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LIQUIDITY RISK MONITORING FRAMEWORK: A SUPERVISORY TOOL

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Liquidity risk monitoring framework: A supervisory tool

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Abstract

Over the last 12 months, the supervision of liquidity has become one of the most discussed issues by the central banks and the financial market authorities. The objective of this paper is to describe the off-site liquidity monitoring framework recently implemented as one of the supervisory tools of the Banque centrale du Luxembourg. In our approach, the liquidity position of every bank is described by two different scores that take into account the bank's liquidity position across "peer" banks as well as over time. The framework has three major outputs. First of all, it helps supervisors to identify banks with weaker liquidity positions. Secondly, the scores can be decomposed among 21 risk factors. Finally, the framework creates a basis to draw conclusions about the general trends within the Luxembourg banking sector for the purpose of ensuring financial stability. Unlike common supervisory scoring systems generally based on banks' balance sheet and profit and loss data, our framework integrates on- and off-balance sheet data and general and idiosyncratic market data as well as macroeconomic data.

Keywords: Liquidity risk, Stress-test, Banking sector, Prudential supervision, Scoring system, Off-site supervision

JEL classification: G01, G21

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The views expressed in this paper are personal views of the authors and do not necessarily reflect those of the Banque centrale du Luxembourg. The principal component analysis described in the Box 1 was performed with a use of Tanagra (open source software: http://eric.univ-lyon2.fr/~ricco/Tanagra/fr/tanagra.html)

Résumé non-technique

Dans cette étude, nous décrivons le système de monitoring des liquidités utilisé en tant qu'outil de la surveillance des liquidités effectuée par la Banque centrale du Luxembourg. Ce système d'évaluation de la liquidité des banques individuelles est basé sur une approche de comparaison mutuelle. La situation en matière de liquidité de chaque banque de la Place est comparée selon deux dimensions directrices. D'un coté, nous comparons les banques analysées du point de vue des variables de liquidité respectives (approche de matrice). D'un autre coté, nous comparons les variables de liquidité pour chaque banque dans le temps. Cette méthodologie nous permet de répondre à deux questions cruciales pour toutes les banques: (i) Quelle est la position relative de chaque banque par rapport aux autres banques en matière de liquidité ? (ii) Quelle est l'évolution de la position de liquidité d'une banque dans le temps ? Les réponses à ces questions sont présentées sous la forme de deux "*scores*" calculés pour l'ensemble des banques de la Place financière.

Nos calculs sont basés sur plusieurs types de données. Nous avons utilisé des données bilan et hors-bilan provenant des rapports statistiques et prudentiels. Ces données comptables nous ont permis d'analyser la situation individuelle de chaque banque. Nous avons aussi utilisé des données du marché financier (prix d'action de la société mère et sa volatilité, valeur des indices boursiers principaux et l'écart entres les différents taux d'intérêt), ainsi que des données macroéconomiques (indicateur de confiance des consommateurs au Luxembourg, indicateurs de confiance économique des pays respectifs publiés par l'OCDE et les "*special drawing rights*" du FMI). Cette méthode qui consiste à utiliser aussi bien des données du marché financier que des données macroéconomiques nous aide à considérer la situation générale de la maison mère, les conditions sur des marchés financiers et les développements macroéconomiques qui contribuent ensemble à la position de l'entité locale en matière de liquidité. Les *scores* calculés pour toutes les banques locales intègrent quant à eux quatre groupes de variables ayant un certain impact sur cette position: (i) la situation de l'entité luxembourgeoise, (ii) la situation de sa maison-mère, (iii) le développement sur les marchés financiers et (iv) le développement macroéconomique général.

Pour effectuer des analyses pratiques des banques individuelles, les scores peuvent être décomposés en facteurs de risque spécifiques en prenant en considération la contribution respective de ces facteurs aux scores. Cela nous permet d'identifier les sources de problèmes potentiels, qui peuvent être idiosyncratiques ou généraux. Néanmoins, la décomposition des scores *ex post* a identifié des caractéristiques communes des banques en situation de *stress* pendant l'automne 2008 (Box 2). De l'autre coté, une analyse agrégée des facteurs de risques nous permet de tirer des conclusions sur le développement du secteur bancaire luxembourgeois.

En ce qui concerne les derniers résultats (septembre 2009), la situation de la plupart des banques en matière de liquidité s'est améliorée pendant les deux derniers trimestres, mais reste toujours moins favorable qu'avant le début de l'année 2008. Les banques dont la situation est plus favorable, sont en général des banques avec des sommes de bilan plus importantes. En conclusion, on peut dire que : (i) les plus grandes banques de la Place sont généralement en peu plus liquides que les banques de petite taille, (ii) la situation individuelle des banques de toute taille est moins favorable qu'avant le début de la crise.

Introduction

Monitoring liquidity in credit institutions has been a rising matter of debate among regulators since the beginning of the liquidity crunch in August 2007, in particular with respect to the banking sector, where several authors focused on macro stress test exercises [Van den End 2008, Boss et Altera 2007]. Nevertheless, the literature on frameworks adopted by central banks and financial regulators on monitoring liquidity risk of single banks is scarce. In this context, a paper issued by Bank of Japan [2009] tackles the issue of liquidity monitoring in the banking sector. In this analysis, the central bank perspective is highlighted as well as complexity of liquidity risk, and as a consequence, the difficulties embedded in the monitoring process itself. Assessment of liquidity risk based on indicators (with a dynamic, forward-looking perspective) has been proposed by the Financial Services Authority (FSA) [2009] through its consultation papers on strengthening liquidity standards, which also propose a set of metrics for liquidity monitoring. In this latter discussion papers, several issues arise regarding comparability across different banks as well as the problems related to the intrinsic value of such liquidity metrics extrapolated from their economic and financial context.

Market developments from this period have also reminded us about the tricky nature of liquidity risk. Based on this experience, this study contributes to the existing literature as it considers liquidity risk from a different perspective, namely as a relative problem. Indeed, our framework does not define a threshold below which a bank would be considered as illiquid. Our assessments are always relative, since they result from comparisons. In this context, we believe that, in order to evaluate the liquidity position of a bank, it is reasonable to compare its liquidity variables in two aspects. On one hand, the liquidity variables of a bank are compared to the liquidity variables of similar banks, if the latter can be identified. On the other hand, these variables are compared to the liquidity variables of the bank itself over time. In other words, we focus on two principal dimensions in our analysis: (i) the definition and evaluation of the liquidity position of a selected bank across a sub sample of similar banks previously identified through a matrix-based approach and (ii) the definition and evaluation of the liquidity position of a selected bank by comparing it to its past liquidity. This latter dimension integrates a scenario-based set of weighted indicators combined with a set of market and macroeconomic data, for each bank located in Luxembourg. The outcome of this process is a scoring-based system which allows us to evaluate the relative degree of liquidity risk of each bank at a certain point in time and helps us to understand the nature of liquidity risk by decomposing it into individual risk factors.

As highlighted by the FSA [2009], comparability across banks implies the use of standardized metrics. These metrics would trigger a biased assessment of their liquidity profile when applied to a heterogeneous population of banks in terms of sources of liquidity risk. Similar ratios may imply different liquidity risk levels across diverse businesses. This is true for the Luxembourg banking sector, which is characterized by a large number of subsidiaries and branches of foreign banking groups which often focus on several niche businesses (e.g. custody, private banking and covered bond issuance). A set of indicators identified as relevant for each business activity was defined partly on the basis of Rychtárik Š. [2009]. Moreover, the peculiarity of the Luxembourg banking sector requires the inclusion in the scoring process of a set of ratios assessing the liquidity and (to a certain extent) the financial situation of the banking group as well as the

economic situation of the country of origin of the local entity. This allows for a more comprehensive and more realistic assessment of the local entity's liquidity position. As regards the choice of macro variables, we integrate results of several studies. The definition of a subset of variables which are significant for the assessment of the liquidity profile of each bank originates from several analyses. The choice and the relative literature will be discussed in the related paragraphs.

The observation of the individual scores suggests that in the autumn of 2008, most of the banks located in Luxembourg have experienced their tightest liquidity situation since 2003. For a majority of the banks, the results for September 2009 show better liquidity positions than a year ago, but these remain less favourable than before 2008. On a peer basis, the liquidity position of several bigger banks tends to be a little more robust than that of the rest of the banking sector.

2 Methodology

This study is based on a panel of 145 banks (all banks located in Luxembourg at the time the study was conducted) and on an historical reference dataset.[1] Our database includes both balance sheet data and financial market and economic indicators. The methodology consists of one basis foundation and two core pillars:

- The foundation consists of a risk factor matrix approach that allocates a set of liquidity risk factors with respective weights to each bank, based on its business activities (see section 2.1 The foundation: the risk factor matrix).
- The first pillar evaluates the liquidity position of a selected bank vis-à-vis that of similar banks ("peers"). Thus, it attributes a "peer score" to each bank, based on the selected set of liquidity risk factors. This score is calculated on the basis of each bank's on- and off- balance sheet figures compared to the other banks for different time periods (see section 2.2 The first pillar: the peer score).
- The second pillar assesses the current liquidity position of a selected bank over time vis-à-vis its historical values. It defines a "time score" for each bank, which integrates both a micro- and a macro-component. (see section 2.3 The second pillar: the time score).

These scores can be further analysed bank by bank as they change over time and they can also be decomposed to identify the main liquidity risk factors for every bank (see section 3.1 Liquidity risk profile of individual banks). Moreover, the framework can be used as a tool in general banking sector analysis e.g. for financial stability purposes (see section 3.2 Aggregated results)

2.1 The foundation: the risk factor matrix

Different types of banking activities are often related to different sources of liquidity risk. Therefore, the analysis or the quantification of liquidity risk needs to be tailored to the set of local banking activities. The BCL previous research [Stragiotti, F. 2009] showed that

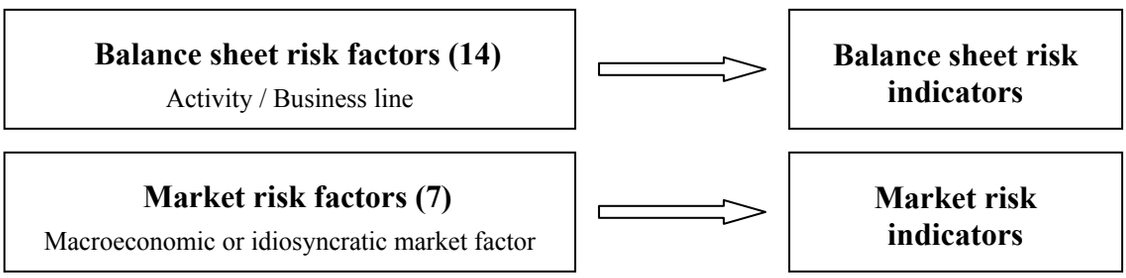
[1] 1Q / 2003 - 3Q / 2009 for the market data and 4Q / 2005 – 3Q / 2009 for the on- and off-balance sheet data

Luxembourg banking sector is characterized by a rather high level of specialization. Several banks are active in a few highly specific activities, such as custodian or depository banks, covered bond issuance banks, etc… The average level of activities is not often characterized by less than two business activities per bank. This implies that banks may not be merely classified by allocating a bank to one and only business activity. Similarly, even if there are some typical combinations of business lines (e.g. private banking and fiduciary deposits, custody and asset management), to cluster banks located in Luxembourg into several "peer" groups would necessarily result in an oversimplification of reality. To avoid it, the methodology presented in this paper is founded on a matrix of weighted liquidity risk factors, translated into indicators and mapped for every bank in the sample.

For this purpose we have selected and defined 14 on- and off- balance sheet risk factors and 7 market risk factors. We believe that these 21 risk factors cover, altogether, even though with different importance, a large spectrum of the potential sources of liquidity stress relevant for the banks active in Luxembourg. For the calculations of the scores, these risk factors were transposed to concrete variables, i.e. the risk indicators (Figure 1).[2]

This chapter describes the reasons behind the selection of risk factors and their translation into indicators. First, we focus on the balance sheet risk factors (Table 1) and then on the market risk factors (and Table 3).

Figure 1 Balance sheet and market risk factors



2.1.1 Balance sheet risk factors

Since the character of liquidity risk depends also on the type of business run by banks, it is necessary to identify the main banking activities located in Luxembourg. Our main sources of information were: (i) regulatory reporting data, also treated by a principal component analysis (Box 1), (ii) annual reports of the banks, (iii), questionnaires[3], (iv) meetings with banks, (v) on-site visits and (vi) other sources (e.g. The Luxembourg Bankers' Association[4]).

The aggregation of the knowledge acquired via these different channels, allowed us to identify 6 leading business lines:

Luxembourg retail: the main component of this activity is the local (Luxembourg) origin of the banks' client base. This consists on the collection of deposits from locally

[2] List of all variables, indexes and abbreviations used in the paper are in Annex D
[3] See Stragiotti [2009]
[4] For more information on this organization please visit: www.abbl.lu

established households and small and medium-size enterprises. On the asset side it focuses on providing credits, including mortgage loans, to the same category of clients. Generally three types of banks are active in this segment: (i) domestic Luxembourg banks, (ii) some of the multiline international banking groups and (iii) "*Bausparkassen*".

Wealth management: this defines mainly private banking activities, whereas the geographic origin of clients is less relevant. Indeed, private clients' deposits originate mainly from other countries. This activity is often related to asset management services observed in banks' off-balance sheets as well as from deposits from private clients. These services are often provided through a special entity (subsidiary or branch) of a large international banking group or as a part of a multiline subsidiary. Many of the banks active in this business provide the liquidity surplus to members of the parent banking group.

International corporate banking: we refer here to the provision of credits and syndicated loans to large international enterprises or financial holdings usually located in several countries. These assets are often denominated in euro or US dollars. Banks involved in this activity are characterised by a large credit book, rather heterogeneous from a geographical point of view. However, the corporate banking often implies significant volumes of corporate deposits on the banks' balance sheets, or funds received from the parent banking group.

Investment fund and investor services: it mostly concerns fund administration, custodian and depository functions. Banks active in this business area have usually large off-balance sheets and a certain volume of activity with investments funds on the asset and liability side of the balance sheet. In general, custodian banks are rather specialised; this business line is usually combined only with assets and liabilities related to the fund industry.

Asset management for their own banking group: The assets of these banks are dominated by different types of securities, mainly debt instruments and structured finance products. In a number of cases it consists of treasury activities on behalf of the group as well as trading. Liability side can be characterised by intra-group or interbank deposits as well as issuance of debt instruments.

Issuance of securities: similarly to the previous business line, this activity can be often understood as a strategy of a banking group to use its Luxembourg entity to issue debt on behalf of the group. These issuances are mainly covered bonds given the favourable local legislation. The liquidity received from the issuance is generally transferred to the parent banking group or invested in debt securities.

All these leading banking activities are further translated into liquidity risk factors to capture the liquidity risk resulting from respective business lines (Table 1). Apart from these main business lines, some other activities were identified as potential sources of liquidity stress. These are mostly liability driven factors e.g. deposits from investment funds, deposits from off-shore centres (OECD, 2007) and fiduciary deposits. These activities were also translated into risk factors. Finally, regarding the host character of Luxembourg banking sector and general conditions in the euro interbank market, additional liquidity risk factors were added to our analysis. Finally, we have identified 14 risk liquidity factors that can be defined by on- and off-balance sheet data (Table 1).

Table 1 Balance sheet risk factors

Risk factor	Type of trigger	Description
Freeze of interbank market	Macro	Banks are not willing to lend to each other which leads to a substantial decrease of interbank positions, both long and short.
Capital markets shock	Macro	Fall in debt securities prices results in a decrease in the value of liquid assets.
Retail run in Luxembourg	Idiosyncratic	Withdrawal of certain volume of household deposits, triggered by rumours.
Private run	Idiosyncratic	Withdrawal of certain volume of private deposits, triggered by rumours.
Corporate run	Idiosyncratic	Withdrawal of certain volume of corporate deposits triggered by rumours.
Withdrawals by funds	Idiosyncratic	Withdrawal of fund deposits triggered by banks' rating downgrade or as a result of fund redemptions
Issuance problems	Macro / Idiosyncratic	Problems to raise funding by new issuance triggered either by unfavourable market conditions or banks' rating downgrade.
Custodian operational issues	Idiosyncratic	Due to operational issues in settlement the bank runs into overnight liquidity shortage.
Committed credit lines	Idiosyncratic	Generous loans commitments given during favourable market conditions are drawn down by the counterparties.
Foreign exposures	Macro	Credit risk problems in foreign country / currency exposures result in a liquidity problem.
Fiduciary deposits	Legislative	Due to changes in regulation, fiduciary deposits become more volatile.
Off-shore centres	Legislative	Due to stricter regulation of off-shore centres, some of the flows become more volatile.
Eurosystem refinancing	Idiosyncratic	Conditions of accessing the Eurosystem liquidity become stricter (e.g. collateral criteria and haircuts)
Group liquidity	Group idiosyncratic	Netting of the position with banks from the parent banking group

Definition of the balance sheet risk indicators

In this section we define our 14 balance sheet risk indicators. We use them both as an input to calculate the peer score in the first pillar and as an input for time score calculations in the second pillar. They are based exclusively on available on- and off-balance sheet data. The values of the balance sheet indicators are specific for every bank (b) and every period (t).[5]

The 14 indicators share two major common characteristics. First, in order to make the liquidity ratios comparable among different banks, the denominator usually contains the information about the size of the bank (TA). Second, since the concept of liquidity buffer seems to be one of the crucial factors in liquidity risk, we have introduced a variable of liquid assets (LA), which is an important component in all liquidity indicators.

Our definition of liquid assets (LA) contains cash (T), central banks receivables (C_{cb}), short term deposits with other banks (${}^{1Y}C_b$) and with related party banks (${}^{1Y}_{rp}C_b$) and debt

[5] To make the formulas in this section more readable, we do not include indexation of b and t, still the values of the indicators are bank and time specific.

securities portfolio (S_j). To take into account the volume of securities pledged in Eurosystem and used in refinancing operations, the amount borrowed from the central banks (D_{cb}) is deducted from liquid assets.

$$LA = T + C_{cb} + {}^{1Y}C_b(1 - v_{{}^{1Y}C_b}) + {}^{1Y}_{rp}C_b(1 - v_{{}^{1Y}_{rp}C_b}) + \sum_{d=1}^{K}\left[S_d(1 - v_d)\right] - D_{cb} \qquad (1)$$

As regards the debt securities portfolio (S_d), we apply a set of valuation haircuts (v_d) for different types of issuer and the sovereign rating of the country of the issuer. Since no data about overnight deposits are available, we also apply haircuts on ${}^{1Y}C_b$ and ${}^{1Y}_{rp}C_b$ to take into account the volume of Nostro accounts available at any moment in time. [6]

According to the European Central Bank [2006], more diversified funding sources may have a positive impact on a bank's risk profile. We use the Herfindahl-Hirschmann concentration index (h[7]) as a proxy for the diversification of funding of individual banks. The more concentrated are a bank's liabilities, the lower is the diversification effect.

For each risk indicator, α_i represents the stress parameter. As regards risk factors of a general nature (e.g. freeze of the capital markets, capital market shock) the stress parameters are applied symmetrically to all banks. For risk indicators that are more idiosyncratic (e.g. household, private or corporate run), the stress parameters (α_i) are calculated for individual banks to take into account the different volatility of their balance sheets.[8]

Freeze of interbank market

In this scenario, we simulate a situation where banks are not willing to lend to each other. This leads to a substantial decrease of interbank positions, both long and short.

$$\frac{LA - {}^{1Y}C_b(1 - v_{{}^{1Y}C_b}) - \alpha_i((D_b - {}_{rp}D_b) - (C_b - {}_{rp}C_b))}{h(TA - \min(\alpha_i(D_b - {}_{rp}D_b), \alpha_i(C_b - {}_{rp}C_b)))} \qquad (2)$$

First we deduct the interbank component [${}^{1Y}C_b(1 - v_{{}^{1Y}C_b})$] from the liquid assets (LA) to avoid the double counting of interbank assets included in the definition of liquid assets (LA). Afterwards, the modified liquid assets are adjusted by the net interbank position ($D_b - C_b$) excluding the position with the banks belonging to the same banking group (${}_{rp}D_b - {}_{rp}C_b$) and normalised by the total assets (TA). As a result, banks being short on the interbank market suffer from this scenario, while banks being net liquidity providers improve their liquidity position.

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[6] For more details about valuation haircuts (v) see Annex A.

[7] For more details about the composition of Herfindahl-Hirschmann index (h) see Annex B

[8] For more details about stress parameters (α_i) see Annex F

Capital markets shock

In this second market scenario we test the banks' sensitivity to a fall in asset prices. For this purpose we introduce a new matrix of valuation haircuts, applying different haircuts according to the type of issuer and the sovereign rating of the country of origin of the issuer.[9] The ratio is defined as a share of stressed liquid assets (LA_s) over the balance sheet total (TA).

$$\frac{LA_s}{TA} \tag{3}$$

Household run in Luxembourg

The withdrawal of the retail deposits is one of the most common liquidity risk channels. In this indicator we assume the liquid assets (LA) to be used to face an outflow of deposits by Luxembourg households (D_h^{LU}).

$$\frac{LA - \alpha_i^b D_h^{LU}}{h(TA - \alpha_i^b D_h^{LU})} \tag{4}$$

Unlike the stress parameters of previous ratios applied equally to all banks (α_i), stress parameters in this scenario are bank specific (α_i^b) and depend on the historical volatility of the respective item, in this case, household deposits.[10] The application of such an approach will differentiate between banks with higher and lower volatility of deposits.

Private run

The structure and the logic of this scenario is the same as the previous one. The only difference is in the use of private banking deposits (D_p) instead of the Luxembourg households' deposits (D_h^{LU}):

$$\frac{LA - \alpha_i^b D_p}{h(TA - \alpha_i^b D_p)} \tag{5}$$

Corporate run

Similarly to all "run" scenarios, we deduct the stressed value of deposits, in this case the deposits by the corporate clients (D_c), from the liquid assets.

$$\frac{LA - \alpha_i^b D_c}{h(TA - \alpha_i^b D_c)} \tag{6}$$

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[9] For more details about stress valuation haircuts see Annex A

[10] For more details about stress parameters (α_i) see Annex F

Withdrawals by funds

Since the investment fund industry is very important in Luxembourg, many banks have to deal with the volatility of important amounts of deposits by investment funds. In this scenario we subtract the deposits by related parties' funds (${}_{rp}D_f$), we are assuming that own banking group entities' behaviour would not contribute to liquidity stress of another group entity:

$$\frac{LA - \alpha_i^b (D_f - {}_{rp}D_f)}{h(TA - \alpha_i^b (D_f - {}_{rp}D_f))} \tag{7}$$

Issuance problems

Negative bond market development or idiosyncratic factors can have an impact on the roll-over of the short-term debt instruments (B_{1Y}). Banks with higher liquid assets (LA) and higher funding diversification are less sensitive to this scenario.

$$\frac{LA - \alpha_i B_{1Y}}{h(TA - \alpha_i B_{1Y})} \tag{8}$$

Custodian operational issue

Banks providing custodian services generally face a short-term liquidity risk as a result of settlement problems, when they need to bridge the cash-flows by intra-day credit. The probability and the magnitude of such issue is partly a function of the volume of assets under custody (OF_f) and banks would likely be using their liquid assets (LA) in this case.

$$\frac{LA - \alpha_i OF_f}{LA} \tag{9}$$

Committed credit lines usage

The liquidity risk is partially defined as the loss of ability to fund increases in assets (Basel 2000, 2008). Increased rates of use of committed credit lines (C_g) can be a result of unexpected liquidity needs of corporate clients e.g. arising after tightening of the lending conditions.

$$\frac{LA - \alpha_i C_g}{hTA} \tag{10}$$

Foreign exposures

Many banks located in Luxembourg are exposed to debtors in foreign countries or hold assets in foreign currencies.[11] Since in this scenario the liquidity risk is rather a result of a

[11] For data on foreign countries / currencies exposures see Annex E

credit event rather than market risk, we consider the country factor to be more important than the currency factor (Table 2).

Table 2 Exposures in foreign countries / currencies by sovereign rating

		Country of debtor	
		AAA	Non-AAA
Currency of country of debtor	AAA	Baseline risk	Much higher risk
	Non-AAA	Higher risk	Much higher risk

Following this logic, we focus on the last column and we neglect the denomination of the exposure. Such an approach should address the fact that many debtors from non-AAA countries are funded in EUR or USD.

$$\frac{LA - \alpha_i TA_{oc}}{TA - \alpha_i TA_{oc}} \tag{11}$$

In this scenario we do not differentiate between credits or securities of other types of exposures; all is aggregated under total assets (TA).

Fiduciary deposits

Fiduciary deposits[12] are an important funding source for many banks located in Luxembourg. However they make a volatile source of funding and are also partly dependent on the banking regulation.

$$\frac{LA - \alpha_i D_{fid}}{h(TA - \alpha_i D_{fid})} \tag{12}$$

Off-shore centres

In this scenario we simulate a netting of the positions with the clients from off-shore centres (OECD, 2007).

$$\frac{LA - \alpha_i((TL^{OF} - {}_{rp}TL^{OF}) - (TA^{OF} - {}_{rp}TA^{OF}))}{h(TA - (\min(\alpha_i(TL^{OF} - {}_{rp}TL^{OF}), \alpha_i(TA^{OF} - {}_{rp}TA^{OF})))} \tag{13}$$

Eurosystem refinancing

Since August 2007, the main refinancing operation (MRO) and, a couple of months later, the long term refinancing operation (LTRO) became important funding channels for many of the Euro-zone banking groups. The importance of these operations grew also partly due to more favourable valuation haircuts applied on different types of securities, including structured finance instruments. The system of valuation haircuts plays a crucial

[12] For a definition of fiduciary deposits please visit: http://www.fsc.gi/download/adobe/banking/Note08.pdf

role in this funding channel and it is a competence of the ECB (European Central Bank, 2008).

To take into account these circumstances, we have introduced an indicator reflecting a scenario in which the liquidity borrowed from the Eurosystem (D_{cb}) must be replaced by the bank's liquid assets (LA).

$$\frac{LA - \alpha_i D_{cb}}{h(TA - \alpha_i D_{cb})} \tag{14}$$

Group liquidity

In previous scenarios (e.g. fund deposits withdrawal) we have excluded possible negative effects coming from the parent banking group. Nevertheless, recent experience shows that this aspect should be taken into consideration. In our last scenario we simulate a situation where the parent banking group is not willing or not able to provide funding to its Luxembourg entity. Basically a netting of the balance sheet position with the banks from the parent banking group takes place.

$$\frac{LA - {}^{1Y}_{rp}C_b(1 - v_{{}^{1Y}_{rp}C_b}) - ({}_{rp}D_b - {}_{rp}C_b)}{h(TA - \min({}_{rp}C_b, {}_{rp}D_b))} \tag{15}$$

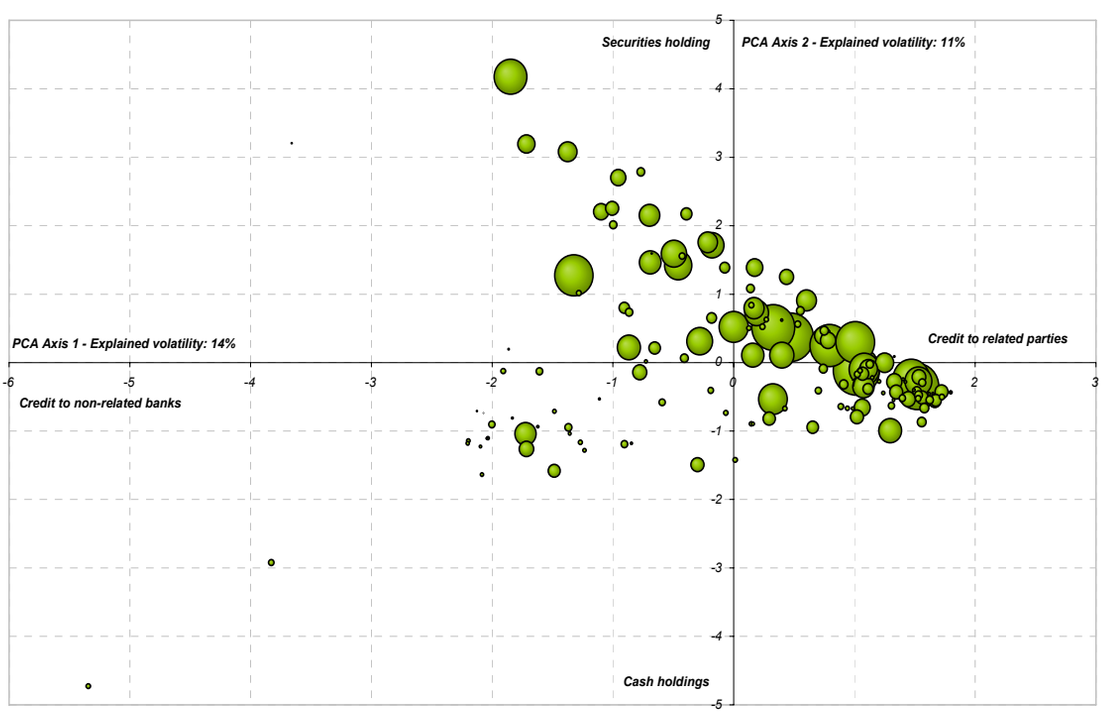
As in the interbank scenario, we adjust the liquid assets to avoid the double counting of the risk parameter (intra-group positions) in the definition of the liquid assets. In the net intra-group position we include only credits to related banks (${}_{rp}C_b$), and deposits from the related banks (${}_{rp}D_b$), and other entities from the group (e.g. funds and financial holdings) are excluded. The total position normally includes securities issued by related banks, and some off-balance sheet items (e.g. collateral, loan commitments). Securities issued by related banks are not included as they simply cannot be netted. As regards the off-balance sheet items, not enough data is available.

Although the structure of this ratio is similar to the one referring to the freeze of the interbank market (i.e. both calculate with "netting of the position"), the methodology of their impact is different. In the interbank scenario, the net position (short or long) led symmetrically to a decrease or to an increase in the liquid assets. In the intra-group scenario, banks cannot benefit from their net long position with the parent banking group. This is because the lack of capacity or willingness of the mother banking group to provide funding (i.e. the concept of the scenario) does not imply repayment of the loans provided by Luxembourg entities. As a result, this risk indicator comes with a zero weight for the banks that are net liquidity providers.

Box 1: A principal component decomposition of the Luxembourg banking sector

We have investigated banks located in Luxembourg by the means of a data mining technique called principal component analysis[13] (PCA). The purpose of this analysis is to identify and possibly isolate similar banks according to their major characteristics. This technique allows us to draw general conclusions in terms of main liquidity risk drivers for the local banking sector. Based on these conclusions, we define several risk factors (and the related indicators). For the purposes of PCA analysis, the balance sheets of the local banks are disaggregated in a number of items according to their relevance in terms of liquidity risk. Assets and liabilities are analyzed separately. The balance sheet items are considered in relative terms: each balance sheet item is divided by the total assets in order to eliminate bias from the results in favour of larger banks. The reason for this choice is that our interest lies in the composition of the banks' balance sheet rather than in their absolute size. These results are described in Chart 1[14].

Chart 1: PCA - Assets side



- Source BCL, authors' calculations

[13] Data mining refers to a set of various statistical techniques which allow for the exploitation of large database repositories. The advantage of these techniques is the possibility offered to visualize relationships between variables in an n-dimensional matrix by reducing this matrix complexity (from n to usually 2 or 3 dimensions). These new dimensions are better fit to capture the variability within the database. For more information on these techniques and their interpretation, see e.g. www.cs.otago.ac.nz/cosc453/student_tutorials/principal_components.pdf and http://www.cs.princeton.edu/picasso/mats/PCA-Tutorial-Intuition_jp.pdf

[14] The correlation scatterplots in Annex I provide an explanation for the existing relationships across the main components of axis 1 and 2.

In the chart, Axis 1 describes 14% of the sample's asset volatility whereas and Axis 2 describes 11% of the total sample volatility. In the chart each "bubble point" represents one bank, whereas the size of the bubble represents its total assets[15]. Statistically, the choice of the most relevant axes is usually based on Kaiser's criterion: therefore 5 axes should be retained. Anyway, for the purpose of visualization, only 2 axes are included in the analysis, as suggested by the Scree's test results. On the right hand side of Chart 1 we identified banks granting credit to related parties. These banks are usually not particularly active in the inter-bank market. Indeed, we could argue that credits to related parties and credits to non-related banks are highly negatively correlated activities, as they lie on the same axis at the opposite extremes. The main components of axis 2 are investments in securities and cash holdings, the former being more relevant in order to characterize the sample. In addition, it emerges from the observation of Chart 1 that larger banks are more prone to grant credits to related parties.

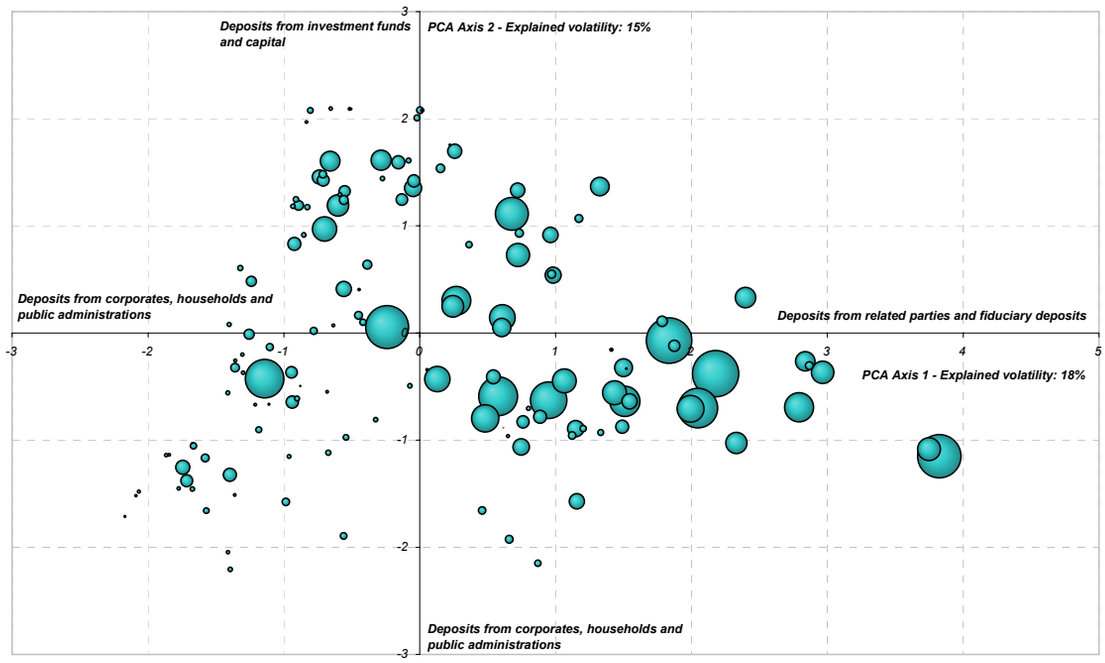
For a better comprehension of the characteristics of the local banking sector we integrate axis 3 in our description. Axis 3 is characterized by a positive correlation with the category "credits to other financial institutions"[16] and "credits to corporates". This analysis highlights that:

- Local banks are either active as providers of liquidity to the parent banking group or distribute their excess liquidity in the inter-bank market. These two activities seem to be mutually exclusive. We could argue that it is rather unlikely that the same bank would be exposed to an "inter-bank market squeeze" and to a "mother company contagion": hence the need for two separate scenarios.
- The holding of a large portfolio of securities is also a representative activity of banks located in Luxembourg. This justifies the need for a capital market shock scenario and for a Eurosystem refinancing scenario.
- The provision of credit to other financial institutions as well as to corporates is an important activity. In particular the type of exposure to countries characterized by lower rating is of potential interest in our analysis.
- As regards the relative importance within the local banking sector, larger banks often grant credits to related parties.

In Chart 2 we investigate the liabilities side of banks located in Luxembourg. The level of granularity is higher as we separate a particular type of financial product called "fiduciary deposits" from other types of deposits. The chart below illustrates our findings. We observe that axis 1 describes roughly 18% of the sample's volatility while axis 2 describes 15% of the total sample volatility. As in the previous chart, each "bubble point" represents one bank, whereas the size of the bubble represents its total assets.

[15] By considering the size of the total asset we address to some extent the issue of liquidity risks from a perspective based on each banks relative importance in the local banking sector.
[16] In Luxembourg this category includes mainly credit to investment funds.

Chart 2: PCA – Liabilities' side



- Source BCL, authors' calculations

We notice that the largest banks are located in the right hand side of the chart, which is characterized by banks receiving deposits from related parties and fiduciary deposits. On the left hand side, lower quadrant, of the chart we observe banks receiving mainly deposits from households and corporates. These banks are active in the local retail as well as in private banking business. Their balance sheet sizes are rather limited if compared with the rest of the sample. It appears that a certain number of banks could be affected by a bank-run event, both on the corporate and the household side. An event which could potentially hit the local banking sector could also originate from changes in regulations. Such an event could affect a number of large players.

On the liabilities' side, the population is characterized by a higher degree of heterogeneity. Nevertheless, in general, the results show that banks taking deposits from related parties are rather inactive in the households and corporate businesses. These two activities are negatively correlated. The conclusions we draw from the observations are the following:

- Heterogeneity is higher across the population as regards the liability side.
- Household deposits and deposits from related parties are mutually exclusive activities. Two scenarios should be envisaged to cover these two potential liquidity risks.
- A scenario involving a withdrawal of fiduciary deposits could theoretically affect the largest banks.
- Banks active as custodian, whose balance sheet is mainly driven by deposits from investment funds, should be separately investigated, as they incur short term liquidity risk in their custodian business.

2.1.2 Market risk factors

The market risk factors are included in our framework for three main reasons. First, according to Principles for Sound Liquidity Risk Management and Supervision (BIS 2008), supervisors should also use the market information in the process of liquidity risk assessment.[17]

Second, the host character of the Luxembourg banking sector implies rather high dependence of the local entities on the overall situation of the parent banking group[18]. Therefore the plain on- and off-balance sheet data reported by these local entities in the large majority of cases do not contain enough information to complete the picture of their liquidity position. Given that we do not have direct access to internal documents, reports or other information as regards the liquidity position of the parent banking group, we deemed it appropriate to include among the liquidity ratios a set of indicators which could be a proxy for the liquidity profile of the parent company.

Finally, the economic literature stresses the existence of several factors as predictors for financial crises which could potentially hit the banking sector[19]. In general the below-mentioned papers often integrate the perspective and forecasting power of the suggested indicators. In this regard our study does not rely on the idea of causality in the definition of the set of macro economic indicators to be included in our framework. However, we derive from the above-mentioned approaches the potential causal relationships and linkages between a bank and the deterioration of its group/country economic/financial situation. In this context, the integration of the risk factors in our framework, as suggested by the literature, is a first step in the process of formulating a more precise linkage between these variables and their role as early warning indicators. These are indeed the "canary in the mine" that signal an increased probability of occurrence of a situation of stress in a specific banking group/country.

In this context, one widely accepted phenomenon is the so-called "twin crises" event. This latter refers to the joint accrued probability of banking and currency crises happening simultaneously. Kaminsky and Reinhardt [1998] discuss the linkages and highlight potential cause-effect relationship between these two crises. Moreover, they define a set of economic and financial variables in order to detect possible common patterns in terms of origin of banking and currency crises. They find that banking crises lead currency crises and, in general, *indicators of real economy activity* do a better job in forecasting banking crises. In addition, their results show that the fiscal sector is in general not a strong predictor for either type of crises.

In the context of the above mentioned analysis, Kaminsky [1999] proposed a set of early warning indicators for currency and banking crises. The author emphasizes the role of excessive capital inflows, which could lead to excessive exposures of banks to stock and real estate markets. This behaviour could potentially make banks more vulnerable to asset bubbles. In order to capture at least partly the "bubble burst" accrued risk phenomenon,

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[17] Principle 15: Supervisors should supplement their regular assessments of a bank's liquidity risk management framework and liquidity positions by monitoring a combination of internal reports, prudential reports and market information

[18] These specific characteristics of each local banking sector should be taken into considerations also according to Kaminsky and Reinhardt [1999] and Hermosillo [1999], cited.

[19] For a review of early warning indicators in banking crises see: Gaytán and Johnson [2002], cited.

the *stock market of the country of reference* is added to the indicators. Moreover, the role of *real exchange rate* emerges as a best indicator for banking and currency crises. Furthermore, Santor [2003] in his study identifies similar channels for banking crises and contagion. As in Kaminsky and Reinhardt, he finds that slow economic growth and high credit growth are both associated with an accrued likelihood of a banking crisis. Similar conclusions were made by Jurča and Zeman (2008) who identified the real GDP, exchange rate and 3-months inter-bank market rate as the three most important external variables for the banking sector in this context.

As regards the importance of the spread between the secured vs. unsecured inter-bank markets as a measure for a liquidity squeeze, Eisenschmidt and Tapking [2009] find that the widening of this spread is linked to a funding liquidity risk. In the paper the authors exclude the possibility that an increase in probabilities of counterparty default could be the cause of *inter-bank spread widening*. Linzert and Schmidt [2007] found similar results by investigating the spread of the Euro Over-Night Index Average and the European Central Bank policy rate. In this case, the widening of this spread was an indicator of a situation of stress in the inter-bank market. The integration in our model of the spread between the Eurepo vs. Euribor inter-bank market rates allows the capturing of a shared feature of liquidity risk common to banks active in the interbank market. In case of widening of the spread, banks active in the inter-bank market will all be affected by the deterioration of this indicator, therefore worsening the overall score of these banks vis-à-vis their peers and over time. Moreover, given that the inter-bank market is a contagion channel for financial crises, as suggested by Degryse and Nguyen [2004] and Santor [2003], the monitoring of stress in this channel is critical to the central bank.

Based on the literature and data availability, we have defined four main indicators for market risk: financial markets, interbank market, macroeconomic conditions and currency issues.

Definition of the market risk indicators

Like the balance sheet part of our framework, the market risk factors need to be translated into indicators with three levels of specificity. While the first two indicators (namely Euribor / Eurepo spread and Luxembourg consumer confidence indicator) are applied symmetrically to all the banks, the next three indicators (economic sentiment, stock exchange index and special drawing rights) are common for banks originating from the same country. The final two indicators (stock price and stock price volatility) are related to the parent banking group.

Euribor / Eurepo spread

The analysis integrates a measurement of the liquidity in the interbank market. This indicator is defined as the spread between Euribor 3 months and Eurepo 3 months (unsecured vs. secured market rates). The Euribor-Eurepo spread was selected, as most banks are hosted in the Euro-area countries. This indicator detects a liquidity squeeze: a widening of the spread between the two rates implies a drying-up of liquidity in the interbank market.

Consumer confidence indicator of Luxembourg

The worsening of the Luxembourg consumer confidence indicator could affect indirectly the liquidity position of the banks as the reputation risk for the financial place could trigger foreign deposits' withdrawals. This indicator is calculated and published by the Banque centrale du Luxembourg. It measures the conjuncture as perceived by consumers. It is methodologically independent of GDP or other macroeconomic variables, although there is a correlation with economic growth. The indicator is calculated as an average of a set of answers to four questions concerning (i) the financial situation of Luxembourg households for the next 12 months, (ii) perception of general economic conditions over the next 12 months, (iii) evolution of unemployment for the next 12 months and (iv) savings ability for the next 12 months.

Economic sentiment indicator of the country of the banking group

The OECD leading economic indicator captures the potential deterioration of the real economic conditions in the country of origin of the bank[20]. Indeed, liquidity risk in banking activity may also originate from macroeconomic crises. This relationship may arise from a downfall effect of an economic downturn on banking books, through various transmission mechanisms. The deterioration of economic conditions worsens the quality of banks credit books, hence decreasing borrowers' ability to repay their loans. This could have an impact on the flow of liquidity to banks.

Stock exchange index

The stock exchange index is the main stock exchange index of the country where the head of the banking group is located. It should act as trigger for the asset-price-related issues highlighted in a number of cited papers. Moreover, the index performance should capture an increase in liquidity risk through a general depreciation of stock prices: this effect is likely to affect the relative stock price performance of each banking group.

Special Drawing Rights

Special Drawing Rights (SDR)[21] take into account the deterioration of the currency value over time, and eventually highlight the occurrence of a situation of stress in a specific currency. The ratio used is the reciprocal of the SDR per currency unit rate. It should integrate the potential relationship between banking and currency crises.

Stock price of the parent company and its volatility[22]

The idiosyncratic aspect (reputation risk) of liquidity risk is captured in our model by the use of banks' stock prices. The mother company stock price and its implied volatility[23] represent a proxy for the fluctuating price for liquidity that each bank has to pay on the

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[20] For a more detailed review of the methodology behind this indicator, we refer to Nilsson [2000], cited.
[21] For further explanation see Annex G.
[22] It is important to mention that not all the parent companies of the local entities are listed in a regulated stock market. Some of them are government or privately-owned. When this case occurs, the bank is simply scored according to the residual market variables. Anyhow, this is the case for 70 banks.
[23] This data is not available for all the banks in Luxembourg banking sector, as some of the banks are non-listed. For non-listed banks, this indicator comes with the weight of 0.

financial market to fund its activities. The rise of certain needs for liquidity would imply, in case of scarcity of internal funds, the recourse to financial markets, either through debt instruments or stock issuances. Eventually, from a liquidity point-of-view, the stock price should reflect the cost of issuing new capital in financial markets. Moreover, the price of a stock should incorporate market perception of risk in the business activities of the firm[24]. This risk perception includes liquidity risk. The stock price of a bank should act as a proxy for the market perception of risk in the bank's underlying activities. Credit default swap spreads could also be included in the dataset. However, according to Byström, H. [2005], the stock price volatility has been found to be significantly correlated with CDS swaps. The lack of credit default swap trades for a large number of banks was one amongst the main criteria for our choice in favour of stock prices.

It is a set of market variables, which could be classified according to the following matrix (Table 3) which describes the components of the market risk factor, the breadth (market-wide, country specific and idiosyncratic) and the type (financial vs. macroeconomic).

Table 3 Market risk indicators

	Financial markets	Macroeconomic
Common indicator across the sample	- EURIBOR-EUREPO spread	- Consumer confidence indicator of Luxembourg
Common for banking groups from the same country	- Reference stock exchange index	- Economic sentiment indicator (ESI) of the country of origin - Foreign exchange rate (SDR) of the country of origin
Idiosyncratic (bank-specific)	- Stock price - Stock price volatility	n/a

2.1.3 Risk factor weights determination

After the risk factor is selected and translated into risk indicators we need to determine the relative importance of these risk factors to every bank for every period.

Balance sheet risk factors weights

The balance sheet risk factors weight ($w_i^{b,t}$) is a normalised intermediary risk weight ($iw_i^{b,t}$) to sum up to 1, depending on how many risk factors are relevant for individual banks:

$$w_i^{b,t} = \frac{iw_i^{b,t}}{\sum_{i=1}^{K} iw_i^{b,t}} \tag{16}$$

[24] In this overall assessment performed by market participants, liquidity risk should also play a role. While we recognize that stock price dynamics are affected by several other factors, such as risk-performance considerations, nevertheless we expect a sharp stock price deterioration to signal a situation of stress in the bank's business profile.

The intermediary risk weight ($iw_i^{b,t}$) is a function of the relative share of the risk parameter ($r_i^{b,t}$)[25] over the liquid assets ($LA^{b,t}$) and the volatility of this parameter over time.

$$iw_i^{b,t} = \frac{r_i^{b,t}}{LA^{b,t}} * \frac{stdev(r_i^b)}{\overline{r_i^b}} \tag{17}$$

As a general rule, the higher the importance and the volatility of the risk parameter ($r_i^{b,t}$), the higher the balance sheet risk factor weight ($w_i^{b,t}$). This allows us to integrate the effect of changes in banking activity into the balance sheet of the banks over time.

Market risk factors weights

Unlike balance sheet risk factors weights ($w_i^{b,t}$), the market risk factors weights ($w_j^{b,t}$) do not depend on the relative balance sheet importance and volatility of the risk parameter, but on the number of market risk factors. As some of the banks are not listed and no stock price data are available, not all of the banks have the same number of market risk indicators. As a result, the market risk factors weights ($w_j^{b,t}$) are calculated as a function of number of market risk indicators available for every bank in different periods. The weights equal to either 1/7, if all indicators are available, or to 1/5, if the bank is not listed and thus the stock price and its volatility are not available.[26]

2.2 The first pillar: the peer score

The objective of the first pillar is to provide a relative score from 1 (the best) to 9 (the worst) for every bank at a moment in time. This score is a weighted average of the position of a bank's risk indicator in the distribution of risk indicators calculated for all relevant banks.

2.2.1 Data

The peer score is based exclusively on the data from regulatory reporting, i. e. the balance sheet and off-balance sheet data of the Luxembourg entities. There is no reference to the parent banking group risk profile, to general financial market or to macroeconomic development. Thus, the only risk factors considered in this calculation are the 14 balance sheet risk factors (see Table 1).

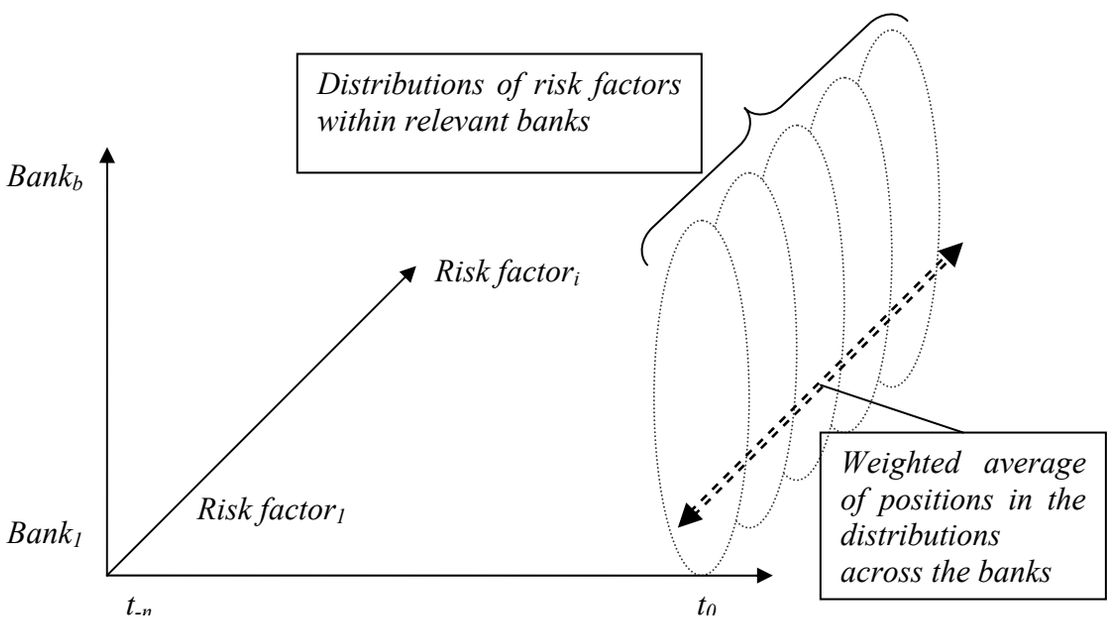
[25] The risk parameter is the core variable of the risk indicator, see Annex C

[26] The market factor weights can be further calibrated according to characteristics of the local banking sector

2.2.2 Calculation

In our framework, if the risk factor weight ($w_i^{b,t}$) exceeds a defined threshold[27], the risk factor is considered relevant and enters to the calculation of the distribution. A distribution of every balance sheet risk indicator is calculated, taking into consideration only those banks for which that indicator is relevant. Based on the relative position of the bank's risk indicator in the distribution, a score is assigned. This is done separately for each of 14 balance sheet risk factors (Figure 2).

Figure 2 Peer score calculation for $Bank_n$ **in** t_0



A bank gets a balance sheet risk factor specific peer score ($BRPS_i^{b,t}$), unless its corresponding weight $w_i^{b,t}$ is below the threshold. According to the position of the risk indicator in the different percentiles of the distribution, this risk balance sheet factor peer score ($BRPS_i^{b,t}$) spans from 1 to 9. The final peer score ($PS^{b,t}$) is an average of the balance sheet risk factor peer scores obtained for different risk factors ($BRPS_i^{b,t}$) weighted by their relative importance and volatility ($w_i^{b,t}$)

$$\forall t,b \rightarrow PS^{b,t} = \sum_{i=1}^{K} \left[w_i^{b,t} * BRPS_i^{b,t} \right] \tag{18}$$

As a result, the peer score depends only on a bank's relative liquidity position within the banking sector, measured by the balance sheet risk factors, and doesn't reflect possible changes of the banking sector as a whole.

[27] For the Luxembourg banking sector, the threshold of 0.05 was set based on the expert's judgement calibration.

In other words, the peer score only provides us with information about an individual bank's liquidity position relative to its peers. It does not capture parallel trends in all the banks in the sample. This is captured by the second pillar, namely the time score.

2.3 The second pillar: the time score

To complement the first pillar score, the objective of the second pillar is to provide a score relative to the bank's previous experience. In this exercise we do not compare the banks among them (Figure 2) but we confront the bank with its past liquidity positions (Figure 3).

2.3.1 Data

Compared to the first pillar, for the time score we have added 7 external market variables (Table 3) to take into consideration developments in the financial markets, situation of the parent banking group and general macroeconomic outlook for relevant countries. The introduction of these 7 external variables reduces the interdependence of the peer score and the time score. As a result, the difference between the two pillars lies not only in different methodology (peer comparison vs. comparison over time) but also in the variables considered.

2.3.2 Calculation

As in the first pillar, every bank gets a score which spans from 1 (the best) to 9 (the worst) at a precise moment in time. In general, the time score ($TS^{b,t}$) depends on the positions of a bank's risk indicators in the distribution of the respective risk indicators calculated for previous periods (Figure 3). This is done separately for balance sheet and market components to calculate risk factor specific scores ($BRTS_i^{t,b}$ and $MRTS_j^{t,b}$) within both components. As a result, two intermediary scores are assigned to every bank, i.e. the balance sheet time score ($BTS^{b,t}$) and the market time score ($MTS^{b,t}$). Finally, the time score ($TS^{b,t}$) is a weighted average of the intermediary scores (Figure 4).

$$\forall b,t \rightarrow TS^{b,t} = bs * BTS_i^{t,b} + ma * MTS_j^{t,b} \tag{19}$$

Where:

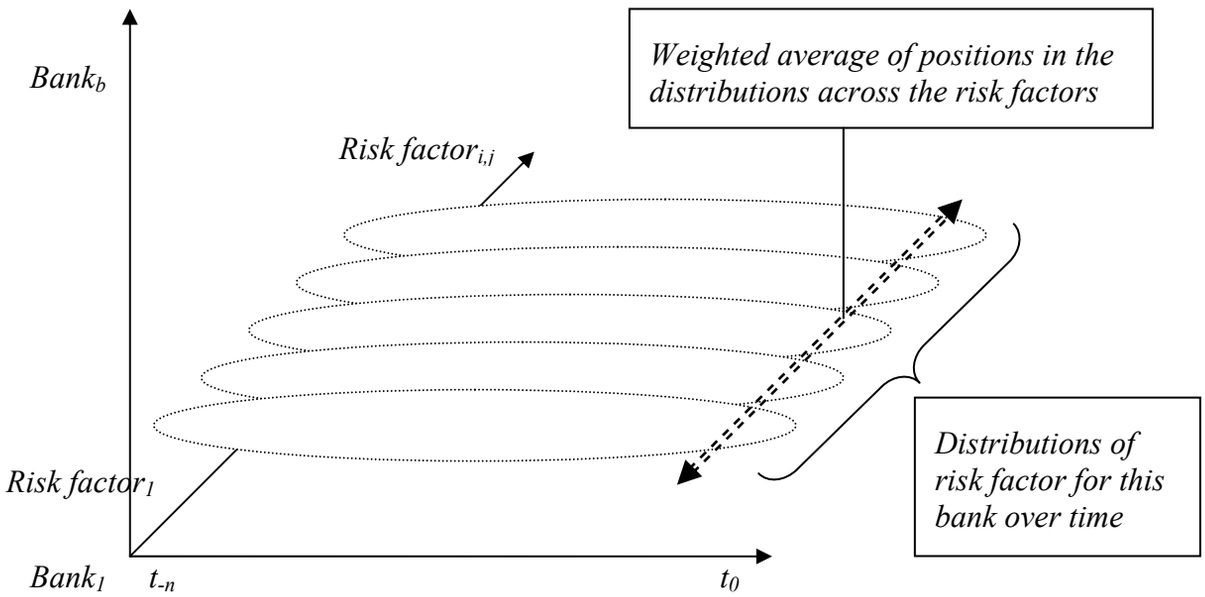
$$bs + ma = 1 \tag{20}$$[28]

$$\forall b,t \rightarrow BTS^{b,t} = \sum_{i=1}^{K} \left[w_i^{t,b} * BRTS_i^{t,b} \right] \tag{21}$$

$$\forall b,t \rightarrow MTS^{b,t} = \sum_{j=1}^{K} \left[w_j^{t,b} * MRTS_j^{t,b} \right] \tag{22}$$

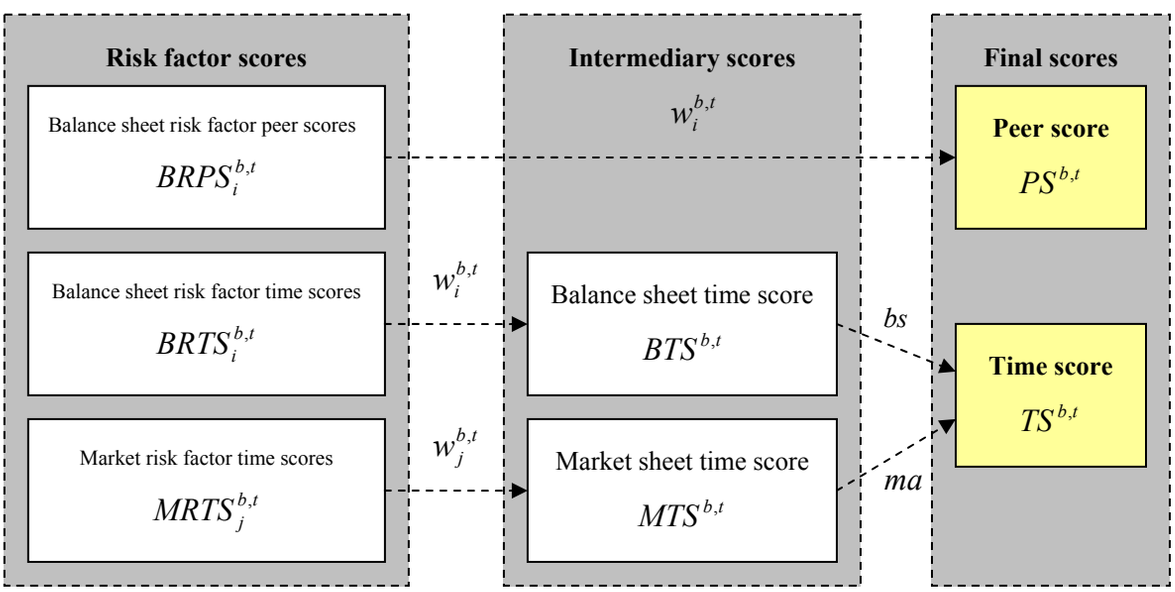
[28] For the purpose of this study, the weights for the balance sheet and market component are 0.5 both. This reflects their similar importance in the context of the Luxembourg banking sector.

Figure 3 Time score calculation for $Bank_n$ in t_0



As a result, at every moment in time, each bank is characterised by two scores. On one hand we can see the bank's liquidity position, described by reporting data, which depends primarily on comparison among different banks in Luxembourg banking sector. On the other hand we can observe a dynamic picture where every bank is analysed in terms of its own vulnerability on standard balance sheet scenarios under dynamic macroeconomic conditions and general soundness of its parent banking group.

Figure 4 Sequence of scores



3 Application and examples of the results

This chapter demonstrates how the results could be analysed and what conclusions could be drawn from the monitoring framework. These results can be applied both in the process of supervision of individual banks and in general banking sector liquidity risk analysis for supervisory or financial stability purposes.

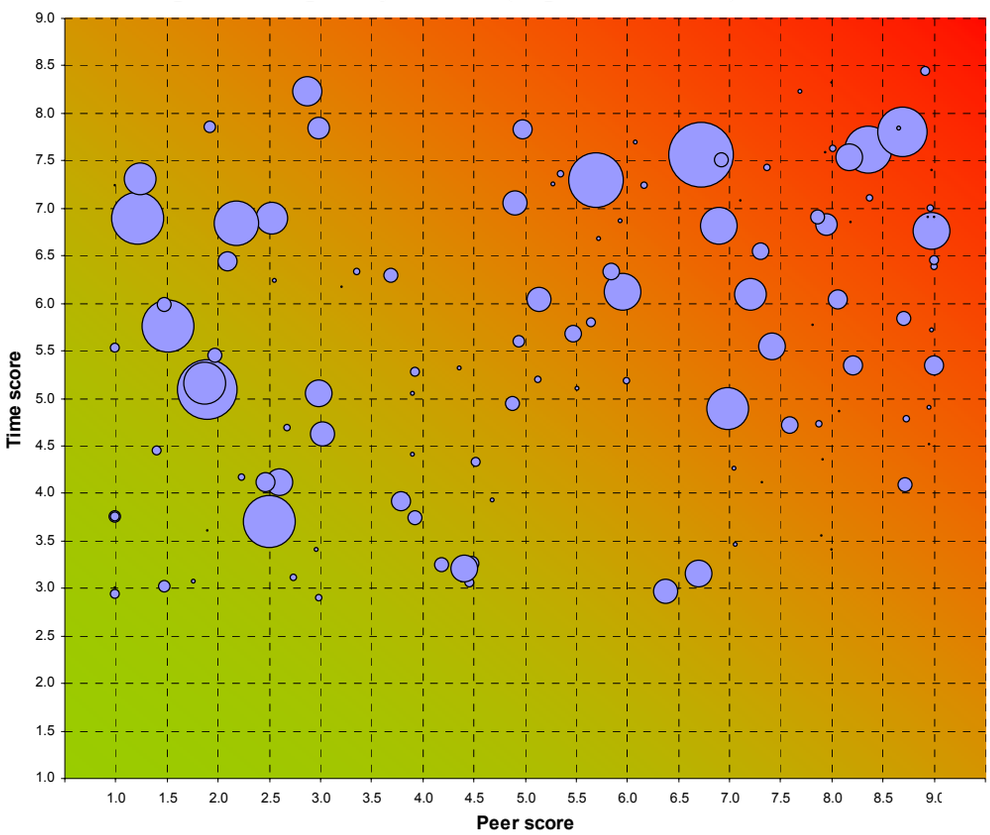
3.1 Liquidity risk profile of individual banks

Analysis of the scores ($PS^{b,t}$ and $TS^{b,t}$) can be decomposed into three levels: (i) comparing the scores of all banks in a selected time period (Liquidity matrix), (ii) analysing changes of the scores of a selected bank over time (iii) decomposition of the scores of a selected bank into individual risk factors.

3.1.1 Liquidity matrix

In every time period all the banks can be displayed in a liquidity matrix. If such analysis is done for t_0, the supervisors are able to spot the outliers, to better focus their attention and to allocate analytical resources more efficiently. The liquidity matrix also contains a third dimension of information, which is the size of individual banks represented by the size of the bubbles (Chart 3).

Chart 3 Example of a liquidity matrix (September 2009)

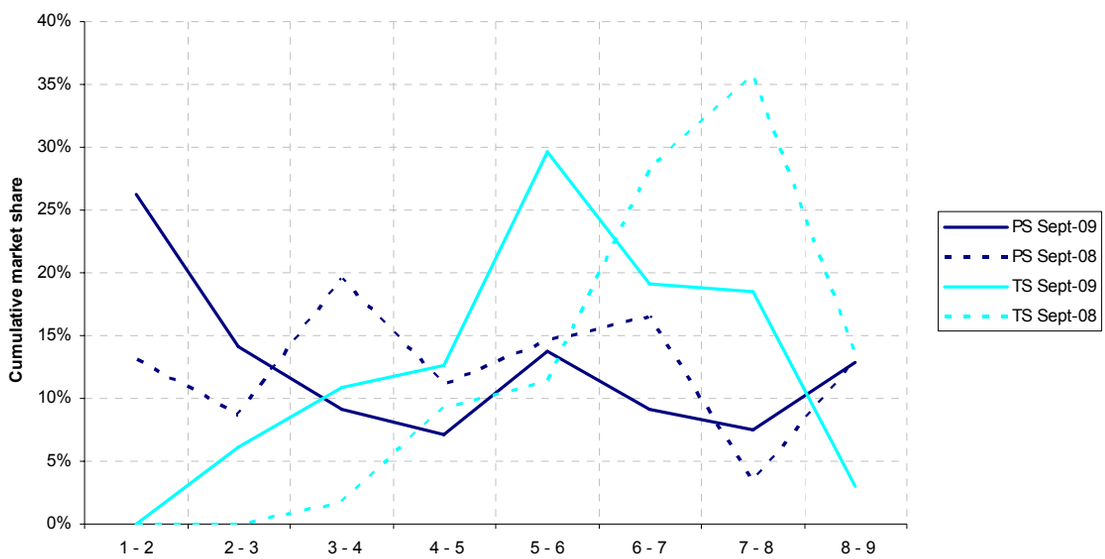


- Size of the bubble represents the size of the balance sheet
- Source BCL, authors' calculations

As the size of a bank could be correlated with its systemic importance, such information can be useful in the field of financial stability, as well.

To give a practical example, the results for the September 2009 displayed on the Chart 3 could be analysed in the following way. Although the bigger banks are spread all over the matrix, in the first band of peer score (1-2) is dominated by banks with relatively greater market share. In other words, except for a few big banks the peer liquidity positions of Luxembourg entities do not generally depend on size. From a time point of view, no bank fell into the best time score band. In general, this means that Luxembourg entities are in relatively more difficult liquidity positions than is the benchmark of their 4 years history. The biggest banks dominate the score bands from 4 to 8. From a supervisory point of view, attention should be focused on the banks in the upper right hand corner, to analyse and understand the reasons for their liquidity positions.

Chart 4 Cumulative market share of banks in different score bands



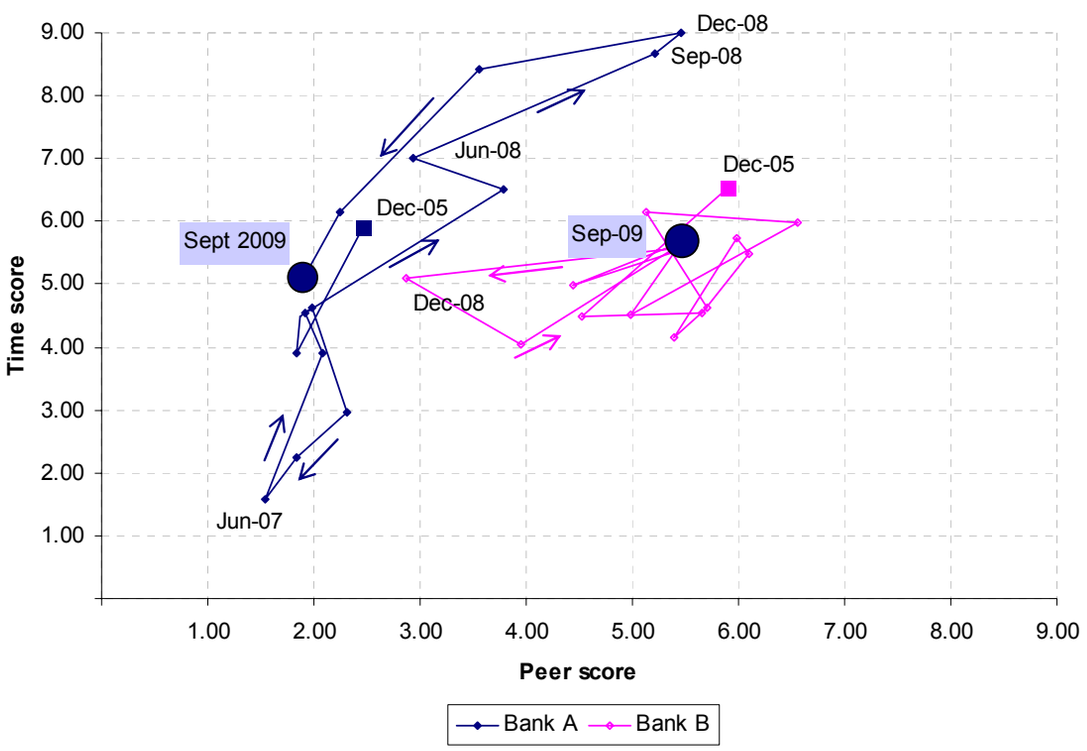
- Different intervals of scores are on the horizontal axis
- Source BCL, authors' calculations

Such conclusions are in line with the results of aggregation of the market share of banks in different score bands (Chart 4). As regards the peer score, banks with scores between 1 and 2 hold 26% of the assets of the Luxembourg banking sector. In September 2008 the best peer score was assigned to banks holding only 13% of the banking sector. This implies that as regards the liquidity, bigger banks are recovering more rapidly than the smaller ones. Similar positive development can be observed in the time score, where the peak shifted from the band of 7 - 8 to the band of 5 – 6. The fact that in September 2009 the liquidity position of the part of the market dominated by big banks was better than the rest of the Luxembourg banking sector could have a stabilising effect on liquidity risk in the Luxembourg market. Nevertheless, for financial stability purposes, we have to take into consideration the time scores, which have still to recover from the financial crisis.

3.1.2 Evolution of the scores over time

The liquidity matrix can be analysed by studying the liquidity position of a bank over time. On Chart 5 we can observe the trajectory of the positions of two examples of banks in the liquidity matrix. Bank A can be characterised as multiline and Bank B is a custodian bank. As regards Bank A, from December 2005 to June 2008, the bank has belonged to the group of the most liquid entities within the Luxembourg banking sector (peer score below 2.45). In this period, only the time score was subjected to some volatility (between 1.48 and 5.89) with the best situation in June 2007, just before the beginning of the subprime turmoil in the summer of 2007. The situation has changed in March 2008, when the time score jumped from 4.6 to 6.65; still with a favourable peer score. This difference between the time and peer score can be explained by the fact, that the time score also contains the parent banking group information. In this case, the bank started to suffer from the issues originating from the parent banking group 6 months before its peer position deteriorated significantly (rose to 5.12). This development occurred in September 2008, when the bank came under a real stress in both dimensions, peer and time. The stress peaked in December 2008 (historical maximums of both scores), and declined quite rapidly during the 2009. In September 2009, the bank's liquidity position was very similar to that of March 2006.

Chart 5 Examples of changes of the bank's position in the liquidity matrix

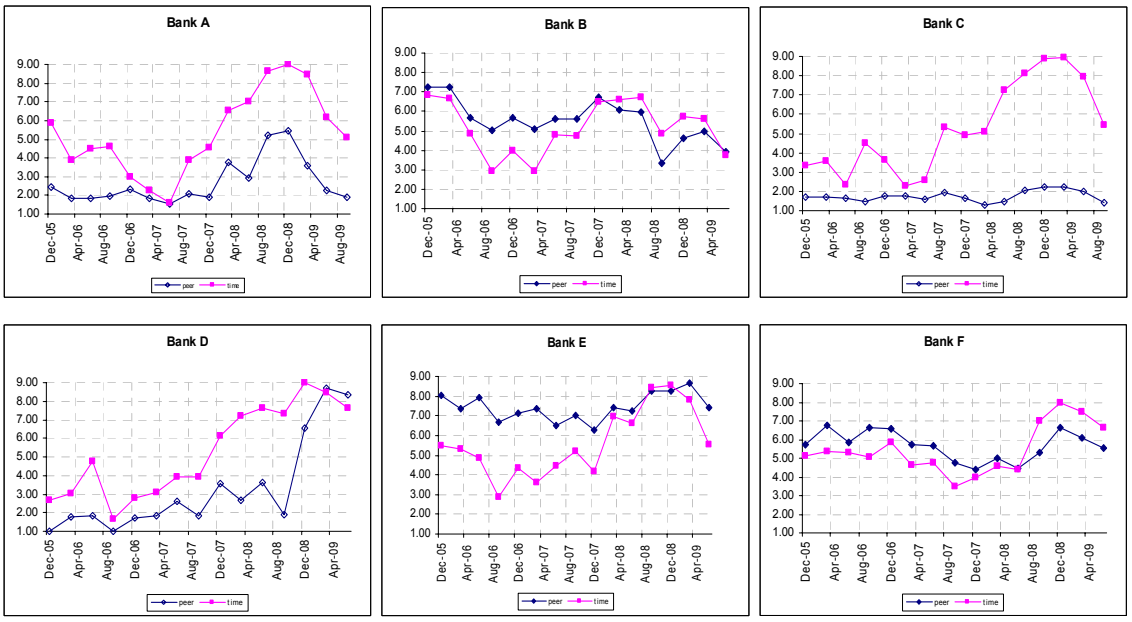


- Source BCL, authors' calculations
- The bubbles represent the last observation

Bank B is quite a different example. Although a lot of volatility in both scores occurred during the last four years, there is no clear impact of the financial crisis on its liquidity position. Indeed the bank achieved its best peer score in December 2008. Moreover, as regards the time score, the evolution of the balance sheet component counterbalanced the

negative macroeconomic and financial market developments that would worsen the score. From a liquidity risk perspective, this implies a sort of counter-cyclical behaviour of the bank; it has decreased the balance sheet risk during the adverse market developments. Such results can be also related to the specific business model of this bank which is mainly active as a custodian and in investment fund services combined with a certain volume of fiduciary deposits.

Chart 6 Examples of the evolution of the scores over time



- Source BCL, authors' calculations

More examples of the evolution of the scores are displayed in Chart 6, and include Bank A and Bank B, already discussed above. The Bank C is a multiline bank active in many types of banking services; Bank D is mostly active in collecting corporate and fiduciary deposits and providing the liquidity to entities of the parent banking group; Bank E is a liquidity hub for the parent banking group and Bank F is an example of pure custodian bank.

3.1.3. Decomposition of the scores

Since the final scores ($PS^{b,t}$ and $TS^{b,t}$) are weighted averages of scores calculated for different risk factors ($BRPS_i^{b,t}$, $BRTS_i^{b,t}$, and $MRTS_i^{b,t}$), we can calculate the contribution ($c_i^{b,t}$) of each risk factor to the final scores. In the case of the peer score such decomposition identifies the main balance sheet risk factors:

$$ {}^{PS}c_i^{b,t} = \frac{BRPS_i^{b,t}}{PS^{b,t}} \qquad (23) $$

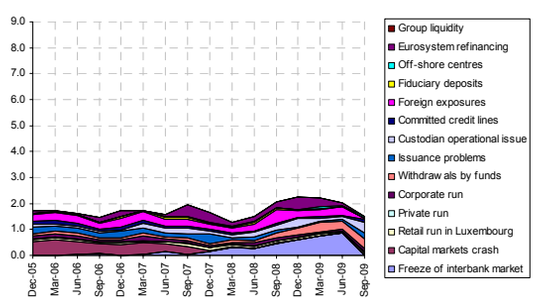
As regards the time score we can separate between the market and balance sheet risk factors.

$$ {}^{TS}_{b}c_i^{b,t} = \frac{BRTS_i^{b,t}}{TS^{b,t}} \qquad {}^{TS}_{m}c_i^{b,t} = \frac{MRTS_i^{b,t}}{TS^{b,t}} \tag{24} $$

The decomposition of the scores helps us to understand the main driving forces of liquidity risk separately for each bank in the Luxembourg banking sector. From a supervisory point of view and from an early warning perspective, such analysis is very important. According to the back-testing done on a sample of troubled banks, before their individual crisis would unfold, the composition of the score of these banks has changed significantly, while the value of the score usually remained rather stable at already high levels (Box 2).

As an example of decomposition we take Bank C, already displayed on the Chart 6. The peer score has been rather stable over the whole period, with some volatility in autumn of 2008, while the time score started to grow by the end of 2007. The decomposition of these scores helps us to identify the main underlying factors of such development.

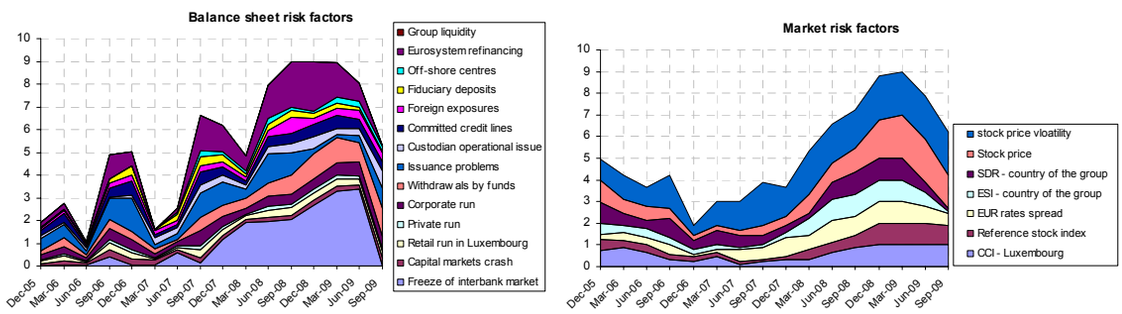
Chart 7 Example of decomposition of the peer score (Bank C)



- Source BCL, authors' calculations

The decomposition of the peer score (Chart 7) suggests that Bank C is a rather diversified bank in terms of liquidity risk. Until December 2007 the bank was exposed to the negative developments at the capital markets, together with the exposures to countries with lower ratings more than the other banks in Luxembourg. From the beginning of 2008, Bank C started to be short on the interbank market. In this period the bank also increased its dependence on the Eurosystem refinancing operations.

Chart 8 Example of decomposition of the time score (Bank C)



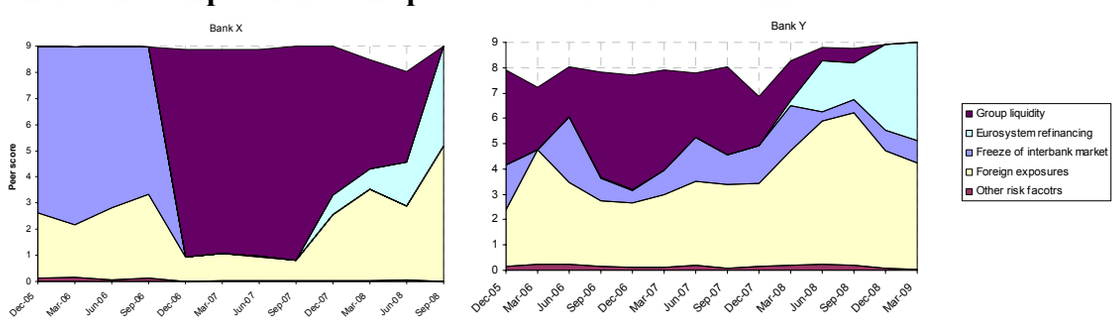
- Source BCL, authors' calculations

From a time point of view (Chart 8) both the balance sheet and market risk factors have been growing since the autumn of 2007, apart from some volatility of the balance sheet component in 2006. On the balance sheet risk factors side, the growing short interbank position and the dependence on the Eurosystem refinancing operations were the main components of the time score. On the market risk factors side, Bank C suffered from almost all risk factors, but above all from a decrease of the stock price of the parent undertaking. In the last quarter, the bank improved both components of the time score. On the balance sheet side, it was due to a significant decrease of the short interbank position and the borrowing from the Eurosystem; on the market side, the bank benefited mainly from the improvement of the macroeconomic conditions of the country of origin.

Box 2: Examples of the peer score decomposition of troubled banks

The peer scores of banks that underwent very serious liquidity pressure during the autumn of 2008 were always very high (between 7 and 9), which means that the liquidity positions of these banks were constantly weaker than the average of the Luxembourg banking sector. However, there are several other banks with constantly high peer scores, but which did not witness such negative developments. This would lead us to conclude that the value of the peer score alone is not a good predictor of materialization of the liquidity risk. However, the contribution of different risk factors in the peer score changed long before these banks came under serious stress (Chart 9).

Chart 9 Decomposition of the peer scores of troubled banks



- Source BCL, authors' calculations

Both banks faced one major common issue. While their relative liquidity positions have been always weak, at some moment in time the banks switched from the liquidity dependence on the mother company to liquidity dependence on the Eurosystem. The combination of three variables (constantly high peer score, no more funding from the parent group and increasing dependence on the refinancing operations within the Eurosystem) was a sign of the coming liquidity shock.

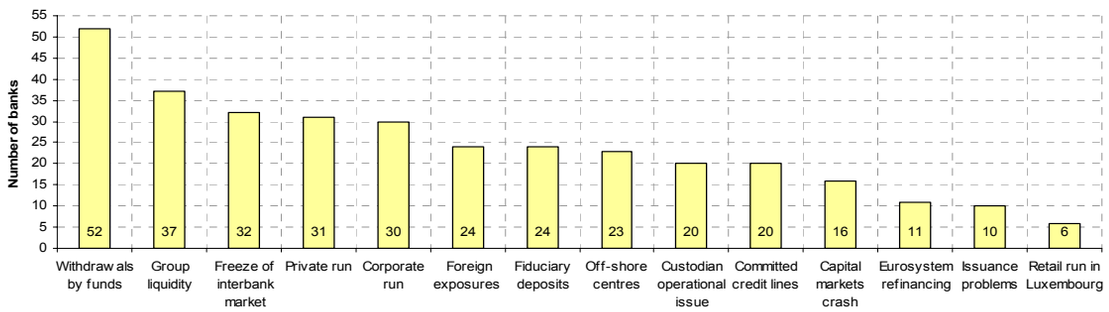
3.2 Aggregated results

The main objective of the framework is to identify possible weaknesses in liquidity positions of individual banks. Nevertheless, it serves also as a basis for drawing conclusions about the relevance of different risk factors (stress scenarios) to the banking sector as a whole.

3.2.1 Relevance of different risk factors in t_o

One possible application is the assessment of the most relevant risk factor at t_o. The number of banks with $c_i^{b,t}$ larger than 0.05 for different risk factors is shown on Chart 10. In other words, for every risk factor, we count the number of banks, for which this factor contributes to the final peer score by more than 5%.

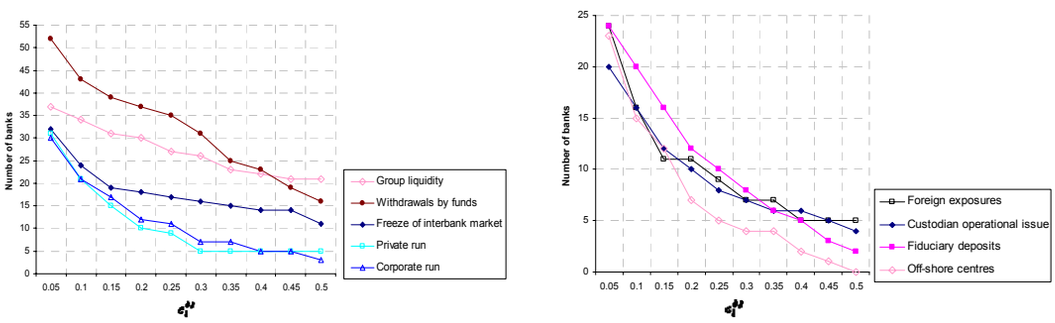
Chart 10 Relevance of the risk factors based on the $c_i^{b,t} > 0.05$



- Source BCL, authors' calculations

With this threshold of contribution of 5%, the most relevant scenarios are: withdrawal of deposits by investments funds (52 banks), netting of the position with the parent banking group (37 banks), interbank market (32 banks) and the withdrawals of private banking and corporate deposits (31 and 30 banks). However, risk factors such as foreign lending, fiduciary deposits and off-shore centres still affect 24 banks (Chart 10). Such conclusions are in line with the general knowledge about the Luxembourg banking sector namely that it services the fund industry and is active in private banking. The Luxembourg banking sector is also very much a host banking sector; this is reflected in the relevance of parent banking group in terms of liquidity.

Chart 11 Number of banks affected by risk factors with different $c_i^{b,t}$ (Sept-2009)



- Source BCL, authors' calculations

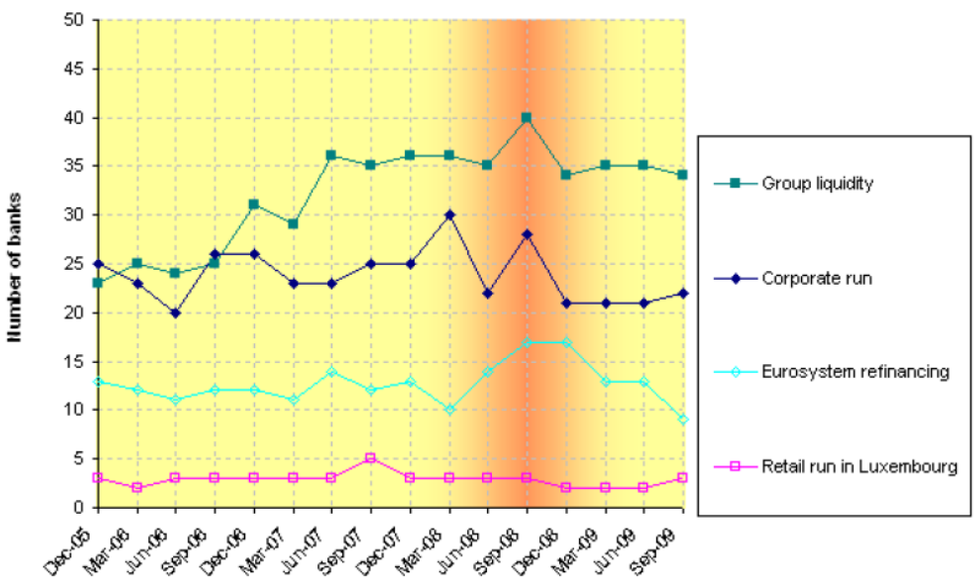
However, in Chart 10 we only see those banks which would be affected by risk factors (scenarios) with a contribution of more than 5%. To identify the most relevant scenario, we also need to analyse the impact with higher values of $c_i^{b,t}$ (Chart 11). In this context sensitivity on deposit withdrawals by investment funds and dependence on the parent banking group seem to be very relevant, as the number of banks concerned does not

decrease significantly with increasing $c_i^{b,t}$. Even where the contribution exceeds 50%, 16 and 21 banks respectively remain affected by these risk factors. By contrast, the relevance of the private banking scenario decreases more significantly with the increasing $c_i^{b,t}$ (5 banks with a contribution of more than 50%), meaning that, even if many banks located in Luxembourg are involved in private banking, this scenario embraces the most important risk factors for only a few of them.

3.2.2 Evolution of the risk factor relevance over time

With a constant $c_i^{b,t}$ [29] we can observe the evolution of the risk factor relevance over time (Chart 12). As a result, we can analyse the potential influence of the financial crisis on the general risk profile of the Luxembourg banking sector.

Chart 12 Number of banks affected by risk factors over time, with constant $c_i^{b,t}$



- Source BCL, authors' calculations

The number of banks exposed to the retail run in Luxembourg is rather stable and does not significantly change during the first peak of the crisis. It is a logical consequence of the long term nature of this business line. Usage of Eurosystem liquidity is a very different example. The number of banks dependent on refinancing operations with the Eurosystem increased significantly during the stress period and decreased again in March 2009.

[29] For this purpose we set the $c_i^{b,t}$ to 0.05, meaning that contribution to the score of more than 5% is considered as relevant

4 Conclusions

In this paper we described the off-site liquidity risk monitoring framework used by the Banque centrale du Luxembourg. Our framework integrates several types of data (regulatory reporting, financial markets, macroeconomic) and therefore, takes into account different sources of liquidity risk, including potential problems at the mother company level or general market stress. The methodology is based on a matrix of 14 on- and off-balance sheet and 7 market risk factors assigned with different weights to all individual banks and then evaluated in relative terms. As a result, the liquidity position of every bank is described by two liquidity scores (comparison to the peers and comparison over time).

The practical application of our framework can be summarised in a following way: Firstly, we have calculated both dimensions (peer and time score) of the liquidity position of every bank located in Luxembourg. In this matrix, we could spot the banks which are less liquid than their peers or less liquid than before and evaluate the systemic importance of these institutions.

Secondly, we have chosen several examples of banks with different business models to demonstrate the evolution of both scores over the last four years. Such trend analysis proved to be important mainly in the case of banks with a weak liquidity position. In these cases, we need to discriminate between constantly illiquid banks and those which have deteriorated recently.

Thirdly, on an example of one bank, we have shown the potential benefits of the closer analysis of the scores. By decomposing the scores, the most relevant risk factors can be identified for each and every bank. We have also demonstrated the importance of this approach on examples of troubled banks, which witnessed similar patterns in the composition of the scores and in their change before the escalation of stress.

Finally, the relevant risk factors of all banks located in Luxembourg can be aggregated and sorted by frequency of occurrence to determine their general relevance to the banking sector as a whole. In such analysis we could observe risk factors with rather constant contribution (e.g. the retail business) and risk factors, whose contribution depends more on recent market developments (e.g. dependence on the refinancing operations with the Eurosystem).

As a result, two major types of information can be drawn from the framework. Firstly, the most vulnerable banks can be filtered from the whole sample and can be recommended for further supervisory analysis. Secondly, the most relevant liquidity risk factors for the Luxembourg banking sector can be determined.

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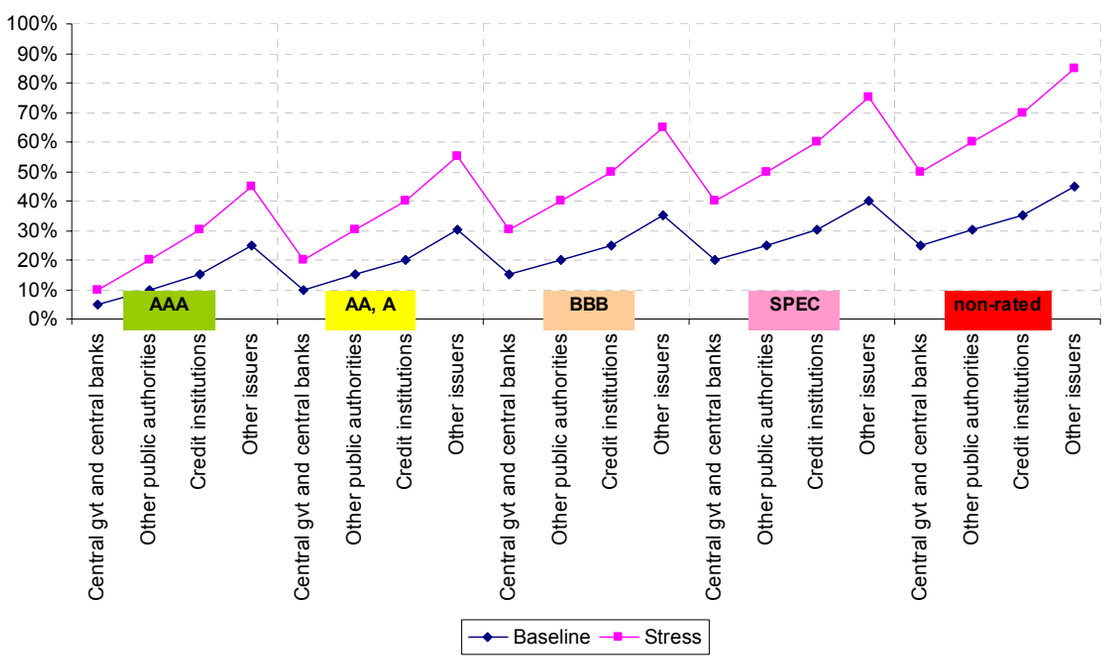
Annex

A Debt securities valuation haircuts (v_i)

Our system of valuation haircuts is based on the data availability, i.e. it was not possible to set the haircuts according to the maturity or rating of securities. We assign different haircuts to the types of securities classified by two dimensions: (i) type of issuer and (ii) sovereign rating of the country of the issuer (Chart 13). We recognise that, in general, duration and rating of single securities would be better proxies for the calculation of valuation haircuts. However, we prefer this approach based on the level of detail in the available data.

Note that there is no special system of valuation haircuts for the debt securities issued by the related parties. For the future work we believe that higher valuation haircuts should be applied on such securities, since there is no evidence they would ever be traded elsewhere than within the respective banking group. Moreover, such securities are not eligible for the Eurosystem refinancing operations. As regards changes occurring in sovereign ratings across countries, these changes are reflected in each quarterly update. Therefore, these changes are automatically reflected in the liquidity buffer evaluation.

Chart 13 Valuation haircuts



Since no data about the overnight deposits are available, we have introduced valuation haircuts of 0.5 and 0.2 for ${}^{1Y}C_b$ and ${}^{1Y}_{rp}C_b$ to take into account certain volume of Nostro accounts available at any moment in time.

B Herfindahl-Hirschmann index composition (h_t)

We have the Herfindahl-Hirschmann index to address the benefits of diversification of funding. We have identified three dimensions of diversification: (i) type of liability, i.e. deposit, issued bonds and other liabilities (ii) country of origin i.e. Luxembourg and non-Luxembourg and (iii) economic sector, i.e. public administration, credit institutions, investment and money market funds, non-financial institutions and households (Table 1). We do not consider other dimensions e.g. currency or maturity.

Table 4 Composition of the Herfindahl-Hirschmann index

Liability item	Economic sector	Country of origin
Deposits	Public administration	Luxembourg
Deposits	Public administration	Non-Luxembourg
Deposits	Credit institutions	Luxembourg
Deposits	Credit institutions	Non-Luxembourg
Deposits	Investment and money market funds	Luxembourg
Deposits	Investment and money market funds	Non-Luxembourg
Deposits	Non-financial institutions	Luxembourg
Deposits	Non-financial institutions	Non-Luxembourg
Deposits	Households	Luxembourg
Deposits	Households	Non-Luxembourg
Issued bonds	All economic sectors	Luxembourg
Issued bonds	All economic sectors	Non-Luxembourg
Other liabilities	All economic sectors	Luxembourg

For future work we suggest to base the Herfindahl-Hirschmann index on the correlation analysis. Such an approach would fine tune the results, as different banks could have different composition of the HHI index tailored to their business.

C Risk parameters (r_i)

Risk factor	Risk parameter
Freeze of interbank market	Volume of net interbank position excluding related parties
Capital markets shock	Value of debt securities portfolio
Retail run in Luxembourg	Sum of deposits by Luxembourg households
Private run	Sum of private banking deposits
Corporate run	Sum of deposits by non-financial institutions
Withdrawals by funds	Sum of deposits by investment funds
Issuance problems	Sum of short-term debt securities issued
Custodian operational issue	Sum of assets under custody
Committed credit lines	Sum of loan commitments given
Foreign exposures	Sum of exposures to clients from non-AAA countries
Fiduciary deposits	Sum of fiduciary deposits
Off-shore centers	Volume of net position with the clients from off-shore centers excluding related parties
Eurosystem refinancing	Sum of borrowings from the central banks
Group liquidity	Volume of net position with related party banks

D List of variables, indexes and abbreviations

Risk indicators		**Scores and parameters**	
TA	Total assets	PS	Peer score
TL	Total liabilities	TS	Time score
LA	Liquid assets	BTS	Balance-sheet time score
T	Cash	MTS	Market time score
C	Credits / receivables, deposits made	$BRPS$	Balance-sheet risk factor peer score
S	Debt securities	$BRTS$	Balance-sheet risk factor time score
D	Deposits received	$MRTS$	Market risk factor time score
B	Debt securities issued	w	Risk factor weight
h	Herfindahl-Hirschmann index	iw	Intermediary risk factor weight
v	Valuation haircuts	r	Risk parameter
α	Stress parameter	R	Distribution of relevant ratios
Indexes:		c	Contribution to the score
$_d$	Type of debt security	bs	Weight of the balance-sheet component of the time score
$_b$	Banks	ma	Weight of the market component of the time score
$_h$	Households	**Indexes:**	
$_p$	Private banking	$_i$	Balance sheet risk factor
$_{rp}$	Related parties	$_j$	Market risk factor
$_f$	Investment funds	$_t$	Time
$_c$	Corporate banking	$_b$	Bank
$_{fid}$	Fiduciary		
$_g$	Granted credit lines		
$_{OC}$	Originating from non-AAA countries		
$_{1Y}$	With maturity less than one year		
$_{LU}$	Originating from Luxembourg		
$_s$	Stressed values		

E Banking activity according to country and currency

currency	country	Min	Lower quartile	Median	Upper quartile	Max	Average weighted by total assets
AAA	**AAA**	0.00	0.50	0.70	0.87	1.00	0.67
non-AAA	**AAA**	0.00	0.00	0.01	0.04	0.74	0.04
AAA	**non-AAA**	0.00	0.05	0.16	0.37	0.99	0.27
non-AAA	**non-AAA**	0.00	0.00	0.01	0.02	0.43	0.02

F Stress parameters (α_i)

Freeze of interbank market	50%
Capital markets shock	see Annex A
Retail run in Luxembourg	$stdev(r_{i,b}) / \overline{r_{i,b}}$
Private run	$stdev(r_{i,b}) / \overline{r_{i,b}}$
Corporate run	$stdev(r_{i,b}) / \overline{r_{i,b}}$
Withdrawals by funds	$stdev(r_{i,b}) / \overline{r_{i,b}}$
Issuance problems	50%
Custodian operational issue	5%
Committed credit lines	$stdev(r_{i,b}) / \overline{r_{i,b}}$
Foreign exposures	10%
Fiduciary deposits	80%
Off-shore centers	80%
Eurosystem refinancing	50%
Group liquidity	80%

G Data sources and data proceeding

This framework used several data sources. The on- and off-balance sheet data was taken from the prudential and statistical regulatory reporting. The most important constraint in the definition of the balance sheet risk indicators is the data availability. We are fully aware of the fact that the reporting database currently available at the BCL which is used in our study is not perfectly liquidity-risk-oriented. However, there is always a trade-off between reporting burden for the sector and the value-added that can be potentially produced by the regulator. In the sense our primary constraint is the available set of data.

The macro indicators adopted in this study have been gathered from several sources. Moreover, for the selection of each indicator we followed the principles of consistency (the indicators are intended to be equal over time and across the sample) and availability (when an indicator was not available a proxy was chosen for the analysis).

Most of the market indicators are assigned to the Luxembourg entities according to its parent banking group (stock price and its volatility) and the country of origin (economic sentiment indicators, special drawing rights and reference stock index). As a result application of such indicators is sensitive to change of owner. To address this issue, we apply a new set of data for the entity from the period the owner has changed. The previous scores remain unchanged. As described in Table 3, this study integrates:

The Special Drawing Rights (SDR)[30]

The SDR is a currency unit defined by the International Monetary Fund. It is a virtual currency and represents a basket of currencies which is weighted according to the relative size of the economy of a country (measured by GDP) at a certain point in time. The

[30] For a more detailed definition of the Special Drawing Rights, please refer to the following internet address: http://www.imf.org/external/np/exr/facts/sdr.htm

weights are revised on a regular basis by the IMF. In order to capture the relative importance of exchange rates the use of special drawing rights (SDR) was preferred to a USD-based exchange rate system, where all currencies are converted in USD. This latter system lagged the impact of currency movements vis-à-vis other non-USD currencies.

SDRs have been preferred due to their ability to capture foreign exchange rate movements across a large currency sample as ours. The SDRs have the advantage to capture appreciation/depreciation of the selected currencies through a parameter which is unique for all. A potential bias of our SDR-based system is the valuation of the SDR, which is constructed on an economic strength basis[31]. Anyhow, given this revision process takes place every 5 years, we consider this indicator to be consistent during the period of reference of this study (12-2006 to 09-2009). As regards SDRs, these indicators are consistent across the whole sample and are available for each bank across the whole period of reference. The related historical time series have been downloaded from the official website of the International Monetary Fund[32]. As regards the calculations, we have used the relative changes of the quarterly averages of the respective currency units per SDR.

A set of Economic Sentiment Indicators

For banks having their headquarters in a country member of the OECD, we integrated the leading economic indicator[33]. This indicator is available during the period of reference for all the locally established banks whose parent company is established in a country member of OECD. As concerns any banks whose headquarter is located within a country not covered by the OECD (or that has not reported any data for the period of reference), we refer to the available proxies, as follows:

- Israel: the State of the Economy Index[34]
- Lebanon: the Coincident Indicator[35]

As regards these latter countries we acknowledge the existence of an issue of consistency. This refers to the lack of harmonization of these indicators with the OECD methodology[36]. Nevertheless, we believe that, for the purpose of this exercise, the indicators adopted in this study are good proxies for the underlying risk of the sampled bank with respect to its home economy.

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[31] For the methodology used to define the basket of currency composing the SDR currency, please refer the following website : http://www.imf.org/external/np/exr/facts/sdr.htm

[32] http://www.imf.org/external/np/fin/ert/GUI/Pages/CountryDataBase.aspx

[33] All the data are downloadable free of charge from: http://stats.oecd.org/Index.aspx

[34] For further details please visit: http://www.bankisrael.gov.il/deptdata/mehkar/indeng.htm

[35] As regards this indicator we acknowledge the limits to harmonization due to the implicit difference of perspective (coincident vs. leading) of these two indicators. For the purpose of this study and given that only one bank includes this ratio within its set of market data, we believe this measure not to affect significantly our investigation.

[36] This issue has already been investigated by the OECD. For more details about this topic please refer to: http://www.oecd.org/dataoecd/9/37/33654955.pdf

A set of stock market indexes

This set includes the main available stock market indicators for each country of origin of each bank registered in Luxembourg. The quarterly data represent the 3 months average of the daily closing prices of each index. The following indexes were included for the reference period[37] (Table 5).

Table 5 Reference stock market indexes

Country	Stock index	Number of entities concerned
Luxembourg	LuxX 20	5
Belgium	BEL 20	7
Italy	FTSE Mib 40	14
Germany	DAX 30	43
France	CAC 40	14
Stockholm	OMX Stockholm 30	8
Oslo	OMX Oslo 20	2
Copenhagen	OMX Copenhagen 20	1
San Paolo	IBovespa 50	4
New York	DJIA 30	12
London	FTSE 100	4
Athens	FSTE Athex 20	2
Istanbul	IMKB XU100	2
Tel Aviv	TA 100 Index	3
Lisbon	PSE 20	2
Moscow	MICEX	1
Shanghai	SSE Composite	4
Tokyo	Nikkei 225	4
Toronto	S&P TSX 60	2
Reykjavik	OMX Iceland 15	2
Amsterdam	AEX 25	3
Switzerland	SMI 20	9
Finland	OMX Helsinki 25	1

We acknowledge the existence of an information bias carried by the above mentioned indexes in terms of representing a fair "portrait" of each country real economic situation. The informative power depends mainly on the degree of efficiency of each market, on the share of the whole economic activity represented by the market capitalization as well as from investors' irrational behaviour episodes. Albeit we cannot exclude a bias originating from these factors, we believe these indexes to be a fair representation of the "status" of the economic conditions of the country where each banking group headquarters is located, at each specific point in time.

The interest rate spread between Euribor and Eurepo 3 months maturity

This indicator is unique for each and every bank under the assumption that each bank, by being located in the Luxembourg market provides or drains liquidity from the inter-bank

[37] The historical data series for these stock markets are downloadable free of charge from several websites.

market. An indicator for measurements of market liquidity is the spread between the secured and the unsecured lending[38].

The indicator of Luxembourg Economic Activity

In order to capture the trend of the Luxembourg economy we integrate the data for the conjuncture indicator[39]. This indicator is consistent across the whole sample.

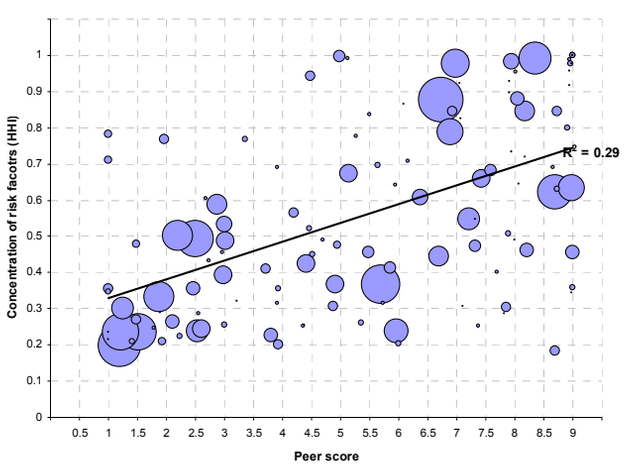
The stock market price of each local bank's parent company

The stock price of each Luxembourg bank belonging to a banking group listed in a regulated stock exchange market has been included in the market indicators. The quarterly data represent the 3 months average of the daily closing prices for each stock. Given that several banking groups have registered more than one entity in Luxembourg, the stock price of the related banking group is repeating several times across the sample. Where the stock price is not available, no other information is included for the moment. We envisage in the future integrating potentially informative market data such as bond spread of credit default swap spreads (when available). The latter should be however analysed to avoid duplicity with the stock price volatility (see Byström 2005). The historical time series for each listed parent undertaking has been downloaded from Bloomberg.

H Peer score, concentration of risk factors and bank size

The peer score does not seem to be affected by the number of relevant risk factors, nor by the size of the banks (Chart 14).

Chart 14 Peer score, concentration of risk factors and bank size



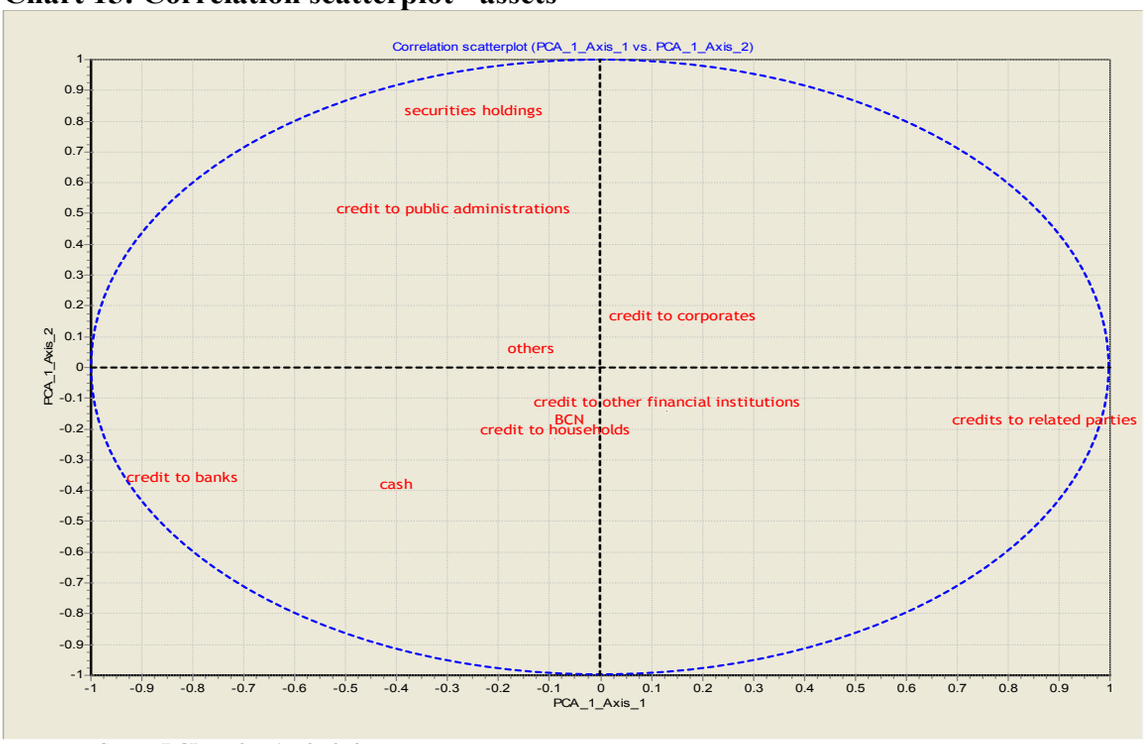
- Source BCL, authors' calculations

[38] For a technical explanation of the fixing of this rate, historical time series and member of the Euribor panel please refer to: http://www.euribor.org As regards the Eurepo, please refer to the following internet website: http://www.eurepo.org.

[39] For more information please visit the following website: http://www.bcl.lu/common/tools/download.php?url=/fr/statistiques/methodo_notes/methodology_statistics.pdf&t=Explications méthodologiques des statistiques

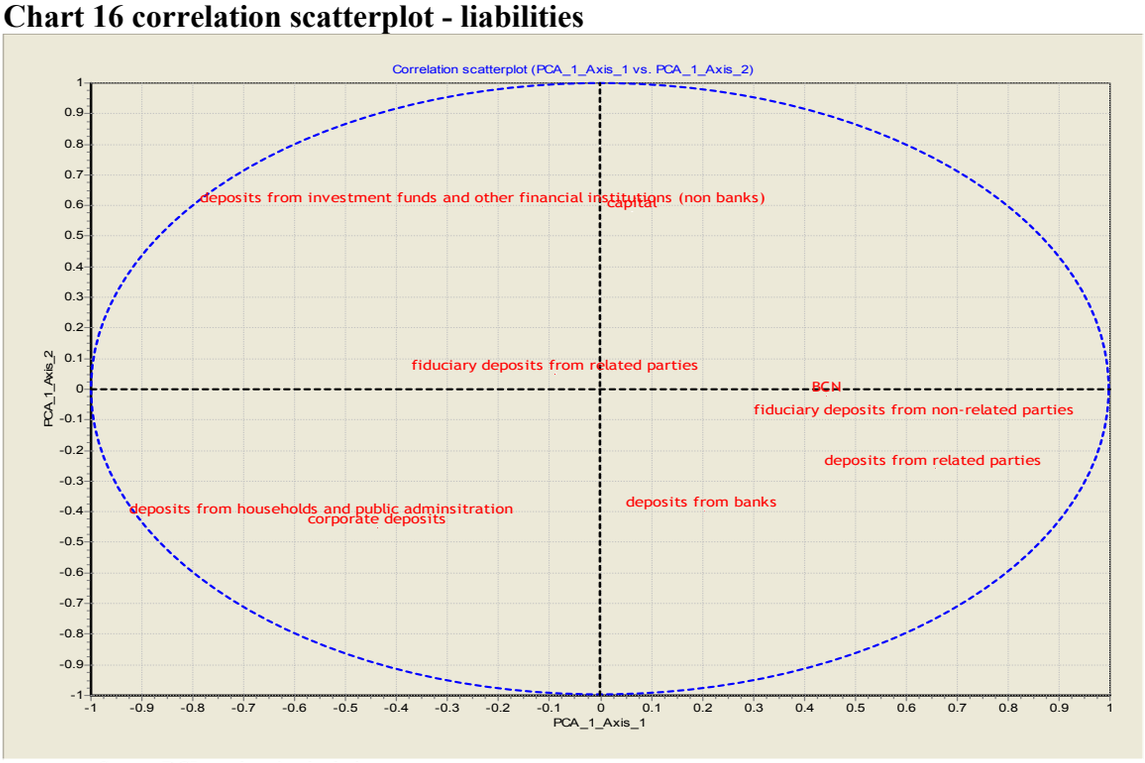
I Correlation scatterplots – assets and liabilities

Chart 15: Correlation scatterplot - assets



- Source BCL, authors' calculations

Chart 16 correlation scatterplot - liabilities



- Source BCL, authors' calculations

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