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AN EMPIRICAL STUDY ON THE IMPACT OF BASEL III STANDARDS ON BANKS' DEFAULT RISK: THE CASE OF LUXEMBOURG

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An empirical study on the impact of Basel III standards on banks' default risk: the case of Luxembourg[‡]

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Abstract

We study how the Basel III regulations, namely the Capital-to-assets ratio (CAR), the Net Stable Funding Ratio (NSFR) and the Liquidity Coverage Ratio (LCR), are likely to impact the banks' profitabilities (i.e. ROA), capital levels and default. We estimate historical series of the new Basel III regulations for a panel of Luxembourgish banks for a period covering 2003q2 to 2011q3. We econometrically investigate whether historical LCR and NSFR components as well as CAR positions are able to explain the variation in a measure of a bank's default risk (proxied by Z-Score), and how these effects make their way through banks' ROA and CAR. We find that the liquidity regulations induce a decrease in average probabilities of default. Conversely, while we find that the LCR has an insignificant impact on banks' profitability, those banks with higher NSFR (through lower required stable funding, the NSFR denominator) are found to be more profitable. Additionally, we use a model of bank behavior to simulate the banks' optimal adjustments of their balance sheets as if they had had to adhere to the regulations starting in 2003q2. Then we predict, using our preferred econometric model and based on the simulated data, the banks' Z-Score and ROA. The simulation exercise suggests that basically all banks would have seen a decrease in their default risk if they had previously adhered to Basel III.

Keywords: Basel III, bank default, Z-Score, profitability, ROA, GMM estimator, simulation, Luxembourg.

JEL classification: G21, G28.

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Résumé non-technique

Dans cet article, nous contribuons à la discussion sur l'efficacité des règles de Bâle III. Nous analysons la façon dont le ratio de capital sur les actifs, le ratio LCR ("Liquidity Coverage Ratio") et le ratio NSFR ("Net Stable Funding Ratio") sont susceptibles d'influencer la probabilité de défaut des banques. Pour ce faire, nous utilisons l'indice Z-score en tant qu'indicateur du risque de faillite des banques. Egalement, nous étudions séparément les principaux composants du Z-Score, à savoir le rendement moyen des actifs (ROA) et le ratio capital/actifs (CAR). Cette approche désagrégé nous permet de tenir compte de la relation endogène entre la rentabilité, mesurée par le ROA, et la capitalisation des banques, mesurée par le CAR. Nous sommes ainsi en mesure de rendre compte le plus précisément possible des avantages potentiels, dérivés d'une réduction du risque de faillite, et des coûts éventuels, provoqués par une réduction des profits des institutions, de la réglementation de Bâle III pour le cas du Luxembourg.

Nous utilisons des données bilantaires désagrégées sur les banques au Luxembourg couvrant la période 2003q2-2011q3. Premièrement, nous construisons des séries par banque pour le LCR et le NSFR. Etant donné le niveau de détail nécessaire au calcul des nouvelles règles de Bâle, des données issues des rapports des banques (reportées à des fins statistiques) à la Banque centrale du Luxembourg sont utilisées. Nous cherchons ensuite à savoir si les positions historiques des banques vis-à-vis des composantes du LCR et du NSFR sont statistiquement liées à leur risque de faillite. Pour ce faire, nous estimons les coefficients d'un système de trois équations comprenant une équation pour la rentabilité, une pour la capitalisation et une dernière pour l'indice Z-score. Cette spécification du modèle économétrique permet de tenir compte explicitement de la relation endogène entre le niveau de rentabilité et de capitalisation des banques. Plus précisément, nous supposons que les banques choisissent leur niveau de levier financier dans le but d'améliorer leur rentabilité future. Cela signifie que le ratio de levier financier affecte ROA dans les périodes suivantes. En outre, plus de bénéfices aujourd'hui permettraient d'augmenter les fonds propres par le biais des profits non distribués. Par conséquent, tandis que la rentabilité et le ratio de levier financier sont liés de façon simultanée dans ce dernier sens de la relation de causalité, dans l'autre sens, la relation est décalée dans le temps.

L'estimation économétrique des coefficients du système est effectuée équation-par-équation, en utilisant un estimateur de type "Generalized Methods of Moments". Les résultats indiquent que, parmi

les règles de Bâle III que nous étudions, le ratio de levier financier et le NSFR contribuent à réduire le risque de faillite. Ainsi, nous soutenons le point de vue du comité de Bâle qui prône la reforme de Bâle III comme étant susceptible d'améliorer substantiellement la résistance des banques aux chocs externes. Toutefois, en ce qui concerne l'impact des normes de Bâle III sur la rentabilité des banques, les résultats ne sont pas aussi facilement lisibles. Plus précisément, nous avons trouvé que l'effet des composants du LCR n'est pas statistiquement significatif et que l'impact du NSFR est expliqué par l'effet négatif de son dénominateur, ce dernier étant essentiellement déterminé par le stock d'actifs de long terme.

Notre dernière analyse cherche à mesurer l'effet de la conformité des banques avec les règles de Bâle III sur le risque de faillite. La difficulté de cette évaluation réside dans le fait que l'impact sur les probabilités de défaut va dépendre de la façon dont les banques vont réaliser les ajustements dans leurs bilans afin d'être en conformité avec les nouvelles règles. Donc, pour tenir compte des effets de substitution entre les différentes composantes du bilan, qui pourraient être déclenchés par le processus de mise en conformité avec les règles de Bâle III, nous simulons un modèle de comportement selon lequel la banque maximise ses profits sous les contraintes imposées par les nouvelles règles et les identités comptables. Ainsi, pour chaque banque nous construisons des séries simulées pour les différentes composantes du bilan considérées dans l'exercice. Les résultats des estimations économétriques précédentes permettent ensuite de construire des séries simulées pour le ROA et le Z-score. Finalement, la comparaison des séries simulées avec celles observées restitue la mesure dans laquelle on peut espérer un système bancaire plus résistant aux chocs et éventuellement moins rentable. Cette analyse met en évidence le fait que pratiquement toutes les banques auraient vu leur risque de faillite diminuer et leur rentabilité améliorée si elles avaient été en conformité avec Bâle III précédemment.

A partir des analyses présentées nous concluons que la reforme de Bâle III devrait renforcer la solidité financière du secteur bancaire.

Contents

1 INTRODUCTION

In response to the financial crisis of 2007-2009, the Basel Committee on Banking Supervision[1] (BCBS) decided to strengthen bank soundness by introducing new regulations, collectively called Basel III (BCBS [9], [8], Angelini et al. [3]). Our contribution in this article is to analyze whether or not these new regulations are likely to lead to a banking sector that will be in a better position to absorb shocks and thereby be more resilient in future crises. We focus on the three standards that are currently under evaluation, namely the Leverage Ratio (defined as the capital-to-asset ratio, CAR), the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR). All three regulations target different sources of risk and are likely to have sizable impacts on banks' balance sheets and profits. The CAR measures in how far banks are able to absorb losses. The CAR regulation constrains banks in their ability to leverage up their balance sheets and may be viewed as countercyclical in nature (BCBS [8]), especially due to the procyclicality of leverage (see Adrian and Shin [1], Giordana and Schumacher [34]). The LCR is essentially a measure of a bank's exposure to short-run liquidity risk (BCBS [9], p.3), while the NSFR is a measure of maturity mismatch aimed at promoting more medium and long-term funding (BCBS [9], p.25).

Our main objective is to analyze whether and how the Basel III regulations will impact banks' default risk. With this aim we rely on a measure of distance-to-default commonly known as the Z-Score index (see De Nicolo [27], De Nicolo et al. [28]), which assesses to which extent banks' equity can cover losses. It is defined as the sum of the average return on assets plus the capital-to-total assets ratio normalized by the standard deviation of the return on assets. In order to provide a more precise picture, we also study how these regulations impact the components of Z-Score.[2] We proceed in three steps.

Our first step is to calculate the LCR and the NSFR based on bank level data for a sample that covers the 50 largest banks in Luxembourg for the period 2003q2 to 2011q3. Due to the level of detail required to construct the LCR and NSFR, banks' statistical reporting to the central bank is used for this purpose.

[1]The BCBS is an international committee constituted by central bank representatives from all around the world and other banking supervisory authorities. It has no legally-binding authority but provides an international forum of discussion for guidelines and rules for banking supervision that local authorities may implement.

[2]The Z-Score index of banks in Luxembourg is calculated by the Central Bank of Luxembourg. Aggregated figures are published annually in the Financial Stability Review.

As a second step we empirically investigate the impact of the LCR, the NSFR and the capital-to-asset ratio on banks' profitability (measured by the return-over-assets ratio, ROA), leverage ratio and Z-Score. The econometric specification we propose allows to identify how the impacts of the new regulations on default risk are likely to be channeled through banks' profits and leverage decisions. Through this we intend to obtain a precise picture of the potential effects of the Basel III regulations, and of how the Z-Score will potentially evolve once banks adhere to the new standards.[3]

In the final step we aim at measuring the effect of compliance with Basel III on banks' default risk. One problem is that banks would need to optimally trade off several regulations and thereby the final impact on default probabilities is depending on how banks achieve the balance sheet adjustments needed for compliance. To account for these trade-offs and substitution effects among the different balance sheet components, we simulate a model of bank behavior where banks maximize their profits subject to their balance sheet constraint as well as to the new Basel III regulations. Thus, for each bank and each period, we obtain simulated balance sheet data (e.g. simulated CAR, high-quality-liquid assets) from 2003q2 onwards. We then use our regression results to predict the Z-Score and ROA based on our simulated data. Finally, we compare the observed and the simulated Z-Score and ROA, which provides us with an understanding of whether or not we should expect lower probabilities of default and a less profitable banking sector due to Basel III.

Our main results are as follows. In our econometric analysis we find that the new regulations induce a statistically significant decrease in banks' probabilities of default. Our disaggregated analysis on the components of our measure of distance-to-default allowed us to identify channels through which Basel III would mainly impact. We show the impact on default risk would essentially be driven by the regulatory limits to the leverage ratio (i.e. inverse of CAR) and the components of the NSFR. Indeed, our findings point out that a higher NSFR relates to a higher level of bank capitalisation for those banks that have a sufficient amount of stable funding and it also relates to a higher return-on-assets provided that banks hold a limited amount of long-term assets.. Finally, the econometric results indicate that the effect of the LCR on banks' profitability is statistically insignificant and that a higher capital-to-asset ratio is associated with lower a return on assets. This suggests that better capitalized

[3]One may argue that the Basel III regulations have not yet been implemented and, therefore, have not been targeted by banks. However, we consider the historical positions of estimated LCR, NSFR and capital-to-assets ratio as bank balance-sheet characteristics (or business model) and we measure to which extent they relate with banks' performance and resilience.

banks tend to have a more cautious investment profile and a lower return on equity given the level of total assets. As expected, we also find a positive relationship between CAR and ROA suggesting that banks tend to increase their capital through retained earnings.

Based on the simulation outcome and on our preferred econometric models we predict that all banks would have seen their probabilities of default decrease if they had previously adhered to the regulations. This result is due to improvements in both banks' profitability and capitalisation. Thus, we conclude that the Basel III regulation will diminish bank default risk and thereby improve the soundness of the financial sector. As the new Basel III ratios will also be applied globally, we would expect the results presented here to equally apply to other banking sectors.

There exist now several articles that study the impact of Basel III regulations (see BCBS [10], Slovik and Cournède [50], Giordana and Schumacher [33]). Most large-scale studies have been undertaken by the BCBS itself. However, the main focus is on the shortfalls associated with the regulations, as well as on some potential impacts through dynamic general equilibrium models. We view our econometric approach as complementary to their analysis and our estimation of the predicted Z-Score and banks' profitability and capitalisation, under compliance with Basel III (based on the simulated data), as the actual innovation. Our article is also related to the large literature on capital regulation and risk-taking (e.g. Lam and Chen [43], Gennotte and Pyle [32], Besanko and Kanatas [17], Wagner [52]). These articles study, theoretically or empirically, the relationship between capital regulation, banks' liquidity and their risk-taking. We contribute to this literature by our empirical assessment of the latest Basel III regulation. In addition, we complement existing results on the positive impact of bank soundness and information provision (e.g. Demirgüç-Kunt et al. [25], Barth et al. [7], Podpiera [49]). Finally, we contribute to the large literature on banks' profitability (Berger [13], Goddard et al. [36], Athanasoglou et al. [6], Berger and Bouwman [14] among others) by providing additional empirical evidence based on a comprehensive assessment of liquidity risk and on robust econometric estimations.

The article is organized as follows. Section 2 discusses the chosen measure of distance-to-default and, based on the empirical literature on banks' profitability, the endogenous relationship between banks' leverage and profits. Additionally, the Basel III standards are described. Section 3 presents the econometric specification and section 4 the data used in the study. In section 5 the results of the econometric study and of the simulation exercise are presented and analyzed. Finally, section 7 concludes.

2 Basel III regulations and the probability of default

2.1 Probability of default, leverage and profitability of banks

The economic and finance literature provides several measures of probability of default (see e.g. Merton [46], Duffie and Singelton [31], Campbell et al. [22], Basurto and Espinoza [11], Chan-Lau and Sy [23], and for applications to Luxembourg see Jin and Nadal-de-Simone [40]). In this study, we resort to the Z-Score index as the measure of bank distance-to-default[4] which has increasingly been used in the academic literature (see e.g. De Nicolo [27], De Nicolo et al. [28], Berger et al. [16], Wolff and Papanikolaou [53], Maechler et al. [45]). The Z-Score can be derived from balance sheet and profit and loss data. It is calculated as:

$$\text{Z-Score}_{it} = \frac{\text{E}_{it}/\text{A}_{it} + \text{ROA}_{it}}{\text{sd}(\text{ROA}_{it})}. \tag{1}$$

Where E_{it} is bank i's Tier 1 capital at time t, A_{it} are its total assets, then $\text{E}_{it}/\text{A}_{it}$ is the capital-assets ratio (CAR), ROA_{it} is the return on assets calculated as after tax profits divided by total assets, and $\text{sd}(\text{ROA}_{it})$ is the standard deviation of ROA_{it}. It is a measure of insolvency risk insofar as the square of its inverse is the probability that losses exceed equity for normally-distributed returns.

The appeal of this indicator as a proxy for banks' distance-to-default relies on the few assumptions that underly this measure and on its transparency and conclusive link to banks' fundamentals. However, some issues arise when coming to understand the impact of changes in its components. Looking at equation 1, one would be inclined to conclude that banks with higher leverage (i.e. CAR^{-1}) would be penalized by this index, since these banks have a smaller share of equity that could compensate for their losses. Similarly, one may expect that higher ROA_{it} leads to lower default risk and that the standard deviation on the return on assets, $\text{sd}(\text{ROA}_{it})$, reduces the Z-Score since it increases the

[4] Other related proxies are the Moody's financial strength ratings (e.g. Demirgüç-Kunt et al. [25]); Merton-KMV model (e.g. Merton [46], Anderson and Sundaresan [2]); default-mode models (e.g. Dietsch and Petey [29]); Value-at-Risk models (e.g. Duffie and Pan [30]). For a survey see Crouhy et al. [24]; for a discussion Jackson and Perraudin [39]; for a comparison Gordy [37].

probability that equity falls short of losses. However, opposite conclusions might be reached once the simultaneity of CAR and ROA is taken into account. In other words, the level of leverage affects the ROA and vice-versa, modifying the relationship between Z-Score and its components. For example, if a bank improves its ROA by increasing its leverage it is entirely possible that the increase in ROA brings this bank closer to default.

One would expect that a higher level of capital reduces the return on assets as it might signal that the bank is implementing a cautious investment strategy. Thus, other things equal, it reduces the risk on equity. However, a number of studies have found a positive relationship between capital and profits (Berger [13], Goddard et al. [36], Athanasoglou et al. [6], Berger and Bouwman [14]) while others found a negative one (Goddard et al. [35]). This suggests a bi-directional causal relationship between capital (or leverage) and profitability. Indeed, using a Granger-causality test, Berger [13] finds a positive association between CAR and ROE in both senses of the causal relationship. The arguments backing the negative relationship are consistent with the standard one period model of perfect capital markets with symmetric information between a bank and its investors. Though, as Berger [13] suggests, relaxing the assumptions of this model may yield opposite results. For example, an asset expansion that is fueled by attracting additional deposits (i.e. reduction in CAR) would reduce a bank's profits if the deposit supply curve faced by the bank is upward slopping.

The empirical evidence on banks' profitability suggests that a bank's leverage and profits might be related or simultaneously determined. As a consequence, the endogeneity issue should be reflected in the choice of the econometric methodology in order to deal with the potential bias of the estimations. In particular, instrumental variables (IV) estimators should be employed. The empirical studies within this literature examine bank-specific, industry and macroeconomic determinants of profitability defined as ROA or return-on-equity (ROE). Among the macroeconomic factors considered are the inflation rate and the long-term interest rate (Molyneux and Thornton [47], Bourke [20]) as well as GDP growth (Demirguc-Kunt and Huizinga [26]), the unemployment rate and interest rate differentials (Bikker and Hu [18]). The industry level determinants studied relate to measures of market concentration and industry size (Berger [12], Smirlock [51]). Finally, among the subset of bank-specific determinants employed one can find variables such as capital, size, efficiency, credit and liquidity risk indicators (Athanasoglou et al. [6], Goddard et al. [36] and [35], Berger [13], Demirguc-Kunt and

Huizinga [26], Berger and Bouwman [14]). Besides the assessment of the potential impact of the new regulations on profitability, we contribute to this literature by considering more sophisticated indicators of liquidity risk. Indeed, liquidity risk measures the ability of generating enough inflows to meet the net cumulative cash outflow within a certain time period. We propose to take into account all the dimensions of liquidity risk, namely the encumbrance and marketability of assets, the cash-flows and the maturity structure of a bank's balance sheet. Thus, we include as regressors the components of the Basel III liquidity regulations which we describe in the next section.

2.2 The Basel III regulations

On the background of the financial crisis 2007-2009, the BCBS introduced several new regulations and supervisory tools for banks in order to improve their resilience to shocks. The new regulatory framework enhances the risk coverage and the consistency of the capital base, reduces the procyclicality, banks' liquidity risk and their maturity mismatches (BCBS [9], [8]). Among the set of regulations we focus on three new standards, namely the Capital-to-Assets Ratio (CAR), the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR).

The CAR is defined as Tier 1 capital divided by total assets. The current Basel III proposal demands banks to hold a CAR of 3% (see p. 64 of BCBS [8]). It ensures that banks are able to cover a sufficient percentage of total assets with their own funds and constrains procyclicality by limiting the build up of leverage. In addition, given that it is a non-risk-based capital requirement, it will also contribute to the dampening of the procyclical behavior of banks by delinking the level of total regulatory capital required from the evolution of risk perceptions.

The LCR is introduced to improve banks' ability to cope with short-run liquidity needs and market liquidity risk.[5] It is calculated as the ratio of the stock of high quality liquid assets (HQLA) over the net cash outflows that are expected to arise during one month under an acute stress scenario. Once implemented, banks will be required to adjust their balance sheets such that this ratio is at least equal to one, meaning that the stock of HQLA covers the expected net outflows for one month. High quality liquid assets comprise those unencumbered assets that may be easily converted into cash without

[5]"*Market liquidity* is low when it is difficult to raise money by selling the asset at reasonable prices. In other words, market liquidity is low when selling the asset depresses the sale price. When market liquidity is low, it is very costly to shrink a firm's balance sheet" (Brunnermeier et al. [21], page 14).

significant haircuts, for example highly rated government securities. Outflows comprise deposits and other funding sources which a bank might lose during a period of stress. These liabilities receive different haircuts depending on how stable they are expected to be during financial distress. Net outflows (NO) then are calculated as outflows minus inflows, where only those inflows are included that are expected to be fully performing. Furthermore, inflows are restricted to 75% of outflows in order to assure that banks hold a certain minimum of liquid assets.

The Net Stable Funding Ratio (NSFR) is a measure of maturity mismatch risk aimed at promoting more medium-term and long-term funding of the assets of a bank. Thus, the NSFR tends to reduce the exposure to funding liquidity risk.[6] It demands the amount of Available Stable Funding (ASF) to be greater or equal to the amount of Required Stable Funding (RSF). The ASF consists of capital, liabilities with maturity greater than a year or those that are expected to be stable during a stress period. The RSF places more weight on those assets that are less liquid during stress periods and therefore require a more stable source of funding. Banks that fall short of the NSFR requirement will need to either increase their capital or those liabilities that are not likely to be withdrawn during stressed periods, or to reduce their investments in less liquid assets.

3 ECONOMETRIC SPECIFICATION

In this subsection we describe the econometric model specification and explain the choice of the estimators. We start with the model specification for the main components of Z-Score, namely the capital-to-assets and return-on-assets ratios. Then, we describe the econometric specification for Z-Score. We normalize ROA and CAR by the standard deviation of ROA (i.e. σ_{ROA}) because this allows us to derive straightforwardly the Z-Score model (equation 4) by substituting equations 2 and 3 in definition 1. The interpretation of the econometric results should be done taking into account this transformation.

In terms of bank behavior, we are assuming that banks choose their level of leverage in order to improve future profitability. This means that leverage affects future profits. In addition, higher profits today would allow increasing the equity share through retained earnings. Thus, leverage is

[6] "*Funding liquidity* describes the ease with which investors can obtain funding from financiers. Funding liquidity is high when it is easy to raise money" (Brunnermeier et al. [21], page 14).

contemporaneously related to the return-on-assets. Therefore, we consider CAR as a predetermined regressor in the ROA model[7] and the ROA series as endogenous in the CAR model.[8]

The return-on-assets is a commonly used indicator of banks' profitability which measures the ability of the bank's management to generate profits given the asset size. However, this variable might be a biased measure of profitability if the off-balance sheet activities represent an important share of a bank's return. Hence, we include the ratio between the off-balance sheet commitments and total assets as a control variable. We specify a dynamic model for ROA by including one lag of the dependent variable as a regressor. This allows us to evaluate the degree of profit persistence. Similar to previous empirical studies, we consider, as determinants of banks' profitability, several bank-specific variables as well as macroeconomic indicators. Hence, we include a comprehensive set of bank specific characteristics such as the capital-to-assets ratio (i.e. the inverse of leverage), the balance sheet size (measured by total assets), and indicators of liquidity risk and efficiency. Most importantly, we introduce our calculations of the new liquidity regulations (i.e. the components of the LCR and NSFR) as liquidity risk proxies.[9] Furthermore, we look at the efficiency of banks by means of the ratio of gross income over administrative and labor expenses. Finally, we account for the impact of macroeconomic and funding conditions on bank profits by considering the GDP growth rate, the GDP gap and the change in the short-term interest rate (i.e. Euribor three-months) as regressors, though only the later variable is retained in the final specification.[10]

The capital-to-assets ratio, the second component of Z-Score that we study, is an indicator of the bank risk profile. As is the case for the ROA model, we include one lag of the dependent variable as a regressor and we consider bank-specific and macroeconomic indicators as determinants of CAR. As previously discussed, we include the contemporaneous level of ROA. As indicators of liquidity risk we also consider the components of the Basel III liquidity ratios (over total assets), namely the ratio of high-quality liquid assets, the net-outflows ratio as well as the amounts of available and required stable funding. Finally, we include the change in the short-term interest rate as well as crises and seasonal dummies.

[7]Then, CAR_{it} is correlated with $\epsilon_{1,it-1}$ and earlier shocks but is uncorrelated with $\epsilon_{1,it}$ and subsequent shocks.

[8]This implies that ROA_{it} is correlated with $\epsilon_{2,it}$ and earlier shocks but is uncorrelated with $\epsilon_{2,it+1}$ and future shocks.

[9]The introduction of the components of the LCR and NSFR allows assessing the impact of the alternative possible ways to comply with these regulations.

[10]As an indicator of credit risk we also considered the ratio of provisions-to-loans. We did not not retain it in the final specification since the coefficient it was not statistically significant.

The ROA and CAR specifications are given in equations 2 and 3.

$$
\begin{aligned}
\left(\frac{\text{ROA}}{\sigma_{\text{ROA}}}\right)_{it} &= \alpha_{1,0}+\alpha_{1,1}\left(\frac{\text{ROA}}{\sigma_{\text{ROA}}}\right)_{it-1}+\alpha_{1,2}\left(\frac{\text{CAR}}{\sigma_{\text{ROA}}}\right)_{it-1} \\
&+\alpha_{1,3}\text{HQLAR}_{it-1}+\alpha_{1,4}\text{NOR}_{it-1}+\alpha_{1,5}\text{ASFR}_{it-1}+\alpha_{1,6}\text{RSFR}_{it-1} \qquad (2)\\
&+\alpha_{1,7}ln(\text{TA}_{it-1})+\alpha_{1,8}\text{OBSR}_{it-1}+\alpha_{1,9}\text{EFF}_{it-1}+\alpha_{1,10}\Delta\text{IR}_t \\
&+\alpha_{1,11}C_{lt}+\alpha_{1,12}C_{st}+\sum_{q=Q2}^{Q4}\alpha_{1,q}d_q+\epsilon_{1,it},
\end{aligned}
$$

$$
\begin{aligned}
\left(\frac{\text{CAR}}{\sigma_{\text{ROA}}}\right)_{it} &= \alpha_{2,0}+\alpha_{2,1}\left(\frac{\text{CAR}}{\sigma_{\text{ROA}}}\right)_{it-1}+\alpha_{2,2}\left(\frac{\text{ROA}}{\sigma_{\text{ROA}}}\right)_{it} \\
&+\alpha_{2,3}\text{HQLAR}_{it-1}+\alpha_{2,4}\text{NOR}_{it-1}+\alpha_{2,5}\text{ASFR}_{it-1}+\alpha_{2,6}\text{RSFR}_{it-1} \qquad (3)\\
&+\alpha_{2,7}ln(\text{TA}_{it-1})+\alpha_{2,9}\text{EFF}_{it-1}+\alpha_{2,10}\Delta\text{IR}_t \\
&+\alpha_{2,11}C_{lt}+\alpha_{2,12}C_{st}+\sum_{q=Q2}^{Q4}\alpha_{2,q}d_q+\epsilon_{2,it},
\end{aligned}
$$

$$
\begin{aligned}
\text{Z-SCORE}_{it} &= \beta_0+\beta_1\left(\frac{\text{ROA}}{\sigma_{\text{ROA}}}\right)_{it-1}+\beta_2\left(\frac{\text{CAR}}{\sigma_{\text{ROA}}}\right)_{it-1} \\
&+\beta_3\text{HQLAR}_{it-1}+\beta_4\text{NOR}_{it-1}+\beta_5\text{ASFR}_{it-1}+\beta_6\text{RSFR}_{it-1} \qquad (4)\\
&+\beta_7 ln(\text{TA}_{it-1})+\beta_8\text{OBSR}_{it-1}+\beta_9\text{EFF}_{it-1}+\beta_{10}\Delta\text{IR}_t \\
&+\beta_{11}C_{lt}+\beta_{12}C_{st}+\sum_{q=Q2}^{Q4}\beta_q d_q+\epsilon_{zs,it}.
\end{aligned}
$$

where, as defined in section 2.2, the HQLAR, NOR, ASFR and RSFR are respectively, the stock of high-quality liquid assets to total assets ratio, the amount of net-outflows total assets ratio and the level of available and required stable funding over total assets; OBSR is the off-balance sheet commitments to total assets ratio; EFF is an indicator of a bank's efficiency, ΔIR_t is the change in the short-term interest rate; C_{lt} and C_{st} are binary variables indicating, respectively, the 2007-2009 liquidity crisis and the ongoing sovereign debt crisis; d_q are seasonal dummies (i.e. one per quarter) and $\epsilon_{j,it} = \mu_{j,i} + \nu_{j,it}, j = 1, 2$ (and for equation 4, $\epsilon_{zs,it} = \mu_{zs,i} + \nu_{zs,it}$) represents the error term which encompasses individual fixed effects. Table 1 in the Appendix provides a precise definition of each variable.

Given definition 1, the coefficients β_j in equation 4 are non-linear combinations of the αs in equations 2 and 3.[11] The estimation of the α and β parameters can be either done by running estimations for each equation separately or for the system of equations formed by the triplet. In order to deal with the bias introduced through the dynamic specification[12] in equations 2, 3 and 4,[13] and through the assumed pre-determinated relationship between ROA and CAR, we adopt an equation-by-equation estimation strategy. We resort to a type of Generalized Method of Momements (GMM) instrument variables estimator known as system-GMM (Arellano and Bond [4], Arellano and Bover [5], Blundell and Bond [19]). In addition to the traditional specification tests (i.e. non-autocorrelation of the errors, exogeneity of the matrix of instruments), we verify that the coefficient of the lagged dependent variable estimated by the system-GMM estimator falls in the interval given by the coefficient estimated by the ordinary least squares and within estimators. Moreover, in order to keep the instrument exogeneity tests reliable, we systematically check that the number of instruments does not exceed the number of groups. Finally, aiming at dealing with potential heteroscedasticity and inter-group multicollinearity and to perform sound inferences, we recur to two-step robust standard errors.

However, a system wide estimation strategy might increase the efficiency of estimates as it adds information from the potential relationship between equations of the system, though it does not deal with the dynamic panel bias. In fact, given that the β coefficients are non-linear combinations of the α, the efficiency improvement might be sizable. Moreover, considering that we have a panel dataset with 35 periods, the dynamic-panel bias may be low (Judson and Owen [41]). In such a case a Seemingly Unrelated Regression estimator on the transformed equations (i.e. first difference or Helmert orthogonal transformation) would produce unbiased estimates. Thus, as a robustness check-up, and in order to take into account the information conveyed by the non-linear constraints on the β coefficients in the system of equations, we resort to a two-step feasible generalized non-linear least squares estimator[14].

[11] The fifth column of Table 7 provides definitions for the βs.

[12] The dynamic-panel bias is introduced through correlation between the lagged dependent variable and the fixed effects (Nickell [48]).

[13] The Zscore specification encompasses a proper AR(1) process if it is assumed that $\beta_1 = \beta_2$

[14] We use the “nlsur” command in Stata 11.

4 Data description

In this section we describe the data that we use. The analysis in this article is based on bank level data from a sample of banks in Luxembourg representing between 67 and 78 percent of the banking sector total assets (depending on the period). In regular intervals banks have to report their precise balance sheet positions to the Banque centrale du Luxembourg, as well as detailed positions on security holdings and transactions. This precise information allows us to produce an accurate estimation of the LCR and NSFR for each individual bank. Since the Basel III regulations explicitly ask for an assessment of both the LCR and the NSFR based on consolidated data, we exclude less significant branches from our analysis. Larger branches that themselves could be a source of financial instability are, nevertheless, kept in the sample. If banks report consolidated data, then we take their consolidated reports in order to calculate the LCR and the NSFR. For all other banks we rely on unconsolidated data. Finally, we constrain the sample of banks to only those that are still active in 2011q3 (i.e. in the last period of our sample).

Table 2 shows summary statistics of the variables used in the present study and Figures 1(a) to 1(d) plot the evolution of, respectively, ZSCORE, ROA and CAR, LCR and NSFR (and their components). Figure 1(a) depicts the evolution of the the median values of the natural logarithm of Z-Score for our sample of banks in Luxembourg for 2003q2 - 2011q3. We see that this variable has been increasing after the period marked by the "dotcom" crisis. Then, it decreases during 2005 reflecting potential effects of the implementation of Basel II. After a period of relative stability (2006-2007) the Z-Score starts decreasing during the recent financial crisis. Indeed, we observe a significant drop in the median Z-Score in 2007q4, which can be associated with an increase in the probabilities of default, during the financial crisis. Since the third quarter in 2009 we see improvements in the Z-Score which reaches pre-crisis levels by mid 2011. In the second half of 2011 Z-Score starts deteriorating potentially as a consequence of the European sovereign debt crisis.

Figure 1(b) depicts the median values of the normalized CAR and ROA (such that ZSCORE can be obtained by summing up them). Basically, the median of the normalized CAR is the main driver of ZSCORE and thus shows a similar evolution. In particular, Figure 1(b) shows that the continuous improvement of ZSCORE from 2009q2 onwards is mainly explained by the development of the capital-to-assets ratio. Finally, it is worth noting that at the median, banks in Luxembourg comply with the new leverage requirement (i.e. minimum of 3% on CAR) whose implementation is expected by the end of 2013. The median of the normalized ROA shows a cyclical pattern. It has been increasing until 2006q3 and then decreasing until mid 2009. A recovery phase has started in 2010 and continued in 2011, though it seems to be starting to decrease again in 2011q3. The later evolution of ROA fits the one of the Z-Score just described.

The calculation of the LCR and NSFR requires detailed information on the banks' balance sheet components. Most of these are available in the quarterly reporting of banks to the BCL on the individual balance sheet components and profit and loss accounts, with levels of detail that are broken down according to country, currency, sector of counter party and maturity. In addition, the BCL's security-by-security reporting allows to derive a virtual one-to-one mapping of the items required for high quality liquid assets. We merge the security-by-security data with the historical list of ECB eligible assets and, in order to calculate their risk-weights according to the Basel II Standardized Approach, we obtain the securities' ratings from Bloomberg. Some of the categories required by the LCR demand information in excess of that available in the banks' reports (e.g. some definitions of operational relationship). In these few cases we impose assumptions relying on bank-specific background information.

The evolution of the median LCR and its' components (i.e. high quality liquid assets and net outflows) for Luxembourg is depicted in Figure 1(c) for the period 2003q1 to 2011q3. We see that this measure has remained fairly stable until the recent liquidity crisis was triggered in 2007q4. Banks' liquidity risk increases throughout the crisis because of reductions in the stock of HQLA and increases in NO levels. Subsequently, since 2010 banks moved back to high quality liquid assets while modifying their funding strategy in order to take control of the net-outflows; Figure 1(c) clearly shows that this evolution is still ongoing.

Looking at Figure 1(d), we observe that the NSFR has been decreasing since 2003q1 and has stabilized during 2007-2008. Then, after a further reduction, it has started to increase during the second half of 2010. In particular, banks have drastically reduced their medium and long term lending, which implies strong reductions in the amount of RSF since 2008q3. Similarly, the amount of ASF has been draw down due to losses during the crisis and, during 2009, it has started to improve, driving the recovery of the NSFR.

5 Econometric Results

We now present our results from the econometric analysis based on the data described above. We start off by analyzing the results from the equation-by-equation estimation of the profitability, capitalisation and Z-Score models. After that, as a robustness exercise, we compare our results with those obtained by estimating the parameters of the system of equations defined by equations 2 to 4. In order to simplify the presentation, we do not mention the transformation of the variables and simply refer to CAR and ROA.

5.1 Profitability

Table 4 provides the results of the estimation of the ROA model (equation 2) using three alternative estimators, Ordinary Least Squares (OLS), fixed effects (FE), and Generalized Method of Moments (GMM).

We focus on the results from the GMM estimator (regression 3). The coefficient estimated on the lagged dependent variable falls between the interval given by the OLS and FE estimator indicating that the dynamic-panel bias is properly taken into account. It is high (0.899) and statistically significant, suggesting considerable persistence of profits in the Luxembourg banking sector.

The CAR coefficient in regression (3) is negative and statistically significant[15]. This relationship is likely signaling that a higher capital-to-asset ratio is associated with a more cautious investment profile. However, the coefficient is rather small, an increase in CAR of one percentage point reduces ROA by 0.00308 percentage points.

Regression (3) shows a limited impact of Basel III liquidity regulations on ROA. Both LCR components, i.e. the HQLA and the NO ratios, have statistically insignificant coefficients. This result indicates that our measures of a bank's short-run liquidity needs, which one can relate to a bank's exposure to market liquidity risk, have weak links with its profitability. Conversely, the RSF, which is the denominator of the NSFR, exhibits with a significant coefficient. A one percent increase in the RSF

[15] In order to improve the rendering of the estimation results table, ROA and CAR has been multiplied by 100 (in percentage points) when performing the estimation.

ratio reduces ROA by 0.157 percentage points. This result suggests that those banks with long-term investments, which relate to maturity mismatch and funding liquidity risk, tend to have a worse profitability. Some empirical studies introduce the liquid-assets ratio in the econometric model in order to account for liquidity risk. Molyneaux and Thornton [47] find a negative and significant relationship between the level of liquidity and profitability. Similarly, Goddard et al. [35] find a predominantly negative relationship when studying various European countries. In contrast, our approach allows us to disentangle the impact of liquidity risk on profitability and show that funding liquidity risk would be a more relevant concern for banks in Luxembourg than market liquidity risk.

As was found in previous studies on European banks, the size of banks' assets and the share of off-balance sheet activities do not have a significant impact[16], and the efficiency indicator has a positive effect on profitability. In particular, a one percent increase in the efficiency indicator increases ROA by 0.155 percentage points. The estimated coefficient of the change in the interest rate equals 0.120 and is statistically significant. A positive coefficient can be related to Luxembourg's banks' activity as liquidity providers to other financial institutions (essentially intra-group activities) if their lending rates increase faster than their funding costs. Finally, the liquidity crisis dummy is significant and has a negative sign. Likewise, the sovereign debt crisis dummy has a negative sign but it is slightly statistically insignificant.

5.2 Leverage

Now we turn to the analysis of the estimation results of the CAR model. Table 5 presents the estimated coefficients of equation 3 using OLS (regression 4), FE (regression 5) and GMM (regression 6) estimators. We focus our analysis on regression (6).

The ROA coefficient is positive and statistically significant; a one percentage point increase in ROA enhances CAR by 5.82 percentage points. Hence, a good performance allows banks to improve their capitalisation through retained earnings.

[16] There is no clear prediction on the sign of the size-profit relationship. While size certainly accounts for economies or diseconomies of scale, it can be correlated with various financial, legal and political factors that may affect profitability. The empirical evidence is not clear either. For instance, Smirlock [51] finds a positive and significant relationship while Berger et al. [15], among others, suggest that increasing the size allows for little cost saving. In a more recent European cross-country study, Goddard et al. [35] do not find convincing evidence for any consistent or systematic relationship between size and profitability. Likewise, Athanasoglou et al. [6] show that the effect of bank size on profitability is not important.

Regarding the relationship with the Basel III liquidity regulations, we can deduce from the estimated coefficients of the components of the ratios that the impacts on CAR are contained. In particular, the ASF ratio (numerator of NSFR) coefficient is the unique statistically significant component; a one percent increase in ASF ratio raises CAR by 7 percentage points. We expected these results since own funds are considered the main source of stable funding in the Basel III framework.

Regression (6) shows that asset size has no statistically significant relationship with CAR. We introduce this variable to control for potential scale effects and expected it to have a negative sign. However, the lack of statistical significance is likely to result from the fact that the banks in our sample are of similar size. Changes in the short-term interest rates do not significantly affect CAR. Finally, the liquidity crisis dummy has a statistically significant coefficient and shows up with the expected negative sign. Indeed, during the recent liquidity crisis the CAR decreased mainly due to losses. Despite that during the ongoing sovereign debt crisis banks have been engaged, on average, in a process of increasing their level of capitalisation, the sovereign debt crisis dummy is not statistically significant.

5.3 Z-Score

Table 6 presents the estimations of equation (4) using the OLS (regression 7), the FE (regression 8) and the GMM estimator (regression 9). This model results from the sum of equations 2 and 3 (after substitution of equation 2 into equation 3). As such, we expect the results stated previously to directly extend to this case. We focus our analysis on regression (9) in Table 6. For the purpose of the econometric estimation, we have applied a natural logarithm transformation to the Z-Score index (i.e. left-hand side of equation (4)).

As expected, the coefficients of lagged ROA and CAR are positive and significant. However, an AR(1) process for the Z-Score is not supported since the hypothesis of equality of the lagged ROA and CAR coefficients is strongly rejected.

We now analyze the effects of the Basel III liquidity regulations on Z-Score. While both components of the NSFR have a significant impact on the Z-Score, those of the LCR do not. In particular, a one percent increase in the ratio of available stable funding to total assets boosts the Z-Score by 0.326 percent. Similarly, a one percent rise of the ratio of required stable funding to total assets reduces

Z-Score by 0.222 percent. These results can be traced back into the previously discussed estimations of ROA and CAR. Thus, the Z-Scores of Luxembourg banks seem to be strongly driven by measures related to the time structure and stability of funding.

The estimated coefficients of the other bank's characteristics that we consider, i.e. banks' size, off-balance sheet activities and efficiency, are all statistically insignificant. These results fit the outcomes of the estimations of ROA and CAR models. It is worth noting that the efficiency indicator was statistically significant in both the ROA and CAR estimations but it showed-up with opposite signs. Regression (9) also shows that the change in the short-term interest rate has a positive sign; a one hundred basic points increase in the interest rate improves Z-Score by 0.184 percent. As we pointed out above, this might be possible if the lending rates of Luxembourg's banks increase faster than their funding cost. Although testing this hypothesis is beyond the scope of this study, it can be viewed as plausible since Luxembourg's banks play a role of liquidity providers within their banking groups. Finally, regression (9) shows that the liquidity crisis dummy is statistically significant while the sovereign debt crisis dummy is insignificant.

Thus, we conclude that the Basel III regulations are likely to improve the Z-Score of banks and thereby induce lower rates of bank default. Additionally, our results point-out that the leverage and the NSFR standards are underlying this likely positive effect. This backs the Basel III regulations and suggests that, once these regulations are binding, we are likely to see a more stable banking sector in the future.

5.4 Robustness: estimation of the system of equations

Table 7 presents the estimated coefficients resulting from the system estimation strategy. The first two columns contain the estimated parameters and their standard errors of the ROA equation, the next pair of columns those of the CAR equation and the last two columns the ones of the Z-Score equation. As can be seen, the fifth column shows the definition of the Z-Score equation parameters as a non-linear combinations of those from the ROA and CAR.

We have compared the coefficients depicted in Table 7 with those previously obtained through the GMM estimator. The results of the statistical tests are shown in Table 8. In the case of the ROA equation, the differences observed between the two alternative estimations are statistically significant for the lagged dependent variable, the lagged CAR and the coefficients of the RSF ratio (i.e. denominator of NSFR). The comparison of the estimated parameters of the CAR equation shows quite different results. The coefficient of the lagged dependent variable and of ROA$_t$, among others, are not significantly different. In contrast, the differences in the coefficients of the ASFR (NSFR's numerator), the size variable and the liquidity crisis dummy are statistically significant. In the case of the Z-Score equation, the variables whose coefficients have not statistically significant differences with respect to those of the equation-by-equation estimation strategy are: the components of the Basel III regulations (with the exception of HQLAR), the lagged ROA, the off-balance sheet ratio,the size and efficiency indicators, the change in the interest rate and the sovereign crisis dummy.

We see these results as supportive for the equation-by-equation estimation strategy. In particular, the significant differences between the coefficients of the lagged dependent variables in both the ROA and CAR models obtained through the alternative estimation strategies, lead us to prefer the equation-by-equation approach. Indeed, the GMM instrument variable estimator is explicitly designed to deal with the dynamic-panel bias.

6 When banks adhere to the regulations

We now investigate as to what is likely to happen once banks actually adhere to the regulations. In a first step we simulate, for each bank and each period, an optimal balance sheet requiring each bank to adhere to the three Basel III regulations. We restrain banks to keep their banking model constant when they adjust their portfolios. Banks minimize a loss function subject to the balance sheet, the leverage, LCR and NSFR constraints. The loss function is defined by the profits (multiplied by -1) and, as we do not know the true costs of adjusting assets and liabilities,[17] we assume that banks face a vector of independently distributed adjustment cost factors (Lucas [44], Kopecky and van Hoose [42]). We constrain the adjustment cost terms to be quadratic[18]. The complete simulation model is described in detail in Giordana and Schumacher [33].

The result of this simulation exercise is given in Table 3. We find that our simulation predicts

[17] Indeed, these costs could be direct and indirect, ranging from haircuts when selling the assets to potential reputational damage.

[18] For a discussion see Hamermesh and Pfann [38].

that the banks' assets increase, on average, by 14%. Furthermore, all new Basel III regulations have a higher mean. Finally, using the simulation outcome and based on our estimates of equations 2 (regression (3) of Table 4) and 4 (regression (9) of Table 6), we predict for each bank and period a "simulated" ROA and Z-Score which we call, respectively, $R\bar{O}A$ and $ZSC\bar{O}RE$. Both, $R\bar{O}A$ and $ZSC\bar{O}RE$ have higher means than the observed variables.

Figure 2a and 2b plot the median difference between the simulated and observed values of, respectively, ROA and Z-Score. Then, positive values indicate that the median bank would have improved its' profitability and/or Z-Score if it had been complying with Basel III. The dark blue line shows the median difference and the light blue ones the limits of a 90% confidence interval. The median difference in ROA is significantly positive in every period; the confidence interval is quite narrow and its lower limit does not overlap with zero. This is mainly explained by the increase of the high-quality liquid assets and available stable funding ratio as well as the reduction in the required stable funding ratio that compliance with the LCR and NSFR would imply (see Table 3). Similarly, one can see in Figure 2a that, even if the confidence interval is wider than in the ROA case, the median difference is significantly positive in every period.

Our results support the view of the BCBS, which believes that the new Basel III regulations raise the resilience of banks to periods of potential financial distress. In other words, we expect the LCR, the NSFR and the leverage standards to significantly reduce expected probabilities of default in Luxembourg's banking sector. It is worth noting that both, the differences in ROA and Z-Score, tend to increase during the period covering the last financial crisis and tend to decrease in 2011 during the deepening of the sovereign debt crisis. This suggests that Basel III regulations would tend to improve banks' resiliency more strongly in liquidity-type crisis periods than in financial crises arising from different underlying problems.

Of course, this result is subject to the Lucas's critique. We assume that there is no qualitative change in banks behavior once the Basel III regulations are imposed. This is, certainly, not an innocuous assumption. For example, Wagner [52] shows that higher liquidity increases a bank's stability as the bank may liquidate assets more easily during a crisis period. However, Wagner [52] also shows that these banks with higher liquidity are more likely to take on higher risks since the increased liquidity tends to make crises less costly for banks. He concludes that, overall, a banking sector's stability might actually decrease. Similar results are obtained with respect to capital regulations by Besanko and Kanatas [17], Lam and Chen [43] as well as Gennotte and Pyle [32]. Clearly, our empirical study cannot take these second-round effects into account. Nevertheless, we would expect our results to hold as long as the mechanics underlying the return on average assets do not change too much as a consequence of Basel III.

7 CONCLUSION

In this article we contribute to the recent discussion on the usefulness and effectiveness of the Basel III regulations by analyzing how the capital-to-assets ratio, the Liquidity Coverage Ratio and the Net Stable Funding Ratio are likely to impact banks' distance-to-default. We used the Z-Score as the indicator of banks' distance-to-default. We have also studied the components of Z-Score, namely the return-on-average-assets (ROA) and the capital-to-assets ratio (CAR). This approach allows us to account for the endogenous relationship between banks' profitability and capitalisation, and then to provide an accurate picture of the potential benefits (i.e. reduced default risk) and costs (i.e. reduced profits) of Basel III regulations for the Luxembourg case.

We focus on a unique panel dataset based on banks in Luxembourg covering the period 2003q2 - 2011q3. Our point of departure was the construction of historical series of the banks' positions with respect to the new Basel III regulations. We then empirically investigated whether historical positions of the LCR and the NSFR components affect banks' distance-to-default. We focused on the endogenous relationships between ROA, capital-to-assets ratio, the proxies of Basel III standards and other balance-sheet characteristics. For this we resorted to a GMM type instrumental variables estimator. Our econometric results are robust and rather clear: among the Basel III regulations that we investigate here, the leverage and NSFR standards will contribute to reduce the risk of default. Thus, we support the view of the BCBS that Basel III is likely to improve banks' resilience to outside shocks. However, regarding the impact of Basel III standards on banks' profitability we found less clearcut evidence as the impact of the LCR components is not significant and the effect of the NSFR is driven by the negative impact of its denominator, i.e. the long-term assets.

We used a model of optimal bank behavior to estimate individual balance sheets for each point in time, constraining banks to adhere to the new regulations. Our model assumes that banks minimize a loss function composed by their profits and a set of adjustment cost terms, subject to the balance sheet constraint as well as the Basel III regulations. In addition, we constrain banks' business models to remain unchanged. This gives us estimates of the banks' balance sheets and positions with respect to the Basel III regulations, assuming that these regulations had previously been put in place. We use this simulated data to derive, based on our preferred econometric models, simulated ROA and Z-Score series when banks adhere to the regulations. Based on this analysis we predict that basically all banks would have seen a decrease in their expected defaults if these banks had previously adhered to the regulations. Thus, we predict that the Basel III regulation will diminish the risk of bank defaults and improve the financial soundness of the banking sector.

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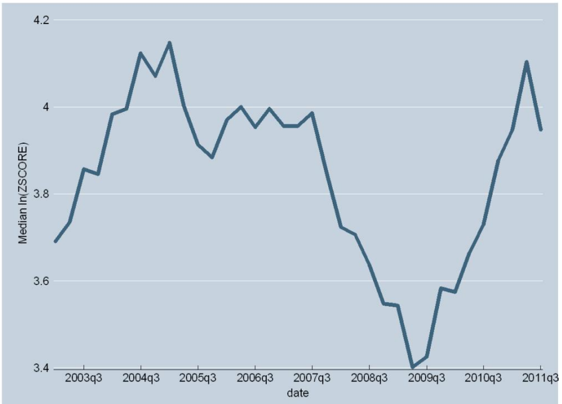
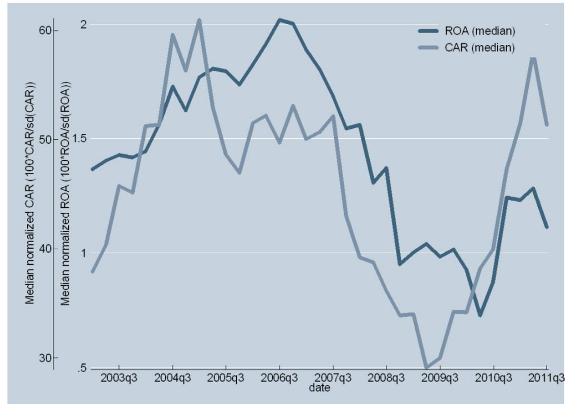
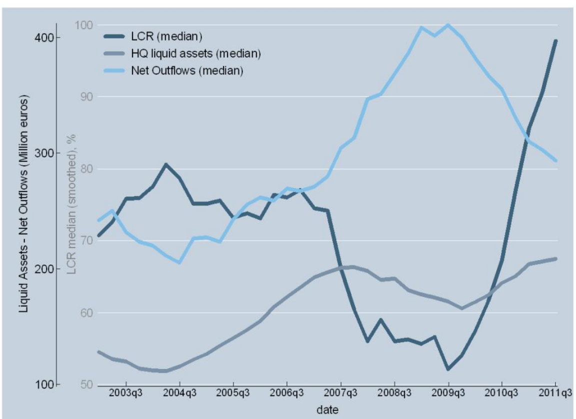
Figure 1: Evolution of main variables, 2003q2-2011q3



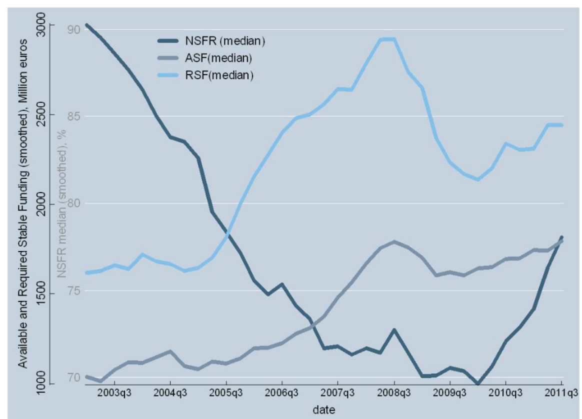
(a) Evolution of Z-Score, 2003q2-2011q3



(b) Evolution of ROA and CAR, 2003q2-2011q3

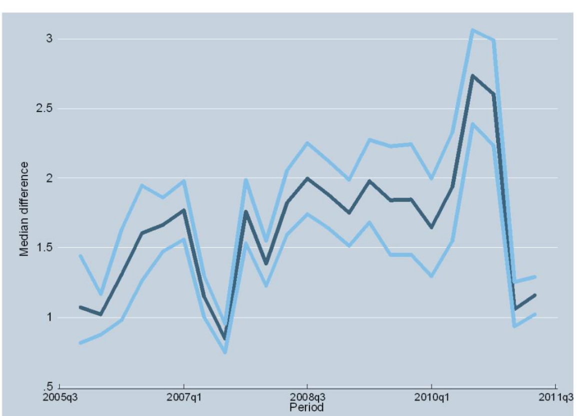


(c) Evolution of LCR, 2003q2-2011q3

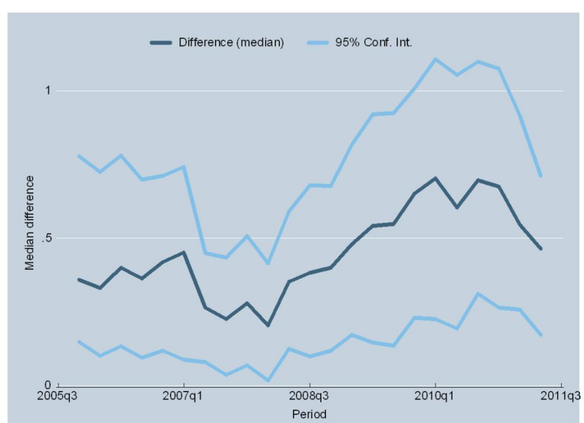


(d) Evolution of NSFR, 2003q2-2011q3

Figure 2: Comparison of simulated versus observed ROA and Z-score



(a) Median difference between simulated and observed ROA



(b) Median difference between simulated and observed Z-Score

Table 1: Variables definition

Variable	Description
ROA	Return on assets (after tax results over total assets ratio) times 100 over sd(ROA).
sd(ROA)	St. Dev. of ROA calculated using an eight periods moving window.
LEV	Total assets-to-equity ratio.
CAR	Capital-to-assets ratio times 100 over sd(ROA).
TA	Total assets.
OBSR	Off-balance sheet activities over total assets.
LCR	Liquidity Coverage Ratio (Basel III new liquidity regulations).
NSFR	Net Stable Funding Ratio (Basel III new liquidity regulations).
HQLAR*	High-quality liquid assets over total assets ratio.
NOR*	Net-Outflows to total assets ratio.
ASFR*	Available Stable Funding to total assets ratio.
RSFR*	Required Stable Funding to total assets ratio.
EFF**	Gross income over Administrative and staff expenses (proxy of efficiency).
PLR	Provisions over loans (proxy of credit risk).
C_l	Liquidity crisis dummy variable. It equals 1 if $2007q3 \leq t \leq 2009q4$ and 0 otherwise.
C_s	Sovereign debt crisis dummy variable. It equals 1 if $2011q2 \leq t \leq 2009q4$ and 0 otherwise.
IR	Short term interest rate, proxied by the Euribor 3 month rate.
Q_j	Seasonal dummies ($j = 2$, 3 and 4).

Source: Bank level data, quarterly reporting. Banque Centrale du Luxembourg's calculations.

* See section 2.2 for precisions.

** EFF is only available at the sector level (i.e. only time varying).

Table 2: Summary statistics

Variable	Mean	Median	St.Dev.	Min	Max
ZSCORE*	3.74561	3.80847	0.82709	0.86331	5.59041
ROA**	1.80289	1.50411	1.62894	-0.62719	12.35660
CAR**	55.34792	43.48417	43.42491	2.11129	265.62676
sd(ROA)	0.15030	0.09038	0.19677	0.00908	2.26599
TA***	11.340	5.876	14.049	0.231	91.185
OBSR	0.10345	0.04272	0.16453	0.00000	1.15886
LCR	150.81319	68.48145	188.54850	0.01696	973.95569
NSFR	98.42879	75.58552	78.27500	8.29574	513.70575
HQLAR	0.05968	0.02896	0.07029	0.00001	0.54906
NOR	0.07918	0.04882	0.10275	0.00060	0.68762
ASFR	0.30091	0.28243	0.16088	0.01187	0.78739
RSFR	0.39566	0.39229	0.19831	0.01550	0.86704
EFF	2.43958	2.40807	0.33597	1.60588	3.09685
IR	2.28481	2.11150	1.30486	0.42080	4.53940

* In natural logarithm, ** In percentage, *** Billion of euros.

Table 3: **Summary statistics: Simulated data**

Variable	**Mean**	**Median**	**St.Dev.**	**Min**	**Max**
Z-SCORE$_{sim}$	4.396	4.281	0.861	2.232	12.146
ROA$_{sim}$*	2.731	2.779	2.933	-16.285	7.894
CAR$_{sim}$*	82.382	58.506	93.603	3.066	1,035.199
TA$_{sim}$**	12892.134	7,390.733	15193.787	231.340	1.11e+05
OBS$_{sim}$	0.003	0.000	0.008	0.000	0.059
LCR$_{sim}$	291.181	100.000	737.764	76.261	16183.845
NSFR$_{sim}$	551.376	135.845	6,680.333	100.000	2.60e+05
HQLAR$_{sim}$	0.080	0.051	0.079	0.000	0.404
NOR$_{sim}$	0.050	0.033	0.055	0.001	0.398
ASFR$_{sim}$	0.403	0.388	0.244	0.000	1.557
RSFR$_{sim}$	0.238	0.247	0.162	0.000	0.758

Source: Bank level data, quarterly reporting. Banque Centrale du Luxembourg's calculations

* In percent. ** Billion of euros.

Table 4: Estimation results: Normalized ROA

	(1)		(2)		(3)	
	OLS		FE		GMM	
ROA$_{t-1}$	0.910***	(0.0532)	0.834***	(0.0412)	0.899***	(0.0568)
CAR$_{t-1}$	-0.00302***	(0.000676)	-0.00264***	(0.000960)	-0.00377*	(0.00225)
ln(HQLAR$_{t-1}$)	0.0230**	(0.0111)	0.00229	(0.0177)	0.0319	(0.0273)
ln(NOR$_{t-1}$)	0.00164	(0.0149)	-0.0289	(0.0404)	0.00413	(0.0486)
ln(ASFR$_{t-1}$)	0.0879***	(0.0288)	0.0519	(0.0497)	0.161	(0.109)
ln(RSFR$_{t-1}$)	-0.0864*	(0.0467)	0.0386	(0.0631)	-0.157*	(0.0911)
Size$_{t-1}$	-0.00459	(0.0147)	0.0328	(0.0597)	0.308	(0.198)
OBSR$_{t-1}$	-0.00320	(0.0428)	-0.0370	(0.0428)	0.0399	(0.103)
EFF$_{t}$	0.0806	(0.0524)	0.116**	(0.0555)	0.155**	(0.0618)
Δ IR$_{t}$	0.0736*	(0.0391)	0.104**	(0.0405)	0.120**	(0.0512)
C$_{l}$	-0.185***	(0.0443)	-0.204***	(0.0546)	-0.273***	(0.106)
C$_{s}$	-0.0335	(0.0818)	-0.0541	(0.0786)	-0.141	(0.0928)
Obs.	1590		1590		1590	
Hansen test, p.v.					0.183	
AR(1) p.v.					0.000216	
AR(2) p.v.					0.238	
Groups (Instr.) Nr.			58		58(36)	
Wald, p.v.					0.000	

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Estimation results: Normalized CAR

	(4) OLS		(5) FE		(6) GMM	
CAR_{t-1}	0.655^{***}	(0.0552)	0.450^{***}	(0.0678)	0.641^{***}	(0.0986)
ROA	6.473^{***}	(0.913)	12.47^{***}	(1.979)	6.049^{**}	(2.708)
$\ln(HQLAR_{t-1})$	1.274^{***}	(0.321)	2.134^{**}	(0.924)	0.766	(0.728)
$\ln(NOR_{t-1})$	-1.967^{***}	(0.580)	-0.0434	(1.695)	1.615	(1.406)
$\ln(ASFR_{t-1})$	2.597^{***}	(0.980)	1.350	(2.945)	6.972^{**}	(2.993)
$\ln(RSFR_{t-1})$	0.333	(1.003)	-0.267	(2.174)	-0.0320	(2.517)
$Size_{t-1}$	-0.770	(0.487)	-3.724	(3.256)	10.89	(6.681)
EFF_t	-3.874^{***}	(1.474)	-4.168^{***}	(1.314)	-13.30^{**}	(5.215)
Δ IR_t	1.865	(1.142)	1.175	(0.986)	1.523	(1.165)
C_l	-3.450^{***}	(1.143)	-4.745^{***}	(1.676)	-4.656^{**}	(1.869)
C_s	4.846	(3.107)	5.921^{*}	(3.029)	2.443	(2.476)
Obs.	1590		1590		1590	
Hansen test, p.v.					0.492	
AR(1) p.v.					0.0003	
AR(2) p.v.					0.485	
Groups (Instr.) Nr.			58		58(49)	
Wald, p.v.					0.000	

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Estimation results: ln(ZSCORE)

	(7) OLS		(8) FE		(9) GMM	
ROA_{t-1}	0.0390*	(0.0218)	0.0575	(0.0424)	0.0923*	(0.0536)
CAR_{t-1}	0.0118***	(0.00118)	0.00918***	(0.00170)	0.00835***	(0.00160)
$\ln(HQLAR_{t-1})$	0.0413***	(0.00942)	0.0187	(0.0146)	-0.0265	(0.0322)
$\ln(NOR_{t-1})$	-0.0215	(0.0152)	-0.0498*	(0.0258)	0.0447	(0.0631)
$\ln(ASFR_{t-1})$	0.130***	(0.0283)	-0.109*	(0.0640)	0.326***	(0.0652)
$\ln(RSFR_{t-1})$	-0.129***	(0.0264)	0.0707	(0.0571)	-0.222*	(0.113)
$Size_{t-1}$	0.0203*	(0.0113)	-0.0891	(0.0565)	0.171	(0.124)
$OBSR_{t-1}$	0.0304	(0.0786)	-0.0863	(0.0719)	-0.0680	(0.148)
EFF_t	-0.0123	(0.0411)	0.0151	(0.0504)	0.00888	(0.0438)
Δ IR_t	0.0515	(0.0324)	0.0737**	(0.0337)	0.184**	(0.0817)
C_l	-0.0756**	(0.0296)	-0.122**	(0.0533)	-0.162*	(0.0931)
C_s	-0.00147	(0.0738)	0.000916	(0.0620)	-0.105	(0.0919)
Obs.	1590		1590		1590	
Hansen test, p.v.					0.320	
AR(1) p.v.					0.0000810	
AR(2) p.v.					0.443	
Groups (Instr.) Nr.			58		58(51)	
Wald, p.v.					0.000	

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Robustness: Non-linear SUREG estimation

	ROA		CAR		ZSCORE		
ROA_t			0.713***	(0.009)			
ROA_{t-1}	0.794***	(0.018)			$\alpha_{11} \cdot (1+\alpha_{22})$	0.166***	(0.009)
CAR_{t-1}	0.001*	(0.001)	0.713***	(0.001)	$\alpha_{21} + \alpha_{12} \cdot (1+\alpha_{22})$	0.713***	(0.01)
$\ln(HQLAR_t)$	-0.012	(0.015)	0.337***	(0.114)	$\alpha_{23} + \alpha_{13} \cdot (1+\alpha_{22})$	0.335***	(0.112)
$\ln(NOR_{t-1})$	-0.016	(0.025)	-0.129	(0.231)	$\alpha_{24} + \alpha_{14} \cdot (1+\alpha_{22})$	-0.133	(0.229)
$\ln(ASFR_{t-1})$	-0.004	(0.048)	0.674*	(0.376)	$\alpha_{25} + \alpha_{15} \cdot (1+\alpha_{22})$	0.673*	(0.37)
$\ln(RSFR_{t-1})$	0.024	(0.043)	0.219	(0.386)	$\alpha_{26} + \alpha_{16} \cdot (1+\alpha_{22})$	0.224	(0.382)
$Size_{t-1}$	0.087**	(0.038)	-0.173	(0.249)	$\alpha_{27} + \alpha_{17} \cdot (1+\alpha_{22})$	-0.155	(0.242)
$OBSR_{t-1}$	-0.012	(0.064)			$\alpha_{18} \cdot (1+\alpha_{22})$	-0.002	(0.013)
EFF_t	0.143***	(0.049)	0.259	(1.016)	$\alpha_{29} + \alpha_{19} \cdot (1+\alpha_{22})$	0.03***	(0.01)
Δ IR_t	0.074**	(0.036)	0.597	(0.42)	$\alpha_{210} + \alpha_{110} \cdot (1+\alpha_{22})$	0.613	(0.418)
C_l	-0.065*	(0.036)	-1.841***	(0.479)	$\alpha_{211} + \alpha_{111} \cdot (1+\alpha_{22})$	-1.855***	(0.479)
C_s	-0.049	(0.092)	0.662	(1.407)	$\alpha_{212} + \alpha_{112} \cdot (1+\alpha_{22})$	0.652	(1.408)
Cons	-0.309**	(0.119)	-2.03	(2.506)	$\alpha_{20} + \alpha_{10} \cdot (1+\alpha_{22})$	-3.885	(2.797)
Obs.	1587		1587			1587	
R.sq	0.6943		0.6963			0.9912	

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Coefficient comparison test: equation-by-equation versus Non-linear SUREG estimation

	ROA		CAR		ZSCORE	
Variable	z	$P(Z > \|z\|)$	z	$P(Z > \|z\|)$	z	$P(Z > \|z\|)$
ROA_t			0.78	0.435		
ROA_{t-1}	1.768	0.077			1.328	0.184
CAR_{t-1}	2.069	0.039	0.244	0.808	69.957	0.000
$\ln(\text{LAR}_{t-1})$	1.387	0.165	1.073	0.283	3.1	0.002
$\ln(\text{NOR}_{t-1})$	0.368	0.713	1.447	0.148	0.372	0.71
$\ln(\text{ASFR}_{t-1})$	1.381	0.167	1.825	0.068	0.925	0.355
$\ln(\text{RSFR}_{t-1})$	1.806	0.071	1.108	0.268	1.122	0.262
Size_{t-1}	1.1	0.272	2.08	0.038	0.055	0.956
OBSR_{t-1}	0.424	0.672			0.472	0.637
EFF_t	0.154	0.877	1.173	0.241	0.447	0.655
$\Delta\ \text{IR}_t$	0.735	0.462	0.732	0.464	1.006	0.314
C_l	1.86	0.063	1.648	0.099	4.135	0.000
C_s	0.698	0.485	1.26	0.208	0.537	0.592

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