underlying these scenarios.

Lastly, a sectoral gross value added projection exercise was also conducted under the assumption that the measures to restrict movement adopted by the authorities have different impacts for each sector of activity. To measure the degree of restriction, the Oxford COVID-19 Stringency Index (which measures the severity of the social distancing measures) is used, and the relationship between the effective employment ratios in the sectors most sensitive to COVID-19 and the monthly average of this stringency index for Spain between February and October 2020 is estimated. The impact on other sectors is calculated on the basis of the spillover effects (via an input-output model) arising from changes in activity in the sectors most sensitive to COVID-19.

Aggregate results of the FLESB exercise with impact of measures

The FLESB tool proved to be very useful to rapidly assess the impact on deposit institutions' solvency of the scenarios of possible macroeconomic deterioration associated with the course of the pandemic. In view of the uncertainty triggered by the outbreak of COVID-19, this type of stress test was particularly significant owing to its forward-looking nature and the need to anticipate potential paths of adverse changes in the macro-financial environment.

In the period 2020-2021 banks faced unprecedented global and synchronised falls in economic activity. These considerations are included in the baseline and adverse projection scenarios both for the Spanish economy and for others important for the Spanish banking sector's business abroad. A significant characteristic of the stress testing exercises carried out from the onset of the COVID-19 pandemic is the existence of different economic policy support measures implemented in response to the negative macro-financial consequences of the health crisis.[26] The beneficial effect of the measures on the macro-financial scenario

26 The mitigation measures considered in different FLESB exercises conducted since April 2020 include State guarantees on loans for productive activities, bank loan payment moratoria, the ECB's new TLTRO programme and, in the prudential sphere, the recommendation not to make dividend payments. As some of these measures started to be withdrawn, they were also eliminated from the exercises (e.g. decrease in the volume of TLTRO and end of the moratoria programmes), while others, such as credit guarantees, continued to have a significant effect on the latest exercises carried out in 2022 (see Box 2.2 of the Banco de España's autumn 2022 *Financial Stability Report*).

and their direct contribution to the absorption of losses incurred over the exercise's horizon were taken into account within the FLESB framework (e.g. application of State guarantees to reduce gross losses given default on loans to firms). There is a trade-off on these support measures: while they are beneficial under both the baseline and adverse scenarios in the nearest time horizon, in different cases they entail fiscal costs or greater indebtedness in the private sector. The FLESB has been a useful complementary tool to measure some of the benefits and costs associated with these measures.[27]

To illustrate these exercises, the results for autumn 2021 are presented. Activity at the time was on a recovery path which cemented progressively after the unprecedented shutdown of activity in 2020 Q2. However, uncertainty about the fallout of the pandemic persisted. This prompted considering adverse scenarios in which aggregate demand and supply were negatively affected by a potentially adverse unfolding of the health situation. The results showed that the aggregate Spanish banking sector was able to withstand the high economic impact of the health crisis (see Chart 7.3), with the support of the mitigating effect of the measures implemented by the economic authorities. Given the nature of this crisis, which has asymmetric effects on activity and employment in different sectors, the FLESB framework was used to estimate heterogeneous effects on the credit quality of firms of different sizes and sectors, based on the framework of sectoral probabilities of default described in Ferrer, García Villasur, Lavín, Pablos and Pérez Montes (2021) (see Chart 7.4).

Although the presence of heterogeneity in the results of individual institutions around the aggregate for the group has to be considered, this result indicated that the banking system was able to maintain its intermediation function even if a worsening of the pandemic had slowed the pace of recovery. As the situation evolved, with a reduction of the direct economic risks associated with the COVID-19 pandemic and changes in the support policies, assumptions in the stress test exercises were adapted dynamically to the identification of new risks and vulnerabilities.

4.2 Macro-financial tensions in the context of the war in Ukraine

At end-2021, global economic activity was on a path of recovery (although still uneven across geographical areas and sectors) from the impact of the COVID-19 pandemic. Inflation in different geographical areas remained higher and more persistent compared with expectations in previous quarters. Against this background, the Russian invasion of Ukraine in February 2022 heightened inflationary pressures largely, albeit not exclusively, due to its impact on the prices of energy goods, leading to an increase in both the downside risks to growth and uncertainty. An early analysis was carried out of the macro-financial risks associated with this development in spring 2022, applying several analysis frameworks of the Banco de España.

27 For example, the estimations of possible ranges of defaults associated with State-guaranteed loans for productive activities provide a confidence interval for bank savings in terms of provisioning costs and of the fiscal cost for the State associated with the enforcement of guarantees.

First, an analysis was conducted of the impact on emerging market economies of the tightening of global financing conditions and rising commodity prices in the context of the war in Ukraine.[28] Vector auto-regressive (VAR) models were used for Brazil, Mexico and Turkey (the countries the Spanish financial system is most exposed to). The first step was to use a sign-restricted structural VAR model to decompose historical monetary policy surprises in the United States. In a second step, individual VAR models were estimated to derive the average historical impact of unexpected changes in US monetary policy in the three above-mentioned countries. Then, the effect of a rise in the US policy rate on these economies, which have historically been very affected by increases of this kind, was simulated.

The results of this analysis showed how a tightening of monetary policy in the United States, as a plausible response to the risks of greater inflation identified since early 2022, would reduce growth in the three countries. Nonetheless, the scale of the impact on real activity in these economies would depend on their degree of vulnerability. In addition, the rise in the US policy rate, coupled with increased risk aversion arising from the considerable uncertainty stemming from heightened geopolitical tensions, could give rise to an appreciation of the dollar that would slow capital flows to these countries. But the Ukraine war could also give rise to a substantial increase in commodity prices, with a favourable effect on capital flows to commodity-exporting (mainly Latin American) economies. However, the estimated model suggested that substantial capital outflows could take place in these countries should all these circumstances materialise simultaneously (see Chart 8.1).

Second, the Banco de España developed a series of adverse scenarios in the immediate context of the onset of the war in Ukraine.[29] These are hypothetical scenarios which model the impact on the Spanish and international economies of certain extreme events related to this conflict. These events translated into a series of shocks in terms of commodity price rises and inflation, worsening of financial conditions and economic agents' confidence, etc. These shocks were calibrated on the basis of the recent and historical calibrations of the different variables in order to generate substantially adverse, albeit plausible, scenarios. In these exercises, the effect of the shocks on the macroeconomic projections for the Spanish economy was obtained by means of simulations carried out using the MTBE. Also, the input-output tables for the Spanish economy were used to model the uneven impact of this shock on gross value added (GVA) growth in the different economic sectors, on the basis of how intensive energy consumption and production in each sector is.

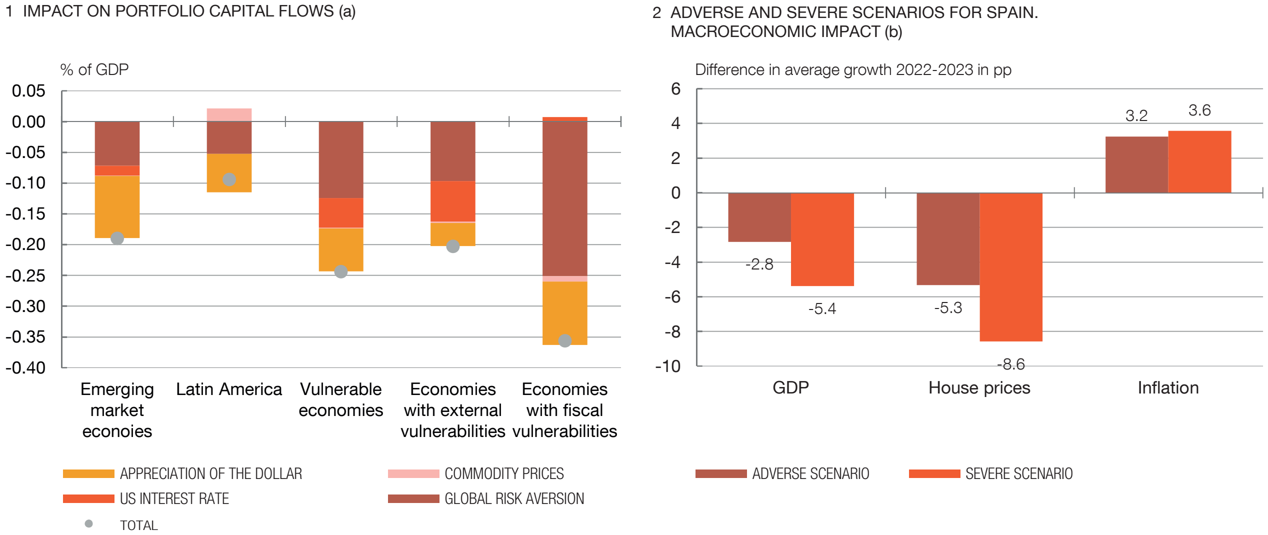
These scenarios calibrated that inflation in Spain would grow with respect to the baseline scenario by between 3.2 pp and 3.6 pp in average year-on-year terms in 2022 and 2023 under the adverse and severe scenarios, respectively. This increase in prices would be accompanied by lower GDP growth, with average downturns of 2.8 pp and 5.4 pp under the adverse and severe scenarios, respectively, in addition to a fall in the average growth of

28 See Box 1.2 of the Banco de España's autumn 2022 *Financial Stability Report*.

29 See Box 1.3 of the Banco de España's autumn 2022 *Financial Stability Report*.

Chart 8

IMPACT ON CAPITAL FLOWS IN EMERGING MARKET ECONOMIES AND MACROECONOMIC IMPACT FOR SPAIN, BY SCENARIO



SOURCES: Banco de España, Refinitiv and IMF.

a Estimate from a quarterly panel model for 23 emerging countries since 1999 (see Molina and Viani 2019), simulating the impact of a 100 bp rise in the US policy rate coupled with a 132 bp increase in global risk aversion, a 4.1% appreciation of the dollar and a 15.2% increase in commodity prices, based on historical correlations between federal fund rates and the first two variables, and the change observed in the commodity price index over the first week of the war.

b Impacts are defined as percentage point differences in the value of the variables presented, applicable to the baseline forecasts of the analysis, for scenarios with a varying degree of materialisation of macro-financial risks (higher in the severe scenario than in the adverse scenario).

house prices of between 5.3 pp and 8.6 pp, respectively, under the same scenarios, for 2022 and 2023 (see Chart 8.2).

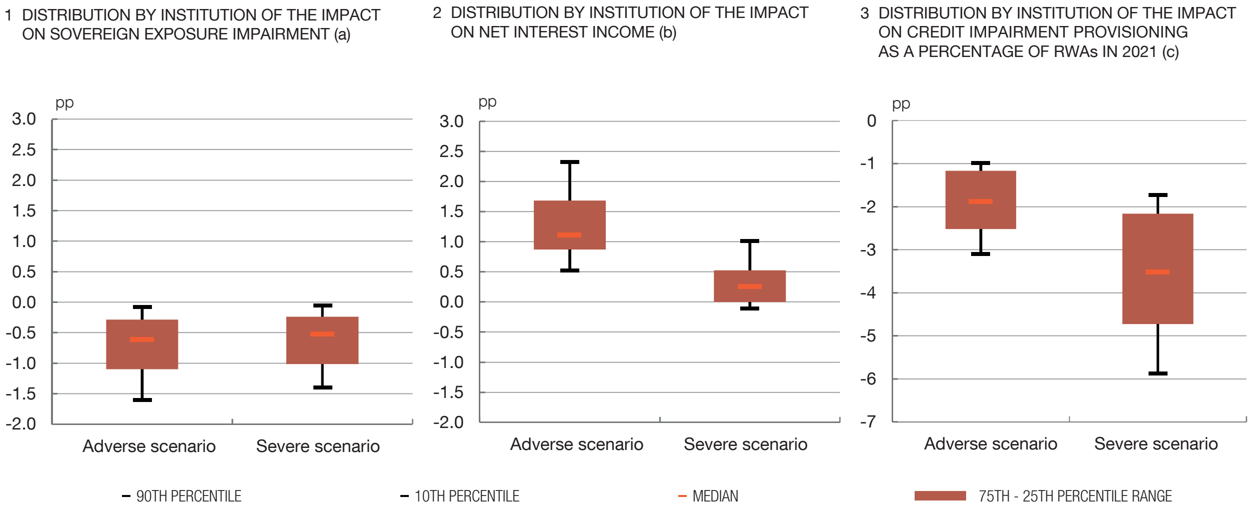
Third, the Banco de España published in 2022 an initial analysis of the impact on the banking sector of different scenarios owing to the uncertainty generated by the global geopolitical situation, using the FLESB stress testing tool.[30] To this end, the impact on banking solvency of the adverse but plausible scenarios described in the above paragraphs was measured. As noted earlier, these scenarios were characterised by a sharper than expected increase in inflation, which also triggered a further monetary tightening and, in the case of the most severe scenario, a deterioration in consumers' and firms' confidence.

The results showed that if any of these scenarios were to arise, with a significant probability of risks materialising, the Spanish banking system as a whole would be able to absorb their impact. However, they would lead to a reduction in the CET1 ratios of up to 3 pp relative to the baseline expectations. The negative impact of these scenarios would occur through several channels. First, credit risk impairment losses, which are somewhat heterogeneous across institutions and exposure sectors, would increase in Spain. Second,

30 See Box 2.1 of the Banco de España's autumn 2022 *Financial Stability Report*.

Chart 9

IMPACT ON THE SPANISH BANKING SYSTEM OF THE POTENTIAL MATERIALISATION OF THE RISKS TO FINANCIAL STABILITY IDENTIFIED FOLLOWING THE OUTBREAK OF THE WAR IN UKRAINE



SOURCE: Banco de España.

a The chart shows the distribution by institution of the impact under the adverse scenarios on the cumulative consolidated sovereign exposure losses in 2022-2023 (as a percentage of 2021 RWAs). Consolidated business. The boxes represent the values between the 25th and 75th percentiles, while the bars show the 10th, 50th (median) and 90th percentiles. The 15 largest institutions in terms of their RWAs are considered.

b The chart shows the distribution by institution of the impact under the adverse scenarios on cumulative net interest income in 2022-2023 (as a percentage of 2021 RWAs). Business in Spain. The boxes represent the values between the 25th and 75th percentiles, while the bars show the 10th, 50th (median) and 90th percentiles. The 15 largest institutions in terms of their RWAs are considered.

c The chart shows the distribution by institution of the impact under the adverse scenarios on impairment provisions for loans to the private sector in Spain in 2022-2023 (as a percentage of 2021 RWAs). Business in Spain. The boxes represent the values between the 25th and 75th percentiles, while the bars show the 10th, 50th (median) and 90th percentiles. The 15 largest institutions in terms of their RWAs are considered.

the impairment of the sovereign bond portfolio would be another significant impact channel related to the rate hike, owing to the aforementioned tightening of monetary policy caused by rising inflationary pressures. Lastly, this rate rise also entails certain mitigating elements, as it improves net interest income from the business in Spain by increasing the spread between asset and liability rates. Chart 9 shows the distribution by institution of these impacts, taking as reference the sectoral probability of default framework described in Ferrer, García Villasur, Lavín, Pablos and Pérez Montes (2021).

As expectations and macro-financial risks changed following the Russian invasion in February 2022, both the projection exercises and the stress tests were updated to reflect the new flow of information.[31] In the still highly uncertain current context, the dynamic use of these tools to adjust expectations and risks is likely to remain of high importance in the coming quarters.

31 See "Macroeconomic projections for the Spanish economy (2022-2024)", October 2022, and Box 2.2 of the Banco de España's autumn 2022 *Financial Stability Report*

5 Conclusions

The Banco de España has developed a wide range of economic and financial models to analyse the impact of the materialisation of risks on economic activity and financial stability. They include both empirical and theoretical models, which evolve according to how the real sector interacts with the financial sector.

Theoretical models generally provide a simplified representation of reality by modelling economic agents' behaviour assuming that they maximise certain specific objectives subject to restrictions. These models provide an understanding of economic and financial sector dynamics and of the way potential risks and policies may affect economic and financial stability. The most common of these types of models are the so-called DSGE models, which are used to reproduce the intertemporal consequences of different economic agents' decisions in risky environments. In recent years the Banco de España has developed a wide range of DSGE models, incorporating different types of financial frictions, changes in agents' preferences and the impact of technological change.

Empirical models seek to verify the qualitative forecasts of theoretical models and transform them into numerical estimates. They make it possible to identify how different types of risks affect the macro-financial variables and the way they interact. Of note among the empirical models used by the Banco de España are the macroeconomic forecasting models for estimating economic activity expectations, macro-financial interaction models for identifying financial imbalances and their impact on economic growth, financial market models for identifying risks related to financial crises, and bank stress testing models for measuring the impact of the materialisation of macro-financial scenarios on the solvency and liquidity of the financial system.

All these models can be used to determine the impact of the different types of risk stemming from sources both endogenous (as the global financial crisis) and exogenous (as the COVID-19 pandemic and the war in Ukraine) to the financial system. With respect to the latter events, the framework developed by the Banco de España has allowed it to rapidly identify the consequences of these shocks on economic activity and financial stability. However, the absence of valid historical references with which to compare these events has posed a major challenge in developing the models and has highlighted the need to incorporate new tools and monitoring variables (for example, models for identifying impacts under very adverse scenarios and high-frequency indicators).

Overall, the constant changes in the relationship between the real and financial sectors, the fast pace of technological developments in the financial sector, the materialisation of unexpected shocks and the non-standard policy responses have evidenced the importance of the set of models developed by the Banco de España and have fuelled an important learning process that fosters continuous improvement and innovation in the methods used.

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