



## IV SPECIAL FEATURES

### A COUNTRY-LEVEL MACRO STRESS-TESTING PRACTICES

*Just as banks are increasingly using stress-testing to assess risk at the institution level, macro stress tests are becoming an increasingly important tool for financial stability analysis by central banks. These tools can be used by central banks to assess the capability of the financial system, especially the banking system, to weather extreme but plausible shocks to its operating environment. Given the importance of credit risk for banks, this Special Feature discusses various conceptual aspects of designing macro stress-tests for the banking system, with a special emphasis on credit risk.*

#### INTRODUCTION

Stress tests are commonly used to quantify the impact of some extreme but plausible shock to a financial institution or a country's entire financial system. More narrowly defined, macro stress-testing is a way of quantifying the link between macroeconomic variables and the health of either a single financial institution or the financial sector as a whole.<sup>1</sup> In particular, in this Special Feature macro stress-testing refers to determining the resilience of the financial system.

Using stress tests has become an increasingly common practice for both financial institutions and central banks.<sup>2</sup> Considering the latter, several euro area NCBs have adopted stress tests as a tool for assessing the strength of the financial sector, focusing primarily on banks. For many of these countries, the practice was spurred on by the introduction of macro stress tests as part of the Financial System Assessment Programs (FSAPs) conducted by the International Monetary Fund (IMF).<sup>3</sup> The fact that IMF FSAPs in many cases constituted a starting point for country practices in several euro area countries may have also contributed to creating a common set of basic elements in terms of stress-testing methodologies. Nonetheless, an established procedure or "state of the art" for conducting stress tests is still missing.

Central banks use stress-testing as one part of their financial stability assessments. The tool can provide a framework for discussion about risks, enabling progress to be made in quantifying the likely impact of risks. This can also facilitate a ranking of risks by their importance, thereby better focusing surveillance work more generally.

Looking forward, as advances are made in quantifying the importance of various sources of risk, stress tests are likely to become increasingly common. This is because the increasing complexity of financial markets and financial institutions requires new and better tools for risk measurement. Moreover, forthcoming regulatory changes – in particular Basel II – are expected to affect all credit institutions in the EU starting from 2007,<sup>4</sup> potentially enhancing progress in this area.

The rest of this Special Feature describes what components could be considered when designing a macro stress test. This involves reviewing practices adopted at the country level and taking stock of the experience gained by euro area NCBs.

- 1 For an extensive review of the literature on macro stress-testing, see M. Sorge (2004), "Stress-testing financial systems: an overview of current methodologies", *BIS Working Paper*, No 165.
- 2 See, for instance, Committee on the Global Financial System (2005), "Stress testing at major financial institutions: Survey results and practices". Supervisory authorities are also increasingly using stress tests, but given that their analysis in most cases has a different focus in this context, they are not covered in this Special Feature.
- 3 The following euro area countries have undergone IMF FSAPs including stress tests: Belgium (2006), Germany (2003), Greece (2006), Spain (2006), France (2005), Ireland (2000 and 2006), Italy (2006), Luxembourg (2002), the Netherlands (2004), Austria (2004), Portugal (2006) and Finland (2001). Some countries do not publish the full results of the stress tests incorporated in the FSAP. For an overview of the IMF approach to stress-testing, see M. Jones and P. Hilbers (2004), "Stress testing financial systems: What to do when the governor calls", *IMF Working Paper*, 04/127.
- 4 In particular, banks adopting the internal ratings-based approach of Basel II will be required to implement stress tests for credit risk under Pillar II. See Basel Committee on Banking Supervision (2004), "International convergence of capital measurement and capital standards".

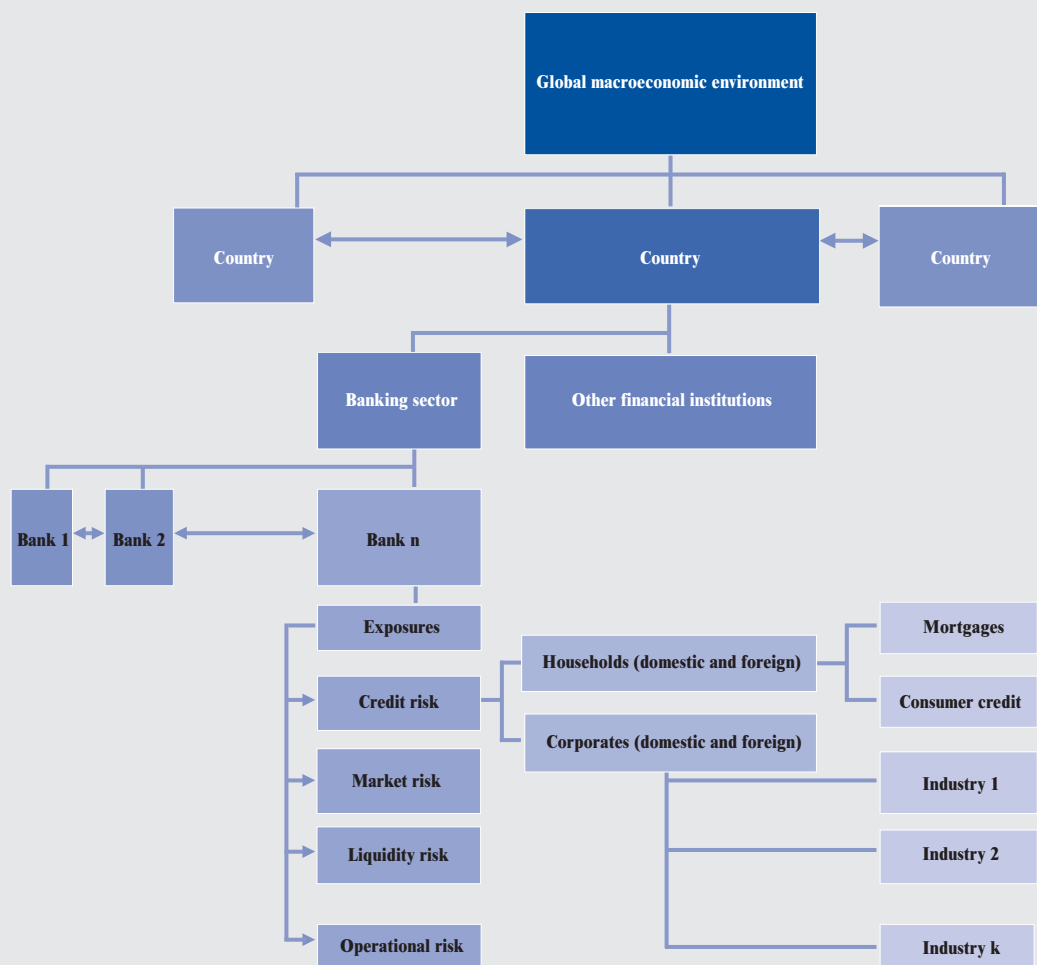
## FEATURES OF STRESS-TESTING PRACTICES

When designing a macro stress test, it is first necessary to identify the most important channels across the various parts of the economy that would be affected by a shock, and to examine how they are linked together. The level of detail in the design of a stress test must be guided by the ultimate purpose of the exercise. As mentioned above, central banks are mostly concerned with systemic stability, i.e. those events that are likely to impair the functioning of the financial system to the point where costs are likely to be imposed on the economy. For

this reason, the focus on aggregate costs of risks may justify a certain degree of approximation, not only to the extent that aggregate figures need to be used, but also in relation to the number of interlinkages to be considered.

The number of potentially important channels is inevitably very large, thus making the practice of stress-testing subject to some feasibility constraints. As an example of this, Figure A.1 illustrates a largely simplified structure of the banking sector of an economy. For each country, there are several banks linked to each other, and

Figure A.1 Example of relevant interlinkages



Source: ECB.

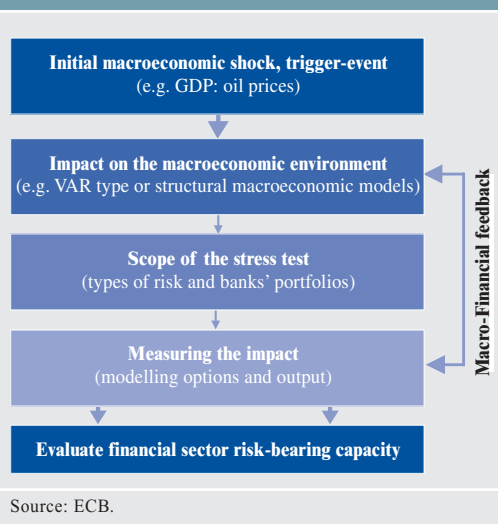
for each of them a lending portfolio composed of lending to households (consumer and mortgage loans) and lending to the corporate sector (broken down at the industry level).

Although this schematic representation is already rather simple, the conduct of stress tests requires additional simplifications in the structure under consideration. Country experiences suggest that ultimately, when conducting stress tests, it is best to pursue a parsimonious specification, based on an empirical assessment that identifies the essential components to be included for a meaningful analysis of a financial system under stress. The degree of complexity of the exercise can then be increased at a later stage, depending on feasibility constraints.

In conducting stress-testing at the country level, two possibly complementary approaches have been used. One is the “bottom-up” approach, in which banks are requested to run an identical stress scenario using their own in-house modelling infrastructure, with the central bank subsequently aggregating the results at the systemic level. Alternatively, a “top down” approach can be used, in which the central bank designs and calculates the test in-house. As bottom-up stress tests tend to be very costly in terms of aggregation, and only allow limited flexibility with regard to adjustment or fine-tuning of the exercise as it proceeds, many central banks tend to restrict themselves to a top-down approach. While the latter approach has a central disadvantage in that it does not benefit from institution-specific information, and is therefore less precise, for pragmatic considerations this level of approximation nevertheless often proves necessary.

Having identified the main operational features of a macro stress test for the banking sector, the next requirement is to design the stress test itself. As shown in Figure A.2, a few basic elements in this process can be defined, following five main steps. The first step is to design a scenario and the initial shocks, e.g. a decline in GDP or a spike in oil prices. Second,

Figure A.2 A simple structure of a macro stress test



a macroeconomic engine may be introduced to describe the impact of the initial shock on the macroeconomic environment. Third, the scope of the stress test should be defined, i.e. by addressing the different types of risks affecting banks’ portfolios. Fourth, modelling options to measure the impact of the shock on the banking sector are investigated and a quantitative output is produced. Fifth, the output of the stress test can be combined with other pieces of information to assess the strength of the financial sector. Each of the first four points are addressed in the following sections, on the basis of how they have generally been addressed by euro area NCBs.<sup>5</sup>

## SCENARIOS AND SHOCKS

The starting point of any stress test exercise is the initial shock, which is the materialisation of a risk affecting the financial sector. Depending

<sup>5</sup> Several contributions have been made by euro area NCBs to the area of stress-testing. For examples of EU NCBs publications discussing stress test-related conceptual issues, see A. Kearns (2004) “Loan losses and the macroeconomy: A framework for stress testing credit institutions’ financial well-being”, *Central Bank of Ireland Financial Stability Report*; O. De Bandt and V. Oung (2004), “Assessment of ‘stress tests’ conducted on the French banking system”, *Banque de France Financial Stability Review* (5), November; and P. Bunn, A. Cunningham and M. Drehmann (2005), “Stress testing as a tool for assessing systemic risks”, *Bank of England Financial Stability Review*, June.

on whether single shocks are examined one at a time or whether a combination of two or more shocks simultaneously is being considered, the exercise can be classified as a sensitivity analysis or a scenario stress test. In terms of euro area NCB practices, scenario stress tests have been applied to a greater or lesser extent depending on the level of sophistication of the respective countries' practices and the type of risk underlying the initial shock. In general, sensitivity analysis has been the most common approach used to assess market risk, whereas for credit risk, which is closely linked to business cycle conditions and spreads through more complex channels of transmission, scenario stress tests have been more frequently applied by euro area NCBs.

The initial shock (or shocks) is (are) collected in a scenario, the type of which can vary according to the methods employed. Scenarios can take four forms: historical (i.e. designed to replicate historical episodes of stress, such as the 1987 stock crash or the 1998 emerging markets crisis); hypothetical (i.e. they do not match historical events and are not quantified according to either of the two following methods); probabilistic (i.e. constructed on the basis of the empirical distribution of the relevant risk variable, corresponding to extreme percentiles in this distribution); or reverse-engineered to match a predefined amount of losses to be endured by the financial sector.

The design of scenarios typically differs across countries, but in general historical and hypothetical scenarios have been more frequently used, possibly on account of their more straightforward interpretation. In addition, due to data limitations, some euro area NCBs have tended to work more with hypothetical scenarios. Indeed, short time series and insufficient data coverage often make the use of historical scenarios impossible. In addition, structural breaks and rapidly changing economic environments in some European countries have further limited the scope for drawing lessons from earlier episodes of stress.

In designing scenarios in practice, euro area countries adopting either historical or hypothetical scenarios have generally employed one of the following three approaches. In some cases, a set of assumptions in line with a former IMF FSAP has been applied.<sup>6</sup> Alternatively, the set of original assumptions in the IMF FSAP was modified according to the current circumstances. The possibility of designing scenarios in this way, however, depends on the modelling capacity of the country in question.<sup>7</sup> The third option has been to let the NCB's most recent macroeconomic projections determine the size and type of shocks to be considered. The standard procedure has been to assess misalignments on the basis of regular macroeconometric models usually adopted for forecasting for monetary policy purposes.

Irrespective of the type of scenario adopted, it is important that the underlying shock is plausible, extreme and of systemic relevance. While the first requirement is self-explanatory, the other two may benefit from clarification. Financial stability analysis does not focus on baseline scenarios, which by construction are assigned a high probability. Meaningful stress scenarios must incorporate low-probability shocks, which necessarily represent extreme realisations of the underlying risk factor. Finally, not all extreme shocks may put the financial system under stress when overall conditions are particularly benign, which means that it is the extreme realisation of shocks capable of putting the financial system under stress that matter for stress testing. However, information on such extreme realisations of shocks is normally not available *ex ante*, but is only learned after the stress test has been carried out.

6 The usual procedure followed at the time of the FSAP was for the central bank to propose a scenario, which was then discussed with IMF staff before being implemented.

7 The strong growth in house prices, for example, has recently been a cause for concern in some euro area countries, and was in some cases accounted for in the projections of bank losses. However, there are still limitations in the analytical framework regarding the possibility of including these sources of risks in stress-testing.

## INTRODUCING A MACROECONOMIC ENGINE

In a macro stress test the initial shock affects the macroeconomic environment in which banks operate. In order to ensure consistency across various macroeconomic variables, the design of the stress test should include some sort of macroeconomic engine.<sup>8</sup> For doing this many central banks have, for instance, used their structural macroeconometric models, which were originally designed as forecasting tools for monetary policy purposes. These models benefit from their exhaustiveness by providing a comprehensive picture of the macroeconomy, and they allow a policy reaction to the initial shock to be modelled. They also permit an internally consistent representation of the full economy under stress, and enable the authority to “tell a story” about the interpretation of the results of the exercise.

A second option has been to use Vector Autoregressive (VAR) models, where a set of macroeconomic variables is jointly affected by the initial shock, so that the combined impact on this set of variables rather realistically depicts the reaction of banks’ operating environment, and can be used to study their resilience to shocks.<sup>9</sup> An explicit macroeconomic engine has, however, not been employed in all cases, and in some instances the dynamics of the macroeconomic variables have been obtained from simple unconditional historical correlations.

## TYPES OF RISK

When a macroeconomic risk materialises, the financial system is exposed to financial shocks. For banks, the main sources of risks can be broadly categorised as credit risk, market risk, liquidity risk and operational risk. Of these, *credit risk* represents the largest source of risk for banks, and for this reason has received closer attention in central bank stress tests. In addition, in the context of a macro stress test, given the fluctuations in the macroeconomic

variables underlying the stress scenario at business cycle frequencies, changes in credit risk tend to move more closely with the business cycle. For these reasons, a study of macro stress tests based on credit risk more closely matches the initial purpose of running stress tests for a financial stability analysis that assumes, as a starting point, swings in macroeconomic variables.

*Market risk* is generally regarded as the second most important risk category facing banks. Adapting market risk to the analytical framework discussed in the previous section may be less straightforward than for credit risk, as the former (generally represented by some form of asset prices) adjusts over a much shorter time frame (usually days or months). This also implies that the joint treatment of market and credit risk is problematic, and further work is probably needed in this area.<sup>10</sup> For these reasons, and unlike the case of credit risk, various sources of market risk have been in general treated separately in sensitivity-type stress tests, without the need for a macroeconomic engine.

*Liquidity risk* and *operational risk*, on the other hand, have not been as extensively considered in macro stress tests at the country level to date. In those cases where stress-testing involved shocks to liquidity, the ratio between liquid assets and short-term liabilities has been commonly used as an indicator against which the initial shock has been evaluated, conditional on some initial assumptions regarding the

8 The macroeconomic variables to be considered in a macro stress test include: domestic variables (short-term and long-term interest rates, inflation, GDP and unemployment) and external variables (external demand, foreign interest rates, exchange rate fluctuations, etc.).

9 More recently, a global VAR (GVAR), which explicitly models the interaction between the economy under study and the rest of the world, has been considered for use in stress tests (see for example S. Dees, F. di Mauro, M. H. Pesaran and L. V. Smith (2005), “Exploring the international linkages of the euro area: A global VAR analysis”, *ECB Working Paper*, No 568).

10 See M. Sorge (2004), *op. cit.*

withdrawal of interbank deposits and other market developments.<sup>11</sup>

## MODELLING CREDIT RISK

Several options are available when modelling risks for macro stress-testing. For the sake of simplicity, some selected examples are offered in this section, taking into account euro area NCBs' experiences.

Focusing on credit risk, its impact, as measured with some indicator of default, together with some (usually ad hoc) values for recovery rates, has been assessed against either loan loss provisions or non-performing loans. Concerning modelling options, various techniques and approaches at different levels of aggregation have been applied in modelling credit risk in macro stress-testing so far, mostly depending on data availability.<sup>12</sup> One approach has been based on the use of micro-level data covering either the household or the corporate sector.<sup>13</sup> Data on corporate balance sheets and credit registers have, for instance, been used to estimate models for default probabilities under different economic conditions.<sup>14</sup> A similar analysis has also been applied to survey data on households, employing Probit-type models.<sup>15</sup> Alternatively, when micro-level data are not available, macro stress tests have addressed more aggregated measures of borrower default either at an industry or a sectoral level. These models have recently received particular attention in national practices across the euro area.<sup>16</sup>

As a final output of macro stress tests, several indicators have been used. For an NCB with supervisory responsibilities, for instance, the effects on capital adequacy ratios (CARs)<sup>17</sup> are generally considered to be particularly useful.<sup>18</sup> When central banks have no supervisory powers, and when the objective is to assess financial stability conditions more generally, stress-testing of single banking indicators (e.g. loan losses) in a partial framework might be sufficient. In the same vein, the effects of macroeconomic shocks on banks' earnings have

been modelled, taking factors such as growth in lending and credit conditions into account.<sup>19</sup>

## REMAINING CHALLENGES

While substantial progress has been made in the development of macro stress-testing techniques, current practices still suffer from some important limitations. If current stress-testing practices are to advance from an art towards a science, progress is required on two main fronts: data availability, and the modelling of financial system interlinkages.<sup>20</sup>

Concerning data availability, a first limitation is that country practices have frequently been moulded by data availability, which differs

11 See M. Boss, G. Krenn, M. Schwaiger and W. Wegschaider (2004), "Stress testing the Austrian banking system", *Österreichisches Bankarchiv*, November; Deutsche Bundesbank (2004), "Stress tests at German banks – methods and results", *Monthly Report*, October; and C. Corcóstegui, L. González-Mosquera, A. Marcelo and C. Trucharte (2003), "Analysis of procyclical effects on capital requirements derived from a rating system", Bank of Spain, mimeo.

12 Concerning examples from euro area publications, see for instance M. Boss et al. (2004), op. cit.; and Deutsche Bundesbank (2003), "Stress testing the German banking system", *Monthly Report*, December.

13 The availability of this type of data differs from country to country, and therefore implies differences in country practices.

14 For applications utilising accounting-based credit scoring models (pooled as well as country-specific) and performing panel regressions, see for instance ECB (2005), "Assessing the determinants of financial distress in French, Italian and Spanish firms", *Financial Stability Review*, June.

15 Household micro-data have recently received increasing attention by central banks; see for instance O. May and M. Tudela (2005) "When is mortgage indebtedness a financial burden to British households? A dynamic Probit approach", *Bank of England Working Paper*, No 277, October.

16 See for instance M. Boss (2003), "A macroeconomic model for stress testing the Austrian credit portfolio", *Österreichisches National Bank Financial Stability Review*, 4, and K. Virolainen (2004), "Macro stress-testing with a macroeconomic credit risk model for Finland", *Bank of Finland Working Paper* No 18.

17 The use of CARs as an output of macro stress tests is not specific to credit risk only.

18 For an approach modelling CARs using transition probabilities, see O. De Bandt and V. Oung (2004), op. cit.

19 An explicit example of direct modelling of bank profitability in the literature is a dynamic panel targeting the net interest margin on banks. See O. De Bandt and V. Oung (2004), op. cit.

20 For additional considerations on the limitations of presently available tools for financial stability analysis, see ECB (2005), "Measurement challenges in assessing financial stability", *Financial Stability Review*, December.

substantially across countries, concerning both banks and borrowers, not only in terms of aggregate figures, but also at the micro level. In addition, there is often a lack of sufficient historical data, which limits the scope for drawing accurate insights from previous episodes of stress. This is problematic when it comes to studying credit risk, as relatively long time series are needed, containing data over a complete business cycle.<sup>21</sup> Furthermore, even when relatively long time series are available, changes in macroeconomic conditions – for example following the transition to inflation targeting or the introduction of the euro – may also give rise to limitations.

At the current state of development in stress-testing practices, where partial equilibrium models are mostly being used at an aggregate level, access to micro data could be perceived as a second-order concern. However, using disaggregated data would in many instances improve modelling capacities and substantially enrich the stress test analysis.

Concerning modelling shortcomings, possibly the most important limitation associated with existing approaches concerns the absence of feedback effects inside the financial sector, from banks to other financial institutions<sup>22</sup> and to the financial markets, and between the financial and the real side of the economy. In addition, interbank linkages have typically been considered separately from the original model for credit risk.<sup>23</sup> These limitations imply that the potential second-round effects of the initial shock tend to be ignored in the design of scenarios. Nonetheless, these feedback effects are complex to model, and at this stage there is no established practice. Similarly, another practical challenge is related to the inclusion of an appropriate policy response following a shock, and work is still ongoing in order to overcome this limitation.<sup>24</sup>

Another modelling shortcoming is related to the macroeconomic engine used in the modelling process. Macroeconometric models produced for regular forecasting purposes might not be

best suited for stress-testing because they have not been specifically designed for financial stability purposes. For instance, financial transmission channels are usually not included. In addition, these linear models are unable to capture the fact that the relationships between macroeconomic variables may become non-linear at times of stress.<sup>25</sup>

### CONCLUDING REMARKS

Macro stress-testing frameworks at the country level, such as those often applied in the context of IMF FSAPs, are increasingly being used to make quantitative assessments of the resilience of financial systems to adverse disturbances. Owing to existing limitations (e.g. the exclusion of macro-financial feedback effects), further work in this area still needs to be conducted.

One possible direction for further work on stress-testing that is specific to the euro area could take the form of stress-testing at the level of the euro area. There are various good reasons for considering such an extended geographical scope for a macro stress test. For instance, the

21 Low data quality is also a concern, together with the problem of interpreting changes in reporting standards. In addition to limitations associated with data quality, difficulties in matching credit register data with balance sheet information are often present.

22 Other parts of the financial sector have also been considered in euro area stress tests and, depending on country-specific characteristics, may have to be included in order to paint a realistic picture of the strength of the national financial sector. See, for instance, the French FSAP, in which the insurance sector was combined with the banking sector in the model of the financial sector for stress-testing (O. De Bandt and V. Oung (2004), *op. cit.*). Similarly, in the Dutch FSAP pension and insurance funds were included in the stress test exercise, although separately from the banking sector (see DNB (2004), “Stress testing the Dutch financial sector”, *Quarterly Bulletin*, September). Finally, an additional drawback in considering only banks could arise because of the emergence of instruments to transfer credit risks between banks and other financial institutions, which is changing the activities and risk profiles of financial institutions.

23 On the modelling of interbank linkages, see C. Upper (2006), “Contagion due to interbank credit exposures: what do we know, why do we know it, and what should we know?”, BIS, mimeo.

24 Policy reactions have been modelled before in various contexts using Taylor-rule specifications. See for instance P. Bunn et al. (2005), *op. cit.*

25 For an example of a study on the introduction of non-linearities in VARs, see M. Drehmann, A. J. Patton and S. Sorensen (2005), “Corporate defaults and large macroeconomic shocks”, mimeo.

increasing degree of cross-border economic and financial integration might imply a higher level of dependency between national banking systems, and as such, there may be potentially negative externalities across euro area countries in times of stress that cannot be fully captured by stress tests applied at the country level.