TOP-DOWN STRESS TESTS AS A MACRO-PRUDENTIAL TOOL: METHODOLOGY AND PRACTICAL APPLICATION

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In this article, we present a practical guide for the implementation of top-down solvency tests capable of measuring the impact on individual and system level capital ratios of adverse macroeconomic and financial shocks. The advantages and limitations of this method are discussed in the context of the recent experience in the application of the different types of stress tests. We provide specific details on the experience of the application of this method during the Financial Stability Assessment Process conducted by the IMF on the Spanish banking sector in 2012.

1 Introduction

The macro-prudential policy framework is mainly orientated to ensure that the financial system is capable of absorbing adverse shocks without the participation of the public sector. This form of prudential policy is devoted to minimize the risk of a disruption in the provision of financial services in the economy, limiting the need for public rescue programs and other forms of government emergency aid.

The recent economic crisis has taken to the fore the relevance of the correct design and adequate implementation of macro-prudential policy. The application and development of this policy is perceived to be critical to reinforce the strength of financial systems around the world.

The toolkit of macro-prudential policy is still in phase of design and definition; however, some of its main elements have already been applied.[1] In particular, stress tests have recently been widely used to evaluate banking systems. It goes beyond the shadow of any doubt that the stability of the financial system as a whole rests essentially on that of the banking system. Thus, evaluating its resistance to shocks that can affect its normal functioning is considered of utmost importance and at the root of the main objectives of macro-prudential policy.

The guiding principle in the application of stress tests is that these exercises, considered as a diagnosis tool, must help to evaluate and formulate regulatory and supervisory policies with the aim of enhancing the soundness of the banking sector and the efficiency of financial intermediation. This would improve the overall allocation of scarce resources in the economy, with the resulting positive impact on social welfare. Stress tests are thus thought to enhance preventive policies which are at the core of macro-prudential mandates. These tests can also help credible disclosure of supervisory information to financial markets, as pointed out in Gick and Pausch (2012).

In their origin, stress tests were carried out by banks themselves with no need of prescriptive requirement to run them by the supervisory authorities. These tools were an element of business analysis and risk management, designed and implemented for strategic purposes: pursue of management policies more attuned to bank risks, better allocation of the funds raised by banks and improvement of the quality of their business in anticipation of possible unfavourable shocks. The extension of the VAR techniques to manage the risks of financial firms through the late 80s and early 90s exemplifies the private sector search

1 Other tools are countercyclical capital buffers [see Repullo, Saurina and Trucharte (2010) for a thorough discussion], dynamic or countercyclical provisions [see Saurina (2009)] or G-SIBs capital surcharges [see BCBS (2011)].

for stress testing tools. The collapse of the New York Stock Exchange in 1987 and the turbulence in the European monetary market in the early 90s provided strong incentives for more sophisticated risk management tools such as Value at Risk (VAR).[2]

Based on the initial impulse provided by banks, supervisors with micro-prudential responsibilities realized that they could also use stress tests as a tool to assess the overall resilience of individual entities. These are the so-called bottom-up stress tests where, under a certain economic shock, each bank assesses its individual solvency and resilience under the scrutiny of micro-prudential supervisors. A model of credit risk is at the heart of the internal ratings-based approach to capital requirement calculation in Basel II. Supervisors started to incorporate bottom-up stress test as an additional tool for market, credit and liquidity risk assessment, which has gained special relevance in recent years. In the context of Basel II regulation, the prudent management requirements under Pillar 2 would contemplate this use of stress tests.[3] The application of this tool is varied, and particularly adapted to the specific idiosyncrasies surrounding a given exercise: type of entity, business, analyzed portfolios, scope of the exercise, time-horizon, etc.

As a complementary tool to bottom-up stress tests, macro-prudential authorities, mainly central banks, with or without bank supervision responsibilities, have started to develop and use top-down stress tests. These alternative tests provide an overall picture of the resilience of the banking sector as a whole. They are becoming also a core macro-prudential tool for the achievement of an accurate and adequate assessment of the situation and condition of the whole banking system. Sorge (2004) provides an early overview of this form of stress test. Burrows *et al.* (2012) and FRB (2012) summarize the methods for the macro-prudential tests applied in the U.K. and the United States. Greenlaw *et al.* (2012) provide analysis of the recent international experience with this form of test.

In general, the main objective of top-down stress tests is to evaluate the loss absorption capacity of a system under scrutiny. These stress tests aim to identify vulnerabilities while assessing and evaluating the loss-absorption capacity of a given banking system when these vulnerabilities crystallise and become real shocks. Consequently, macro-prudential stress tests should be regarded as a supplementary tool for supervisory activity, which provide firm and certain criteria to take proactive and reactive measures to cope with the impact of a predefined shock to the system. Particularly, a top-down stress test aims to provide an order of magnitude estimate of capital needs. This is achieved by adding up bank by bank results based on a general model of the banking sector, rather than on specific information and models at the individual bank level, which is the aim of a bottom-up stress test.[4]

Hence, stress tests, run either by banks themselves (management purposes), or bottom-up carried out by micro supervisors, or top-down elaborated by macro-prudential authorities (diagnosis purposes), can serve as a basis for fostering prudential techniques of protection against adverse situations and, therefore facilitate prevention and early warning response tasks to deal with hypothetical but plausible adverse situations.

2 See Jorion (2006) for a complete review of VAR techniques. J.P. Morgan is regarded as an early adopter of this technique in the late 1980's. This bank later spun-off its VAR analysis activities into the company Riskmetrics, which provides risk management services to this day.

3 See Part 2-Section III of BCBS (2006) for internal ratings-based calculation of Basel II capital requirements and Part 3 for Pillar 2 requirements. Supervisory expectations of standards for bottom-up stress-testing have developed over time. See CEBS (2010).

4 Individual bottom-up stress test results can also be added up to evaluate a system and gain insight from granular bank information and models. The use of bottom-up tests for this purpose implies a more complex implementation and heterogeneous treatment of different banks. Additionally, it must be noted again that the original purpose of bottom-up stress tests is to analyze individual banks.

In addition to the reasons considered above, the design and implementation of stress tests has taken on particular importance in recent years due to the recommendations of the International Monetary Fund (IMF) and the World Bank. These institutions recommend running stress tests regularly and these exercises have been assigned a major role in the FSAP program («Financial System Assessment Program») to assess the stability of international financial systems in both developed and emerging economies.[5] These recommendations and the concerns in relation to financial stability reviewed above highlight the need to establish a series of basic principles and guidelines for a systematic approach to stress tests. These principles would apply to both top-down and bottom-up stress tests, to enhance both their rigour and simplicity. This article is intended to contribute to this goal.

The rest of the article is organized as follows. Section 2 briefly describes the most representative features of stress test exercises and its main elements. Section 3 explains stress test methodology and design in depth. This section is presented, in indicative terms, as a practical guide on how to set up and carry out a stress test exercise appropriate for the structure, complexity and risk profile of a given system under examination. Section 4 describes the practical application of these methods to Spanish 2012 IMF's FSAP. Finally, Section 5 presents further considerations on the main objectives and actual effectiveness of this tool.

2 Description of the types and main elements of stress tests

A stress test is usually defined as a set of techniques, tools or, in general, procedures used by either individual institutions or supervisory authorities to gauge, as objectively as possible, the financial condition of the system under examination. In particular, stress tests are normally focused on the evaluation of the solvency and liquidity of the banking system. These tests aim not only to identify possible vulnerabilities (expressed in the form of adverse shocks) that can affect the financial situation of a certain institution or financial system, but also to estimate and evaluate as accurately as possible the quantitative impact of those shocks. In short, the objective is to test the stability and resilience of the system or institution being assessed and analysed.

It is generally accepted that carrying out any stress test normally involves the following stages: 1) Delimitation of the scope of application of the test; 2) Definition, design and calibration of the shocks with which the system under examination is to be stressed; 3) Estimation of the impact of the shocks chosen and quantification of that impact in terms of variables determining the financial condition of the system to be tested, and 4) Identification of the possible considerations and policy measures deriving from the results obtained in the point above. Figure 1 summarizes the details of each stage.

The scope of application is chosen based on the implications that are to be drawn from the stress exercise, which is basically a matter of selecting between a general analysis of the financial system and a study of specific portions.

Tests of a general nature (broadly speaking, macro-prudential tests) encompass the analysis of the greater part of the financial system, or at least that of its most significant components. Their objective is therefore to test the resilience and stability of the financial system as a whole.

In this type of exercise, the system can be treated at aggregate level (a general model of the banking sector is used), so that in order to subsequently descend to individual-institution

5 IMF (2010) details the incorporation of the financial stability tests to the FSAP exercises. IMF(2012a) provides guidelines for this exercise and a summary of the experience of the IMF in its application.

STRESS TEST IMPLEMENTATION FIGURE 1

SCOPE OF THE STRESS TEST EXERCISE

1 **Top-Down:** Whole system/Significant Portion, Homogeneous Data and Framework of Analysis.
2 **Bottom-Up:** Bank Level, Bank Specific Model and Data.

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CALIBRATION OF MACROECONOMIC/FINANCIAL SHOCKS

1 **Shock Type Specification:** Domestic Macro Shock, Financial Markets, International Shock.
2 **Shock Size Determination:** Sensitivity Analysis (Historical Calibration of selected variables) or Scenario Analysis (Consistent hypothesis for multiple macro-finance variables).
3 **Shock Effect Specification:** Choice of Econometric Model relating Macro variables to Bank Financial Condition Variables.

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ESTIMATION OF THE IMPACT OF MACRO SHOCKS

1 **Data Collection:** Macro Variables, Bank Level Variables, Loan Level Variables.
2 **Model Estimation:** Econometric estimation for the model of the shocks chosen.
3 **Measurement of the effect on financial stability measures.**

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POLICY FORMULATION STAGE

1 **Adoption of Remedy Actions in response to detected weaknesses.**
2 **Communication Strategy.**

SOURCE: Author's elaboration.

level, the results obtained are applied to each separate component of the system (top-down approach). Alternatively, if models and information at the individual level from a sufficiently representative number of financial institutions (by size or by type of business) are used, then this exercise is regarded as a bottom-up approach.

There is another type of stress tests of a much more specific nature. This is carried out at individual level (micro-test) and the analysis relates to one particular financial institution (or a very small group of them). A more specific form of stress test focuses within each institution on one or more portfolios, which are analysed because of their relative importance.

Additionally, the time horizon considered is another key parameter to be taken into consideration. Typical stress tests cover more than one business year (two or three business years). A trade-off arises at this point. On the one hand, sufficient time must be allowed for the consequences of the shocks to fully crystallise, and on the other hand, a longer time horizon may imply an excessive loss of reliability in the estimates with which to determine the final impact and results of the exercise.

The second stage of a stress test consists of establishing those improbable, but plausible adverse shocks that may negatively affect the stability of the system being tested and with respect to which the system's soundness and resilience is to be checked. The process of characterising the shocks to be considered consists in turn of various sub-stages.

First, the type of shock to be considered must be determined (identification and definition). Subsequently, the shock is calibrated (the size of the shock to be considered is specified) and then implemented (introduction into the system and quantification of its impact). It must be noted that stress tests are not forecast exercises. On the contrary, shocks although plausible are highly improbable. The probability of occurrence is another parameter to be considered in the stress exercises. The credibility and utility of the results obtained depend to a great extent on the selection of acceptable scenarios both in terms of macro-variables affected and in the probability assigned to them.

Based on the above terms, once the shock is chosen on the basis of the risks to be measured and calibrated according to the type of analysis to be conducted, then it is implemented using the main variables (certain specific key parameters) that, due to their nature and availability, have the most significant direct or indirect effect on those risks.

The determination of the size of the shock (shock calibration) depends on the nature of the analysis to be conducted. In sensitivity analysis, the usual practice is historical calibration, under which the size of the shock is chosen according to the largest change that a certain variable to be shocked has undergone during a certain time period. The choice of this time period is closely related to the type of risk being analysed and to the market circumstances prevailing over that period. The periods are generally between 20 and 30 years, although in the case of certain variables lacking historical depth, this interval may be limited to 10 or 15 years.

The most complete and common approach to determine the size of the shock is using scenario analysis. In terms of completeness and adequacy, this is the best way of determining the resilience of a system under consideration. Scenario analysis contemplates the variations of a broad set of variables (macro-variables) and how these changes affect the system. As for the single variable case commented above, the scenario chosen is assigned a certain probability of occurrence. The final credibility and utility of the stress exercise depends again, among other factors, on the probabilistic calibration considered.

The third stage of a stress test is to specifically estimate the impact of each shock. In this stage, it must be decided how the shocks defined and calibrated in the previous stage are to be included in the system, i.e. a quantitative assessment is to be made of the impact on the system's financial condition, so that its resilience to the shocks used can be evaluated.

This stage is based on the relationships established (usually via an econometric model) between macro-variables and the main elements, under the form of economic and financial variables, of the banking system. It consists of choosing certain key variables that directly affect the financial condition of the system analysed (for example, a certain portfolio or some of its components) and estimating how they change in response to the defined shock.

This part of the stress test thus consists of determining how macro variables change and then expressing those changes in terms of the variables that determine the financial condition of the system under examination (generally profitability and solvency).

As a corollary to the previous stages, policy responses must be considered once the impact on financial stability and the estimated resilience of the system have been determined from the results of the stress exercise. There is a need to consider what measures will help the smooth working, efficiency and continued stability of the system under examination. This is usually known as the policy-oriented phase. If major weaknesses have been detected and remedying them is a priority, it will be necessary to focus on revising, adjusting and strengthening the existing prudential elements currently in place.

3 Methodology design and practical application of scenario analysis

This section deepens in the details of the design and practical implementation of a specific macro-stress exercise considering that the scope of application is the banking sector as a whole and that the objective of the test is to measure the solvency of this system. It is intended to serve as a model for how to approach stress testing and as a practical implementation guide for possible use by supervisory authorities.

Scope of the stress-test

As just mentioned above, the scope of application of this type of stress tests is the financial system as a whole, although depending on the type of analysis or risk considered, the scope may be confined to the most significant part of the system,[6] which is formed by a specific group of representative institutions (chosen either for their size or type of business) with a high relative importance within the system. The kind of approach (top-down or bottom-up) to be used in the stress test will be primarily determined by the availability of data to the supervisory authority. Both approaches have strengths and weaknesses.

From the supervisory standpoint, the top-down approach calls for a stress test structure that is both common (in terms of tools and methodology) and standard (applied identically to all participating entities). This normalised structure allows to define a test which is applied coherently and consistently regardless of the type and number of banks taking part in it. The use of a proprietary framework applied uniformly for all participants yields results free from the arbitrariness and heterogeneity caused by internal differences in the methodology, calculations, importance and type of business of each individual institution.

The main weakness of this approach is the lack of the detailed individual information that is the main strength of the bottom-up alternative. The richness of the information and the level of detail available to individual institutions enables a much more accurate perception of their risk profile and the impact that a particular shock would have. This greater level of detail, as compared with the uniformity of the common method, is the trade-off that must be weighed up when deciding which approach to use.

The most complete stress exercise would undoubtedly be one in which the data available to the supervisory authority and to the individual institutions are fairly similar (e.g. via regular reporting by the latter). The exercise would be carried out by the authority (top-down approach) for the system as a whole. Simultaneously, the participating banks would carry out exactly the same type of test (the same assumptions and shocks) as the supervisor. These results would then be aggregated (bottom-up approach) and examined for convergence between those obtained in the two different approaches. Ideally, it would be found that the exercise carried out by the authority replicates the results reported by the individual institutions using their own methodology.

In any event, the availability of data will determine the robustness of the analysis and whether the exercise can be conducted for the total system by the supervisory authority and/or individually by the participating institutions. Together with data availability, the quality of data is essential for the accuracy and appropriateness of the exercise.

Macro-financial model/ system shocks

A stress exercise generally involves two types of analysis: a very simple sensitivity analysis, and other much more complex and complete scenario analysis. Sensitivity analysis seeks to estimate how the main determinants of the financial condition of credit institutions are

6 Since the activity of the financial system of many countries is, in terms of relative weight, dominated by banks, its soundness can be gauged using a stress test confined to the banking system. This simplification, which does not limit the applicability and usefulness of the exercise described above, is followed in this article.

impacted by certain one-off shocks to specific risk factors (e.g. the determinants of credit risk) of bank portfolios. Unlike sensitivity analysis, scenario analysis generally uses econometric models to estimate how the main macroeconomic and financial aggregates of the system would be affected in a certain stress scenario.

The application of scenario analysis will use the balance sheet and the profit and loss account to model the transmission of the macroeconomic shock. That is, the shock will impact business risk that affects balance sheet items and certain elements of the profit and loss account, and credit risk affecting the profit and loss account via credit provisions - expected losses. Depending on the approach chosen, these financial statements would be either those of the system as a whole, or those of individual participating institutions.

We consider that the role of modelling in scenario analysis should not be reduced to estimating a single equation that, as usually occurs, is the bottom line of the profit and loss account; rather the analysis should be developed further so as to provide a more comprehensive breakdown that distinguishes different balance sheet items and their contribution to the profit and loss account. This approach considerably enriches the exercise and it enables step-by-step monitoring of the various items comprising a bank's main activities and operations. Basing the analysis only on the bottom line of the profit and loss account carries the danger of concealing individual effects that may be very significant for certain balance sheet groupings (or for their contribution to the profit and loss account). These concealed effects influence and alter the interpretation of the banks' risk profile and sensitivity to certain risks.

Distinct balance sheet items show differing sensitivities to certain shocks and they may also vary by different amounts in response to changes in the value of certain macroeconomic variables. For instance, interbank financing positions and equity instruments respond differently to a scenario of falling stock market prices. As an additional example, credit growth and fee and commission income respond differently to an economic recession deriving from a stress scenario of contraction in domestic demand. The items of the profit and loss account that would be typically considered in this exercise include interest income, fees and commissions, operating expenses and provisioning charges (impairment losses). We examine in more detail some of these income elements below.

Business risk

As stated above, business risk is measured by simulating the balance sheet and profit and loss account of the total system (or those of each individual bank), first under the conditions of a baseline scenario and then under those set in each stress scenario. This simulation consists of estimating certain balance sheet groupings, their implicit return and certain profit and loss account components. To do this, use is generally made of econometric models, accompanied by supervisory judgment in case of poor performance of regression equations.

We briefly consider the model for net interest income as an example. This is one of the main items that a stress test exercise should include. To model this item of the profit and loss account, different elements of the balance sheet are taken into consideration. Basically, financial products that produce income on the asset side (interest income), and products on the liability side that imply costs (interest cost). These elements are introduced in the stress framework with equations that relate interest rates and exposures to macro-variables. A particular example would be the mortgage credit portfolio, which is one of the elements from the asset side generating income and is subject to be included in the model. In this respect, the stress test framework models on the one hand the average rate charged to the loans in this portfolio, an on the other hand, the average mortgage exposure. Their interaction (multiplication of the price and volume of this element) provides the contribution of this asset item to net interest income. The rest of the asset elements of the balance sheet that produce income are modeled in an analogous way.

Similarly, modeling financing costs (rates and amount of financing obtained) from the liability side provides its contribution to interest costs. Aggregating the cost of all financing sources allows us to arrive at the total cost of liabilities. Finally, net interest income is obtained by subtracting from the asset contribution the liability cost.

In Section 4, we provide a detailed description and explanation of the regression equations and the macro-variables in the model for the balance sheet and profit and loss items of the main banks in the Spanish financial sector.

Credit risk

Regarding the impact on credit risk (via borrowers' creditworthiness), the approach proposed here is not based on estimating an equation for credit loss provisions (based on macro and financial variables)[7] and using those estimates to adjust the bottom part of the profit and loss account. The basic weakness of this approach is the arbitrariness and lack of uniformity at international level in the regulation and application of the provisioning systems.

Stress tests for this type of risk should begin by distinguishing between portfolios (different asset types), e.g. a differentiation between risk exposures to firms and individuals (within the latter, mortgage loans should be distinguished from the rest, basically consumer credit). This separation enables the specific design, calibration and adequate determination of the impact of the shock in question on every differentiated exposure. A particular shock may have a different impact (to the point of having or not having an effect) depending on the portfolio considered. Given the different levels in the values of the risk parameters that characterise each portfolio, it is absolutely necessary to distinguish between them so that the amount of shock can be accurately determined for calibration purposes.

The key parameters in credit risk analysis are basically the following: probability of default (PD), loss given default (LGD) and exposure at default (EAD). Determining the amount of the shock to which they are to be subjected is the next step in the stress exercise for this particular risk.[8]

In order to measure more exactly the credit quality of the banks's borrowers, we use the obligors' probability of default (PD). The reason for this decision is based on the fact that this parameter is the measure generally used by banks in their internal models to evaluate and manage credit risk. Since the world-wide implementation of Basel II, it is also the basic reference parameter for the supervisory authorities in assessing this type risk.

We thus propose that the estimated change in credit loss provisions under each stress scenario be driven and, ultimately, determined by the change in the expected loss resulting from variations in the PD due to shocks to the economic variables used in each scenario.

7 The dependent variable explained by this equation is generally either the system's non-performing loans ratio, the projected value of which is the basis for determining the volume of provisions to be used given the stress macroeconomic scenario, or directly the volume of provisions (flow or stock).

8 The probability of default is one of the central concepts for measuring credit risk used by the Basel Committee on Banking Supervision in its publications, particularly that instituting the current framework for international convergence on capital measurement and capital standards. See BCBS (2006) for more details and for its definition.

The parameterisation of the PD entails the development of a statistical model to relate it to different factors, some of which must be macroeconomic and financial system variables, e. g., economic activity (GDP growth), unemployment rate, interest rates and other variables likely to affect the debt service capacity of bank borrowers. This would yield a cyclical PD dependent on the economic conditions of each scenario.

Granularity in the PD estimation is achieved by differentiating several key portfolios within total banks' credit exposures. Particularly, for our stress test framework, we distinguish among the mortgage portfolio, exposures to real estate developer loans, loans to other non-financial firms, and consumer lending. To take an example, the PD of the mortgage portfolio depends on interest rates, economic activity and the housing price index. As for business risk, details of this element of the model can be found in Section 4, together with the equations that relate the PD of the other portfolios to macroeconomic variables.

The full pass-through of a stress scenario to credit risk will be achieved once LGD and, where applicable, EAD can also be expressed in terms of macroeconomic variables, as described for the probability of default. For example, changes in loan-to-value ratios, real estate prices or interest rates directly affect the value of LGD for modelling purposes.

The customary procedure for LGD is to assume an ad-hoc increase by a given percentage thereof or to define some kind of range of variation and use it to calculate the change in credit risk.

As regards EAD, it will move in line with estimates of credit growth given by the macroeconomic scenario and the values assumed for the macroeconomic variables used. EAD should also be, in principle, dependent on cyclical fluctuations in economic activity, affecting total credit exposure of banks.

Once the stressed values of the risk parameters are known, the stressed expected losses associated with each scenario can be found immediately, and this determines the volume of provisions to be set aside by banks to meet those losses and, finally, their impact on the profit and loss account.

Other modelling considerations and interpretation of results

A remaining challenge in scenario analysis is to take into account second-round and feedback effects not usually addressed in this type of stress exercise. As mentioned above, in the scenario analysis described so far, shocks only move in one direction. However, a complete analysis of their total impact should reflect the amplified effects on the financial system once the initial consequences of the original impact are reintroduced into the macro model equations of the real sector.

We present a simplified example to illustrate the feedback problems. We assume a scenario of zero growth in economic activity. This, among other effects, will induce a decrease in the credit quality of banks' borrowers (increase in credit risk). Banks will react by cutting back on new lending, which will clearly affect economic agents (basically households' and firms' borrowing capacity), aggravating the initial general economic situation and therefore amplifying the original shock. The initial scenario of zero growth will worsen, turning into one of negative growth, which obviously will affect obligors' credit quality more adversely than initially. The convergence mechanisms of the multi-equation model would eventually bring the feedback process to an end and the total amount of the shock would be fully determined.

The dynamics of the effects described so far seem, in principle, easy to understand. However, the complicated relations between the financial and the real sector are hard to define and accurately estimate. Nevertheless, a very simplistic approach could be used to approximately evaluate these feedback effects. This would consist of amplifying, to some extent, the initial amount of shock coming from the originally predefined stressed scenario. That increase must be large enough to account for the additional impact that feedback effects would have on the financial system.

In all, once a shock and its size have been determined, its impact on the financial condition of the system is estimated with the final aim of testing the system's resilience. This is done by assessing that impact on the different items of the profit and loss account. Additionally, the impact on expected losses is derived from the estimated change in the PD and LGD and, where applicable, from the exposure to be considered.[9] Once the bottom line of the profit and loss account is obtained, the impact on solvency is calculated accordingly. The change in the capital ratio is determined from the estimated loss (or lower profits) and therefore the decrease in reserves.

Although the calculation of the impact on profit and solvency seems to be immediate, care must be taken with how this is done when the time horizon exceeds one year. Apart from the mere comparison of annual figures in the baseline and stress scenarios, it is of interest to analyse the effect of the shocks by aggregating the profit figures for each year to give, finally, the cumulative figure for the last year of the time horizon. This aggregated figure best reflects the impact of the stress test on the system's financial condition for each of the scenarios considered.

Accordingly, the impact on profitability is obtained as the difference between the profits calculated under the baseline scenario and those for each of the specified scenarios. Similarly, the impact on solvency is determined by comparing the ratio of the baseline scenario with that of each of the stress scenarios taking the cumulative effect of that comparison on the capital ratio at the end of the predefined time horizon (last year of the period considered).

In principle, the guidelines given in this paper for treating business and credit risk in scenario stress tests would be valid for gauging whether the capital of banks would be able to absorb a given shock or, for example, whether the capital cushion in excess of the regulatory minimum requirement is sufficient to cope with the related shock.

4 A practical application of top-down stress testing methodologies: International Monetary Fund's 2012 FSAP in Spain

During the first half of 2012, the International Monetary Fund, IMF henceforth, carried out, in close collaboration with the Banco de España, a top-down stress test exercise as an important part of the 2012 FSAP of Spain.[10] A FSAP is designed to assess the stability of the financial system as a whole and, as such, a stress test exercise is one of the most relevant elements of this assessment process.

4.1. DESCRIPTION OF 2012 FSAP IN SPAIN

The top-down stress test framework detailed in previous sections was used for the implementation of a solvency exercise included in the FSAP. It was conducted to assess solvency risks under a baseline and two adverse scenarios (see Table 1). The stress test covered over 95 percent of the domestic banking sector (by total assets, excluding foreign branches), over a two-year horizon (2012-2013), with use of end-2011 supervisory information as base for the balance sheet and profit and loss projections of the exercise.

9 In principle, the amount of impairment losses would be equal to the point-in-time expected losses on the loan portfolio.

10 For more details see: http://www.imf.org/external/pubs/ft/scr/2012/cr12137.pdf.

FSAP SCENARIOS **TABLE 1**

Variable		Scenarios					
		Baseline		Scenario 1		Scenario 2	
	2011	2012	2013	2012	2013	2012	2013
Real GDP Growth (in percent)	0.7	-1.7	-0.3	-2.5	-0.7	-4.1	-1.6
GDP deflator (in percent)	1.4	1	1	0.6	0.5	0	-0.5
Nominal GDP growth (in percent)	2.1	-0.7	0.7	-1.9	-0.2	-4.1	-2.2
3-month Euribor rate (in percent)	1.4	0.9	0.8	1.4	1.3	1.9	1.8
12-month Euribor rate (in percent)	2	1.6	1.5	2.1	2	2.6	2.5
Change in consumer price index (in percent)	3.1	1.8	1.6	1.6	1.2	1.1	0.2
Unemployment rate (in percent)	21.6	23.8	23.5	24.2	24.5	25	26.6
Exchange rate in US dollar	1.4	1.3	1.3	1.3	1.3	1.3	1.3
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Madrid Stock Exchange index price	-14.6	-1.3	-0.4	-21.3	-0.4	-51.3	-0.4
Credit growth (in percent):							
Households	-1.5	-3.8	-3.1	-4.9	-5.8	-6.8	-10.5
Non-Financial Firms	-3.6	-5.3	-4.3	-5.6	-3.8	-6.4	-3
House price change (in percent)	-5.6	-5.6	-2.8	-10.6	-3.1	-19.9	-3.6

SOURCE: IMF (2012b).

The baseline economic growth projections for Spain were consistent with the IMF's World Economic Outlook Update (January 2012), while the two adverse scenarios comprised more adverse economic scenarios, with a specific focus on real estate prices. These alternative scenarios are purely hypothetical and designed to test the resilience of the system. They are not forecasts and they do not even represent probable economic conditions. However, the scenarios are internally consistent, as they are elaborated with a general equilibrium model of the Spanish economy.

(Scenario 1) A "double-dip" recession scenario of one standard deviation from the baseline GDP growth trend over the two-year horizon ("IMF adverse" scenario). In this scenario, most of the shock to economic growth occurs in the first year resulting from a sharp decline in output, further declines in house prices close to levels observed in 2002, and rising unemployment.

(Scenario 2) An alternative adverse scenario ("BdE adverse") where the shock to the two-year real GDP growth is more modest, i.e., the fall in GDP is reduced by 2.5 percentage points relative to the "IMF adverse" scenario.

The scenarios also included valuation haircuts on sovereign debt held in trading and available for sale portfolios. The haircuts were estimated based on the impact of the forward term structure of sovereign credit default swap (CDS) spreads on sovereign benchmark bonds as of the end of 2011.

Additionally, the flexibility of the framework allowed us to include additional provisioning requirements affecting expected losses. In particular, those introduced in the Royal Decree Laws of February and May of 2012, which were approved by the Spanish government to complete the reform of the banking sector.

The staff of the Banco de España involved in the FSAP 2012 completed a top-down stress test based on a model derived from the principles described in this article.[11] They also participated in the adaptation of the general top-down stress test solvency framework developed by the IMF to the prevailing conditions of the Spanish banking system.[12] The communication and joint work of the Banco de España and IMF staff facilitated to adjust both the Banco de España stress test framework and the IMF general methods to the specific circumstances of the Spanish banking sector at the end of year 2011. The participation of staff teams of both institutions in the application of all the different methods also contributed to their cross validation.

The results for the solvency and liquidity stress tests are available publicly in the report FSAP (2012), which presents detailed information for the different scenarios.

4.2. ANALYTICAL MODEL FOR A SOLVENCY TOP-DOWN STRESS TEST

The stress test framework presented in this article is supported by an econometric model which relates balance sheet and profit and loss (P&L) account items with macroeconomic variables. The core elements of the econometric model are the forecasting equations for net interest income, with a distinction of the evolution of exposures and interest rates, net fees and commissions, operating expenses, and credit losses, with differentiated models for different types of credit exposures. These elements are complemented with additional predictions for other elements of the P&L. We detail next the main elements of the model. The Annex to this article contains a full list and description of the model variables.

Net interest income

The interest rate $rate_{ist}$ earned (paid) on a class of financial products s corresponding to an asset (liability) is forecasted by projecting the historical series of this variable onto its own lags and the contemporary and lagged values of the interbank rate, i. e., the Euribor 12 months ($euribor_t$). The subindexes i, t and s denote the bank, time period and the class of financial product, with s = FA for financial assets with interest producing income, and s = FL for onerous financial liabilities with interest cost.

The growth in the exposure of the bank to different assets and liabilities ΔExp_{ist} is modelled separately with a projection on its own lag and macroeconomic variables such as growth in real gross domestic product ΔGDP_t and growth in the housing price index ΔREP_t. The forecast of the exposure to a financial product in a given year t is then calculated as:

$$Exp_{ist} = Exp_{ist-1} (1+\Delta Exp_{ist}) \quad [1]$$

It follows that the forecast of total income or expense from a class of financial products is then defined as:

$$Inc_{ist} = Exp_{ist} (1 + rate_{ist}) \quad [2]$$

The net interest income is then calculated as the difference of interest income on financial assets and interest expense from financial liabilities:

$$NII_{it} = Inc_{i,s = FA,t} - Inc_{i,s=FL,t} \quad [3]$$

Net commission fees

The net commission fees are split into fees for banking services (s'= B) and fees for brokerage services (s'= BR). We model the growth of commissions, $\Delta Com_{is't}$, and its contribution to the margin from each of the previous two categories separately with a

11 The whole stress framework benefited from the interaction and collaboration with the IMF staff.

12 The description of the IMF methods for top-down solvency and liquidity stress tests can be found at Schmieder *et al.* (2011) and Schmieder *et al.* (2012). The market based approach used in the IMF (2012b) of Spain originates from the work in Gray *et al.* (2010).

projection on their own lags and macroeconomic variables such as growth in real domestic product ΔGDP_t and the growth in the Madrid Stock Exchange Index ΔMI_t . The final forecast for the net fees of each class s´ in a given time period t is then defined:

$$Com_{is't} = Com_{is't-1} (1 + \Delta Com_{is't}) \quad [4]$$

and the total net fees and commissions add up over the subclasses corresponding to banking (B) and brokerage services (BR):

$$Com_{it} = Com_{i,s'=B,t} + Com_{i,s'=BR,t} \quad [5]$$

Other financial Income

Income from other financial operations, income from equity instruments, exchange differences and other operating income are calculated using both expert judgement and auxiliary equations. In particular, the auxiliary equation of the growth in return from financial operations, $\Delta RFO_{it,}$, projects this variable onto its own lags, macroeconomic variables and credit growth. The forecast of income from financial operations RFO_{it} is then given by:

$$RFO_{it} = RFO_{it-1} (1 + \Delta RFO_{it}) \quad [6]$$

The auxiliary equation of the growth of equity instruments, ΔEII_{it} , projects this variable onto its own lag and macroeconomic variables. The forecast of income from equity instruments EII_{it} is given by:

$$EII_{it} = EII_{it-1} (1 + \Delta EII_{it}) \quad [7]$$

The auxiliary equation of the growth in other operating income, ΔOI_{it} , projects this variable onto its own lag, macroeconomic variables and credit growth. The forecast of other operating income OI_{it} is given by:

$$OI_{it} = OI_{it-1} (1 + \Delta OI_{it}) \quad [8]$$

The auxiliary equation of the growth in gains from exchange differences, ΔFX_{it} , depends on its own lags and macroeconomic variables. The forecast of income from foreign exchange differences DFX_{it} is given by:

$$DFX_{it} = DFX_{it-1} (1 + \Delta DFX_{it}) \quad [9]$$

The gross operating margin GOM_{it} is then computed as:

$$GOM_{it} = NII_{it} + Com_{it} + RFO_{it} + EII_{it} + OI_{it} + DFX_{it} \quad [10]$$

The model for the growth in operating expenses ΔGX_{it} is also given by an auxiliary equation for the growth of this variable as a function of its own lag, macroeconomic variables, labor costs DEX_{it} and credit growth. The level forecast for operating expenses is then:

$$GX_{it} = GX_{it-1} (1 + \Delta GX_{it}) \quad [11]$$

Credit risk, expected losses and provisions

Expected losses and their translation into specific provisions for particular classes of risk (asset classes) are calculated from regulatory data on credit exposures and the risk embedded in those exposures.

We model separately the evolution of credit performance for the mortgage portfolio, the non-financial firms (excluding real estate developers) portfolio, real estate developers' portfolio and consumer lending.

The default events (probabilities of default) are modelled using a logistic model by which a given loan u in credit class NFF (Non Financial Firm), credit class RED (Real Estate Developer) or MORT (Mortgages) in the loan book of bank i defaults at period t if the latent variable $\omega_{s,u,it}$ is below zero ($\omega_{s,u,it} < 0$), where s indexes the credit classes. The latent variables are defined as the sum of a bank-class specific factor $\delta_{s,it}$ and an idiosyncratic component $\varepsilon_{s,u,it}$: $\omega_{s,u,it} = \delta_{s,it} + \varepsilon_{s,u,it}$. Under the assumption that $\varepsilon_{s,u,it}$ follows a type-I extreme value distribution, the probabilities of loan default in large portfolios conditional on asset class factors are given by:

$$PD_{NFF,\,it} = \frac{\exp\left(\delta_{NFF,\,it}\right)}{1+\exp\left(\delta_{NFF,\,it}\right)} \qquad [12]$$

$$PD_{RED,\,it} = \frac{\exp\left(\delta_{RED,\,it}\right)}{1+\exp\left(\delta_{RED,\,it}\right)} \qquad [13]$$

$$PD_{MORT,\,it} = \frac{\exp\left(\delta_{MORT,\,it}\right)}{1+\exp\left(\delta_{MORT,\,it}\right)} \qquad [14]$$

The asset class specific factors ($\delta_{NFF,it}$, $\delta_{RED,it}$, $\delta_{MORT,it}$) are forecasted with projections of these variables on their own lags and macroeconomic variables, creating an effective link between the macro scenario and credit conditions. The asset class specific factors are not observed but they can be recovered from data on default rates with a simple non-linear transformation. For example, a data observation $PD_{NFF,it}$ implies that $\delta_{NFF,it} = \ln(PD_{NFF,it}) - \ln(1 - PD_{NFF,it})$.

The expected losses materialised corresponding to the estimated credit risk incurred is finally calculated as the product of exposure $Credit_{ist}$, times loss given default LGD_{ist} and expected probability of default PD_{sit} :

$$SPROV_{ist} = Credit_{ist} \times LGD_{ist} \times PD_{sit} \qquad [15]$$

Regarding consumer lending, expected losses and therefore, specific provisions, $SPROV_{i,CONS,t}$ are backed up with application of expert judgment to the data on total specific provisions and the specific provisions on other classes of risk. The total credit provisions $PROV_{it}$ to be deducted as an expense adjust additionally for the changes in the generic provision, according to the regulation of the Banco de España.

The framework also includes an auxiliary equation for the growth of provisions related to personnel expenses $\Delta LPROV_{it}$ such as pension fund provisions. These provisions are not related to credit risk. The forecast of the level of this category of provisions is then:

$$LPROV_{it} = LPROV_{it-1}\,(1 + \Delta LPROV_{it}) \qquad [16]$$

Net operating income and pre-tax income

The net operating income is given by the following equation:

$$NOI_{it} = GOM_{it} - GX_{it} - LPROV_{it} - PROV_{it} \qquad [17]$$

The calculation of pre-tax income PTI_{it} can incorporate two additional adjustments from the auxiliary equations or expert judgment for the loss on assets LOA_{it} and other non operating income NOP_{it}:

$$PTI_{it} = NOI_{it} - LOA_{it} - NOP_{it} \quad [18]$$

5 Further considerations

The main objective of stress test exercises as a diagnosis tool is to test the resilience of individual banks and of the whole banking system. When restricted to achieve that goal, stress tests can be considered as a quite useful tool for macro-prudential regulation and supervision. Additionally, stress tests can provide a better knowledge of the financial system under scrutiny to all of its stakeholders. The macro-prudential regulator is well positioned to collect the most comprehensive dataset of the banking sector, and it can then perform better informed stress tests than those elaborated by private agents. Regarding their implementation, they are based on methodologies which are relatively simple. Furthermore, it can be said that they had contributed to foster development of data availability processes.

Stress tests can be an important resource to increase the transparency of the banking sector and, more generally, the financial sector. These exercises can be seen as an auxiliary tool to restore confidence or a mechanism to set up recapitalization schemes. Stress tests on their own are not enough to restore the confidence on a distressed financial system, but they have proved to be an efficient instrument to guide policy action.

However, a problem is certainly posed when too many objectives are placed upon them. The assignment of too many objectives to a single policy instrument can reduce its effectiveness and, in the limit, it can be left with a nihil effect. Stress tests are mostly a diagnostic tool and additional policy instruments must be considered when aiming for more objectives than initially assigned to them. In the case of recapitalization plans, additional elements such as reworking of business strategies, restructuring plans for the sector and recapitalization mechanisms should also be taken into consideration for the success of the entire plan.

It goes without saying that for the sake of reliability of the results obtained from a stress test exercise, data quality is an issue. If the underlying data that feeds the exercise is under question, the usefulness of the stress test as a mean to increase transparency is lower. As commented above, the development and wide use of these exercises heavily dependent on data, have contributed to the refinement of data quality checks and processes, and further improvements can be expected in the future. The better modeling of feed-back effects between the macroeconomic environment and the financial sector condition constitutes an additional avenue for future improvement of this type of stress test exercises.

ANNEX-DEFINITIONS OF THE VARIABLES IN THE P&L MODEL

We use throughout this section the sub index i to refer to an individual bank, t to refer to a time period and s to refer to a class of financial products (s=FA for financial assets and s=FL for financial liabilities). The variables are listed in approximate order of appearance in Section 5:

1 $rate_{ist}$: Interest rate earned on financial assets (s=FA) or paid on financial liabilities (s=FL).
2 $euribor_t$: Annual average of the Euribor 12 months.
3 Inc_{ist} : Income from financial assets or expense from financial liabilities.

4 Exp_{ist} : Exposure to financial assets and financial liabilities.

5 ΔExp_{ist} : Growth in the exposure to financial assets and liabilities.

6 ΔGDP_t : Growth of real GDP.

7 ΔREP_t : Growth in the Housing Price Index.

8 NII_{it} : Net Interest Margin.

9 $\Delta Com_{is't}$: Growth in net fees and commissions from service class s´.

10 Com_{it} : Net fees and commissions.

11 ΔMI_t : Growth of the stock market index.

12 ΔRFO_{it} : Growth in income from financial operations.

13 RFO_{it} : Income from financial operations.

14 ΔEII_{it} : Growth in income from equity instruments.

15 EII_{it} : Income from equity instruments.

16 ΔOI_{it} : Growth in other operating income.

17 OI_{it} : Other operating income.

18 ΔDFX_{it} : Growth in income from exchange rate differences.

19 DFX_{it} : Income from exchange rate differences.

20 FX_{it} : Euro Dollar exchange rate.

21 GOM_{it} : Gross Operating Margin.

22 ΔGX_{it} : Growth in Operating Expenses.

23 GX_{it} : Operating Expenses.

24 DEX_{it} : Direct cost per employee.

25 $\Delta Credit_{ist}$: Growth in credit exposure to risk class s.

26 $Credit_{ist}$: Credit exposure to risk class s.

27 LGD_{ist} : Loss Given Default to be applied to loans of risk class s.

28 $SPROV_{ist}$: Specific Provision for risk class s.

29 $PROV_{it}$: Sum of Generic and Specific Credit Provisions.

30 $\Delta LPROV_{it}$: Growth in provisions related to labor expenses.

31 $LPROV_{it}$: Provisions related to labor expenses.

32 $employee_{it}$: Number of employees.

33 NOI_{it} : Net Operating Income.

34 LOA_{it} : Loss on Assets.

35 NOP_{it} : Non Operating Income.

36 PTI_{it} : Pre tax Income.

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