3 STRESS TESTING: THE IMPACT OF SHOCKS ON THE CAPITAL NEEDS OF THE LUXEMBOURG BANKING SECTOR †

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1 INTRODUCTION

In its broadest sense, macro stress testing refers to a range of techniques employed in generating baseline and adverse scenarios which can be utilized to gauge the response of the financial system to "exceptional but plausible" shocks in the prevailing macroeconomic conditions. The goal of a stress testing exercise is to provide a quantitative measure of the sensitivity of the financial system to various shocks. When performed diligently, stress tests have the ability to become a mitigating factor in preventing the onset of future financial turmoil. For this reason, they are considered a key aspect of the role of supervisory authorities at the macro-prudential level.

Supervisory authorities and central banks increasingly view macroeconomic stress tests as a valuable tool for assessing the vulnerability of the financial system. This is true in the euro area where stress testing exercises have been conducted by the ECB and European supervisory authorities such as the Committee of European Banking Supervisors (CEBS) and many national central banks (NCBs). Furthermore, under the proposed structure of the European Systemic Risk Board (ESRB), testing will be performed on a consistent basis and will focus on assessing the soundness and overall condition of the European financial system. These stress testing programs are intended to identify any potential vulnerability in the financial system so that, in the event of a risk to stability, preventative action to safeguard the financial system can be taken. These developments are not localized to Europe. Given the level of economic globalisation, stress testing initiatives and efforts at the international level have also been ongoing. Such monitoring programs are important because systemic risk arises from the common exposures of many financial institutions to identical risk factors and can accumulate across institutions and through time. As the recent crisis showed, episodes of financial instability can impose large costs on the real economy and adversely impact economic growth.

2 STRESS TESTING MODEL

To evaluate the response of the Luxembourg banking sector to a series of adverse macroeconomic scenarios, an integrated approach was employed. A multivariate macroeconomic model, based upon the stress testing framework published in Wong, Choi and Fong (2008)[1], was used to simulate the impact of other sectors' default on the Luxembourg banking sector. Estimation of the model was conducted using a seemingly unrelated regression (SUR) system in order to capture any contemporaneous correlation in the cross-equation residuals. Within this multivariate framework, the model is able to produce an estimate of the likely shift in the distribution of default rates under various adverse macroeconomic scenarios. This is classed as a top-down approach since it links changes in the macroeconomic environment to the probability of default of the aggregate banking sector. During the simulation of the adverse scenario, macroeconomic variables and future paths are simulated, yielding a distribution for the conditional adverse scenario.

† This contribution is a new technical summary of a BCL working paper currently in progress.

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1 Wong, J., K. Choi, and T. Fong. "A Framework for Stress Testing Banks' Credit Risk", The Journal of Risk Model Validation, Vol. 2, No. 1, pp. 3-23, Spring 2008.

In detailed terms, the macroeconomic model consists of a joint system of six linear equations for the probability of default, the growth rate of Luxembourg GDP, the euro area real GDP growth rate, the real interest rate, the change in real property prices, and the SX5E index returns. This specification allows for feedback effects between the probability of default series and the evolution of the macroeconomic variables. In particular, using one or two lags of the endogenous variables in the regression allows for the persistence and transmission of exogenous shocks through the system. Through the SUR specification, the probability of default can be related to a group of macroeconomic variables thereby linking the fundamental economic environment to the vulnerability of the banking sector as a whole. Any correlation between shocks is captured by the variance covariance matrix of the residual series. This matrix is used to impose the characteristic correlation structure on the macroeconomic variables when conducting the Monte Carlo simulations.

3 MODEL ESTIMATION

To estimate the probability of default of the Luxembourg banking sector's counterparties, an aggregate balance sheet was constructed using the ratio of provisions on loans to total loans over all sectors. This ratio was then used as a proxy for the aggregate probability of default, thereby providing a metric for assessing the vulnerability of the Luxembourg financial system to various adverse macroeconomic scenarios. The historical probability of default series consists of quarterly observations over the period from the first quarter of 1995 until the third quarter of 2009. Since p_t is a probability and therefore lies in the fixed interval $[0,1]$ a logit transform, given by equation (1), is applied:

$$y_t = \ln\left[\frac{1-p_t}{p_t}\right] \qquad (1)$$

This transforms p_t such that y_t takes on values in the interval $-\infty < y_t < \infty$. Note that y_t and p_t are now inversely related to one another. Econometrically, the macroeconomic time series are required to be stationary so the first differences of the log of Euro area and Luxembourg real GDP along with the first differences of the series for real property prices are employed throughout the estimation.

The estimation results showed that increases in the growth rate of both Luxembourg and Euro area GDP result in an increase in the value of the transformed variable y_t, which is inversely related to the probability of default. Correspondingly, a decrease in Euro area or Luxembourg economic growth could result in a positive increase in this probability of default, thereby increasing the risk for the Luxembourg banking sector. A similar effect can be observed for the property price index, although there is a considerable amount of uncertainty in the coefficient. Finally, an increase in the real interest rate will negatively impact y_t. Additionally, the lagged probability of default coefficient was found to be positive and significant, which suggests that the probability of default series will result in exogenous shocks persisting for a time horizon exceeding the duration of the shock. The same observation holds for the macroeconomic variable equations. Therefore, the model correctly captures the expected dynamics between the macro-economy and the probability of default.

4 MONTE CARLO SIMULATIONS

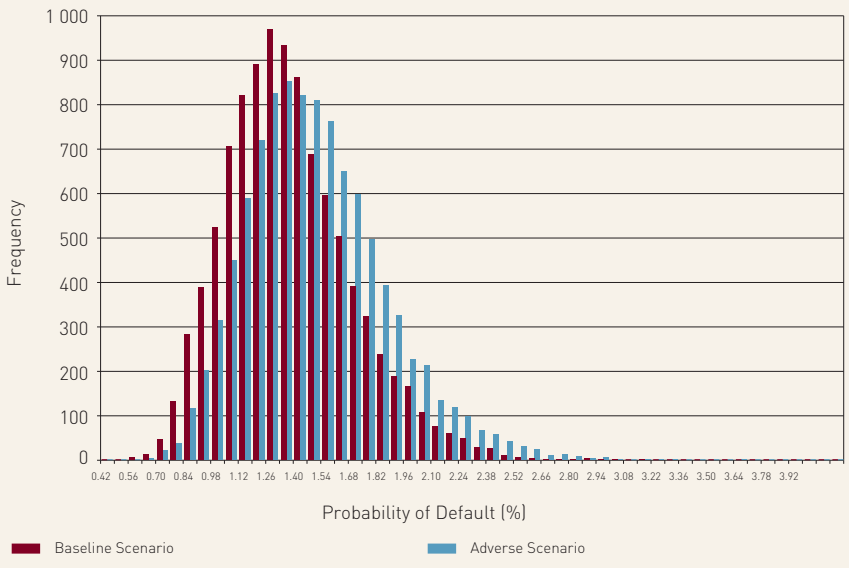
The estimated model can be used to gauge how the probability of default responds to exogenous shocks in the macroeconomic environment. To evaluate the response of the system, a Monte Carlo simulation was used to generate both a baseline and an adverse scenario. The baseline scenario is constructed by first drawing a random sample from a standard normal distribution. In order to impose the model-specific correlation pattern on the simulation, this random vector of normal variates is pre-multiplied by the Cholesky decomposition of the residual variance covariance matrix estimated from the SUR system. This procedure produces a vector of correlated disturbances which are added to the equations. Through

recursion it is possible to generate simulated forward values of both the probability of default and the macroeconomic variables over some finite horizon period. The end result of this process is that a distribution of the unconditional probabilities of default can be constructed thereby providing the baseline scenario.

The adverse scenario is constructed in a similar manner, except that at various periods throughout the simulation horizon exogenous shocks are applied to the individual macroeconomic variable equations. Consequently, the conditional distribution of the adverse scenario probability of default is governed by the dynamics of the macroeconomic variables in combination with the persistence of the shocks induced by the dynamic specification of the model. This ability to generate two separate distributions for the probability of default allows for comparison of the estimated baseline and adverse scenarios when an exogenous shock is applied to a particular macroeconomic variable. The application of the shocks to the variables of the model allows us to analyze the sensitivity of the probability of default distribution to specific adverse macroeconomic developments. Under this deterministic approach, the response of the distribution can be evaluated thus permitting a comparison of the two distributions. Distributional shifts provide information on the probable impact of macroeconomic shocks on the sector's probability of default.

In order to perform the stress test, some exceptional but plausible stressed scenarios must be generated. It is important to select scenarios that are neither too extreme nor too mild in their impact on the system because if the exogenous shocks are chosen inappropriately then the exercise will be of little utility. We choose the magnitude of the shocks to be qualitatively comparable to the recent crisis.

Figure 1
Baseline and adverse scenarios under shocks to Luxembourg real GDP growth



Source: BCL, authors' calculations

Four different stressed scenarios were employed with shocks being applied individually to the selected macroeconomic variables. The scenarios were chosen in order to focus on the various aspects of the transmission mechanism between the macroeconomic environment and the Luxembourg banking sector. The four specific scenarios include both domestic and EU level effects and are taken over a horizon of 9 quarters starting in 2009q3 and ending in 2011q4. The scenarios are comprised of the following:

1. A decrease in Luxembourg's real GDP growth of magnitude 4% starting in 2010q1 and ending in 2010q4.

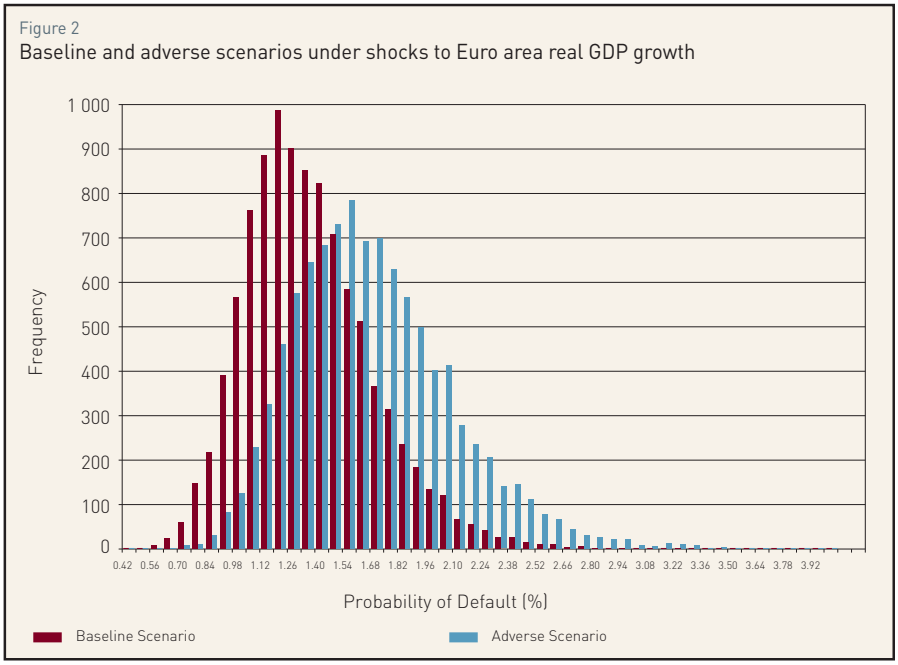
2. A decrease in Euro area real GDP growth of magnitude 1% for the first two quarters of 2010, magnitude of 0.5% in q3 and no shocks in the subsequent quarters.

3. An increase in real interest rates of 200 basis points in the first quarter of 2010 and a further increase of 100 basis points in 2010q3. There are no shocks in q2 or q4.

4. A reduction in real property prices of magnitude 2% in 2010q1 and subsequent losses of 2% over the remaining quarters of 2010.

Shocks of this magnitude represent particularly severe disturbances. It is important to note that if the shocks are too small, the test will provide no insight into the possible impact on the probability of default. Conversely, if the shocks are too large in magnitude, then the probability of such an event occurring would be too small and the testing exercise risks being uninformative. All shocks are applied on a quarter-to-quarter basis over the separate scenarios. For both the baseline and adverse scenarios we performed 10000 Monte Carlo simulations of the model[2] and used the 10000 simulated probabilities of default in the last quarter of 2011 to construct the histograms. The results are displayed in Figure 1 through Figure 4.

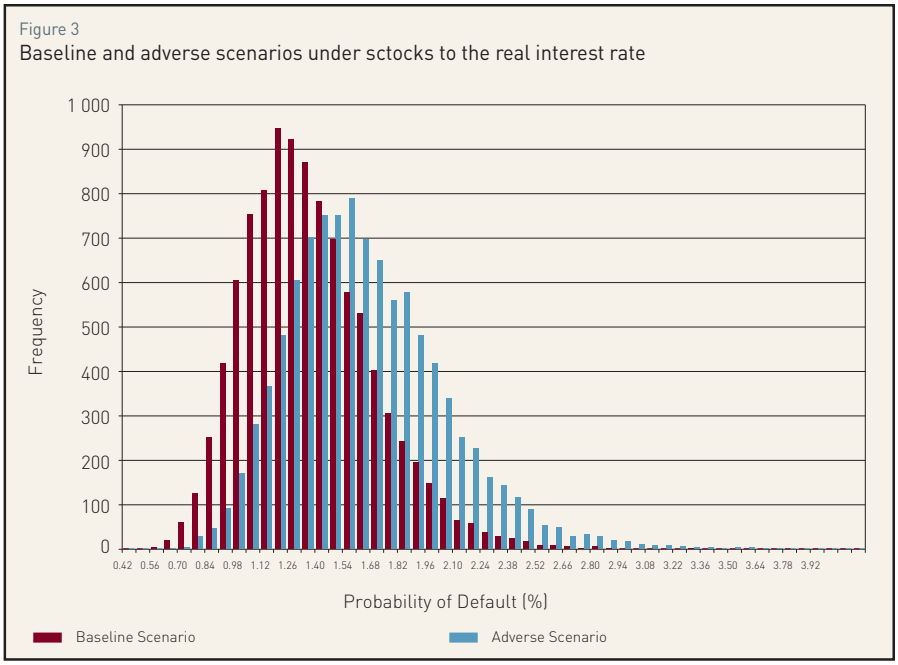
Figure 2
Baseline and adverse scenarios under shocks to Euro area real GDP growth



Source: BCL, authors' calculations

For all scenarios, the histograms exhibit a characteristic shift to the right of the stressed distribution, indicating that the average probability of default under the adverse scenario increases relative to the baseline scenario. An associated increase in the standard deviation is also observed while the tails of the distribution are more pronounced. For the shock to Luxembourg real GDP growth, the mean probability of default increases from 1.31% to 1.46% under the adverse scenario. For the remaining scenarios the increase is from 1.31% to 1.62% for Euro area real GDP growth, 1.31% to 1.58% for an increase in the real interest rate and from 1.31% to 1.61% under shocks to Luxembourg real property prices. Tail probabilities under the stressed scenario rarely exceed 3.5% and no scenario displays probabilities of default in excess of 4%. The results for the selected adverse scenarios suggest that exogenous shocks to fundamental macroeconomic variables have a limited and somewhat mild effect on the average probability of default amongst the counterparties of Luxembourg's banking sector.

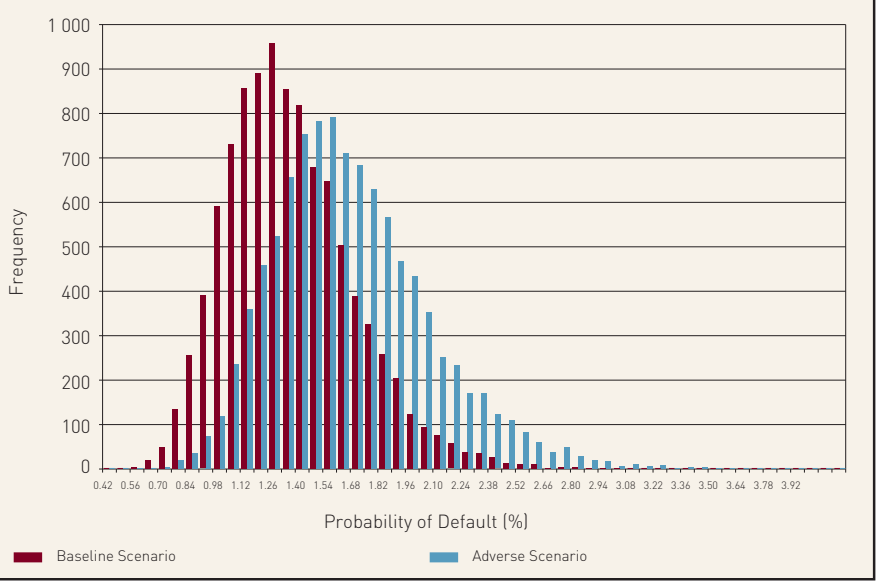
Figure 3
Baseline and adverse scenarios under sctocks to the real interest rate



Source: BCL, authors' calculations

2 More precisely, this corresponds to a total of 20,000 simulations between the two scenarios.

Figure 4
Baseline and adverse scenarios under shocks to real property prices



Source: BCL, authors' calculations

The results of the Monte Carlo simulation can also be used to gain further insight into the solidity of the Luxembourg banking sector. Using equations (2) and (3) for capital requirements for corporate exposures and Basel II tier I capital ratios, respectively, it is possible to calculate capital requirements due to counterparty risk under the adverse scenario.

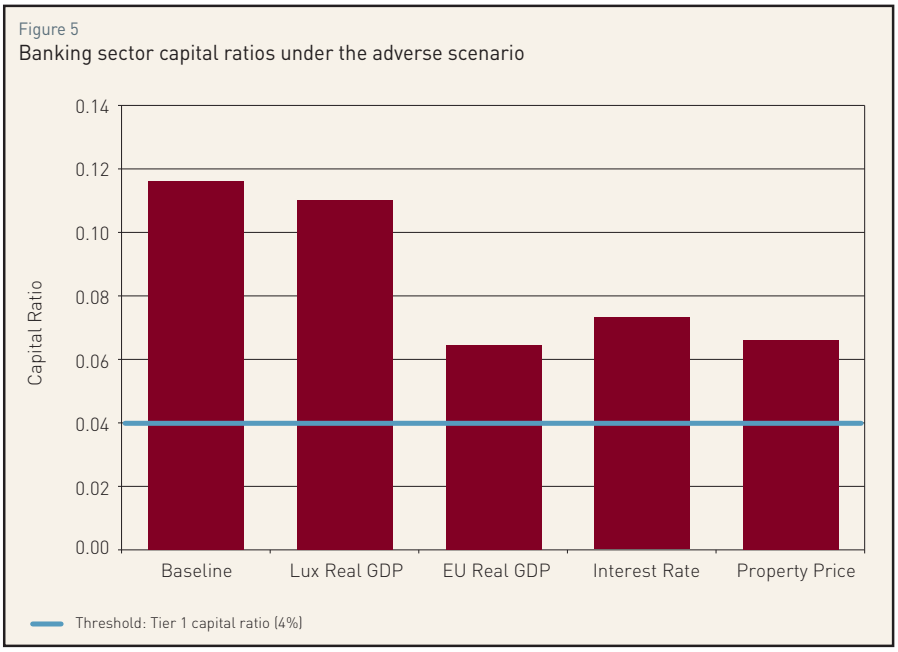
$$k_c^* = \left(LGD \times N\left[\frac{G(PD)}{\sqrt{(1-R_c)}} + \left(\frac{R_c}{(1-R_c)} \right)^{\frac{1}{2}} \times G(0.999) \right] - PD \times LGD \right) \times \left(\frac{1}{1-1.5b} \right) \quad (2)$$

$$capital\ ratio = \frac{K + \Pi}{RWA - 12.5E^c\left(k_c - k_c^*\right)} \quad (3)$$

In equation (2), $G(PD)$ represents the inverse normal distribution with the probability of default, PD, as its argument. Here $N(.)$ is the cumulative normal distribution, R_c denotes asset correlation and b is the maturity adjustment. The asterisk superscript on k denotes capital requirements under the stressed scenario. In equation (3), K denotes tier 1 capital, Π and RWA denote profit and risk weighted assets, respectively, and E^c represents corporate exposures.

To calculate the capital ratio we use data, collected by the supervisory authority, on bank profitability, risk weighted assets, loans and the amount of tier 1 capital held by banks. Due to the level of aggregation, it is important to stress these values represent average quantities. Throughout the analysis, the loss given default (LGD) is assumed to be 0.5, or 50%, and a maturity adjustment is used based on the Basel II regulations for risk-weighted assets for corporate exposures. The mean value of the 10000 probability of default values obtained from the Monte Carlo simulation is used during the calculation of the Basel II correlation and capital requirements. Figure 5 presents a bar chart showing the banking sector capital ratios under the four stressed scenarios in comparison to the baseline scenario.

Figure 5
Banking sector capital ratios under the adverse scenario



Source: BCL, authors' calculations

The horizontal line in Figure 5 represents the Basel II minimum capital requirement of 4% while the bar on the extreme left shows the capitalization ratio of the baseline scenario. Shocks to Luxembourg real GDP growth evidently have little impact on bank capitalization levels, while shocks to the remaining variables, and especially euro area real GDP growth, visibly impact capital ratios in comparison to the baseline scenario. Indeed, in the euro area real GDP case the tier I capitalization ratio decreases from 11.7% to 6.4%.

5 CONCLUSION

The stress test results suggest that, in the aggregate, Luxembourg banks would possess a tier 1 capital buffer sufficient to absorb the decrease in capitalization resulting from the macroeconomic scenarios studied in this particular exercise. More specifically, Basel II tier 1 capital ratios would remain comfortably above the current regulatory minimum of 4% under all the adverse scenarios considered. Luxembourg's banking sector therefore appears well positioned to deal with any further adverse macroeconomic developments.

The same exercise was conducted on the five largest banks, rated by total assets, in Luxembourg. All banks exceeded the minimum tier 1 capital requirement of 4%.