

## JRC TECHNICAL REPORTS

# Review of the SYMBOL model

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## **Foreword: European Commission's Competence Centre on Modelling**

The Commission uses modelling to assess the environmental, economic, and social impacts of policy options and initiatives. Models are also used in other phases of the policy cycle, for instance to support the EU policy implementation.

The Commission's increasing focus on quantification of EU policy requires cross-cutting and robust approaches. The Competence Centre on Modelling brings under one umbrella the Commission's competencies and best practice in building and using models for greater quality and transparency in policy making.

In this way it contributes to the Commission's Better Regulation policy, to the Inter-Institutional Agreement on Better Law Making, and to the Communication on Data, Information and Knowledge Management at the European Commission.

Starting with a Commission-wide modelling inventory (MIDAS, documenting over 200 models in use by the Commission), it supports a proper documentation, use, and reuse of models by making available years of experience in the area of baseline scenarios, uncertainty analysis and sensitivity analysis, and social multi-criteria evaluation.

The Competence Centre on Modelling helps to identify common approaches to quality and transparency of model use. A new community of practice on modelling will combine a web-based forum for sharing best practice and topical knowledge with events and training activities.

## **Acknowledgements**

The authors are solely responsible for the content of this Review Report. The views expressed in this Review Report are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission, the ECB or the Eurosystem of Central Banks.

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## **Abstract**

An integral part of the model quality control and quality assurance at the European Commission is a scientific peer-review of models, including those developed and used by its Directorate-General Joint Research Centre (JRC). The present reports details the outcome of the review of the SYstemic Model of Banking Originated Losses (SYMBOL), which was carried out by an external scientific Review Panel closely following 'Guidelines for the review of models used in support of EU policies'.<sup>1</sup> The review aimed at verifying and consolidating the scientific credibility of SYMBOL and identifying most promising/relevant areas for a future model development. The report includes also a first reaction from the SYMBOL team, detailing among others how Review Panel's suggestions will be addressed.

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<sup>1</sup> European Commission (2018) Guidelines for the review of models used in support of EU policies, Directorate General Joint Research Centre.

# 1 Introductory remarks

Model-based evidence is playing an increasing role in the European Commission's policy support in general and the policy Impact Assessment (IA) process in particular. The Better Regulation Policy aims to ensure that EU decision-making is open and transparent and EU actions are based on evidence and understanding of the impacts.

It is therefore of utmost importance that models used for policy support are credible and transparent both from a scientific point of view and from the perspective of Commission's policy services, the Member States, and other stakeholders. Information on aspects such as assumptions, model architecture, data quality, verification and policy representation mechanisms, needs to be made available, especially if the results of these models are used in policy documents and EC-endorsed studies.

An integral part of the model quality control and quality assurance is a coherent approach for scientific peer-review of models, similar to practices in international organisations and national modelling institutes. The Directorate-General Joint Research Centre (JRC) of the European Commission has developed 'Guidelines for the review of models used in support of EU policies' which have been used in the review of the SYMBOL model. SYMBOL is an acronym of the SYStemic Model of Banking Originated Losses.

The overall objective of the Model Review is to verify and consolidate the scientific credibility of models used for policy support in the Commission. This means that the review process assesses the documented model description and manual, the model performance, the results of sensitivity tests of the model, and the peer review status.

Therefore, the specific objectives of the review are to assess to what extent:

- The model is built following sound scientific principles, based on well-established data, grounded in the prevailing theoretical insights, has well-documented assumptions and embedded expert knowledge, and is described by appropriate mathematical concepts and language.
- The model has been scrutinised in relevant scientific conferences and (for models already used for some time) has passed the peer review processes of top scientific journals in the field.
- The model has been validated, has undergone sensitivity analysis, and its limitations are documented and published.
- Model data, the theoretical framework and the empirical implementation (including model calibration) are transparently documented, stored publicly accessible, and shared with the relevant scientific community.
- All model runs in support of EU policies are documented in detail – including source code and data – and stored accessibly so that, if needed, the reproduction of modelling results can be carried out at any time.
- The results of model runs that are used in studies and policy documents are available on the EU Open Data Portal.
- Links with relevant academic networks are established and maintained, e.g. through annual workshops, to ensure a continuous exposure of the model, the underlying data, and baseline scenario assumptions, etc. to the scientific community.

Each review follows a process that consists of three steps.

1. Well in advance, the modelling team is asked to provide the Review Panel with a complete model documentation. During the preparation of the review process, the Review Panel and modelling team may suggest a number of stylised scenario runs, the results of which would be discussed in-depth at the review meeting. The

modelling team also provides to the Review Panel five scientific papers and/or policy reports that they deem as their best and/or most relevant products.

2. Face-to-face meetings of the model review (usually 1.5-2.5 days) consist of (i) a series of presentations, where the conceptual model structure, underlying data and policy simulations are presented by the modelling team to the Review Panel, and (ii) following consultative meetings where the Review Panel discusses internally and agrees on draft conclusions.
3. In the weeks following review meetings, the Review Panel writes a model review report which is handed over to the modelling team, the senior management and is made publicly accessible. The modelling team is given opportunity address the comments in the draft model review and present suggestions for model improvements or additional runs.

In order to ensure a rigorous, coherent and unbiased review, the model review is undertaken by an external scientific Review Panel. The Review Panel consists of 5-10 experts in the domain of the model, and a Chair of the Review Panel. A Secretariat which provides administrative and secretarial support is provided through the JRC's Competence Centre on Modelling.

The report before you contains the results of the scientific review of the SYMBOL model as carried out from November 2017 to February 2018 by a Review Panel consisting of Leen Hordijk (chair), d'Artis Kancs (scientific secretary), Christoffer Kok (European Central Bank), Steven Ongena (University of Zurich), Loriana Pelizzon (University of Frankfurt). Short bio's of the panel members can be found in Annex 1. The European Commission is very grateful to the members of the Review Panel for the time and effort they have put into carrying out this review. The Review Panel met at the site of the JRC in Ispra (Italy) on November 9 – 10, 2017. The meeting agenda can be found in Annex 2.

The remainder of this report contains a short description of the SYMBOL model (section 2), the results of the review (section 3), reply to the Review Report by the SYMBOL team (section 4) and conclusions (section 5).



## 2 Policy and model development background

The economic and financial crisis decade ago and ensuing recessions have revealed a number of deficiencies in the EU banking sector. For example, a number of European banks were exposed to high levels of non-performing loans (NPLs). As noted by the European Commission (2018), elevated levels of NPLs have impact on the financial stability, as they weigh on the profitability and viability of affected institutions and have an impact, via reduced bank lending, on the economic growth. The recent crisis has also shown how quickly vulnerabilities on the financial side of economy can turn into a strong deterioration of public accounts. For example, in Ireland the gross public debt as a percentage of GDP has increased by almost 100 percentage points between 2007 and 2013, whereas in Spain the debt ratio increased by more than 50 percentage points over the same time period (Benczur et al. 2015).

In order to avoid these and other negative consequences on economies, the issue of NPLs is being increasingly tackled by policy makers. At the European level, since the latest financial crisis the Commission has been enforcing its efforts to address the issue of NPLs in relation to the countries concerned in the context of the European Semester. Building on the policy work initiated by the European Commission, the European Council has adopted a comprehensive "Action Plan to Tackle Non-Performing Loans in Europe" on 11 July 2017. This Plan calls upon various actors to take appropriate measures to further address the challenges of high NPLs in the EU, recognising the balance between necessary actions by banks, Member States and the EU. It invites the European Commission and other institutions to take steps on several fronts to tackle both the legacy stock of NPLs and the risk of build-up in the future.

Internationally, the Basel Committee on Banking Supervision has issued a revised Basel Accord in 2010-2011, which is a global regulatory framework on bank capital adequacy, stress testing, and market liquidity risk. This updated Basel Accord (after Basel I and Basel II) was developed in response to deficiencies in the financial regulation revealed by the last financial crisis in 2007–2008. Since Basel II, the Accord aims to strengthen bank capital requirements by increasing bank liquidity and decreasing bank leverage. Basel II/III set international banking standards of how much capital banks are required to hold to guard against the financial and operational risks that banks face.

Different approaches can be used to determine how much capital a bank should hold. The Internal Rating-Based (IRB) approach adopted for Basel II/III focuses on the frequency of bank insolvencies arising from credit losses that supervisors are willing to accept. The Systemic Model of Banking Originated Losses model (SYMBOL) follows the IRB approach. SYMBOL can estimate the distribution of economic losses and liquidity shortfalls occurring in the banking sector, by taking into account contagion effects due to interbank positions. The SYMBOL model can evaluate banking-related policy questions by providing quantitative estimates of the order of magnitude with respect to changes in the regulatory framework.

SYMBOL has been developed by the DG JRC in cooperation with researchers from academia and representatives from the DG FISMA during the aftermath of the latest financial crisis. Since its original version (as described in De Lisa et al. 2011), the SYMBOL model has been further developed in numerous ways. The panel acknowledges that steering the model development strategically and efficiently is a challenging task indeed, particularly in the context of progressing methodological advances, improving data availability and changing policy needs. This report reviews a 2017 version of the SYMBOL model and gives suggestions for its future development.

### **3 Strengths, caveats and suggestions**

#### **3.1 Validity of the methodological approach**

SYMBOL is a micro-simulation portfolio model that implements the Basel II/III regulatory framework, which imposes that each bank satisfies regulatory capital requirements to guard against the risks the bank may face. This capital provides a buffer against unexpected losses at a specific level of statistical confidence (in Basel II/III fixed at the 99.9% level). The amount of the regulatory capital necessary to support a portfolio of debt securities depends on the probability distribution of the portfolio loss of each bank (Vasicek, 2016). The SYMBOL model simulates this probability density function (PDF) of the banks' credit portfolio.

The starting point of the analysis is the Basel II/III regulatory framework, which provides a credit risk loss function linking balance sheet data (capital, total assets and risk) to the distribution of losses stemming from the portfolio of an individual bank. By inverting this Basel Internal Ratings-Based (IRB) formula for the credit risk allows to derive the average riskiness of the asset portfolio owned by each bank. Using the inverted IRB formula, each single implied obligor's probability of default of each single bank is computed. Next, the average implied default probability (PD) for the asset portfolio of each bank is computed using information on the bank size (total assets) and its riskiness (capital and risk weighted assets).

In a second step, correlated losses for banks are simulated via Monte Carlo using the above estimated implied default probability for the asset portfolio of each bank. Losses for individual banks are simulated by generating correlated normally distributed random shocks. The correlation of shocks among banks is either a consequence of the banks' common exposure to the same borrower or, more generally, to a particular common influence of the business cycle. If at least one bank defaults, all data from the simulation run is kept; otherwise it is discarded. Simulation stops when 100 000 simulation runs with at least one default are generated.

Given the simulated matrix of correlated bank losses, in a third step, the SYMBOL model determines which banks fail. A bank failure happens when simulated obligor portfolio losses exceed the sum of the bank's expected losses and the total actual capital given by the sum of its minimum capital requirements plus the bank's excess capital (if any). According to the Basel II/III regulatory framework, the Value at Risk threshold corresponds to a confidence level of 0.1%, i.e. the minimum capital requirement covers losses from the obligors' portfolio with a probability of 99.9%.

In a final step, an aggregated distribution of losses is computed for the whole banking system (an EU Member State, a group of countries or the whole EU). Aggregate losses are determined by summing losses in excess of capital of all distressed (default) banks in the system in each simulation run. This yields the distribution of the losses of the whole banking system.

The Panel has assessed the validity of the methodological approach by aiming to establish whether the conceptual framework of the model is grounded in state-of-the-art theoretical insights, and whether the methodology implementing the model follows sound scientific principles.

#### *Strengths*

The credit risk loss function embedded in the Basel II and Basel III framework allows to derive an implied probability of default (PD) of the loan portfolio by inverting the IRB formula. Subsequently, individual banks' gross losses can be simulated using Monte Carlo techniques.

- The underlying Basel II/III framework implies that the model is consistent with the assumptions of the current Basel II/III regulation and therefore the objective: to

assess how changes in the regulation would affect bank losses is achieved under the same assumptions of the Bales II/III framework.

- The adopted theoretical framework is internally consistent, the Team is aware of model strengths and limitations and have tried to address some of them with several ad-hoc sensitivity analysis, as discussed under the model validity, see below.
- The model is not a "black box", as all key features of the model are transparently documented and published, they are easy to follow.
- The team is very open for discussions about the key features and limitations of the modelling approach.

### *Comments*

General methodological framework. It is well-known that the mechanism behind Basel II/III to determine bank losses is rather simplistic and the use of it might prevent the model to capture the true bank losses correctly. Among other, the underlying Basel II/III framework has the following critical limitations:

- The correlation of the asset value between banks is constant and fixed at 50%.
- The loss given default is set exogenously at 40%.
- Asset value shocks are normally distributed, no fat tail or other assumptions about the distribution are introduced.
- The collateralization of assets is not considered in the model.
- Derivatives positions are also not considered in the model.
- The model is considering all banks as homogenous. For example, their asset composition is assumed to be always the same and this is clearly not so in reality in a way that is relevant for loss outcomes. The only heterogeneity is introduced on the asset side by the size (i.e. different total assets).
- The partial equilibrium perspective of the model by not accounting for potential feedback effects (e.g. by ignoring the banks' likely reactions to losses such as deleveraging; see also discussion below) may bias the results.

Given these assumptions and shortcuts of the underlying methodological approach, it cannot be excluded that they lead to an underestimation of potential losses.

Contagion module. The SYMBOL model can include contagion effects between banks linked via the interbank market, though contagion effects are not included in the policy work in the current form. Instead, they are used in selected scientific work.

- Only one channel of adjustment is considered in the contagion module: the interbank loan market, where the contagion effect is fixed at 40%. Other important channels, such as the portfolio similarity and secured interbank market and derivatives, cross holding of corporate bonds and sovereign exposure are missing.
- Only domestic inter-bank relations are considered, though also cross border interlinkages through interbank markets could play a role, which is particularly important given the evidence of the recent financial crisis.
- The current situation of the interbank market is that it is still not working very actively, instead, the collateralized interbank market is highly active. Fire-sales contagion effects generated by the asset and liability maturities mismatch are also not taken into account in the model.
- Usually, the contagion module is not included in policy applications, which may lead to an underestimation of losses and distribution.

### *Suggestions*

- The Panel suggests that a more general modelling approach such as the more general copula model family should be developed, which among others is able to capture fat-tail distributions.
- The inclusion of the interbank market (both secured and unsecured) in the analysis would be very important for capturing contagion effects.

## **3.2 Model capacity to adequately address EC policy analysis needs**

The Panel has assessed the model capacity to adequately address EC policy analysis needs by aiming to establish whether the model can answer relevant policy questions in a sufficiently detailed/disaggregated way, and whether the model is capable to capture challenges faced by specificities of the banking sector?

### *Strengths*

The model can answer a number of relevant policy questions by providing quantitative estimates of the order of magnitude with respect to changes in a wide range of regulatory frameworks.

- For example, it can provide an estimate of the order of magnitude of changes in the distribution of bank losses after salient changes in the bank regulation.

### *Comments*

Caution is warranted when interpreting and using the outcome of the model for policy purposes. Especially, the lack of the data granularity and the application of a number of simplifying assumptions may result in a lack of precision in terms of estimated losses as well as their cross-sectional and cross-country distributional effects. Some of the reasons for this lack of a full reliability on this account are as follows:

- In general, the use of publicly available data with limited granularity at the bank level hampers the ability to account for heterogeneous bank characteristics.
- Liquidity Ratio, Net Stable Funding Ratio and partially Leverage Ratio: a comparison of the effect on losses of each of these new regulations is missing.
- The more recent regulation on financial markets is missing. If the purpose of the model is to check only the effects of Basel III then it is fine but, if the request is a more general assessment of the new regulation generated after the global financial crisis, then the new financial regulation should be included in the model.
- The model assumes that the new capital requirement is satisfied by increasing capital and not by shrinking total bank assets or by an asset substitution. This disregards the potentially negative side of the new capital requirement, e.g., lending to corporates, and may underestimate the cost to the real economy and feedback effects on non-performing loans.
- Pillar 2 requirements are not taken into consideration, when calculating the minimum capital requirement.
- Bail-in bank recovery and resolution part of the model is not fully in line with reality.

### *Suggestions*

- Due to critical assumptions and the use of limited public data, policy makers should not rely solely on the SYMBOL model. The use of complementary modelling tools as well as more granular data is encouraged.
- Cooperation with banking authorities in terms of access to more granular data, such as the ECB and the EBA, and other modelling approaches, is encouraged in order to make the analysis more precise and hence more useful for policy makers in terms of the absolute amount of losses, for example.
- When communicating model results to policy makers, it is important to highlight some of these limitations and caveats. In particular, when presenting results to policy makers, more effort could be made to communicate model uncertainty using ranges of simulation results.

### **3.3 Adequacy and validity of data used in the model**

The main input variables in the SYMBOL model are Total Assets, Capital levels and Risk Weighted Assets. In order to construct a model database with a large coverage of the EU28 banking sector, usually, the Team relies on a commercial database such as Bankscope compiled by Bureau van Dijk. As in all public database, Bankscope data present certain quality and coverage issues, such as missing information or errors in the data compilation. In order to fix errors in the data compilation, the Team performs automatic checks to assure the internal coherence among variables. The detection and correction of incoherencies in the original Bankscope database consists of the following steps.

First, in order to avoid using erroneous data (e.g. due to balance sheet incoherencies) or meaningless data for scope of the analysis (e.g. negative equity), observations (banks) are excluded from the sample if at least one of the following criteria is satisfied:

- Total assets are not available;
- Common equity is not available;
- Tier one capital exceeds total assets;
- Regulatory capital larger than total assets;
- Common equity larger than total assets;
- Negative common equity.

Second, the issue of missing values is addressed. In order to have the largest possible set of information, at least for the main variables of the SYMBOL model i.e. capital (both as ratios and as amount) and risk weighted assets, the Team has developed a series of procedures based on robust regression. Robust regression uses estimators that are immune to specific model assumptions and their failures, while allow to identify outliers, i.e. observations which are distant from the bulk of the observed data and can hardly comply with model assumptions. In SYMBOL, the estimation of missing values is done using the Forward Search for Data Analysis (FSDA) of Atkinson and Riani (2000), which is implemented in the Matlab FSDA toolbox. Missing capital ratios are replaced by capital adequacy indicators for domestic banks at the Member State level by the ECB. For each banks' specialisation (in its standard version SYMBOL uses commercial, savings and cooperative banks), missing capital values are estimated using a robust regression by common equity. Missing risk weighted assets are estimated using the capital and the total regulatory capital ratio.

The Panel has assessed the adequacy and validity of the data used in the model by aiming to establish whether the model is empirically implemented using the best available and well-established data sources, and whether the construction and updating of the model data base follows sound scientific principles.

### *Strengths*

The Panel is aware of difficulties in finding good and reliable data on bank assets and liabilities and therefore recognises the team efforts in this respect.

- The model was using the best available and well-established data sources, when it was initially empirically implemented.
- The use of the Bankscope data is consistent and transparent, the data base is updated regularly (annually) associated with publishing a report describing the model data base.
- The Team is putting a huge effort in checking the data consistency and coherence, and in replacing important missing data with regression models output based on similarities.

### *Comments*

- The average ratio of missing data is large, for some countries even critical. The approach adopted for rescaling the sample to the population is critical, as it assumes the randomness of missing banks in the sample and uses a simple average scaling up. Due to non-randomness of the missing data which come largely from small banks, the error introduced by rescaling could be very large.
- The risk-weighted asset and regulatory equity are key variables for simulations. In some cases, these variables are imputed using an estimation based on the homogeneity assumption.
- The fact that current data are transformed via so-called correction coefficients to keep track of the implementation of the latest regulation and the correction coefficient is one number for the whole EU might bias results of the analysis. This is especially so, because the existing literature suggests that there are very large differences between countries. Admittedly, this issue is declining over time as banks are getting closer to the fully-loaded capital requirements.
- The use of unconsolidated data may be potentially problematic for analysing policies such as resolution and recapitalisation, given that recapitalisation and resolution is usually taking place at the consolidated level.

### *Suggestions*

- The rescaling needs to be assessed using more complete recent data.
- At least for the around 130 banks ('significant institutions') supervised by the ECB, risk-weighted asset and regulatory equity data are available either in the EBA stress test analysis / transparency exercises, or directly on the bank web pages, hence could be collected easily.
- Regarding correction coefficients, collaboration with the EBA in order to improve the input data quality is encouraged.
- The consolidated data version of the model should be used on a more regular basis in addition to the unconsolidated data version.
- More granular data are available at the bank level, e.g. the SNL for large banks, which could be used for the calculation of the cross-correlation, inter-bank linkages, portfolio similarities, liquidity ratios, etc.
- More granular data are available also at the market level (inter-bank, bank holding data) that could improve the precision of the analysis.

### **3.4 Policy scenarios**

The SYMBOL model can be used to assess the impact of various what-if scenarios and regulatory and policy initiatives in the realm of banking. A typical scenario analysis using SYMBOL is represented by the Bank Recovery Resolution Directive. This Directive, which was adopted by the European Parliament and the European Council in 2014, introduces and defines the order of intervention of different safety-net tools including: (i) improved standards on minimum capital requirements and capital conservation buffer set up in the CRR/CRD IV package, (ii) bail-in, (iii) Resolution Funds, and (iv) Deposit Guarantee Schemes. The SYMBOL model allows to assess possible effects on public finances of different safety-net tools of the Bank Recovery Resolution Directive.

The Panel has assessed the construction of policy scenarios by aiming to establish whether the robustness and validity of the scenario building approach/process is ensured through interactions with other modelling tools / the involvement of stakeholders.

#### *Strengths*

- The scenario building is consistent with demands of policy makers, and thus largely exogenously driven reflecting regulatory changes agreed at the policy level. No other stakeholders are immediately involved. The robustness and validity of the scenario building can therefore be assessed to be broadly appropriate.

#### *Comments*

- One cause of concern is that the way policy scenarios are implemented does not always seem to fully reflect the details of regulatory changes. For example, the Panel is not convinced that all elements of the Basel III package are fully incorporated nor that the bail-in rule is properly captured in the model according to the most recent regulation. Possibly, this is due to data limitations that do not allow for a more precise scenario calibration (as also acknowledged by the team). Nevertheless, one implication is that policy recommendations may be less precise than intended.

#### *Suggestions*

- Again, these limitations call for caution when interpreting simulation results by policy makers and eventually an effort in including all the elements of the Basel III package.

### **3.5 Transparency of the model and data**

The Panel has assessed the transparency of the model and data by aiming to establish whether: (i) the model is described using appropriate mathematical concepts and language, (ii) all key assumptions and the embedded expert knowledge are well-documented, (iii) the mathematical description of the model, code and data are stored publicly accessible, and shared with the relevant scientific community, and (iv) model runs in support of EU policies are documented in detail – including the model code and data – and stored accessibly so that, if needed, the reproduction of modelling results can be carried out at any time.

#### *Strengths*

- The documentation of the SYMBOL model includes a full mathematical description.

- Part of the model's data base is documented annually in form of JRC Technical Reports.

#### *Comments*

- The model code and data are not publicly accessible and are not shared with the relevant scientific community.

#### *Suggestions*

- The Panel recommends to aim for more openness. For example, a controlled open access would be one option to increase the transparency and hence legitimacy in EU Member States and credibility among the scientific community.

### **3.6 Validation of the model, sensitivity/uncertainty analysis of the model output**

The Panel has assessed the transparency of the model and data by aiming to establish whether: (i) the model has been validated, (ii) the model output is subject to a systematic sensitivity/uncertainty analysis, and (iii) the model limitations are well documented and stored publicly accessible.

#### *Strengths*

- The Team is aware of a number of limiting assumptions of the model and has performed several sensitivity analyses, in particular regarding the correlation structure.

#### *Comments*

- No sensitivity analyses have been undertaken regarding fat tails, the Loss Given Default (LGD) and the ratio between the LGD and the probability of default (or some macro variables).
- SRISK is being used as validation of the model's ability to predict losses. The Panel believes that a comparison with SRISK is not a particularly strong validation approach, given that both SRISK and SYMBOL measures are largely based on leverage. The Panel suspects that this is the main reason why the cross sectional rankings based on both measures are similar.

#### *Suggestions*

- The Panel suggests to perform a cross sectional ranking similar to SRISK by using just leverage and investigate potential differences.
- Another potential check of the model's performance could be to investigate how the model is able to predict bank recapitalisations (both private and public) – using the 2006 or 2007 data to calibrate the model – and then to look at the ability to predict the bank's recapitalisation during 2008, 2009 and/or 2010.
- In the same spirit, it would be interesting to check the model's ability to replicate the EBA's stress test results. Even if the underlying methodologies of the stress test and the SYMBOL model may differ, both approaches aim at capturing adverse tail events. The stress test results therefore provide a relevant reference point.



- To go one step further, it would be interesting to investigate in a horse race type analysis between the output of the SYMBOL model (i.e., bank losses) and the leverage ratio on their ability to predict the actual bank recapitalisations taking place during 2008, 2009 and 2010.
- A further useful validation exercise could be to consider banks non-performing loan data (at least at the country aggregate level) and see how the model is in line with these predictions through time.
- A deep analysis of the actual bank portfolio loss distribution can be suggested as well, to understand the dimension of errors generated by the use of the simple Vasicek model and Monte Carlo simulation. Data provided by the European Data Warehouse could be useful as well as statistics provided by different national central banks on non-performing loans and bank losses in general.
- The model could be augmented with some feedback effects (as argued above). This could also serve a way to assess the model`s robustness.

## **4 Reply to the Review Report by the SYMBOL team**

The team first would like to thank the Panel members for the work the Panel has done in providing comments and suggestions in order to improve the overall performance of the SYMBOL model. Several of the comments and suggestions raised by the Panel are issues which were known to the SYMBOL team and some have been pointed out and discussed during the two days review meeting. All the suggestions will be taken in due consideration and their feasibility and potential will be explored.

### **4.1 General comments**

We would like to stress that the main purpose of the model is not to predict the full extent of changes affecting the banking sector, or the economy as a whole, following a shock with or without a given regulation being in place. Rather, the aim of SYMBOL is to estimate economic losses as a "standardised" measure of the intensity of the consequences of shock under different regulatory settings. Incidentally, it should be noted that economic losses are different from accounting losses as reported in the banks' balance sheet and refer to the present value of realised and emergent losses over the whole life of the portfolio of the bank at the time of simulation. These losses might appear in bank accounts over multiple years as losses, reserves and deteriorated loans.

Economic losses, when compared to loss absorbing capacity and tools, then represent the comparative "pressure" that would be put on economic actors by the simulated shocks under different regulatory scenarios, "ceteris paribus" (i.e. all other things being equal). Losses and capital shortfalls obtained from the model would need to be directly offset by supplying new capital, or could generate other dynamical effects (i.e. request capital injections, de-leveraging, de-risking, restructuring, cascading impacts on the rest of the economy ...), but in any case larger losses would generate stronger pressure on actors and the economy.

Other aspects, as some mentioned in the review (e.g. quantification of dynamical impacts), though important and interesting from an academic and policy perspective are, indeed, out of the scope of SYMBOL as currently conceived. Moreover, increasing the number of assumptions would introduce additional factors driving the results whose analysis would then need to be integrated with a full-fledged model of the economy.

Having said that, exploring further extensions of the model to expand it or integrate it with other dynamic models is surely an avenue worth exploring, and we will engage some of our academic partners on the topic.

As far as collaborations with other policy institutions is concerned, this is already in place, in particular for defining scenarios and for assessing data quality. Nevertheless we also agree that, depending on the possibility of the partner institutions in sharing data, more could be done in this direction.

### **4.2 Specific comments**

#### *Section 3.1 (Methodology)*

The value of LGD is actually 45% as regulatory default value (not 40%).

We run several analyses changing the level of correlation and we also have developed a version of the model where the correlation is not fixed, but calibrated using bank-specific variables (ROA) and macro variables (GDP growth rate). A copula based estimation of banks' assets correlation is now being considered as a potential improvement of the model, as well as using fat-tailed shocks distributions for the simulations.

The contagion module is also undergoing a massive revision to overcome the data availability constraints: we are currently working on the estimation of bilateral banks'

exposures based on the aggregate interbank loans and deposits. The same methodology could be applied, in principle, to different contagion channels (derivatives, etc.). Nonetheless, it should be stressed that data limitations remain paramount in this kind of exercises. Data availability in the EBA stress test could be explored to assess the feasibility of estimating derivatives and traded assets networks besides interbank networks.

### *Section 3.2 (Policy)*

As a general comment, we agree with the Panel that policy initiatives could benefit from multiple sources of modelling support and by integrating modelling and qualitative approaches. For example, cost analysis is not part of SYMBOL based analysis. Cost analyses of new banks regulations are usually incorporated into ex-ante impact assessments involving SYMBOL, but they are based on different models (e.g. CRDIV ex-ante impact assessment provides cost/benefits analysis using SYMBOL and QUEST).

We are always willing to cooperate with other authorities where possible to refine the working assumptions and to overcome the data availability issue. However, even in these cases, data cannot normally be made directly available to us, but we share our data-sets with other institutions who then check it against their own confidential data. For instance, we have recently collaborated with the ECB for an analysis of the size of potential fiscal backstop for the resolution fund. In particular, results obtained from SYMBOL simulations were analysed by ECB using their own additional confidential data. The final outcome of the exercise was then discussed and analysed jointly.

In general, all the official documents and reports we produce clearly spell out all the limitations and caveats we face in our analyses.

In several exercises, we provided results for different crisis levels, which, in part, provides uncertainty assessment. Numerical uncertainty bounds for marginal distributions obtained under bootstrapping are extremely tight, and we are currently working on a methodology to obtain uncertainty bounds for conditional distributions, which are being used more and more often. Data uncertainty bounds (i.e. measurement error to account for inexactly measured data in balance sheets) are not readily computable as error margins for underlying data are not available.

Leverage ratios are indeed being considered as constraints triggering bank recapitalisation (see above discussion, in the general comment part, on the use of recapitalisation needs as a standardised measurement of crisis consequences) in some exercises. Liquidity ratio and net stable funding ratio cannot be easily incorporated in the model mainly because of data availability.

If the Panel refers to MIFID/MIFIR initiatives: those are out-of-the scope of the model.

Pillar 2 data are usually not available, but if they would become available, they could easily be incorporated in the model.

Regarding the resolution framework and the bail-in, we are aware that our model has some limitations: as already mentioned, they are always spelled out in the reports and they are mainly driven by data availability.

### *Section 3.3 (Data)*

Data availability and "cleanliness" is indeed an issue we are aware of. Analysis on representativeness of the sample of small/medium banks versus large banks is under investigation: based on this we would consider a change in the methodology to achieve a better rescaling from sample to population.

In more research-oriented papers we have used the ECB/stress test sample. In this case, missing data are not an issue, even in the public data-sets. The data is however at

consolidated level, which is not suitable for all applications, e.g. in the context of DGS interventions, where interventions often occur at unconsolidated (national) level rather than at group level.

As correction coefficients are concerned, country specific values are not available, and this seems to be an issue that cannot be solved. Nevertheless, we use different correction coefficients to adjust capital and RWA for banks of different sizes. In particular we differentiate SIIBs, large, medium and small banks. The issue of corrector coefficients is also becoming less and less important as the data of full implementation of CRR/CRD is being reached.

Regarding missing variables, they are imputed by differentiating banks with respect to specialisation. While we recognise that this approach has limitations, we stress that we do not assume full homogeneity, as we consider different size classes and typologies of banks.

Based on our research and experience, using consolidated is not a viable way to infer missing values in unconsolidated data. The model is therefore run either on consolidated or on unconsolidated data, depending on the purpose of the analysis.

Regarding the use of confidential data, we in fact had occasions to run the model using confidential data. The results were actually closely in line (at aggregate MS or EU level) with those obtained using publicly available data. In fact, even if only informally, in some recent exercises, comparison of simulations using confidential and publicly available data at individual level (consolidated) has been performed by a third party with access to both sources, leading to the conclusion that results were sufficiently close.

Regarding market level data, if the Panel refers to use annual report data, we confirm that we use them in case some discrepancy is found in our sample, and in any case for very large banks with missing data. In general, it is not possible to use directly annual report information, since the reporting standards and balance sheet schemes differ across different banks, and we need to rely on a commercial provider to reclassify all balance sheets according to a common template and definitions.

#### *Section 3.4 (Policy scenario)*

We are aware that, due to lack of available data, we cannot properly incorporate the entire BRRD framework in SYMBOL simulations, but we need to make some assumptions. However, we always detail all these limitations and working hypotheses to be as transparent as possible.

#### *Section 3.5 (Transparency)*

The model code will be made accessible in the near future. We are currently working with our IPR service to prepare a licensing framework. Data cannot be disclosed in full to the public, because of provider rights. We however normally make estimated distributions and aggregate results available and, depending on conditions, we could run simulations using third party data in order to check results across our own and third party implementations of the model.

#### *Section 3.6 (Validation)*

All the suggestions made in this Section are indeed very interesting, and we are going to explore their feasibility with academic partners which are part of our Community of Practice network (e.g. ability to predict recapitalisations occurred during the crisis, NPLs, etc.)

The SRISK was used not to validate the losses, but to compare individual bank risk contribution ranking and their systemic risk ranking. An analysis of leverage as a driving

factor of SYMBOL and SRISK and other approaches will be considered in the context of further model development work.

An approach incorporating alternative distributions of shocks at individual bank level is being currently explored as part of model development.

Regarding your suggestion on the feedback effects, we would like to emphasise that SYMBOL is a static model (there is no sequencing in the simulated defaults, but they are assumed to occur simultaneously). Its application in the context of feed-back loops would require a number of additional working assumptions and they could not be easily implemented.

## 5 Conclusions

SYMBOL is a micro-simulation portfolio model developed by the JRC of the European Commission that implements the Basel II/III regulatory framework, which imposes that each bank satisfies regulatory capital requirements to guard against the risks the bank may face. This capital provides a buffer against unexpected losses at a specific level of statistical confidence (in Basel II/III fixed at the 99.9% level). The amount of the regulatory capital necessary to support a portfolio of debt securities depends on the probability distribution of the portfolio loss of each bank. The SYMBOL model simulates this probability density function (PDF) of the banks' credit portfolio.

The present reports details the outcome of the review of SYMBOL, which was carried out by an external scientific Review Panel closely following 'Guidelines for the review of models used in support of EU policies'. The review was carried out by scrutinising six areas of the model development and SYMBOL's use for the EU policy support: validity of the methodological approach, model's capacity to adequately address EC policy analysis needs, adequacy and validity of the data used in the model, construction and analysis of policy scenarios, transparency of the model and data, and Validation of the model, sensitivity/uncertainty analysis of the model output.

The review aimed at verifying and consolidating the scientific credibility of SYMBOL and identifying most promising/relevant areas for a future model development. As regards the validity of the methodological approach, the Report details to what extent the conceptual framework of the model is grounded in state-of-the-art theoretical insights, and the methodology implementing the model follows sound scientific principles. As regards the model capacity to adequately address EC policy analysis needs, the Report details to what extent the model can answer relevant policy questions in a sufficiently detailed/disaggregated way, and the model is capable to capture challenges faced by specificities of the banking sector. As regards the adequacy and validity of the data used in the model, the Report details to what extent the model is empirically implemented using the best available and well-established data sources, and the construction and updating of the model data base follows sound scientific principles. As regards the construction of policy scenarios, the Report details to what extent the robustness and validity of the scenario building approach/process is ensured through interactions with other modelling tools / the involvement of stakeholders. As regards the transparency of the model and data, the Report details to what extent the model is described using appropriate mathematical concepts and language, all key assumptions and the embedded expert knowledge are well-documented, the mathematical description of the model, code and data are stored publicly accessible, and shared with the relevant scientific community, and model runs in support of EU policies are documented in detail – including the model code and data – and stored accessibly so that, if needed, the reproduction of modelling results can be carried out at any time. As regards the transparency of the model and data, the Report details to what extent the model has been validated, the model output is subject to a systematic sensitivity/uncertainty analysis, and the model limitations are well documented and stored publicly accessible.

The report includes also a first reaction from the SYMBOL team, noting that several of the comments and suggestions raised by the Panel are issues which were known to the SYMBOL team a priori and some have been pointed out and discussed during the two days review meeting. In any case, all the suggestions will be taken in due consideration and their feasibility and potential will be explored.

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## List of abbreviations and definitions

CRD	Capital Requirements Directive
CRR	Regulation on prudential requirements for credit institutions and investment firms
DG FISMA	Directorate-General for Financial Stability, Financial Services and Capital Markets Union
DG JRC	Directorate-General Joint Research Centre
EBA	European Banking Authority
ECB	European Central Bank
FSDA	Forward Search for Data Analysis
GDP	Gross Domestic Product
IA	Impact Assessment
IPR	Intellectual Property Rights
IRB	Internal Rating-Based
LGD	Loss Given Default
MIDAS	Modelling Inventory and Database Access Services
MIFID	Markets in Financial Instruments Directive
MIFIR	Markets in Financial Instruments Regulation
NPLs	Non-performing loans
PD	Probability of default
PDF	Probability density function
QUEST	QUarterly European Simulation Tool
ROA	Return on assets
SNL	Savings N Loan
SRISK	Conditional capital shortfall measure of systemic risk
SYMBOL	SYstemic Model of Banking Originated Losses



## Annexes

### Annex 1. Biography of the members of the Review Panel

**Leen Hordijk** is emeritus professor in Environmental Systems Analysis at Wageningen University. He led the Review Board in conducting this model review. He has obtained his doctoral degree at the Vrije Universiteit Amsterdam, after which has worked, among others, as the Director-General of the International Institute for Applied Systems Analysis (IIASA) and the Director of the Institute for Environment and Sustainability, the Joint Research Centre of the European Commission (IES-JRC).

**d'Artis Kanacs** is part of the JRC's Modelling, Indicators and Impact Evaluation team. He joined the Commission 10 years ago as modeller developing macroeconomic models for the EU policy support. Since then, he has been leading several modelling teams at the Commission, including the macroeconomic modelling team in Sevilla and the Competence Centre on Modelling in Ispra. He received PhD from the London School of Economics; before joining the Commission, he has held teaching and research positions in the UK, Germany, Austria, USA and Belgium.

**Christoffer Kok** is Deputy Head of the Stress Test Modelling Division of ECB's DG Macroprudential Policy and Financial Stability. He has spent the last 7 years in the DG working mainly on stress testing (including the exercises conducted by EBA and in programme countries) and on macro-prudential and regulatory impact assessments (including various macroeconomic impact assessments of the Basel Committee on Banking Supervision). Prior to that he spent 8 years in the Monetary Policy Directorate. He has degrees in economics and finance.

**Steven Ongena** is a professor in banking at the University of Zurich and the Swiss Finance Institute in Switzerland. He is a research fellow of CEPR and a research professor at KU Leuven. He has published more than 60 papers in refereed journals, including in the American Economic Review, Econometrica, Journal of Finance, Journal of Financial Economics, Journal of International Economics, Journal of Political Economy, Management Science and Review of Finance, and he has published 70 papers in books and other collections. In 2017 he received an ERC Advanced Grant and in 2012 a NYU-Fordham-RPI Rising Star in Finance Award.

**Loriana Pelizzon** is the Program Director of the Research Centre SAFE Systemic Risk Lab. She is also Professor Affiliated at the Ca' Foscari University of Venice and Research Affiliate at MIT Sloan. She graduated from the London Business School with a doctorate in finance. Her research interests are on risk measurement and management, asset allocation and household portfolios, hedge funds, financial institutions, systemic risk and financial crisis. She is a member of the Insurance and Reinsurance Stakeholder Group of EIOPA, a member of an expert panel on banking supervision for the European Parliament and an external expert for the European Commission on digital currency and blockchain technology. Furthermore, she has been involved in NBER and FDIC projects as well as in EU, Europlace, DFG, Eurofidai and Inquire Europe projects.

## **Annex 2. Meetings' agenda of the SYMBOL Review Panel**

### Thursday, 9 November

9:00 – 10:30

Meeting of the Review Panel (Panel members only)

10:30 – 10:45

Welcome and introductions (Chair)

10:45 – 12:45

Presentations by and discussion with the SYMBOL team members, focussing on questions that the chair of the Review Panel has sent before the meeting

12:45 – 14:00

Lunch

14:00 – 15:00

Presentations by and discussion with the SYMBOL team members, focussing on questions that the chair of the Review Panel has sent before the meeting (contin.)

15:00 – 17:45

Meeting of the Review Panel, agreeing on key points to be included in the Report

18:45

Adjourn first SYMBOL review day

20:00

Working dinner of Review Panel members

### Friday, 10 November

09:30 – 12:45

Meeting of the Review Panel, identifying key elements of the review report, drafting conclusions

12:45 – 14:00

Lunch

14:00 – 16:00

Meeting of the Review Panel, identifying key elements of the review report, drafting conclusions (contin.)

17:00

Adjourn second SYMBOL review day

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