5 ANALYSES SPÉCIFIQUES

1 MODELLING FINANCIAL TURMOIL THROUGH ENDOGENOUS RISK AND RISK APPETITE[1]

By
Jean-Pierre Zigrand*

1 INTRODUCTION

Financial crises are often accompanied by violent price changes. Newspaper journalists delect in attributing such unruly volatility to the herd mentality of the financial market participants, or to the fickleness and irrationality of speculators who seemingly switch between fear and overconfidence in a purely random fashion. This view of the markets is perhaps best epitomised by the famous cartoon created by Kevin Kallaugher for *The Economist* of November 1, 1997[2]. Such crisis episodes lead to daily headlines in reputed financial newspapers such as "Risk Aversion Rises on Greece", "Dollar Rises on Risk Aversion", or finally "Risk Aversion is Abating". Close cousins of the *contagious* risk aversion are the fickle *confidence*, *overreactiveness*, *fear* and *liquidity*. The VIX index of 30 day S&P 500 implied volatilities is a popular gauge of market risk aversion. It is well-known that the volatility of the VIX index is much larger than the VIX level itself, illustrating the tremendous variability in risk appetite visible in the exchange-traded options markets. The VIX is not the only such gauge. The Bank of England have explored a risk aversion indicator based on the difference between the physical and the risk-neutral measures (Gai and Vause (2005)). A few banks also publish their own proprietary risk barometers based on a basket of indicators such as the VIX, bull-spread prices, high yield credit spreads, CDS spreads, mutual fund net flows, normalised skew and cash levels, as does the ECB (2007). For instance, the GS risk barometer went from 0 in mid 2006 to 250 a few weeks later, to 300 in October 2008 and back to 0 in mid-2009.

On the basis of this view of the world, regulating such madness does not appear to provide the foundation for a very satisfying supervisory job. It is tempting to believe some public opinion makers when they say that the regulator should enforce stricter rules much as would a kindergarten teacher taming a class of unruly children. In this short note, however, we would rather like to get to the bottom of the perceived random mood swings of the market and understand some of the reasons for the violent changes in risk appetite, and a fortiori in liquidity, and argue that such swings are endogenous and natural outcomes of modern financial markets. The hope is that by debunking the perceived purely random and gratuitous character of valuation swings and uncovering the stable and purposeful channel from fundamentals to risk appetite, financial stability supervisors can attack the underlying reasons for distress episodes, rather than address a series of politically motivated and expedient symptoms after the fact.

Indeed, how can it be that human beings are risk averse one day, in a perfectly coordinated fashion, selling their risky holdings across the board and reinforcing the crisis, only to become contagiously risk loving not too long thereafter, pushing prices back to the pre-crisis levels? Surely they do not all together feel compelled to look right and left ten times before crossing the street one day while blindly crossing the next?

It is fair to say that the vast majority of research in theoretical macro-finance did not emphasize crises such as the one we're in. We agree with Governor Mersch (2008) when he says that "In particular, we need more understanding of the financial market channel, which is usually neglected in economic theory as well as in empirical studies". While a lot has been written about the intuitive mechanics of the crisis, frontline soldiers such as regulators did not have much of a theoretical construct to fall back on and to guide them through the darker days. The **aim** we set ourselves is to provide a formal framework in which realistic

* London School of Economics.

1 This piece is based on work done with Jon Danielsson of the London School of Economics, and Hyun Shin of Princeton University.

2 See http://artofsatire.economist.com/cover-1-zoom.php.

crisis dynamics emerge endogenously and intuitively. We would like the formal model to be parsimonious and easy to use, calibrate and interpret.[3] In the model as in reality, risk appetite needs to be both cause and symptom of endogenous risk. From a macro-prudential point of view, a proper understanding of crisis dynamics requires a dynamic general equilibrium approach so as to make sure that all consequences, intended and otherwise, are carefully spelled out and thought through. Our hope is that regulators and observers find the approach useful to formalise their intuition about the unfolding of crises and to use the model as a testing ground for regulations.

2 ENDOGENOUS RISK AND PRICE MOVEMENTS

Roughly speaking, price movements have *two components*, a largely exogenous innovation component due to the incorporation of news, and an endogenous feedback component due to the trading patterns of the market participants over and above the incorporation of news.

As to the *first component*, large price movements in financial markets are to be expected, and do not constitute a crisis. Public announcements of important macroeconomic statistics are sometimes marked by large, discrete price changes at the time of announcement. These changes are arguably the signs of a smoothly functioning market that is able to incorporate new information quickly.

In contrast, the distinguishing feature of crisis episodes is that they seem to gather momentum from the endogenous responses of the market participants themselves. This is the *second component*, called *endogenous risk* (see the survey paper by Danielsson and Shin (2003)). The analogy with a tropical storm over a warm sea or with the wobbly Millenium bridge in London imposes itself: financial crises appear to gather more energy as they develop. A small gust of wind could set the Millenium bridge to sway a tiny bit. Pedestrians crossing the bridge slightly adjusted their stance as a response, pushing the bridge further in the same direction. Provided sufficiently many pedestrians found themselves in the same situation, they felt compelled to coordinate and lockstep and thereby reinforced the swaying into a rather wild wobble. Similarly, as financial conditions worsen, the willingness of market participants to bear risk seemingly evaporates even in the absence of any further hard news, which in turn worsens financial conditions, closing the loop. Any regulatory interventions might best be aimed at understanding and mitigating those negative spillover effects created purely within the financial system: if one can't prevent gusts of wind, then at least one can make sure the pedestrians do not lockstep and cause the bridge to collapse by critically amplifying the initial swing.

In a nutshell, the workings of endogenous risk are as follows. An initial negative piece of news, leading either to capital losses to the financial institutions (FI) or to an increase in market volatility, must be followed by a risk exposure reduction on behalf of many market participants (or capital raisings, which are difficult to do pull off quickly, especially in the midst of a crisis). The reason for *contagious behaviour* lies in the fact that market prices are *imperatives for action* through risk-sensitive regulations, through prudent rules imposed upon individual traders or desks (say Value-at-Risk (VaR) constraints,[4] or delta-hedging constraints), or through the curtailment of haircuts and leverage by credit providers. Such imperatives occur in the markets in a coordinated fashion through the use of similar (across FIs) risk systems, rational or otherwise, as well as through marking-to-market. As a result, the market is necessarily behaving in a *short-termist* manner. It follows that the initial wave of asset sales depresses prices further, increasing the perceived risk as well as reducing capitalisation levels further, forcing a further round of fire sales, and so on.

3 Also see de Walque, Pierrard and Rouabah (2008) for a general equilibrium financial model calibrated to Luxembourgish data.

4 See Danielsson and Zigrand (2008) where a VaR constraint lessens a free-riding externality in financial markets, and Adrian and Shin (2008) for a model whereby a VaR constraint is imposed in order to alleviate a moral hazard problem within a financial institution.

It follows that the fall in valuation levels is composed of a first chunk attributable to the initial piece of bad news, as well as to a second chunk entirely due to the non-information related feedback effects of market participants. In formal models of this phenomenon, the feedback effects can be many times larger than the initial seed of bad news. The second component increases volatility if and only if FIs' capitalisation levels are low: for low capitalisation levels, the FIs reinforce feedback loops, while for large capitalisation levels FIs reduce the original fundamental volatility by allowing the economy to better absorb risks.

The reverse of the medal is liquidity. Volatility measures the standard amount by which the market price is moved: as all FIs become sellers in a crisis, *liquidity dries up*, which is reflected in the increased volatility since each additional sale needs to move prices further still.

3 THE LEADING MODEL IN A NUTSHELL

In order to illustrate these ideas more precisely, we have the formal dynamic general equilibrium model by Danielsson, Shin and Zigrand (2010) in mind, referred to in this note as the *leading model* (LM). The model has the advantage that its rational expectations equilibrium is solved in closed form. Its aim is to study the workings of an economy in financial distress. The graphs at the end of the paper will be illustrated in their proper context. We chose in this note to focus on the intuitive workings of the setup as well as to elicit the practical applications arising from the model, rather than to delve on its mathematical properties. The latter can be found in Danielsson, Shin and Zigrand (2010).

In a nutshell, time flows continuously. A number of rational forward looking FIs are maximizing profits by investing in a number of risky and a riskless security, subject to VaR constraints stipulating that risk is limited by the amount of capital (tangible common equity).[5] The short rate of interest is determined exogenously, perhaps by a Central Bank. Given rational and correct behaviour, prices, quantities and expectations are shown to be driven in equilibrium by a set of relevant aggregate variables, chiefly the (marked-to-market) capitalisation level of the financial sector. The FIs are interacting with each other and with passive investors (the non-financial investors, including individual investors, pension funds and so forth). News about securities is driven by a number of Brownian motions. The prices of all securities are determined in equilibrium. Security i has an (instantaneous) expected equilibrium return of μ_t^i and a volatility of σ_t^i. The equilibrium processes μ and σ are endogenous and forward looking in the sense that the beliefs about future μ and σ are confirmed in equilibrium. FIs in equilibrium hold diversified portfolios commensurate with those beliefs, scaled down by their effective degree of risk aversion γ imposed upon them by the VaR constraints.

In the leading model, volatility, risk premia as well as generalized Sharpe ratios are all countercyclical, rising dramatically in a downturn, providing ex-ante compensation for the risks taken. Figure 1 illustrates. Notice that the model always generates these shapes, they have not been carefully calibrated to be countercyclical. This aligns with much empirical evidence, and arises naturally in our model with no tweaking required. As can be gathered from the graphs, volatility of financial securities is stochastic. Fundamental news-induced volatility is the volatility when bank capital is zero: no FIs means no feedbacks induced by FIs.

Volatility is lower than fundamental news-induced volatility in times where the financial sector is well-capitalized. FIs perform a socially useful job by insulating non-financial end-users from risk and thereby reducing the volatility of financial markets. FIs are able to do so because by having a sufficient capital level, their VaR constraints are not binding hard and so allow the FIs to act as nearly as risk-neutral risk absorbers. Should their level of capitalisation become critically low, however, then FIs exacerbate manyfold the fundamental risk through the previously described liquidity spirals whereby selling begets selling.

5 In order to emphasize the unique contribution of risk constraints to endogenous risk, all other channels are switched off. In that sense, haircuts for instance are set to zero. With endogenous haircuts (e.g. Geanakoplos (2009)), endogenous risk could be increased further.

The inherent **non-linearities** due to the feedbacks make the regulator's problem very difficult. The critical level below which capital is so low that the banking sector no longer can fulfil its socially useful role but becomes a liability to society would need to be determined by trial and error. Our formal model shows this critical level is proportional to the risk-tolerance of the non-financial sector times the square of the strength of the imposed VaR constraints.[6] The deeper and less price-sensitive the real economy, the more capital is required to insure the risks. The stricter the risk-sensitive behavioural rules that are responsible for the feedback loops, the stronger the feedback effects are for each given capital level, and therefore the larger the capitalisation required to prevent the negative spillovers from outdoing the benefits provided by the financial sector.[7]

Returns on *all* risky assets become highly correlated in a crisis, regardless of their correlation patterns during normal market conditions. Similarly, all securities become jointly more volatile in a crisis. This is a phenomenon also observed in crises: all volatilities and implied volatilities shoot up at the same time, whether it be the implied volatility of S&P 500 options or of interest rate swaptions. Again, all those spikes in comovements are driven by the same unifying heightened effective risk aversion factor, itself driven by the capitalisation level in the economy.

4 ENDOGENOUS RISK IN ACTION, AND WHAT TO DO ABOUT IT

The following observations arise from the formal analysis of the leading model, and bear the stamp of logical consistency.

First, the individually prudent course of action of any one FI causes an overall amplified crisis. This is an illustration of the *fallacy of composition*, famously embedded in Basel II regulations (see the seminal paper by Danielsson et al (2001)), whereby the belief is that, provided that each FI is itself safe, the system overall must be safe as well. Indeed, the endogenous risk episodes of the current crisis illustrate beautifully that the prudent and conservative actions which an individual institution takes to enhance its soundness may undermine the soundness of others. Any one FI's fire-sales leads all other FIs to mark-to-market their entire portfolios to those lower marks. Furthermore, the volatility created from one big seller is reflected in a higher VaR for all other FIs, and therefore is an imperative for all other FIs to sell risky securities, creating further rounds of negative spillovers.

Some mechanisms require daily marking-to-market and settlement. Some credit default swaps (CDS) are in the process of migrating to clearing houses, and perhaps some CDS to exchanges. This is commendable to the extent that a systemic risk build-up in one of the counterparties must be prevented, in particular the seller of insurance. Over and above the question as to which contracts are safe to be centrally cleared (without posing a risk to the credit worthiness of the central counterparty (CCP) itself) and who should decide which contracts are to be centrally cleared, there is the risk that the more contracts go to specialised CCPs, the more procyclical feedback effects can be expected due to 1) the daily settlement, and to 2) the fact that while bilateral ISDA agreements called for net collateral transfers across many asset classes, CCPs seem to specialise in individual asset classes, which leads to inefficient security-by-security collateralisation and more feedback effects.

In conclusion, financial markets embody strong externalities and a global approach is needed for financial stability.

6 In Basel II, the level of tightness of the VaR constraints would be -for market risk- roughly three times the relevant quantile.

7 Of course, there are good reasons for limiting risks taken on by financial institutions, such as limiting free-riding externalities and moral hazard. But the medicine can be harmful a posteriori if the downturn they were supposed to prevent has happened anyhow.

Second, much social cost is borne even in the absence of any FI bankruptcies. Of course, the bankruptcy of a major player has the power to rip through the entire network and beyond, along the lines of the domino theory, and illustrates the potential ex-post usefulness of a living will. But we feel that too much emphasis is sometimes put on bankruptcies, when the most common source of social cost occurs through market prices, even in the absence of any subsequent bankruptcy. This idea is best summarized in a quote due to Hyun Shin (2010):

Rather like a classical Greek[8] tragedy, it is the actions taken by the actors who want to avoid a bad outcome that precipitates disaster.

The delevering and unrisking does curtail credit in the economy and leads to paper as well as to real and welfare losses. Here the role of a *liquidity and capital provider of last resort* becomes evident. While the FIs may be overly levered going into a crisis, the endogenous feedback effects may lead to excessive delevering relative to the true state of the economy, a lack of capital and lending that can only be filled by agents not subjected to risk regulation, such as a few hedge funds (if unencumbered by prime brokers), the sovereign wealth funds, the Buffetts and the Central Banks of this world. To the extent that the downward spiral was in part caused by over-reaction, the liquidity providers can expect to be rewarded for their travails by picking up investment opportunities at attractive prices. This also applies to the treasuries and central banks, with some exceptions (e.g. AIG). As the financial crisis can be viewed as a shortage of financial intermediary balance sheet capacity due to forced delevering and disintermediating, lender of last resort operations tend to offset the decline of that capacity. The Central Banks' balance sheet expansion can thus be viewed as an emergency replacement of lost private sector balance sheet capacity by the public sector. It must also be kept in mind that while Central Banks can provide liquidity as a liquidity provider of last resort and thereby reduce fire-sales (by allowing FIs to get cash through repo'ing securities with the Central Bank instead of selling securities), they cannot provide solvency, i.e. act as capital providers of last resort, so a more permanent solution involves recapitalisation, discussed further below.

In summary, it is not sufficient to focus on bankruptcies. Regulators need to be aware of, and address, the large costs due to market overreactions fed by endogenous risk. Measures include capital adequacy (more below) as well as liquidity provision.

Third, to an outside observer it would appear that from one day to the next, the financial participants all together as a *herd* lose much of their *risk appetite* and engage in a classical *flight to quality* and *liquidity*. To an economist, risk aversion is to some extent like the colour of one's eyes. We would therefore like to distinguish *risk aversion* – the innate unwillingness to accept actuarially fair gambles – with *effective risk aversion*, or its inverse *risk appetite*, which is the *risk aversion* apparent in the actions of the agents. These can dramatically differ in a crisis, while being much more in line in quiet and prosperous times. Consider the following realistic example. Traders, trading desks as well as entire FIs operate under a variety of risk-sensitive regulations, say Value-at-Risk (VaR) constraints for concreteness (the points we make do not hinge upon the risk measure chosen, in particular have nothing to do with some of the well-known short-comings of the VaR measure). They will try to maximize utility or profits subject to not breaching their VaR limits, themselves in turn determined by the allocated capital as well as the forward looking probability distribution. In quiet times with low perceived risk, VaR is low, and the risk on the FIs' books is large. The FIs' portfolios appear risk hungry, perhaps with exotic hard-to-digest risky securities taken on in search for an extra return. Subsequent to a bad exogenous negative shock, capital gets depleted to some extent. Following their individually prudent risk rules, traders curtail their risky exposures to reduce VaR to the new lower level. Those sales put further downward pressure on prices, increasing volatility at the same time. Those sales also appear to show that the traders became more risk-averse since the new portfolios are optimal for a FI with less risk appetite. This feeds back into a further round of derisking and delevering, etc. The overall downward spirals can be

8 No pun intended, this quote predates the Greek Crisis.

vicious, and liquidity disappears. We see that risk-appetite, the tightness of the VaR constraints, and liquidity (or illiquidity) go hand in hand. In the leading model,[9] the coefficient of effective risk aversion is equal to the coefficient of innate utility-based relative risk aversion to which one adds the Lagrange multiplier on the VaR constraint.

To an outside observer, the FIs have highly correlated random risk aversion, all together shedding risk one day and loading up on it another day. But such behaviour, while stochastic, is organised, rather than purely random.

The fact that risk aversion rises and falls uniformly across many FIs and asset classes is a result of the fact that marking-to-market is applied by many FIs and that many FIs use similar risk-sensitive constraints. This appears as *coordinated* or *contagious herding* to an outside observer. The term *herding* is much misused in common parlance, referring derogatively to any situation where agents act as a herd of lemmings and put on similar actions. There may be nothing inefficient about this form of herding; for instance buying and holding the market portfolio in a mean-variance setup would be considered herding. Herding in the specialised literature, however, refers to a situation whereby different actors put on the same (or similar) actions *despite the fact that they have private information to the contrary*. So for instance while their private information suggests the FI should buy a security, the FI ends up selling it anyhow. There lies the social cost of herding: the valuable private information in the possession of the individual traders never gets impounded into prices, and therefore revealed to the general market. This may occur for any number of reasons, such as the strength of the public signal, but in the crisis herding does occur because the VaR constraint forces all actors to sell regardless of their private view of the desirability of the risky securities. Prices become less informative about fundamental value as market participants know that selling is not discretionary and therefore no longer reflects marginal valuations and private information. Markets become not only informationally but also allocationally less efficient since prices no longer steer resources towards their most productive uses.

Especially in a crisis, effective risk aversion drives volatilities, risk premia, Sharpe ratios, implied volatilities, correlations etc. It is itself driven by capital, with less capital making the VaR constraints more tightly binding. The Lagrange multiplier (the γ on Figure 1) measures the extent to which the constraint is binding. It is a gauge of how far from a pain point the economy is. This multiplier is strongly countercyclical, increasing dramatically in bad times, playing its role as feedback accelerator. The reason is that capital is depleted during a downturn, compelling sales of risky assets during a phase of the cycle where risk premia (μ on the graph) and forward looking Sharpe ratios (γ) are high. That is therefore the phase where each additional unit of capital could be invested very profitably going forward. Liquidity goes down a black hole as FIs are unable to provide any, having their hands tied. At the height of the crisis no FI is willing to make markets pretty much at any price. A simplified mean-standard-deviation graph illustrates the main gist of the argument. On Figure 3, bank capital is reduced, ceteris paribus, and the acceptable VaR decreases. This requires the FI to reduce the risk on its books. At the new tangency point, it is as if the FI had a steeper indifference curve, i.e. as if the FI had become more risk averse. Risk appetite diminished, even though the risk is exactly the same in this case because we assumed the efficient set to be undisturbed. In the dynamic model, the efficient set diffuses dynamically of course as per the rational expectations equilibrium.

Once a crisis hits and risk aversion and all the other factors peak, it will take time for risk aversion to come down. This is borne out in the data as well (see Coudert et al (2008)). This is because the effect of risk-aversion on markets does not vanish after the uncertainty is resolved and the extent of the crisis becomes acknowledged, since financial sector capital needs to be replenished.

9 This goes back to an idea originally circulated in 2000 under the title "What happens when you regulate risk?" where risk appetite was shown to lead to procyclicalities through the VaR constraint (Danielsson and Zigrand (2001)). It was published by Danielsson and Zigrand (2008). This goes to show that acceptances for publication suffer from procyclicality as well.

To summarize, the common factor driving crisis events is effective risk aversion, or its inverse, risk appetite. Referring to changing risk appetite is not a tautology or an excuse for not really understanding markets. Risk appetite is the countercyclical driving factor and its stochastic behaviour can be characterized precisely through the undercapitalisation level of the financial sector.

Fourth, leverage is pro-cyclical and capital matters. Leverage in the leading model is simply $\frac{assets}{capital} = \frac{1}{VaR_t}$ where $VaR_t = \alpha\sigma_t$, the imposed strength of the VaR constraint (fixed for instance in Basel II) times volatility (this expression is a consequence of Itô calculus). In other words, the growth rate of the capital ratio is equal to the growth rate of volatility. Leverage is procyclical and builds up in quiet booms where VaR is low and unwinds in violent busts, without any exogenous increases in haircuts during crises. FIs have experienced increased haircuts in the recent crisis, reinforcing the feedback loops further through this second channel of forced delevering, see Adrian and Shin (2009) and Brunnermeier and Pedersen (2009).

Financial crises and strong destabilising feedback effects naturally occur if and only if capital levels are too low, as can be seen on the previous figures. During sufficiently well-capitalised episodes, FIs allow the absorption and diffusion of risk, resulting in calmer and more liquid markets than could otherwise be achieved. But endogenous risk raises the fundamental level of volatility in the economy during periods of low capitalisation and diminishes the fundamental level of volatility otherwise. Low capitalisation episodes therefore go hand-in-hand with low liquidity.[10] The first effects of the current crisis became visible through a liquidity crisis (where Central Bank interventions were crucial), but then the crisis quickly turned into a solvency crisis. The two must be linked.

Two solutions suggest themselves: either make sure capital does not fall below a critical amount, or introduce countercyclical measures that reduce the feedback loops if capital was to fall.

Capital adequacy therefore has a major role to play. Since the strength of the nefarious feedbacks is very sensitive to the pro-cyclicality of capital adequacy rules, a sufficient capital buffer needs to be imposed in conjunction with countercyclical rules. A large capital buffer that either cannot be used (refer to Goodhart's metaphor of the weary traveller and the lone cab driver, in chapter 8 of Goodhart (2009)), or that imposes positive feedback loops, is counterproductive exactly in those situations where it would be needed most. Excessive bank capital tied up in government bonds is socially costly also by holding back the role of a bank which is in part to transform maturities and to take on risks in general. Time will reveal the extent to which Basel III will be able to improve upon Basel II on that front.[11]

Risk builds up during the good times where perceived risk is low and where imprudent leverage and complex financial networks build up quietly, perhaps aided by moral hazard considerations (for a test of this hypothesis, refer for instance to the BIS paper by Altunbas et al (2010)). It is only in a crisis that this risk materialises and becomes plainly visible. A promising avenue to think about capital adequacy (based on an idea in chapters 10 and 11 in Goodhart (2009)) that deserves further thought would be to require FIs to set aside an initial capital buffer, plus an additional variation capital buffer that is a function of the *growth rate* of various assets (both on- and off- balance sheet) as well as of the maturity mismatch (and of the probable liquidity in a crisis) imposed by those asset classes. The variation buffer can then be naturally

10 Recall the earlier discussion on the critical level of capital that would allow the financial system to perform its socially useful role.

11 The proposed *Liquidity Coverage Ratio* has the potential to decrease or increase procyclicality, depending on the implementation details. This liquidity is used during a downturn, possibly dampening the spiral. The question is under which conditions the liquidity coverage ratio is waived during a prolonged downturn (or whether relatively optimistic forward-looking scenarios are chosen). If the buffer needs to be refilled regardless, it will be through the selling of less liquid and risky securities that otherwise might not have occurred, thereby potentially hastening the freezing of the markets for riskier securities that it was aimed to alleviate in the first place.

and countercyclically depleted in a downturn, provided the FIs do not feel compelled to take back onto their balance sheets during the downturn large amounts of hidden toxic assets. To our knowledge, this idea still needs to be formally analysed through.

Notice, however, that while countercyclical regulatory capital requirements are a step forward,[12] they are not sufficient to stem all procyclical forces in the markets. For instance, FIs will still allocate capital to traders according to a VaR formula, forcing them to unwind risky positions if risk shoots up. Haircuts will always go up in a downturn. Central clearing houses will impose daily settlement and contribute to procyclicality, more so the more such central clearing will be effected. Net derivative positions will still be at least partly delta hedged, implying reinforcing feedback effects (on top of the VaR induced feedback effects) if delta hedgers are net short gamma.[13] For instance, when broker–dealers have sold net amounts of puts, they hedge their exposure to changes in the underlying asset price. Such hedging requires selling the underlying asset if the underlying asset price falls, thereby amplifying the fall, which in turn acts as an imperative for further sales, and so forth.

In summary, the omnipresence and inevitability of adverse procyclical spillover effects in financial markets reinforces the need for countercyclical *regulatory* capital rules.

Fifth, risk-sensitive rules have strong effects on correlations. Correlations (or more generally, possibly non-linear co-movements) between assets are of primordial importance to investors. Diversification is often said to be the only free lunch out there. The feedback effects created by well-meaning risk-sensitive constraints imply that in a downturn the FIs need to unload risk. They will try to do so optimally, reducing their overall risky exposures. The sales across assets and asset classes puts downward pressure on all asset classes sold, creating (additional) positive correlations, and denying investors the diversification benefits they expected. The sudden increase in correlations during the crisis is well documented and caused huge losses not only to suddenly undiversified investors, but also to correlation desks in many banks.

Furthermore, we can see from Figure 2 that variances move together, and so do variances with correlations. This is confirmed in the data by Andersen et al (2001) who show that

"there is a systematic tendency for the variances to move together, and for the correlations among the different stocks to be high/low when the variances for the underlying stocks are high/low, and when the correlations among the other stocks are also high/low".

They conjecture that these co-movements occur in a manner broadly consistent with a latent factor structure, and we believe this factor to be risk aversion/capital inadequacy, at least in crises episodes.

In summary, once it breaks out, endogenous risk grips the entire financial markets akin to a contagious disease. Valuations of different asset classes start to move in tandem, as do their volatilities and correlations. Regulators need to be prepared for the fact that if a storm brews, it likely is going to be a perfect one. For instance, many broker-dealers are short correlation, so they would be hit regardless of the direction of asset prices and volatilities.

12 Whereas regulators relaxed capital adequacy requirements during the S&L crisis, no such formal countercyclical regulatory forbearance seems to have been applied in this crisis.

13 Roughly, if σ_t is the volatility of the returns on a security in the absence of delta hedging, then the actual realised volatility in a market with delta hedging feedbacks is $\frac{\sigma_t}{1-\psi_t\theta_t\Gamma_t}-\sigma_t$, where θ_t is the amount of options the delta hedgers are short, ψ_t measures the market impact of a trade in the underlying security (its "depth") and Γ_t measures the net convexity at time *t* of the book of options (which is largest at-the-money and for short maturities).

Sixth, options markets display patterns consistent with endogenous risk. At least since 1987, equity index options markets have pretty much universally displayed a skew that is fanning-out over longer maturities. Out-of-the-money puts have much higher implied volatilities than out-of-the-money calls. Shorter dated options have a more pronounced skew compared to the longer dated options. The fear in the market seems to be of a violent downturn (against which the expensive out-of-the-money puts are designed to protect), while strings of positive news are expected to lead to less volatile returns, the great moderation. This violent downturn is not expected to be permanent, hence the mean-reverting fanning-out of the skew. Our view is that the options market's views align with endogenous risk. Endogenous risk by design embeds an asymmetry between the downside and the upside. The powers of hell are unleashed on the downside, while no such effects operate on the upside. It may be no coincidence that the widely accepted version of the events of October 1987 (see for instance the formulation of Gennotte and Leland (1990)) specifies that feedback effects from synthetic delta-hedged puts embedded in portfolio insurance mandates is largely responsible for the vicious selling pressure.

Over and above the omnipresent implied volatility skew at any given moment in time, our model also predicts that implied volatilities move together in a crisis, which has indeed occurred, across securities as well as across asset classes.

Volatility of volatility ("vol of vol") is a nascent field of research, especially since markets started trading volatility options. Our model predicts that volatility of volatility leads volatility in the sense that as the capitalisation level of the intermediation sector deteriorates, vol of vol picks up before volatility itself increases. Preliminary investigations seem to confirm this, though much more work needs to be done.

In summary, regulators would benefit from having information regarding the net gammas and vegas of broker-dealers to get an early indication of the possible extent of feedback effects. Regulators also may find implied option volatilities and implied correlations useful indicators.

5 CONCLUSION

Each financial crisis has its own peculiarities that make it look different and unique. This time around the impetus lay in subprime mortgages packaged up into CDOs, too many of which were held on- and off-balance sheet by over-levered systemic financial institutions for a variety of reasons, not least for regulatory arbitrage considerations. Be that as it may, once the trigger is pulled, crises develop in much the same fashion. Deleveraging and derisking imply that asset price movements increase manyfold through the feedback effects that are programmed into the financial system itself. The result is a natural combination of liquidity and solvency issues. This paper aims at spelling out the precise mechanism through which endogenous risk manifests itself and suggests ways of mitigating the individually prudent but jointly welfare destroying negative spillovers that worsen a crisis so much.

References

Adrian, Tobias and Hyun Song Shin (2009) "*Prices and Quantities in the Monetary Policy Transmission Mechanism*", FRBNY Staff Report No. 396, October 2009.

Adrian, Tobias and Hyun Song Shin (2008) "*Financial Intermediary Leverage and Value at Risk*", working paper, Federal Reserve Bank of New York and Princeton University. Federal Reserve Bank of New York Staff Reports, 338.

Altunbas, Yener and Leonardo Gambacorta and David Marques-Ibanez (2010), "*Does monetary policy affect bank risk-taking?*" BIS Working Paper 298.

Andersen, Torben and Tim Bollerslev and Francis Diebold and Heiko Ebens (2001), "*The distribution of realized stock return volatility*", Journal of Financial Economics, 61, 43-76.

Brunnermeier, Markus and Lasse Pedersen (2009) "*Market Liquidity and Funding Liquidity*", Review of Financial Studies, 22, 2201-2238.

Coudert, Virginie and Mathieu Gex (2008), "*Does risk aversion drive financial crises? Testing the predictive power of empirical indicators*", Journal of Empirical Finance, Volume 15, Issue 2, March 2008, Pages 167-184.

Danielsson, Jon, Paul Embrechts, Charles Goodhart, Felix Muennich, Con Keating, Olivier Renault and Hyun Song Shin (2001) "*An Academic Response to Basel II*", Financial Markets Group Special Paper 130 http://hyunsongshin.org/www/basel2.pdf

Danielsson, Jon, Hyun Song Shin (2003) "*Endogenous Risk*" in Modern Risk Management: A History, Risk Books, 2003.

Danielsson, Jon, Hyun Song Shin and Jean-Pierre Zigrand (2004) "*The Impact of Risk Regulation on Price Dynamics*", Journal of Banking and Finance, 28, 1069-1087.

Danielsson, Jon, Hyun Song Shin and Jean-Pierre Zigrand (2010) "*Risk Appetite and Endogenous Risk*", FMG Discussion Papers DP647, Financial Markets Group (LSE).

Danielsson, Jon and Jean-Pierre Zigrand (2001) "*What Happens When You Regulate Risk? Evidence from a Simple Equilibrium Model*", FMG Discussion Papers DP393, Financial Markets Group (LSE).

Danielsson, Jon and Jean-Pierre Zigrand (2008) "*Equilibrium Asset Pricing with Systemic Risk*", Economic Theory, 35, 293-319.

de Walque, Gregory and Olivier Pierrard and Abdelaziz Rouabah (2008), "*Financial (in)stability, supervision and liquidity injections: a dynamic general equilibrium approach*", BCL Working Paper No. 35.

ECB (2007), "*Measuring investors' risk appetite*", Financial Stability Review, June 2007.

Gai, Prasanna and Nicholas Vause (2005), "*Measuring investors' risk appetite*", Bank of England Working Paper No. 283.

Geanakoplos, John (2009) "*The Leverage Cycle*" forthcoming in the NBER Macroeconomics Annual.

Gennotte, Gerard and Hayne Leland (1990) "*Hedging and Crashes*", American Economic Review, 999–1021.

Goodhart, Charles (2009), *The Regulatory Response to the Financial Crisis*, Edward Elgar.

Mersch, Yves (2008), "*The recent sub-prime turbulences and their consequences for Luxembourg*", Mimeo BCL.

Shin, Hyun Song (2010), *Risk and Liquidity: 2008 Clarendon Lectures in Finance*, forthcoming.

Figure 1. Equity is the capitalisation of the financial sector. μ is the equilibrium risk premium of one of the risky securities. σ is the equilibrium volatility of one of the risky securities. γ is the endogenous effective risk aversion, in equilibrium equal to the forward looking generalised Sharpe ratio across all securities. Higher levels of capital represent a well-capitalised sector, where vol is below the fundamental yearly vol of 40%. As capital is depleted, vols, risk premia and Sharpe ratios increase: the crisis hits. If capital gets fully depleted, the economy is an economy without FIs, so vol is equal to the fundamental vol.

Figure 1
Equilibrium risk premia, volatility and risk aversion / Sharpe ratio

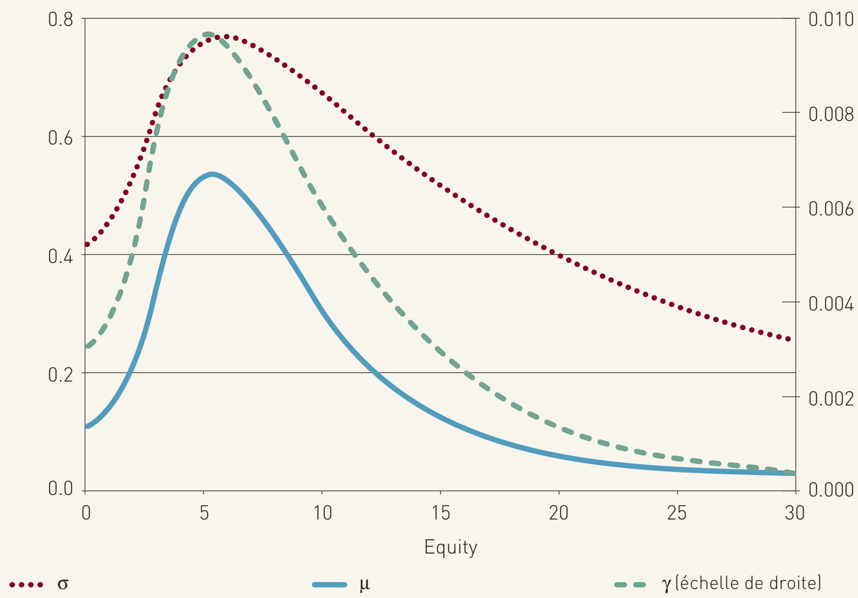

Figure 2. Equity is the capitalisation of the financial sector. Σ^{ii}, (the top curve) is the volatility of the returns on security i. ρ^{ij} (the bottom curve) is the correlation coefficient between the returns on securities i and j. Assume that securities i and j are intrinsically uncorrelated. For a well-capitalised financial sector, variances are low as the financial sector helps absorb risk. For a very well-capitalised financial sector, correlations between the various securities are reduced since the FIs insure the risk-averse investors against risk, which means that the market portfolio is less risky through better diversification. For low levels of capital, however, correlations shoot up dramatically. FIs need to shed their risky exposures. The shedding reduces prices and raises volatility across all securities. This in turn forces FIs to engage in another round of fire sales, and so forth. Risky securities are sold across the spectrum, which entails that all prices tend to move together more, so correlation shoots up.

Figure 2
Equilibrium correlations

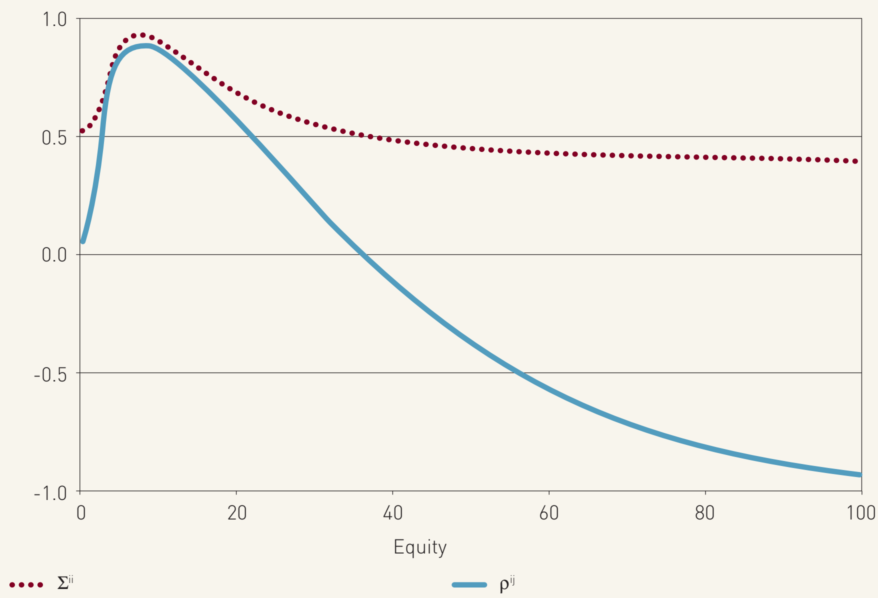

Figure 3
Changing Risk Appetite

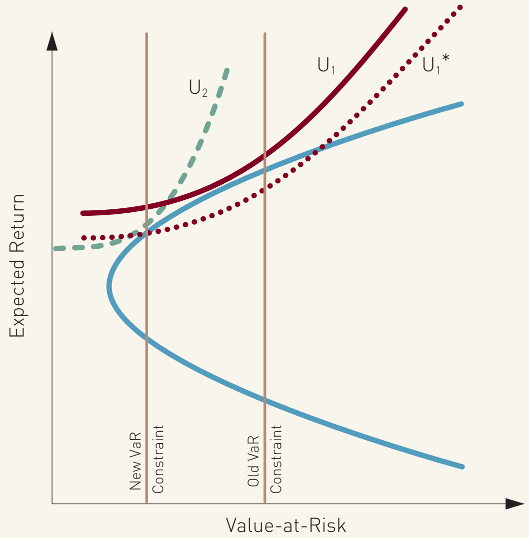

Figure 3. The original indifference curve is U_1 and the original (old) VaR constraint is not binding. Assume that investment opportunities stay constant but that capital is reduced. At the new capital level, the new VaR constraint is binding, and the new optimal portfolio chosen is no longer a tangency point between the indifference curve (shifted down to U_1^*) and the efficient set. This portfolio could also be viewed as the unconstrained portfolio choice of a more risk-averse investor (steeper indifference curve U_2): as if risk aversion shot up to the new γ. In the dynamic model, investment opportunities change endogenously as well of course.

2 LEVERAGE AND RISK IN US COMMERCIAL BANKING IN THE LIGHT OF THE CURRENT FINANCIAL CRISIS[1]

By
Nikolaos I. Papanikolaou*
Christian C.P. Wolff*†

ABSTRACT

In this paper we study the relationship between leverage and risk in US commercial banking market. We employ a representative panel data set of systemically important banks that extends from 2002 to 2009 thus covering both the years before the outbreak of the current financial crisis and those that followed. Several alternative variables are used to capture both on- and off-balance-sheet leverage as well as short-term leverage. Regarding risk, it is proxied by two measures: the systemic risk potential and banks' overall risk. Our findings indicate reliably that both on- and off-balance-sheet leverage contributes to (systemic) risk, which implies that large banks do not maintain a level of leverage that could allow for equity capital to act fully as a buffer, absorbing losses and enabling the business to continue in case of financial distress. In a similar vein, a direct link between short-term leverage and risk is reported, showing that leverage is one of the main factors responsible for the serious bank liquidity shortages that were revealed in the current crisis. We also find that those banks that concentrate on traditional banking activities typically carry less risk exposure than those that are involved with new financial instruments. The latter finding could play a role in the current discussion about a possible revival of the Glass-Steagall Act. Overall, our results provide a better understanding of the main causes of the present crisis and contribute to the discussion on the reinforcement of the existing regulatory framework.

Keywords: financial crisis; risk; leverage; commercial banking

JEL classification: C23; D02; G21; G28

1 INTRODUCTION

The stability and the resilience of the global financial system has been seriously tested for more than two years now. The current crisis, whose origins can be traced in the collapsing valuations in the US sub-prime mortgage market in mid-2007, has revealed several systemic inadequacies which are strongly related to the mal-functioning of the banking sector. An important aspect of these inadequacies is the extent of bank leverage in the years before the crisis.

Bank leverage, in the standard context, refers to the use of debt (*i.e.*, borrowings) in financing investments. More specifically, a loan is used to supplement bank equity capital in financing an investment project, which is expected to produce a higher rate of return compared to the interest rate paid. In case the investment return rate turns out to be smaller than anticipated, a bank's equity will shrink and might become insufficient to repay the loan. All in all, leverage maps the riskiness of an asset position into the corresponding riskiness of its on-balance-sheet equity stake.

Leverage, however, can also be traced *off* the balance sheet. Indeed, commercial banks are eligible to transfer some part of their leverage off their balance sheets through securitization and other modern financial

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* Luxembourg School of Finance, University of Luxembourg.

† Centre for Economic Policy Research (CEPR), London, United Kingdom.

activities.[2] In the years that preceded the current financial crisis, securitization occurred mainly through the setup of Asset Backed Commercial Paper (ABCP) conduits and Structured Investment Vehicles (SIVs) where banks had been transferring their assets together with their risk.[3] As a result, conduits and SIVs contained a significant degree of leverage, known as embedded or implicit leverage. Embedded leverage was thus achieved through the structuring of the financial instruments themselves. The risk -though transferred to conduits- still burdened the sponsoring commercial banks that provided liquidity and credit enhancements to conduits in order to ensure funding liquidity for the vehicles. These enhancements or 'backstops' attracted a low charge under Basle I and were funded mostly by rolling over commercial paper and only by very little equity capital. Hence banks were able to free up capital to originate more assets, generally of lower quality, and hide them in the shadow banking system.[4] By doing so, commercial banks deliberately avoided issuing new (costly) equity capital to originate new assets and finance their activities in general. However, under the aforementioned scheme of credit and liquidity backstops, investors in conduits and SIVs would return the assets back to the bank once they suffered a loss. As a consequence, commercial banks had to take 'bad' assets back on their books in the light of the crisis.

It should be apparent thus far that leverage (either on- or off-balance-sheet) can be potentially harmful for financial stability. In case of over-leverage, a rapid and simultaneous unwinding of leveraged positions of financial institutions triggered by an adverse event (like the adverse price movements in the subprime sector of the securitized US mortgage market) can seriously threaten the soundness of the system. Moreover, in an economy-wide financial turmoil, highly leveraged firms are more likely to fall into financial distress, thus worsening their performance. Indeed, following the corporate finance literature, distress deepens the interest conflicts between bondholders and shareholders and eventually increases the agency costs of debt (Jensen and Meckling, 1976). In a similar vein, the role of leverage as a disciplinary device that reduces free cash flow problems (Jensen, 1986) as well as its signaling power of conveying positive messages to the market (Titman and Trueman, 1986) both become less important when the firm is financially distressed.

Equally -if not more- harmful than leverage per se is the so-called reverse leverage that refers to the phenomenon in which financial intermediaries all together attempt to shrink their balance sheets by reducing their debt. Reverse leverage puts additional downward pressure on financial markets, especially in a system that consists of highly leveraged institutions. Any serious fall in asset prices or any cut in cash flows can exert reverse leverage effects on the system. In the current crisis, the trigger for the deleveraging process was the deceleration of housing prices that was accompanied by an increase in mortgage default rates. The value of mortgage-backed securities was thus dampened, making financial institutions and other investors less willing to hold these securities in their portfolios. The downward spiral was further amplified by the downgrades of the majority of securitized products by the rating agencies. Since a small downgrade can cause a big fall in the price of the downgraded asset, banks had to take immediate steps to strengthen their capital base in order to provide support to their assets. As a result, credit supply was sharply fallen, which negatively affected the whole economic activity.

Although the role that leverage plays with regard to the stability of the financial system has been discussed in a number of theoretical policy and academic studies, not enough empirical evidence has been gathered to provide definite answers to the relevance of leverage in the propagation of a financial crisis. Moreover, little attention has been paid to the *overall* leverage behavior of financial institutions. Indeed, the importance

2 An additional advantage of securitization is that it generates fee income. Since fees do not have to be returned in case the securities later suffer great losses, commercial banks have a great incentive to engage in securitized activities thus leveraging even more their positions.

3 This particular action has become known as regulatory arbitrage. This type of arbitrage refers to the response of commercial banks to strict regulatory rules -especially those on capital requirements- that have been imposed by Basle I and II. Put differently, it is the game that takes place between banks and regulatory authorities whereby the former innovate and develop instruments in order to elude the scrutiny of supervisors and increase their returns, and the latter tighten the rules to avoid excessive risk-taking and safeguard the stability of the financial system as a whole. For a thorough discussion of regulatory capital arbitrage via derivative instruments, see Beuer (2002).

4 Shadow banking consists of non-bank financial institutions like hedge funds, insurance funds, investment funds, pension funds, SIVs, conduits, to name the most important ones.

of commercial banks' off-balance-sheet leverage in today's financial crisis has been rather neglected in the extant literature. In the current study we make an attempt to fill this void by assessing the effect of bank leverage on the soundness of the financial system. More concretely, we investigate empirically the overall leverage-taking behaviour of US 'too-big-to-fail' commercial banks before and after 2007, when the crisis erupted, and to what extent leverage affected the stability of the financial system.

Our focus on commercial banks allows us not only to distinguish on-balance-sheet from off-balance-sheet leverage, but also short- from long-term leverage. Short-term (wholesale) debt via the rolling out of conduits and SIVs has been relatively cheap for commercial banks compared to long-term debt. Indeed, the costs of banks of holding much illiquid capital were largely removed with short-term debt. Nevertheless, short-term borrowing can cause serious liquidity problems, especially in case of financial distress: the funding of long-term investments through short-term securitized debt widens maturity and liquidity gaps, making banks much more vulnerable to runs. Moreover, when the asset growth at banks is funded with short-term debt, the funding risk is increased due to the higher volatility of these funding sources compared to more stable retail deposits. Surprisingly, the crisis literature often does not relate leverage to other aspects of the crisis, notably, liquidity tides and shortages.[5] These relationships are also addressed in this paper, using a proxy measure for bank short-term leverage.

An additional reason that makes the focus on commercial banking of particular interest is that the latter sector is fairly regulated not only in general terms but especially in terms of capital requirements. This is in sharp contrast to investment banks as well as near- and non-banks that do not rely on deposits and, thus, are not obliged to keep much money in the form of capital. This implies that the latter type of institutions faces no serious restrictions on the level of leverage. Hence, an issue that we deal with here is whether the existing capital restrictions are adequate to mitigate an undesirable increase in commercial banks' level of leverage.

Our sample consists of quarterly data for the largest US commercial banks and extends from 2002q1 to 2009q3. The whole data period is divided into two-time segments where the cut-off point is defined by the outbreak of the crisis. Several alternative leverage measures are employed in the regression analysis to test whether and to what degree banks accumulated leverage not only on but also off their balance sheets and how this affected their risk profile. Risk is captured with two different proxies: one for the health of the systemically important sample banks which indicates the likelihood of the occurrence of systemic risk events, and a second for total bank risk-taking which relies on the overall variability of the individual banks' stock market prices. The former risk measure is constructed with accounting data and is thus backward-looking, whereas the latter is a pure market measure of risk and as such it tends to be forward-looking. Last, several control variables that the literature has reported to affect risk are employed in our regression model.

Our findings reveal, among other things, that both on- and off-balance-sheet leverage contribute to systemic risk potential and to banks' overall risk. By the same token, we find that short-term leverage is directly linked to the two measures of risk we use in our empirical analysis. Importantly, banks that concentrate on traditional banking activities of taking deposits from households and making loans to agents that require capital are found to carry less risk exposure than those that are involved with new financial instruments. Overall, our results provide a better understanding of the main causes of the current crisis and contribute to the discussion on the reinforcement of the current regulatory framework.

The remainder of the paper proceeds in the following way. Section 2 provides a description of the data set and a justification of the variables used together with summary statistics. The regression model and the estimation methodology followed are also presented in this section. Section 3 discusses the empirical findings, whereas their corresponding policy implications along with the concluding remarks are presented in Section 4.

5 Berger and Bouwman (2009) stress the lack of tangible liquidity measures as the main reason why liquidity is overlooked in the existing literature.

2 EMPIRICAL ANALYSIS

2.1 Data

Our empirical analysis is based on a data set that consists of the 17 largest US commercial banks as reported by the Federal Reserve Board (the bank names can be found in Appendix I).[6] The banks that are examined are representative of the population of the large US commercial banks as they possess about 60% of the total assets.[7]

There are at least two reasons why we decide to include large and not small- or mid-sized commercial banks in our sample. First, large banks have been engaged in off-balance-sheet activities to a much greater extent than their smaller counterparts. Indeed, the literature (see, e.g., Rime and Stiroh, 2003) has showed that large banks are very prone to universal banking activities in contrast to small- and medium-sized banks which are less diversified and resemble single-line businesses. Hence, the distinction between on- and off-balance-sheet leverage, which is in the focus of the current study, is expected to be more apparent for a sample consisting exclusively of the largest banks. A second reason is that the sample banks are regarded as 'too-big-to-fail' in the sense that US government would be rather reluctant to let any of these banks to go bankrupt as this would have shattering effects on the whole financial system.[8] Indeed, the 17 largest commercial banks that comprise our data sample provide the bulk of financing to industry and households in US, meaning that, if any one of these banks were allowed to fail, this would inevitably cause, *inter alia*, serious systemic liquidity shortages in the economy. This is to say that we focus on some of the most systemically important financial institutions worldwide, which is a fundamental characteristic of our study.

It is important at this point to also justify why we focus our research on the US and not on some other banking system. The first reason is that the present crisis originated in the US before spilled over to other Western-type economies. Hence, by investigating the US banking sector, we can trace some of the root causes of the crisis. Second, Generally Accepted Accounting Principles (GAAP) allow US commercial banks to treat their SIVs and ABCP conduits as being entirely *off* their balance sheets. In contrast, the International Financial Reporting Standards (IFRS) that most large European banks follow is somewhat less opaque on this issue as they require from banking institutions to keep records of this kind of activities *on* their balance sheets. Therefore, US commercial banks have an additional incentive to undertake a higher degree of implicit leverage.

The data we employ are of quarterly frequency and cover the period 2002q1-2009q3. The whole period is divided into two sub-periods: the earlier one (2002q1-2007q2) includes the years before the outbreak of the crisis, which were characterized by stable financial conditions and strong economic expansion. The second period (2007q3-2009q3) refers to the crisis period in which financial turbulence and economic recession prevailed. We chose not to examine the years before 2002 for the following reasons. First, the two big financial crises in Asia and Russia at the end of the 90s, but most importantly the Long Term Capital Management (LTCM) crisis of 1998 partly destabilized the US financial system also affecting the operation of banks until the beginning of the 00s. And second, no considerable regulatory or other similar changes have taken place in the US banking environment during the examined period, which could have affected the behavior of banks.[9]

6 The US Federal Reserve Board compiles quarterly data on domestically chartered large commercial banks from 2001 onwards.

7 Other recent studies that also belong to the burgeoning crisis literature and focus exclusively on systemically important financial institutions are those of Adrian and Shin (2010), who examine the procyclicality of leverage of the 5 largest US investment banks before the crisis and Huang et al. (2009), who construct a framework for measuring and stress testing the systemic risk of 12 US major commercial and investment banks.

8 To provide support to this argument, we mention that not a single US commercial bank amongst those failed from the beginning of the current financial crisis (which amount to 192 as of the end of February 2010 according to the relevant FDIC list) is ranked among the first one hundred large commercial banks.

9 In fact, the latest legislative activity in the US that largely influenced the operation of the banking industry as a whole was the Gramm-Leach-Bliley Act of 1999, which opened up the US financial market allowing commercial and investment banks, securities firms and insurance companies to merge their activities.

Regarding our data sources, all the bank-specific accounting variables are taken from the FDIC Reports on Condition and Income (Call Reports). To construct the proxy measure for embedded leverage we collect data from the Office of the Comptroller of the Currency (OCC)'s Quarterly Reports on Bank Derivatives Activities. The market interest rates used in the construction of total bank risk are from Thomson Reuters Datastream, whereas the short-term interest rates which are needed for the construction of interest rate risk measure are found on Federal Reserve Board website. Finally, macroeconomic variables are obtained from the Bureau of Economic Analysis of the US Department of Labor.

2.2 Variables definition

We now turn to describe the variables employed in the econometric analysis. All variables are summarized in Appendix II, whereas Appendix III reports summary statistics.

2.2.1 Dependent variables

We employ two measures of risk as dependent variables: the systemic risk potential and total bank risk. To proxy for systemic risk potential (SYSTRISK), we construct an index of the joint insolvency risk of all sample banking institutions following De Nicolo et al. (2004). This index relies upon Altman's Z-score and is calculated as follows:

$$Z_q = \frac{(\overline{ROA_{iq}} + \overline{TE_{iq}/TA_{iq}})}{\sigma(ROA_{iq})}$$

$$i = 1, 2\ldots, N=17;\ q=2002q1, 2002q2,\ldots,Q=2009q3$$

where $\overline{ROA_{it}}$ stands for the period average Return On Assets calculated by the mean ratio of net income to total assets (TA_{iq}); $(\overline{TE_{iq}/TA_{iq}})$ is the mean average of total equity to total assets; and $\sigma(ROA_{iq})$ is the period standard deviation of ROA that captures the volatility of returns. Hence, Z-index combines profitability, capital risk, and return volatility in a single measure. Evidently, the index is increasing in banks' average profitability and capital strength and decreasing in return variability. Overall, larger values of the Z-index imply lower systemic risk potential and thus greater financial soundness.

Our second measure of risk represents total bank risk-taking (TOTRISK) and is calculated as the quarterly standard deviation of each sample bank's weekly stock market returns.[10] This metric of risk captures the total volatility of stock market prices for each individual bank incorporating credit risk, interest rate risk, and liquidity risk.[11]

To calculate it, we first obtain the weekly returns for each individual bank using its stock market prices:

$$R_{iw} = \ln \overline{P}_{iw} - \ln \overline{P}_{iw-1}$$

where R_{iw} denotes the weekly $(w=1, 2, \ldots, W)$ stock market returns of bank i $(i=1, 2,\ldots, N)$, and $\ln \overline{P}_{iw}$ stands for the natural logarithm of the weakly average of bank i's stock market daily price P. Total bank risk is then given by the following formula:

10 Similar risk measures have been used in the study of Galloway et al. (1997) and more recently in that of Gonzalez (2005).

11 The shares of five sample banks are not actively traded on the stock market. This means that, in the regression model in which TOTRISK is employed as the dependent variable, 12 out of the 17 banks are utilized in total.

$$\sigma_{iq} = \sqrt{\frac{\sum_{w=1}^{W} (R_{iw} - \overline{R}_{iq})^2}{W-1}}$$

where σ_{iq} is the quarterly *(q=2002q1, 2002q2,…, 2009q3)* standard deviation of bank i's weekly returns and $\overline{R}_{iq}$ is the quarterly average of bank i's weekly returns.

2.2.2 Regressors

2.2.2.1 Leverage measures

We measure on-balance-sheet leverage with three different metrics. In particular, we use the so-called gross balance sheet leverage ratio that is calculated as the ratio of total assets to total book equity capital (*LEV1*), as well as the debt-to-equity ratio that is expressed either as the ratio of total borrowed funds to total assets (*LEV2*), or, in a broader way, as the ratio of total liabilities to total assets (*LEV3*). To measure embedded leverage (*EMBEDLEV*), we follow Beuer (2002) and utilize the on-balance-sheet asset equivalent component of the exposure implied by off-balance-sheet items. This is calculated as the ratio of total notional values of all derivatives outstanding to total regulatory capital comprised by Tier 1 and Tier 2 capital. The numerator stands for the own funds (*i.e.*, equity capital) and borrowed funds (*i.e.*, debt) equivalent bank derivative positions in a replicating portfolio of assets. Put simply, off-balance-sheet derivative positions are mapped onto their on-balance-sheet equivalents. As an alternative, in the regressions that follow later in the paper, we also use a measure of off-balance-sheet leverage (*OBSLEV*) given by the nominal value of off-balance-sheet liabilities scaled by total assets. Finally, short-term leverage (*SHORTLEV*) is measured as the ratio of short-term assets to total assets.

2.2.2.2 Control variables

The combination of the recent financial stability literature (see, e.g., Berger et al., 2009; Uhde and Heimeshoff, 2009) and the bank risk literature (see, e.g., Gonzalez, 2005) provides us with the basis for the selection of the bank-specific and macroeconomic control variables that are expected to have an effect on risk.

Since it is well-established in the banking literature that risky portfolios increase total bank risk exposure undermining the stability of the financial system, we employ banks' provisions for loan and lease losses divided by total loans (*CREDRISK1*) to control for credit risk and loan-portfolio quality. We also use the ratio of non-accrual loans and lease finance receivables to total loans (*CREDRISK2*) as an alternative measure of credit risk. The quarterly standard deviation of the day-to-day 3-month T-bill rate is used to capture interest rate risk (*INTRISK*). This variable is expected to reveal the interest rate cycle movements that influence the deposit-taking and lending activities of banks. Further, the ratio of the book value of fixed assets to total assets is incorporated in our regression model to proxy for the ex-ante operating leverage (*OPERLEV*). Indeed, the impact of operating leverage on risk has been found to be analogous to that of the financial leverage, i.e., to play the role of a multiplier to both gains and losses. Moreover, two proxies for possible alterations in the traditional borrowing and lending bank activities are also included in our model as additional control variables. We use banks' asset composition measured as the ratio of net loans to total assets (*ASSETCOMP*) to account for changes in bank lending activity. To capture changes in the traditional funding sources of banks, we employ a proxy measure for the composition of bank liabilities, which is the ratio of demand deposits to total liabilities (*LIABCOMP*).

Economic performance is widely thought to affect the demand and supply of banking services. More precisely, high levels of banking activity are generally related to favorable economic conditions. In this context, the macroeconomic environment is largely considered to have an impact on the stability of the financial sector. We thus employ the natural log value of GDP (*LGDP*) to control for variations in economic growth.

2.2.3 The model

In order to evaluate the relationship between leverage and risk, we estimate the following panel data model:

$$Y_{iq} = \alpha_{iq} + \sum \beta_k lev_{iq,k} + \sum \gamma_m x_{iq,m} + \varepsilon_{iq} \quad ,$$

i = 1, 2…, N=17; q=2002q1, 2002q2,…, Q=2009q3

k=6 (the total number of leverage variable measures)

m=7 (the total number of control variables)

where Y_{iq} stands for the risk variables;[12] the vector $lev_{iq,k}$ includes all different measures of leverage described above; $x_{iq,m}$ represents the vector of the bank-specific and macroeconomic control variables; ε_{iq} is the regression error term, whereas the vectors α, β, γ contain the parameters of interest to be estimated. As mentioned earlier, the model is run using OLS for the two periods examined. Possible endogeneity bias is resolved by the use of fixed effects and instrumental variables.

3 DISCUSSION OF THE RESULTS

The regression results are presented in Tables 1 to 8. More precisely, Tables 1-4 report the results for the time period that precedes the emergence of the current crisis, whereas Tables 5-8 contain the empirical results for the crisis period.

3.1 Pre-crisis period

The results in Tables 1 and 2 refer to the regressions where the *Z*-index is employed as the dependent variable. A negative and statistically significant relationship between *SHORTLEV* and Z-index is documented, which implies that short-term leverage increases systemic risk potential. However, the coefficients on the rest of the leverage variables are not statistically significant revealing that on-balance-sheet leverage as well as *EMBEDLEV* (Table 1) and *OBSLEV* (Table 2) do not significantly affect systemic risk. Moreover, market turmoil as reflected in the increased level of interest rate risk (*INTRISK*) increases systemic risk. As regards the log of *GDP*, it is positively linked to Z-index. In fact, a number of theoretical and empirical studies have reached the same conclusion (see, e.g., Uhde and Heimeshoff, 2009; Berger et al., 2009).[13] It is noteworthy that the use of *LEV2* or *LEV3* in the place of *LEV1* as well as *CREDRISK2* instead of *CREDRISK1* further reinforces the above findings.

When *TOTRISK* is used as the regressand of the model (see Tables 3 and 4), a positive and statistically significant effect of *LEV1* on total bank risk is reported. Notably, this relationship remains positive and significant even if (any of) the alternative leverage measures (*i.e. LEV2*, *LEV3*) are utilized. Along the same lines, *OBSLEV* is found to have a significantly positive effect on total bank risk-taking. Overall, these results show that banks which are highly levered (either on- or off-balance sheet) exert higher risk. Neither *EMBEDLEV*, nor *SHORTLEV* are found to significantly affect *TOTRISK*. In spite of these non-significant effects, the positive link between leverage and individual bank risk-taking is dominant. Moreover, total bank risk increases with the low quality of loans and leases offered as is evident from the significantly

12 When the dependent variable is the Z-index, the subscript i is omitted since Z is calculated on a mean average basis.

13 We also use the quarterly change in the US inflation rate taken by the US Bureau of Labor Statistics to verify that favorable macroeconomic conditions mitigate SYSTRISK.

negative relationship between *CREDRISK1* and *TOTRISK*.[14] This suggests that large commercial banks need to focus more on credit risk management, which has proved to be problematic the years before the crisis. Indeed, considerable banking problems have arisen from the failure of banks to recognize impaired assets and create reserves for writing off these assets.

Economic performance, as measured by *LGDP*, is found to reduce total bank risk as was the case when *SYSTEMRISK* was used as the dependent variable of the model. More interestingly, *ASSETCOMP* exerts a significantly negative effect on *TOTRISK*. This means that those banks that concentrate on traditional banking activities are in a better position in terms of their overall risk exposure than those that are involved with new financial instruments. In general, the relationship between bank product diversification and risk could be negative, but also positive. There are two channels through which output diversification leads to a reduction in overall bank risk-taking. The first is related to the conventional wisdom among bank scholars and practitioners and shows that non-interest (fee) income is less sensitive to changes in the economic and business environment than interest income. This is to say that banks that rely more on the former type of income are exposed to less risk as they manage to reduce the cyclical variations in profits and revenue. Turning to the second channel, in case there is a negative or a weak correlation between the two sorts of income, then -according to the traditional banking and portfolio theories (see, e.g., Diamond, 1984)- any observed increase in the share of fee-generating activities in the overall portfolio of banking items reduces the volatility of total earnings via diversification effects.

Each coin has two sides. DeYoung and Roland (2001) argue that non-interest income is less stable compared to its interest counterpart, implying that non-traditional activities increase bank riskiness. This is due to the following three reasons: the nature of bank-customer relationships, input mixes, and lower capital requirements for the fee-generating activities. To start with the first one, traditional activities like lending generate relatively stable relationships between banks and their customers as switching and information costs for both lenders and borrowers are high and hence it is not in the interest of either side to walk away. In contrast, these costs are lower in the case of modern financial activities and this renders the demand for the latter lines of business far from solid and continuous. Accordingly, whereas interest income appears to be rather stable, non-interest income is likely to fluctuate more over time. Second, a bank can extend a lending relationship only with a burden on its variable cost (*i.e.*, interest expense). However, if the bank takes the decision to increase the volume of non-traditional services offered to its customers, it will have to hire additional fixed labor inputs, which leads to an increase in its operating leverage. A higher operating leverage, in turn, amplifies revenue volatility into higher profit volatility. Again, the involvement in non-traditional activities is related to a higher degree of risk. Finally, the existing banking regulations allow banks to hold just a small amount of capital against fee-based activities in comparison with the amount that they are forced to hold for traditional items. The differences in capital requirements suggest an enhanced financial leverage, which is related with higher earnings volatility for non-traditional activities, which is perfectly in line with the current empirical findings.

3.2 Crisis period

Let us now turn to the analysis of the regression results for the crisis period. Interestingly, none of the leverage variables has a significant effect on Z-index (see Tables 5 and 6). This resembles the rather weak link between bank leverage and systemic risk potential that was reported in the pre-crisis period (see above). A significantly negative relation between credit risk (both *CREDRISK1* and *CREDRISK2*) and Z-index is found, which indicates that credit risk increases systemic risk. Since no similar result is reported before the onset of the crisis, we interpret the present result as suggesting that the low-quality loans and leases offered by large US commercial banks before the current crisis put immense pressure on the soundness of the financial system. Consequently, a serious threat to systemic stability is formed by the large number

14 An overall negative relationship is confirmed by the use of CREDRISK2.

of bad loans that big banks still hold in their portfolios. Regarding *INTRISK*, it also has a negative sign indicating that the systemic risk potential is higher when the variability of short-term bond rates increases. A traditional banking focus on the liabilities side of banks' balance sheets reduces the likelihood of systemic risk since *LIABCOMP* is positively linked with Z-index, whereas economic growth is again found to boost the resilience of the financial system.

In case *TOTRISK* is employed as the dependent variable in our analysis (see Tables 7 and 8), we find that on-balance-sheet leverage (represented by *LEV3*) is positively and significantly related to total bank risk. This is verified when we replace *LEV3* with *LEV2* (but not when *LEV1* is used instead). In the same context, *SHORTLEV* and *OBSLEV* are found to increase total bank risk, whereas the coefficient of *EMBEDLEV* is not statistically significant. In sum, the negative influence of the degree of leverage on total bank risk that was documented before the crisis is corroborated in the crisis period. Furthermore, operating leverage has a negative effect on *TOTRISK*; this result provides strong support to the analysis previously made. Paradoxically, macroeconomic conditions do not seem to have a statistically significant effect on *TOTRISK*.

4 CONCLUDING REMARKS AND POLICY IMPLICATIONS

We studied how leverage affects risk in the US commercial banking sector. Employing a representative panel data set of large banks that covers both the pre-crisis and crisis periods we model the relationship between (systemic) risk and various forms of on- and off-balance-sheet leverage as well as short-term leverage.

Our formal evidence indicates reliably that leverage contributes to systemic risk potential and to banks' overall risk. Thus, we corroborate the many claims to this end that appeared in the popular press. Indeed, we lend support to the view that systemically important banks do not maintain a level of leverage that could allow equity capital to act as a buffer, absorbing losses and enabling the business to continue in case of a financial turmoil. Instead, banks accumulate leverage, both on- and off- balance-sheet, forcing the system to either fail or consider large-scale bailouts. From the investors' viewpoint, even the most sophisticated ones may tend to underestimate the overall level of an institution's leverage and hence to undervalue risk, as they are not capable of properly pricing the off-balance-sheet leverage. Moreover, the positive relationship that we document between short-term leverage and risk shows that leverage is one of the main factors responsible for the severe bank liquidity shortages in the crisis era. By largely relying on new financial products before the crisis, banks managed to extend the short-term funding of their medium- and long-term assets. This increased the maturity mismatch raising the probability of bank runs and rendering the financial system more fragile. In sum, the direct link between leverage and (systemic) risk provides the necessary condition to the current discussions on further leverage regulation through the imposition of stricter leverage ratios.

We also find quite clearly that those banks that concentrate on traditional banking activities typically carry less risk exposure than those that are involved with new financial instruments.[15] On the asset side of banks' balance sheets, the replacement of traditional loans with tranches of Asset Backed Securities (ABS), Collateralized Debt Obligations (CDO) and other associated derivatives increases both measures of risk used in our analysis regardless of the specific period examined. Although such tranches were often AAA-rated and thus apparently of low risk, the newer assets originated by banks were down-the-quality-curve.[16] Turning to the liability side of the balance sheets, the traditional business of taking deposits from households, which has been relatively declined compared to non-interest income business, is found to lower systemic risk potential. All things considered, these findings could play a role in the current discussion about a possible revival of the Glass-Steagall Act.

15 The banking literature provides ample empirical evidence on the upsurge in the volume of modern activities of US banking institutions before the crisis (see, e.g., Rogers and Sinkey, 1999; Stiroh, 2004).

16 The latter side of things was often not taken into serious consideration by the rating agencies before the crisis.

References

Adrian, T., Shin, H.S., 2010. *Liquidity and leverage*. Journal of Financial Intermediation, forthcoming.

Berger, A.N., Klapper, L.F., and Turk-Ariss, R., 2009. *Bank competition and financial stability*. Journal of Financial Services Research 35, 99-118.

Berger, A.N., Bouwman, C.H.S., 2009. *Bank liquidity creation*. Review of Financial Studies 22, 3779-3837.

Beuer, P., 2002. *Measuring off-balance-sheet leverage*. Journal of Banking and Finance 26, 223-242.

De Nicolo, G., Bartholomew, P., Zaman, J., Zephirin, M., 2004. *Bank consolidation, internationalization, and conglomeration: trends and implications for financial risk*. Financial Markets, Institutions & Instruments 13, 173-217.

DeYoung, R., Roland, K.P., 2001. *Product mix and earnings volatility at commercial banks: evidence from a degree of total leverage model*. Journal of Financial Intermediation 10, 54-84.

Diamond, D., 1984. *Financial intermediation and delegated monitoring*. Review of Economic Studies 51, 393-414.

Galloway, T.M., Winson, B.L., Roden, D.M., 1997. *Banks' changing incentives and opportunities for risk taking*. Journal of Banking and Finance 21, 509-527.

Gonzalez, F., 2005. *Bank regulation and risk-taking incentives: An international comparison of bank risk*. Journal of Banking and Finance 29, 1153-1184.

Huang, X., Zhou, H., Zhu, H., 2009. *A framework for assessing the systemic risk of major financial institutions*. Journal of Banking and Finance 33, 2036-2049.

Jensen, M., 1986. *Agency costs of free cash flow, corporate finance and takeovers*. American Economic Review 76, 323-329.

Jensen, M.C., Meckling, W.H., 1976. *Theory of the firm: Managerial behavior, agency costs and ownership structure*. Journal of Financial Economics 3, 305-360.

Rime, B., Stiroh, K. J., 2003. *The performance of universal banks: evidence from Switzerland*. Journal of Banking and Finance 27, 2121-2150.

Rogers, K., Sinkey, J.F.Jr., 1999. *An analysis of nontraditional activities at U.S. commercial banks*. Review of Financial Economics 8, 25-39.

Stiroh, K., 2004. *Diversification in banking: Is non-interest income the answer?* Journal of Money, Credit and Banking 36, 853-882.

Titman, S., Trueman, B., 1986. *Information quality and the valuation of new issues*. Journal of Accounting and Economics 8, 159-172.

Uhde, A., Heimeshoff, U., 2009. *Consolidation in banking and financial stability in Europe: Empirical Evidence*. Journal of Banking and Finance 33, 1299-1311.

Appendix I: Sample of banks

1. BANK OF AMERICA NA	7. HSBC BANK USA	13. NATIONAL CITY BANK (OH)
2. JP MORGAN CHASE BANK	8. STATE STREET BANK&TRUST CO	14. LASALLE BANK NATIONAL ASSN
3. CITIBANK NATIONAL ASSN	9. KEYBANK NATIONAL ASSN	15. MELLON BANK NATIONAL ASSN
4. US BANK NA	10. SUNTRUST BANK	16. FIRST TENNESSEE BANK NAT ASSN
5. WELLS FARGO BANK NA	11. PNC BANK NATIONAL ASSN	17. NORTHERN TRUST & CO
6. BANK OF NEW YORK	12. WACHOVIA BANK NATIONAL ASSN	

Appendix II: Variables

Variable	Abbreviation	Definition	Data source
Systemic Risk Potential	SYSTRISK	The sum of returns on assets and book equity ratio divided by the standard deviation of returns of assets	FDIC Reports on Condition and Income
Total bank risk	TOTRISK	The quarterly standard deviation of each sample bank's weekly stock market returns	Thomson Datastream
On-balance-sheet leverage	LEV1	The ratio of total assets to book value of total equity	FDIC Reports on Condition and Income
	LEV2	The ratio of borrowed funds to total assets	
	LEV3	The ratio of total liabilities to total assets	
Embedded leverage	EMBEDLEV	The ratio of notional amounts of all derivatives outstanding to Tier 1 & 2 regulatory capital	OCC Quarterly Report on Bank Derivatives Activities
Off-balance-sheet leverage	OBSLEV	The ratio of the nominal value of off-balance-sheet liabilities to total assets	FDIC Reports on Condition and Income
Short-term leverage	SHORTLEV	The ratio of short-term assets to total assets	FDIC Reports on Condition and Income
Credit risk	CREDRISK1	Allowance for loan and lease losses scaled by total loans	FDIC Reports on Condition and Income
	CREDRISK2	The ratio of non-accrual loan and lease finance receivables to total loans	
Interest rate risk	INTRISK	The quarterly standard deviation of the day-to-day 3-month T-bill rate	Federal Reserve Board
Operating leverage	OPERLEV	The ratio of fixed assets to total assets	FDIC Reports on Condition and Income
Asset composition	ASSETCOMP	The ratio of net loans and leases to total assets	FDIC Reports on Condition and Income
Liability Composition	LIABCOMP	The ratio of demand deposits to total liabilities	FDIC Reports on Condition and Income
Macroeconomic conditions	LGDP	The natural logarithm of GDP	Bureau of Economic Analysis, US Department of Labor

Appendix III: Summary statistics

Variable	Mean	Median	Max	Min	Std. Dev.	No of obs
Panel A						
Z-index	6001.91	5009.53	15378.32	2181.80	3372.73	373
TOTRISK	1.48	1.33	4.24	0.30	0.78	263
LEV1	12.53	12.57	17.58	8.41	1.98	372
LEV2	0.08	0.07	0.32	0.00	0.06	372
LEV3	0.89	0.89	0.94	0.83	0.02	372
EMBEDLEV	187.31	36.95	29193.20	1.56	1527.78	367
OBSLEV	0.12	0.00	4.27	0.00	0.50	284
SHORTLEV	3.25	2.62	11.06	0.93	2.10	236
CREDRISK1	0.01	0.01	0.03	0.00	0.00	372
CREDRISK2	0.01	0.01	0.02	0.00	0.00	351
INTRISK	0.09	0.09	0.19	0.02	0.05	372
OPERLEV	0.01	0.01	0.02	0.00	0.00	372
ASSETCOMP	0.53	0.57	0.85	0.05	0.20	372
LIABCOMP	0.07	0.07	0.21	0.00	0.04	372
LGDP	10.09	10.09	10.12	10.06	0.02	372

Variable	Mean	Median	Max	Min	Std. Dev.	No of obs
Panel B						
Z-index	2602.48	1896.08	5239.75	1234.25	1414.03	153
TOTRISK	3.30	2.89	10.06	0.37	1.84	108
LEV1	11.31	11.23	23.97	3.30	3.12	149
LEV2	0.10	0.09	0.31	0.00	0.06	144
LEV3	0.87	0.88	0.95	0.69	0.04	149
EMBEDLEV	124.19	38.38	846.99	3.75	181.08	138
OBSLEV	0.04	0.04	3.25	0.00	0.29	127
SHORTLEV	3.23	2.42	12.49	0.18	2.46	149
CREDRISK1	0.02	0.02	0.05	0.00	0.01	149
CREDRISK2	0.02	0.02	0.06	0.00	0.01	141
INTRISK	0.31	0.33	0.69	0.03	0.22	153
OPERLEV	0.01	0.01	0.03	0.00	0.00	149
ASSETCOMP	0.52	0.55	0.82	0.05	0.21	149
LIABCOMP	0.06	0.06	0.24	0.00	0.04	149
LGDP	10.12	10.12	10.13	10.11	0.00	153

This Appendix reports the summary statistics for all regression variables used in the present paper. Panel A relies on data from 2002q1 to 2007q2. In Panel B we use data over the period 2007q3-2009q3.

Table 1 :

Regression results for the pre-crisis period (2002q1-2007q2).

Variable	Coefficient	t-statistic
constant	-573252.60 ***	-5.25
LEV1	31.82	0.32
EMBEDLEV	-0.11	-1.00
SHORTLEV	-164.89 **	-1.91
CREDRISK1	-7340.21	-0.19
INTRISK	-10570.64 ***	-3.26
ASSETCOMP	-418.75	-0.44
LIABCOMP	-1836.34	-0.37
LGDP	57542.21 ***	5.35

****, **, * correspond to 1%, 5%, and 10% level of significance respectively for a two-tailed distribution.*

The dependent variable is the systemic risk potential (Z-index). As independent variables we include on-balance-sheet leverage (*LEV1*), embedded bank leverage (*EMBEDLEV*), short-term leverage (*SHORTLEV*), allowance for loan and lease losses scaled by total loans (*CREDRISK1*), interest rate risk (*INTRISK*), banks' asset composition (*ASSETCOMP*), banks' liabilities composition (*LIABCOMP*), and the level of economic development (*LGDP*). The number of total (unbalanced) observations is 372.

Table 2 :

Regression results for the pre-crisis period (2002q1-2007q2).

Variable	Coefficient	t-statistic
constant	-560924.20 ***	-4.85
LEV1	20.59	0.20
OBSLEV	131.42	0.29
SHORTLEV	-160.33 *	-1.84
CREDRISK1	-8022.71	-0.21
INTRISK	-10381.86 ***	-3.20
ASSETCOMP	-358.57	-0.35
LIABCOMP	-2724.64	-0.51
LGDP	56332.48 ***	4.99

****, **, * correspond to 1%, 5%, and 10% level of significance respectively for a two-tailed distribution.*

The dependent variable is the systemic risk potential (Z-index). As independent variables we include on-balance-sheet leverage (LEV1), off-balance-sheet leverage (OBSLEV), short-term leverage (SHORTLEV), allowance for loan and lease losses scaled by total loans (CREDRISK1), interest rate risk (INTRISK), banks' asset composition (ASSETCOMP), banks' liabilities composition (LIABCOMP), and the level of economic development (LGDP). The number of total (unbalanced) observations is 372.

Table 3 :

Regression results for the pre-crisis period (2002q1-2007q2).

Variabel	Coefficient	t-statistic
constant	120.49 ***	3.83
LEV1	0.07 ***	2.76
EMBEDLEV	0.00	-0.96
SHORTLEV	-0.02	-0.78
CREDRISK1	20.24 *	1.86
INTRISK	0.36	0.42
ASSETCOMP	-0.86 ***	-3.04
LIABCOMP	1.50	0.95
LGDP	-11.82 ***	-3.80

****, **, * correspond to 1%, 5%, and 10% level of significance respectively for a two-tailed distribution.*

The dependent variable is total bank risk (*TOTRISK*). As independent variables we include on-balance-sheet leverage (*LEV1*), embedded bank leverage (*EMBEDLEV*), short-term leverage (*SHORTLEV*), allowance for loan and lease losses scaled by total loans (*CREDRISK1*), interest rate risk (*INTRISK*), banks' asset composition (*ASSETCOMP*), banks' liabilities composition (*LIABCOMP*), and the level of economic development (*LGDP*). The number of total (unbalanced) observations is 263.

Table 4 :

Regression results for the pre-crisis period (2002q1-2007q2).

Variable	Coefficient	t-statistic
constant	158.25 ***	5.37
LEV2	1.52 *	1.79
OBSLEV	3.57 *	1.84
SHORTLEV	-0.00	-0.09
CREDRISK1	21.07 **	2.01
INTRISK	0.37	0.43
ASSETCOMP	-1.04 ***	-3.49
LIABCOMP	0.32	0.22
LGDP	-15.47 ***	-5.30

****, **, * correspond to 1%, 5%, and 10% level of significance respectively for a two-tailed distribution.*

The dependent variable is total bank risk (*TOTRISK*). As independent variables we include on-balance-sheet leverage (*LEV2*), off-balance-sheet leverage (*OBSLEV*), short-term leverage (*SHORTLEV*), allowance for loan and lease losses scaled by total loans (*CREDRISK1*), interest rate risk (*INTRISK*), banks' asset composition (*ASSETCOMP*), banks' liabilities composition (LIABCOMP), and the level of economic development (*LGDP*). The number of total (unbalanced) observations is 263.

Table 5 :
Regression results for the crisis period (2007q3-2009q3).

Variable	Coefficient	t-statistic
constant	2036713.00 ***	8.28
LEV1	-54.12	-1.10
EMBEDLEV	0.24	0.39
SHORTLEV	14.05	0.21
CREDRISK1	-23800.45 *	-1.92
INTRISK	-7551.71 ***	-10.57
OPERLEV	-28441.01	-1.27
ASSETCOMP	245.20	0.38
LIABCOMP	4819.29 *	1.82
LGDP	201085.50 ***	8.27

****, **, * correspond to 1%, 5%, and 10% level of significance respectively for a two-tailed distribution.*

The dependent variable is the systemic risk potential (Z-index). As independent variables we include on-balance-sheet leverage (*LEV1*), embedded bank leverage (*EMBEDLEV*), short-term leverage (*SHORTLEV*), allowance for loan and lease losses scaled by total loans (*CREDRISK1*), interest rate risk (*INTRISK*), banks' asset composition (*ASSETCOMP*), banks' liabilities composition (*LIABCOMP*), and the level of economic development (*LGDP*). The number of total (unbalanced) observations is 149.

Table 6 :
Regression results for the crisis period (2007q3-2009q3).

	Coefficient	t-statistic
constant	2035953.00 ***	8.31
LEV1	-45.35	-0.94
OBSLEV	268.84	0.79
SHORTLEV	9.79	0.16
CREDRISK1	-23337.17 **	-1.98
INTRISK	-7515.75 ***	-10.52
OPERLEV	-29766.93	-1.33
ASSETCOMP	258.15	0.44
LIABCOMP	5092.77 **	1.98
LGDP	201014.80 ***	8.30

****, **, * correspond to 1%, 5%, and 10% level of significance respectively for a two-tailed distribution.*

The dependent variable is the systemic risk potential (Z-index). As independent variables we include on-balance-sheet leverage (*LEV1*), embedded bank leverage (*EMBEDLEV*), short-term leverage (*SHORTLEV*), allowance for loan and lease losses scaled by total loans (*CREDRISK1*), interest rate risk (*INTRISK*), banks' asset composition (*ASSETCOMP*), banks' liabilities composition (*LIABCOMP*), and the level of economic development (*LGDP*). The number of total (unbalanced) observations is 149.

Table 7 :
Regression results for the crisis period (2007q3-2009q3).

Variable	Coefficient	t-statistic
constant	-490.13	-0.95
LEV3	57.64 ***	2.51
EMBEDLEV	-0.00	-0.92
SHORTLEV	0.20 *	1.73
CREDRISK2	5.17	0.23
INTRISK	-1.30	-0.88
OPERLEV	-330.26 ***	-2.70
ASSETCOMP	-0.12	-0.08
LIABCOMP	-1.17	-0.23
LGDP	43.58	0.86

****, **, * correspond to 1%, 5%, and 10% level of significance respectively for a two-tailed distribution.*

The dependent variable is total bank risk (*TOTRISK*). As independent variables we include on-balance-sheet leverage (*LEV3*), embedded bank leverage (*EMBEDLEV*), short-term leverage (*SHORTLEV*), the ratio of non-accrual loan and lease finance receivables to total loans (*CREDRISK2*), interest rate risk (*INTRISK*), banks' asset composition (*ASSETCOMP*), banks' liabilities composition (*LIABCOMP*), and the level of economic development (*LGDP*). The number of total (unbalanced) observations is 108.

Table 8 :
Regression results for the crisis period (2007q3-2009q3).

Variable	Coefficient	t-statistic
constant	-459.98	-0.92
LEV3	69.11 **	2.92
OBSLEV	16.76 *	1.92
SHORTLEV	-0.10	-0.90
CREDRISK2	9.20	0.43
INTRISK	-1.46	-1.00
OPERLEV	-420.05 ***	-3.42
ASSETCOMP	2.64	1.36
LIABCOMP	0.86	0.17
LGDP	39.31	0.79

****, **, * correspond to 1%, 5%, and 10% level of significance respectively for a two-tailed distribution.*

The dependent variable is total bank risk (*TOTRISK*). As independent variables we include on-balance-sheet leverage (*LEV3*), off-balance-sheet leverage (*OBSLEV*), short-term leverage (*SHORTLEV*), the ratio of non-accrual loan and lease finance receivables to total loans (*CREDRISK2*), interest rate risk (*INTRISK*), banks' asset composition (*ASSETCOMP*), banks' liabilities composition (*LIABCOMP*), and the level of economic development (*LGDP*). The number of total (unbalanced) observations is 108.

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

By
Abdelaziz Rouabah*
John Theal*

1 INTRODUCTION

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

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

2 STRESS TESTING MODEL

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

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

* BCL – Financial Stability Department

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

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

3 MODEL ESTIMATION

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

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

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

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

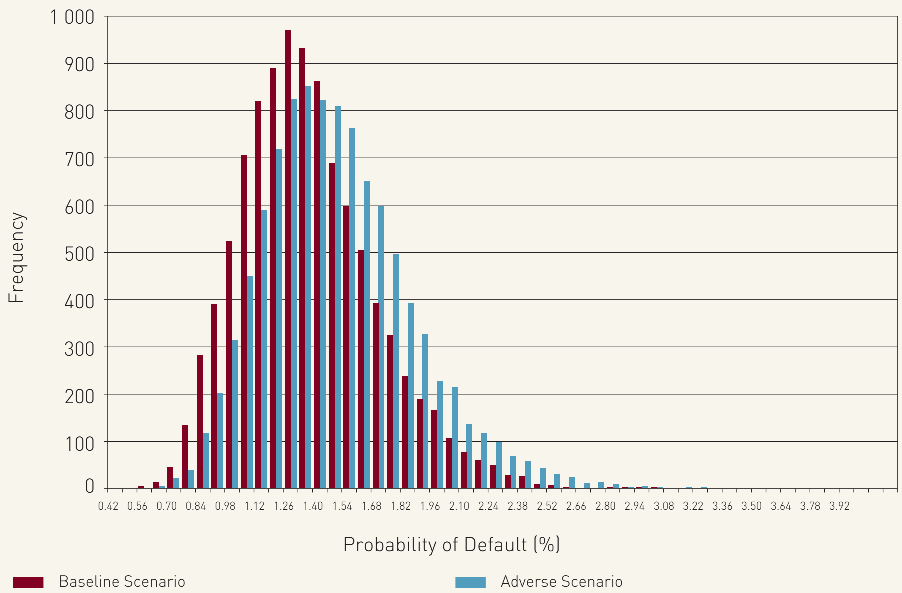
4 MONTE CARLO SIMULATIONS

The estimated model can be used to gauge how the probability of default responds to exogenous shocks in the macroeconomic environment. To evaluate the response of the system, a Monte Carlo simulation was used to generate both a baseline and an adverse scenario. The baseline scenario is constructed by first drawing a random sample from a standard normal distribution. In order to impose the model-specific correlation pattern on the simulation, this random vector of normal variates is pre-multiplied by the Cholesky decomposition of the residual variance covariance matrix estimated from the SUR system. This procedure produces a vector of correlated disturbances which are added to the equations. Through recursion it is possible to generate simulated forward values of both the probability of default and the macroeconomic variables over some finite horizon period. The end result of this process is that a distribution of the unconditional probabilities of default can be constructed thereby providing the baseline scenario.

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

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

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



Source: BCL, authors' calculations

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

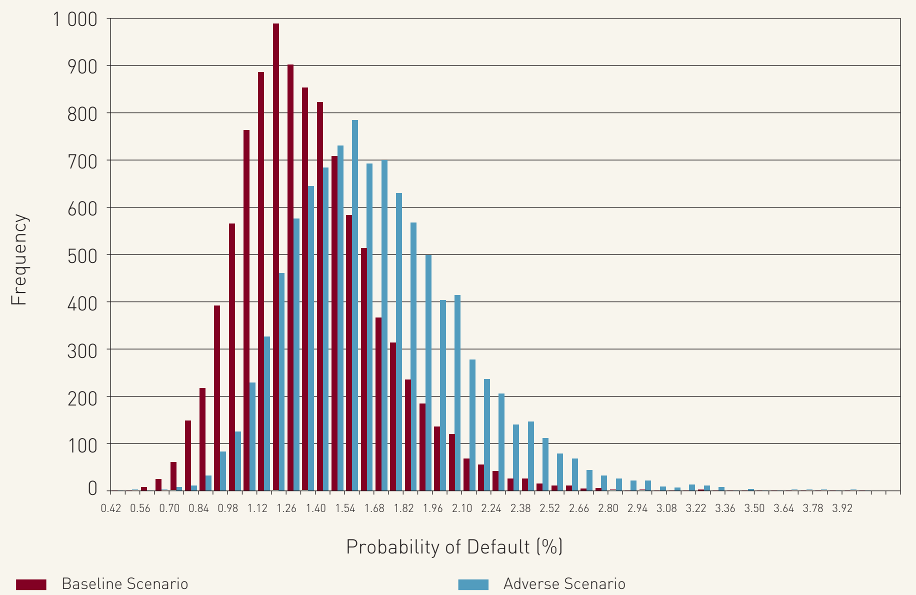
1. A decrease in Luxembourg's real GDP growth of magnitude 4% starting in 2010q1 and ending in 2010q4.
2. A decrease in Euro area real GDP growth of magnitude 1% for the first two quarters of 2010, magnitude of 0.5% in q3 and no shocks in the subsequent quarters.
3. An increase in real interest rates of 200 basis points in the first quarter of 2010 and a further increase of 100 basis points in 2010q3. There are no shocks in q2 or q4.
4. A reduction in real property prices of magnitude 2% in 2010q1 and subsequent losses of 2% over the remaining quarters of 2010.

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

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

Figure 2

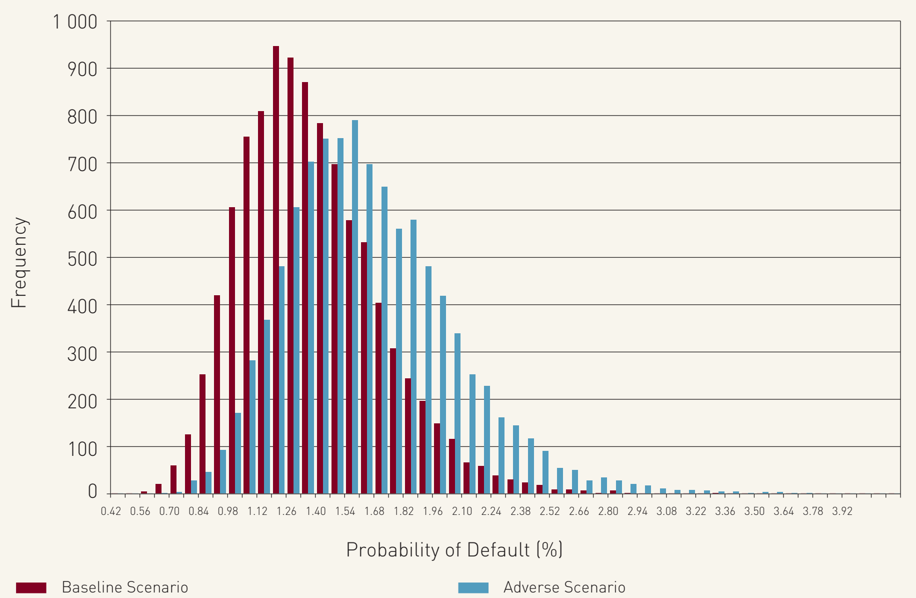
Baseline and adverse scenarios under shocks to Euro area real GDP growth



Source: BCL, authors' calculations

Figure 3

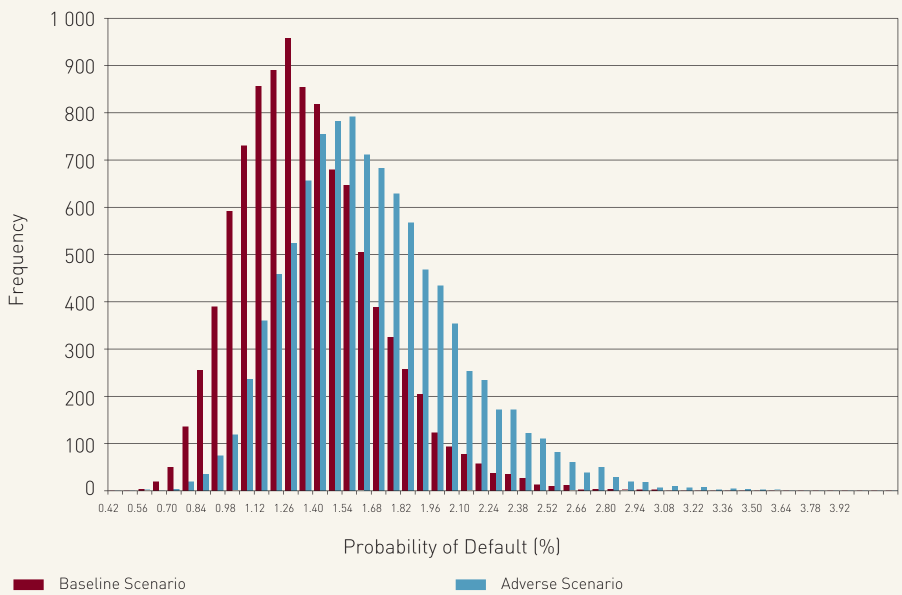
Baseline and adverse scenarios under sctocks to the real interest rate



Source: BCL, authors' calculations

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

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



Source: BCL, authors' calculations

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

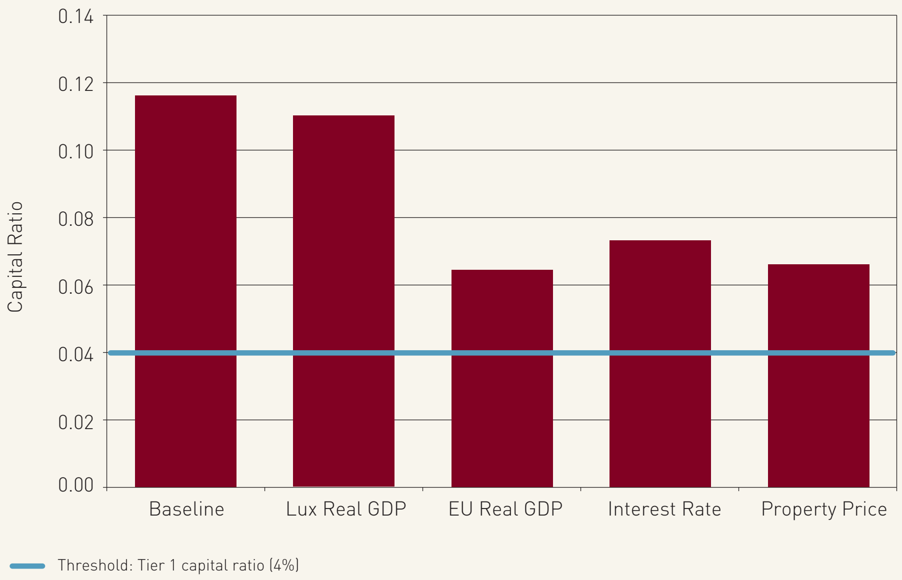
$$k_c^* = \left(LGD \times N\left[\frac{G(PD)}{\sqrt{(1-R_c)}} + \left(\frac{R_c}{(1-R_c)} \right)^{\frac{1}{2}} \times G(0.999) \right] - PD \times LGD \right) \times \left(\frac{1}{1-1.5b} \right) \quad (2)$$

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

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

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

Figure 5
Banking sector capital ratios under the adverse scenario



Source: BCL, authors' calculations

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

5 CONCLUSION

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

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

4 MARKET AND FUNDING SYSTEMIC LIQUIDITY STRESS TESTING OF THE LUXEMBOURG BANKING SECTOR

By
Francisco Nadal De Simone*
Franco Stragiotti†

1 MOTIVATION

The peculiarities of the current crisis have motivated a wide-spread rethinking of modern financial, monetary and supervisory frameworks. From accounting rules to the operation of rating agencies; from the role of central banks and their objectives to the basic paradigm of prudential supervision; academic research, working groups, and high level meetings have started to set the pillars of new institutions and market practices to minimize the risk of future similar crises.

One major policy message from the crisis is the need to develop the macroprudential element of financial stability policy. It is now generally accepted that microprudential regulation and supervision of individual institutions and markets, while necessary, is not sufficient, because it does not consider the interactions among financial institutions and between the financial system and the real sector of the economy. For macroprudential policy to minimize the risk that financial instability would result in broader costs to the economy, it needs to develop quantitative macroprudential operating targets to measure and monitor the main determinants of systemic risk, both in its time series dimension (e.g., countercyclical capital charges) and in its cross-section dimension (e.g., interbank lending concentration limits) (Borio and Drehmann, 2009). As a result, a number of macroprudential instruments are already in use or under consideration.

Macro stress tests belong to the set of operating instruments that have been used by central banks and supervisors to trace the response of the financial system to severe, but plausible shocks. While forward-looking in their nature, they have suffered from the failure to capture in a robust way the feedback effects between the financial system and the macroeconomy, and to capture a key aspect of financial distress, namely, the nonlinearities responsible for the large systemic effects of small shocks (Drehmann, 2009). In a cross-section dimension, stress tests have incorporated the interactions between institutions, markets and infrastructure to study how these contribute to the vulnerabilities of the financial system. However, it was not until well into 2007 that it became clear that a top priority for financial stability is to strengthen the understanding of the role of interconnectedness among financial institutions, of common exposures to risks, of the endogeneity of agents' responses, of the conditionality of parameters on stress events, and other significant systemic features.

One peculiarity of the current financial crisis has been the seizing up of the interbank market. This dramatically revealed the endogeneity of liquidity in a fiat-currency economy and the ensuing need to take into account liquidity risk in stress testing exercises of the banking system. Rapid changes to endogenous liquidity can quickly reverberate through the financial system and exhaust banks' liquidity buffers via asset price changes, drying up of liquidity lines, and paralysis of the interbank market as a result of large increases in counterparty risk and uncertainty. Liquidity stress testing has become an essential part of IMF Financial Sector Assessment Programs since 2001: tests have assumed shocks to deposits, to wholesale funding, and also used cross-border scenarios (Moretti et al, 2008). However, stress-testing models used by monetary authorities and supervisors have not often made clear the systemic implications of liquidity shocks and the intrinsic relation between counterparty credit risk, funding and market liquidity (IMF, 2008).[1]

* BCL – Financial Stability Department
† BCL – Prudential Surveillance Department

1 According to the Basel Committee on Banking Supervision (BCBS) (2008), market liquidity risk is "the risk that a firm cannot easily offset or eliminate a position at the market price because of inadequate market depth or market disruption". According to the BCBS, funding liquidity risk is the risk that a bank will be impaired in its "ability to fund increases in assets and meet obligations as they come due" and "at a reasonable cost". Similar definitions are in Brunnermeier and Pedersen (2009).

Further weaknesses of current stress testing practices can be highlighted. First, in most available stress testing exercises and contingency funding plans, banks do not consider the feedback effect of their behaviour on the price of assets or on their reputation when they take action to recover their desirable liquidity buffers. During the current crisis, some banks did experience difficulties in selling assets or pledging assets in secured lending (ECB, 2008). Second, given the existence of (risk unrelated) deposit insurance and the history of central bank intervention to provide sufficient liquidity during crises, moral hazard considerations suggest that banks hold suboptimal levels of liquidity. Overall, liquidity risk is underpriced and the crisis has made clear that it was excessive. Finally, additional enhancements include incorporating off-balance sheet risks in liquidity stress testing, covering cross-border transmission channels, modelling the behavioural responses of agents, and adding non-bank financial institutions. Looking forward, enhanced frameworks for systemic liquidity stress testing will be a crucial instrument in fulfilling the macroprudential tasks of international bodies such as the ESRB.

In Luxembourg, the Law of 24 October, 2008, made the Banque centrale du Luxembourg (BCL) responsible for the surveillance of the general liquidity situation on the markets and for evaluating financial market operators. As a result, the BCL has been building a series of tools to assess the general liquidity of the market and market participants. Rychtarik (2009) develops an approach to measure the liquidity risk sensitivity of Luxembourg banks from the viewpoint of the impact of shocks on banks' liquidity ratios, in order to identify the most severe scenario (or combination of scenarios) and the most vulnerable banks in the system. Rychtarik and Stragiotti (2009) describe the liquidity position of Luxembourg banks using two different scores, (1) across "peer" banks, and (2) over time, and use them to draw conclusions on trends within the Luxembourg banking sector as a supervisory tool.

The present study represents a natural follow up of work on liquidity risk at the BCL. The framework used in this study draws on the model developed at the De Nederlandsche Bank by J.W. van den End (2008), adapted to take into account Luxembourg idiosyncrasies.[2] The model takes a stochastic approach to systemic liquidity stress testing, while being fully compatible with, and operational for, analyzing bank-level liquidity risk as well (as required by the Law of 2008). It focuses on the effects of market and funding liquidity risk on banks' liquidity buffers; uses industry and ECB-determined haircuts and run-off rates and accounts for uncertainty via Monte Carlo simulations using a log-normal distribution; includes banks' reactions to the shock and; the possibility of a drying-up of funding from cross-border parent banks. In a follow-up paper, second–round, feedback effects due to joint banks' reactions on asset prices and banks' reputation are taken up. Section II discusses the data, haircuts and run-off rates. Section III explains the results of the model simulations. Section IV concludes.

2 DATA, HAIRCUTS AND RUN-OFF RATES

Consistent with the literature on stress testing, the composition and measurement of the liquidity buffer plays a central role in this study (ECB 2008, BIS 2009a). First, the quarterly database used in this study covers 52 banks during the period 2006q1-2009q3; as of 2009q3, the sample represented nearly 90 percent of total bank assets. Second, items of the liquidity buffer are evaluated according to a set of haircuts applicable to each type of financial instrument and featuring the same economic characteristics. Importantly, measurement of assets included in the buffer acknowledges that the same kind of asset may enjoy different liquidity characteristics depending on the currency of denomination, an illustration of a Luxembourg peculiarity of the model.[3]

2 We thank Jan Willem van den End for his valuable assistance and cooperation in this study.

3 The model is flexible enough to be used for an exchange rate shock, but this is not shown here.

The liquidity buffer is a portfolio of high quality, highly liquid unencumbered securities as defined in the BIS guidelines (2009b); those guidelines are also followed for the definition of the haircuts and run-off rates (Tables 1 and 2).[4] As a result, several components of banks' portfolios are withdrawn, such as unlisted stocks and shareholding participations. The most significant off-balance sheet items included are committed credit lines.

Table 1 :
Liquidity buffer: haircuts applied to selected balance sheet items[1)]

TYPE OF BS ITEM	TYPE OF ISSUER	CURRENCY OF ISSUANCE	COUNTRY OF ISSUANCE	RESIDUAL MATURITY - HAIRCUTS			
				<1 year	1<year<2	year>2	unspecified
Listed stocks		EUR	EURO AREA	n/a	n/a	n/a	50%
		USD	US	n/a	n/a	n/a	50%
		JPY	JAPAN	n/a	n/a	n/a	50%
		AAA FOREIGN CCY RATING	AAA FOREIGN CCY RATING	n/a	n/a	n/a	50%
		EUR	EURO AREA	n/a	n/a	n/a	50%
		USD	US	n/a	n/a	n/a	50%
		JPY	JAPAN	n/a	n/a	n/a	50%
		AAA FOREIGN CCY RATING	AAA FOREIGN CCY RATING	n/a	n/a	n/a	50%
Debt financial instruments	Credit institution	EUR	EURO AREA	20%	30%	40%	50%
			G10 (NON EEA)	30%	40%	50%	60%
			EEA (NO EURO AREA)	40%	50%	60%	70%
		USD	EURO AREA	30%	40%	50%	60%
			G10 (NON EEA)	40%	50%	60%	70%
			EEA (NO EURO AREA)	50%	60%	70%	80%
		JPY	EURO AREA	30%	40%	50%	60%
			G10 (NON EEA)	40%	50%	60%	70%
			EEA (NO EURO AREA)	50%	60%	70%	80%
		AAA FOREIGN CCY RATING	EURO AREA	50%	60%	70%	80%
			G10 (NON EEA)	60%	70%	80%	90%
Debt financial instruments	Non financial institutions	EUR	EURO AREA	40%	50%	60%	70%
			G10 (NON EEA)	50%	60%	70%	80%
			EEA (NO EURO AREA)	60%	70%	80%	90%
		USD	EURO AREA	50%	60%	70%	80%
			G10 (NON EEA)	60%	70%	80%	90%
			EEA (NO EURO AREA)	70%	80%	90%	100%
		JPY	EURO AREA	50%	60%	70%	80%
			G10 (NON EEA)	60%	70%	80%	90%
			EEA (NO EURO AREA)	70%	80%	90%	100%
		AAA FOREIGN CCY RATING	EURO AREA	70%	80%	90%	100%
			G10 (NON EEA)	80%	90%	100%	100%

4 Available unencumbered assets are marketable as collateral in secondary markets and/or eligible for central banks' standing facilities.

TYPE OF BS ITEM	TYPE OF ISSUER	CURRENCY OF ISSUANCE	COUNTRY OF ISSUANCE	RESIDUAL MATURITY - HAIRCUTS			
				<1 year	1<year<2	year>2	unspecified
Debt financial instruments	Government	EUR	EURO AREA	2.5%	5.0%	7.5%	10.0%
			G10 (NON EEA)	5.0%	7.5%	10.0%	12.5%
			EEA (NO EURO AREA)	7.5%	10.0%	12.5%	15.0%
			X1	70.0%	80.0%	90.0%	100.0%
		USD	EURO AREA	5.0%	7.5%	10.0%	12.5%
			G10 (NON EEA)	7.5%	10.0%	12.5%	15.0%
			EEA (NO EURO AREA)	10.0%	12.5%	15.0%	17.5%
			X1	80.0%	90.0%	100.0%	100.0%
		JPY	EURO AREA	5.0%	7.5%	10.0%	12.5%
			G10 (NON EEA)	7.5%	10.0%	12.5%	15.0%
			EEA (NO EURO AREA)	10.0%	12.5%	15.0%	17.5%
			X1	80.0%	90.0%	100.0%	100.0%
		AAA FOREIGN CCY RATING	EURO AREA	7.5%	10.0%	12.5%	15.0%
			G10 (NON EEA)	10.0%	12.5%	15.0%	17.5%
			EEA (NO EURO AREA)	12.5%	15.0%	17.5%	20.0%
			X1	90.0%	100.0%	100.0%	100.0%
Money market funds	Credit institution	EUR	EURO AREA	n/a	n/a	n/a	50%
		USD	US	n/a	n/a	n/a	60%
		JPY	JAPAN	n/a	n/a	n/a	60%
		AAA FOREIGN CCY RATING	AAA FOREIGN CCY RATING	n/a	n/a	n/a	70%
Cash	All sectors	All currencies	All countries	0%	0%	0%	0%

1) Derivatives are not included in the buffer at this stage.

The BCL database used for this study encompasses several dimensions. They are the type of balance sheet item (e.g., listed shares, cash), the type of counterparty (e.g., holding companies, international organizations), the country of origin of the counterparty (e.g., non Eurozone countries, AAA-rated foreign countries), and the currency of issuance of financial instruments. Residual maturities are used whenever available.

Haircuts are based on banks' practice in Luxembourg (Rychtarik, 2009, Rychtarik and Stragiotti, 2009), industry standards (Standard & Poor's, 2007), ECB requirements (ECB, 2006), and judgement. The study emphasizes the importance of information regarding geopolitical and macroeconomic data. The country of origin and the currency of each financial instrument play a significant role in haircuts' evaluations. However, given that the available database does not discriminate across types of securities (e.g., callable bonds versus bonds held to maturity), simplifications are necessary.

A haircut does not depend always on the *type* of security. For instance, no distinction is made between the haircuts of asset-backed securities and corporate bonds issued in the same currency by the same type of entity, in the same country. This issue becomes somehow less relevant if put in the context of the approach taken, which is partly inspired by the ECB implementation of monetary policy operations. Indeed, for the latter, the *type* of financial instrument becomes less relevant regarding the eligibility criteria.

The BCL database distinguishes four types of *maturities*. In this context, several hypotheses have to be made. It is not feasible to distinguish across different securities based on their maturities. For example, within the category of debt instruments with a maturity below 1 year, it is not possible to determine what amount represents commercial paper and what amount represents other financial instruments.

The same framework supports the determination of run-off rates. These rates are set to reflect several facets of potential liquidity shocks of systemic and idiosyncratic nature. The run-off rates are based on the historical observation of past shocks in the Luxembourg banking sector; literature references and; (3) information received from surveys of Luxembourg banks.[5]

Table 2:
Run-off rates applied to selected stressed balance sheet items

TYPE OF BS ITEM	TYPE OF ISSUER	CURRENCY OF ISSUANCE	COUNTRY OF ISSUANCE	RESIDUAL MATURITY - RUN-OFF RATES			
				<1 year	1<year<2	year>2	unspecified
Liabilities							
Deposits - retail - Luxembourg		all currencies	all geopolitical areas	n/a	n/a	n/a	20%
Deposits - retail - non Luxembourg		all currencies	all geopolitical areas	n/a	n/a	n/a	20%
Deposits - corporate - all		all currencies	all geopolitical areas	n/a	n/a	n/a	50%
Deposits - banks - non Related Parties		all currencies	all geopolitical areas	n/a	n/a	n/a	65%
Fiduciary deposits - banks 1Y		all currencies	all geopolitical areas	n/a	n/a	n/a	90%

TYPE OF BS ITEM	TYPE OF ISSUER	CURRENCY OF ISSUANCE	COUNTRY OF ISSUANCE	RESIDUAL MATURITY - HAIRCUTS			
				<1 year	1<year<2	year>2	unspecified
Assets							
Interbank deposits	Credit institution	all currencies	EURO AREA	10%	30%	50%	70%
			G10 (NON EEA)	20%	40%	60%	80%
			EEA (NO EURO AREA)	20%	40%	60%	80%

1) The table does not discriminate by type of deposit (in terms of their residual maturity). Local liquidity risk managers suggest that from a liquidity perspective, the type of deposit (e.g., demand versus time deposit) does not play a crucial role in determining the behaviors, and therefore the run-off rates of banks' clients.

The framework used for haircuts and run-off rates is, however, only an operational reasonable starting point. A major weakness of stress testing models has been the use of historic data for haircuts and run-off rates given that realized elasticities under stress conditions are, most likely, going to be quite different. Therefore, this study applies a stochastic approach.

5 Money market funds' deposits are excluded from the table because they are held mostly, albeit not exclusively, by custodian banks. The practice of these banks in Luxembourg seems to exclude these funds from their maturity transformation activity. The BCL database does not allow a distinction between custodian and non-custodian banks (Rychtarik and Stragiotti, 2009, take a different approach, not followed in this paper, and assume as scenario a potential withdrawal of deposits from funds). Note that run-off rates do not refer to intraday liquidity risk, the risk custodian banks face.

Box 1:

SIMULATIONS

Liquidity buffers are made stochastic to overcome, at least partly, not only the short-supply of stress-situations data and their limited value, but also the possibility of rapid changes in asset values, and the uncertainty in the model parameters and banks' reaction functions. Monte Carlo simulations of haircuts and run-off rates are performed by taking 50,000 draws from a log-normal distribution. The use of this distribution is consistent with the nonlinearities of extreme liquidity stress occurrences and risk management practice. In the simulations, the distribution is adjusted to reflect tail events, or three standard deviations. Therefore, the log normal distribution used is Exp ((N(0,1)*(weights(i)/3)). Like in van den End (2008), shocks are simulated by stressing the haircuts and run-off rates; this is the first stage of the exercise. Given the granularity of balance and off-balance sheet information used, shocks can be implemented in a flexible way. Banks' reactions to mitigate the impact of the shocks on their liquidity buffers constitute the second stage. If banks' reactions are quite generalized and similar, or if they are the result of large institutions' actions, they may have systemic consequences in the form of falls in asset prices, increased margins calls, and more expensive funding. This, together with additional losses as a result of the interaction between liquidity risk and credit risk or to reputational effects, constitutes the third stage of the model. This third stage is implemented in a forthcoming paper.

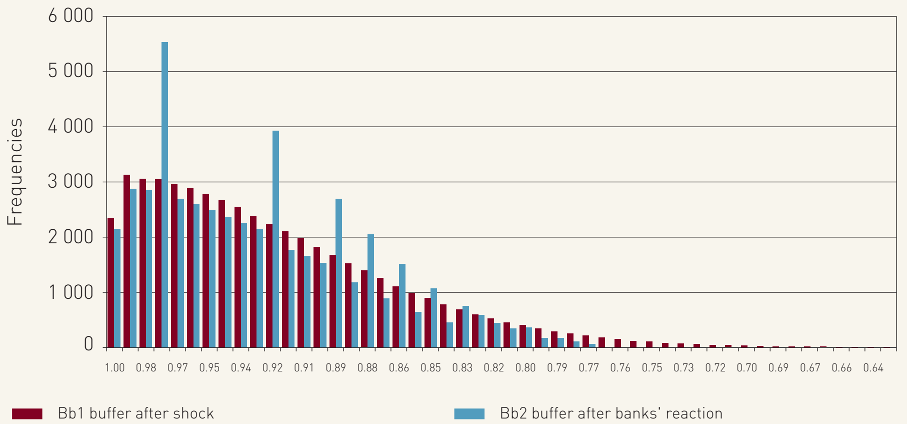
3 SIMULATION RESULTS

The stress testing exercise covers market and funding liquidity risk. The following shocks are used to test the resilience of the Luxembourg banking sector. First, a systemic *shock to interbank loans* is assumed to affect the whole banking sector. The entire stock of interbank loans undergoes a severe, albeit plausible stress. Second, *interbank loans* granted by Luxembourg banks are shocked. In this scenario, each bank suffers a loss proportionate to the share of its interbank loans. Third, a severe, simultaneous run-off of retail *deposits* of resident and non-resident clients, corporate deposits, non-related parties interbank deposits, and fiduciary deposits is instrumented. Finally, a shock affecting the *related entities' deposits* is simulated.

First shock: systemic shock to interbank loans

In the first shock, each bank loses part of the value of its interbank loans. The magnitude of the loss is set by the simulated run-off rates. The shock hits all the banks carrying this type of exposure. In the case of this shock, the interest is not in the outcome for individual banks, but rather for the banking sector as a whole (Figure 1).

Figure 1
Systemic shock to interbank deposits: shock and banks' responses, including related-parties' assets



The chart displays the impact of the systemic shock on banks' buffers *(Bb1)* standardized by the baseline liquidity buffer *(Bb0)*; *Bb1* buffers are calculated by subtracting from the baseline buffer, the first-round effects of the shock. The abscissa shows the remaining share of the buffer of the whole banking sector. The ordinate displays the corresponding frequencies. The largest potential loss incurred by the Luxembourg banking sector after the occurrence of an interbank shock would be around 36 percent of the baseline buffer *Bb0*.[6] *Bb2* describes the buffers' distribution after the banking sector takes mitigating actions following the initial shock.[7] The *Bb2* buffer is, therefore, the result of adding to the set of buffers *Bb1*, the transactions performed by banks as shock mitigating actions.[8] After its reaction, the banking sector is better off and is expected to be left in a worse case scenario with roughly 77 percent *(Bb2)* of its baseline buffer. This implies a potential loss of about 23 percent.[9] Moreover, the associated frequencies indicate that the recovery is in general more likely.

Figure 2
Systemic shock to interbank deposits: shock and banks' responses, excluding related parties

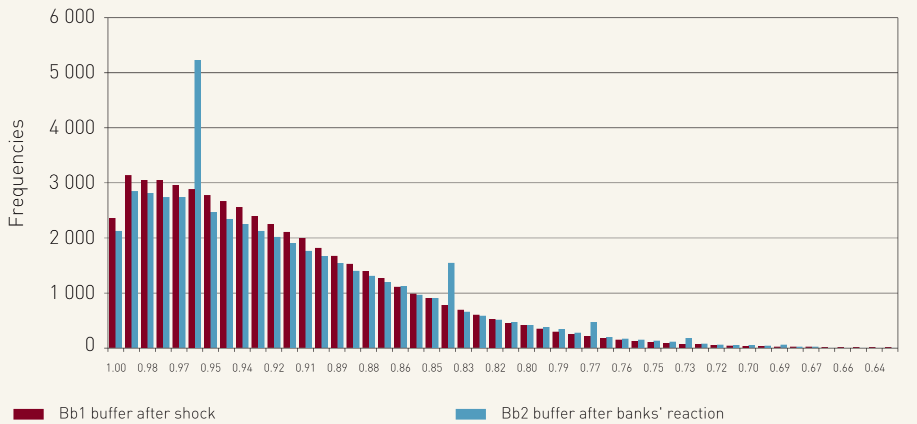


Figure 2 illustrates the response of the banking sector, excluding related parties' deposits. The profile of *Bb2* changes substantially. The likelihood of the banking sector incurring a severe loss increases; in *Bb2*, the largest potential loss rises to roughly 33 percent, from 23 percent. Moreover, the associated frequencies are lower than in the previous case, displayed in Graphique 9. These results highlight the critical role of related parties in the local banking sector.

Second shock: interbank deposits shock, excluding related parties

This shock is different from the previous one in that it emphasizes individual bank's outcomes. The exercise has systemic relevance in that it makes it clear that banks' business lines and banks' interactions, as they are quite diverse in Luxembourg, should be taken into account in assessing the effects of liquidity shocks. In order to illustrate the relevance of those banks' characteristics, five banks are selected according to their relative importance in the Luxembourg banking sector and their business profile. The choice of the selected banks covers most of the spectrum of the current businesses run by Luxembourg banks. Figure 3 shows the results of the interbank shock on three of the banks' buffers distributions.

6 Most Luxembourg banks are subsidiaries or branches of foreign banking groups and play an important role in the financing of the group. Their major source of financing is the interbank market. Interbank liabilities represent about 50 percent of total liabilities, of which three quarters are intra-group.

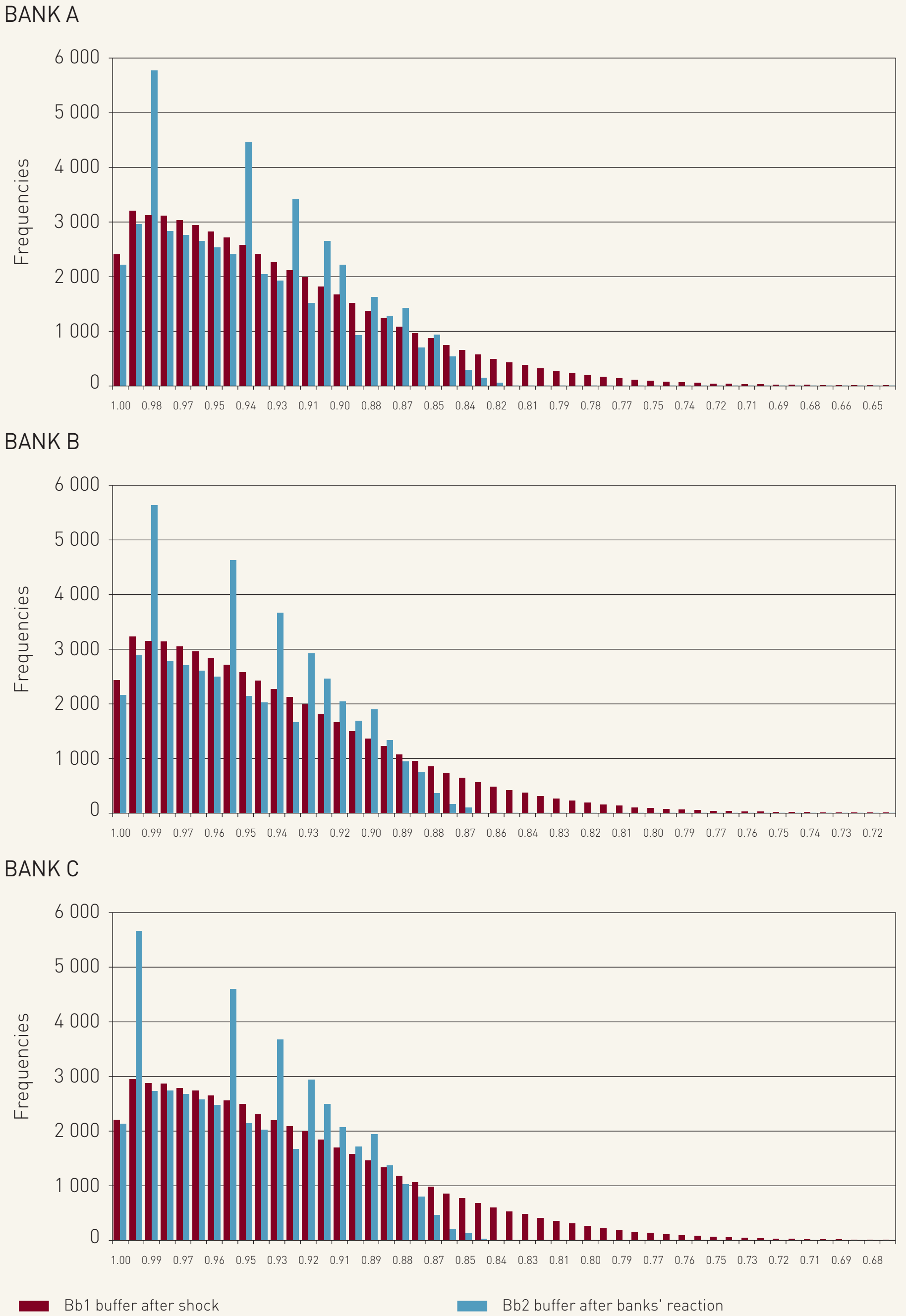
7 Only banks suffering at least a 30 percent loss of their baseline buffers are supposed to react; they represent 71 percent of the sample. The 30 percent threshold was estimated regressing the ranking of the contemporaneous changes in the baseline buffer as a result of the (interbank) shock on the ranking of changes in the balance sheet items for a rho Spearman correlation coefficient at the 99 percent confidence level. This is used as a proxy for the lack of knowledge of banks' risk tolerance levels.

8 Banks are supposed to react, for example, by using securities for repo operations with the central bank, by selling securities, or funding themselves in the unsecured interbank market. Absent a micro-foundation of banks' reactions, as in van den End (2008), the extent to which banks use a particular item of their portfolio to restore the baseline liquidity buffer is determined by the relative importance of the item in the balance sheet, which is obviously a reflection of each bank's business line.

9 As a reference, in the DNB liquidity stress testing exercise of Dutch banks, the baseline buffer loss following a credit shock is 40 basis points and following a banking crisis is about 1.1 percent.

Bank A is mostly a retail bank with important interbank volumes on the assets' side which represent about 38 percent of its baseline buffer. Bank B is active in several business lines (notably retail, custody and corporate); its interbank-buffer ratio is 30 percent. Bank C is mainly a global custodian bank, active in the field of services to investors with an interbank-buffer ratio of 33 percent. Bank A experiences the largest potential impact following the interbank shock. Indeed, its expected buffer in a worse case scenario would be roughly 65 percent of its baseline buffer.[10] Taking remedial actions, bank A would recover roughly 20 percentage points of its baseline buffer loss. Bank B and C are less affected by the interbank shock as they are expected to maintain 70 percent and 67 percent of their baseline buffers, respectively, after the shock. After reacting, bank B would recover roughly 18 percentage points of its baseline buffer loss, and bank C would recover 20 percentage points of its baseline buffer loss. Differences across banks can be explained by the different composition of their portfolios, and therefore, their corresponding simulated haircuts.

Figure 3
Interbank shock: shock and individual banks' responses



Third shock: a run on deposits, excluding related parties

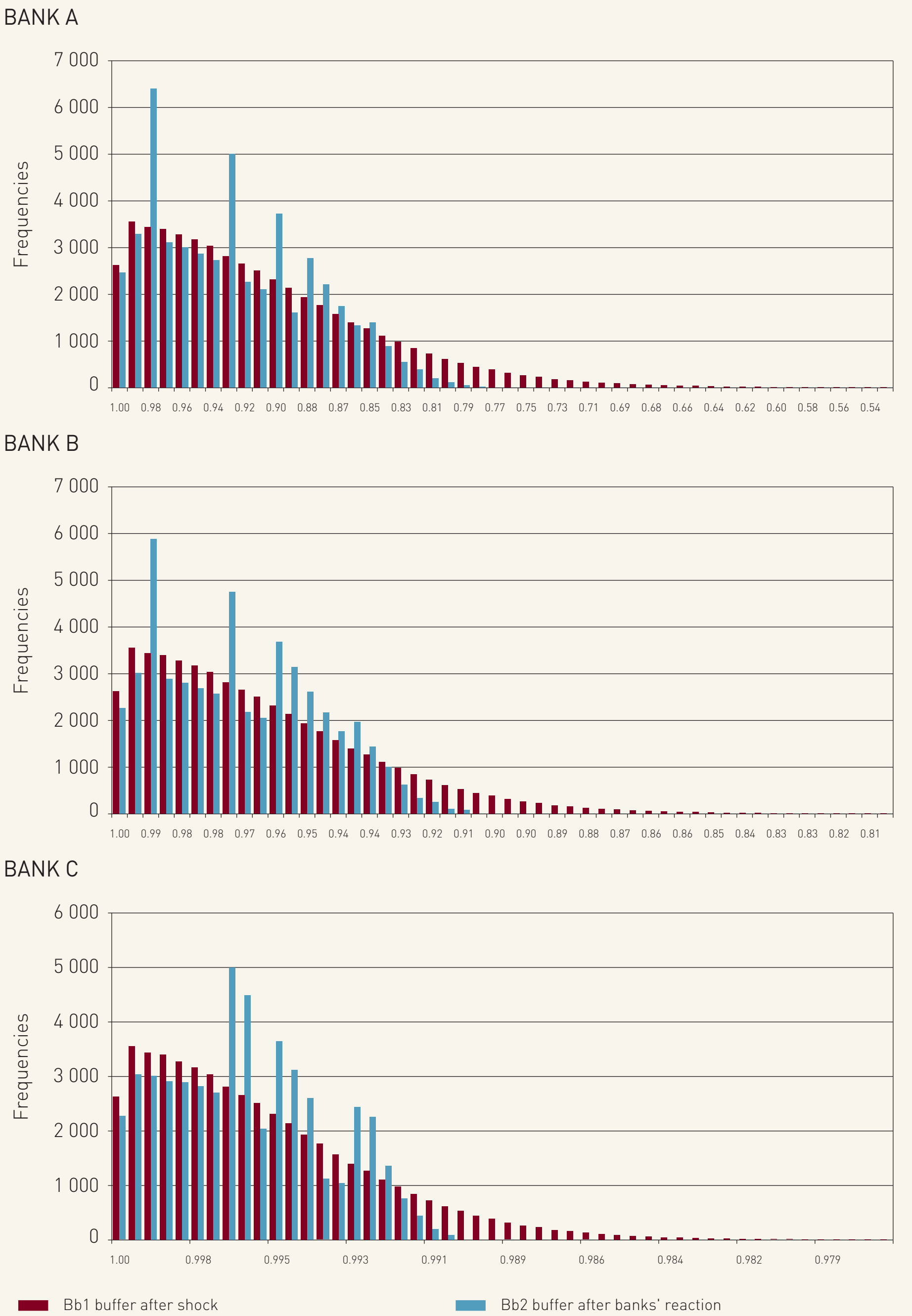
The shock on deposits is a very severe event for bank A and a moderately severe event for bank B; this is the result of the fact that both banks rely on funding from retail and corporate clients. The shares of deposits shocked represent 88 percent and 37 percent of bank A's and bank B's baseline buffers, respectively.[11] In contrast, bank C deposits account for 2 percent of its baseline buffer and the shock's effects are correspondingly really minor. These results are shown in Figure 4.

10 Small losses at the extreme of the distribution are not always visible on the charts due to scaling reasons. The discussion in the text, however, takes these results into account.

11 The main difference between these two banks is the large amount of related-party deposits in bank B.

The shock on bank A's deposits has an important impact on its buffer. Bank A is expected to lose potentially up to 47 percent of its liquidity buffer after the shock. The bank's response improves its buffer allowing it to recover 30 percentage points of its baseline buffer. Although banks B and C do not lose up to 30 percent of their baseline buffers—especially bank C—their reactions are shown here for illustrative purposes. Bank B, whose largest potential loss equals 19 percent of its baseline buffer, has quite a different profile from bank A. Following the bank's mitigating actions, bank B recovers up to 13 percentage points of its baseline buffer. Bank C is less affected by the shock: the expected loss amounts to roughly just 2 percent of Bb0. Accordingly, the bank can face this shock without undergoing a severe stress, and if it were to take mitigating actions, it would recover almost its whole initial buffer.

Figure 4
Run-on-deposits shock: shock and banks' responses

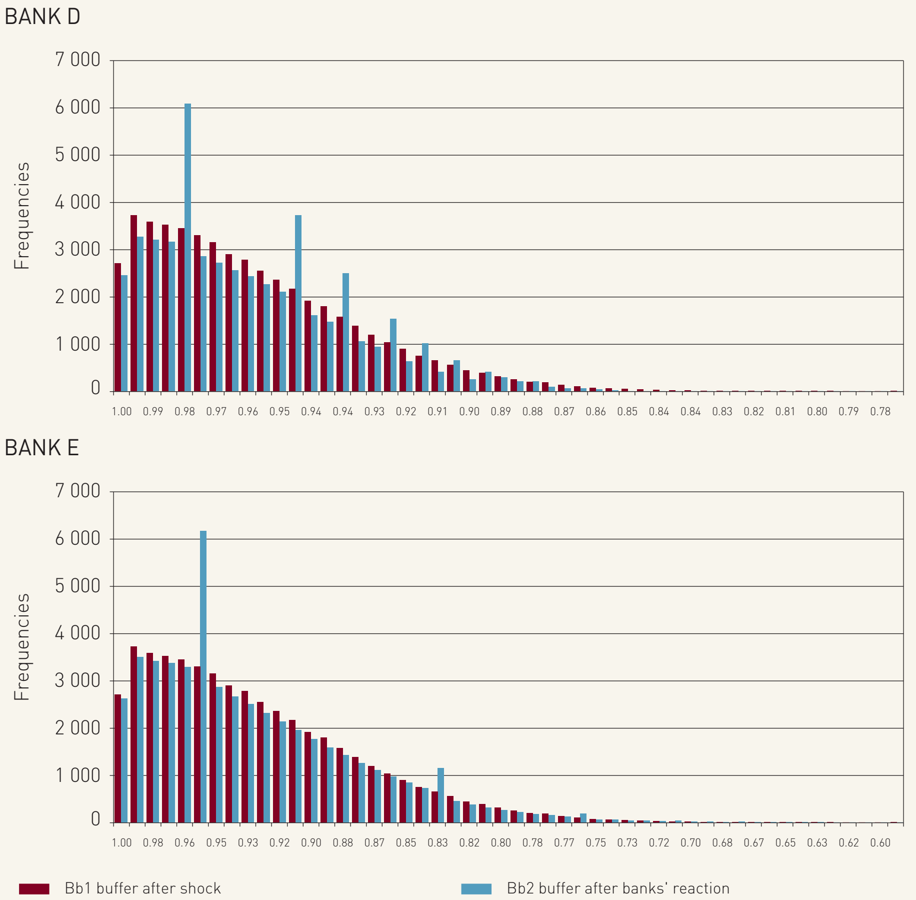


Fourth shock: related parties' withdrawal shock

Given that well over one-third of Luxembourg banks' liabilities are intragroup, this shock is very relevant to assess the survival capacity of Luxembourg banks. In this scenario, related entities withdraw their deposits, an important share of Luxembourg banks' funding. The shock is run on the remaining two, out of the five banks selected. Figure 5 illustrates the effects of this shock. The two selected banks are bank D, with related-parties' deposits representing 22 percent of its baseline buffer, and bank E, with related-parties deposits representing 55 percent of its buffer.

This shock potentially accounts for a loss of 22 percent of bank D's baseline buffer and 40 percent of bank E's.[12] On average, banks' reactions do not allow the banks to recover much of the loss incurred during the shock. Bank D can recover about 8 percentage points of its initial loss and bank E can recover just 3 percentage points. These results show the potentially severe impact that the withdrawal of intragroup positions of Luxembourg banks can have.

Figure 5
Related-parties withdrawal shock: shock and distribution of banks' responses



4 CONCLUSIONS AND POLICY IMPLICATIONS

The results of the liquidity stress testing exercise highlight the systemic relevance of deposits from related parties in the reaction of banks to a shock to interbank loans. The Luxembourg banking sector's largest potential loss becomes 10 percentage points lower if related parties' interbank deposits are included in the reaction of the banks (first shock). Accordingly, banks' likelihood of recovering the baseline buffer increases considerably. The importance of related parties' deposits evinces clearly as well in the case of the related-parties' withdrawal shock (fourth shock). In particular, one of the banks investigated in relation with this shock hardly recovers any buffer loss following its reaction to this event.

In general, it seems that both the business model and the composition of the buffer play a role in determining the profile of the simulated shocks. Indeed, banks' reactions to an interbank shock are more effective than banks' reactions to a non-bank deposit run in order to restore, at least partially, their baseline liquidity buffers. The results of the study stress also the apparent lesser relevance of a "run on the bank" scenario for the observed banks. This may be caused by the characteristics of the local banking sector, populated by several banks active simultaneously in several business lines, and thus more diversified, which makes them more resilient to a specific shock.

Given that the paper includes the liquidity shocks and banks' reactions to mitigate the effects of the shocks on their baseline liquidity buffers (first round effects), a natural follow-up is to also consider the endogenous effects on banks' buffers following banks' collective actions, and their impact on asset prices and banks' reputation (second round effects). Those simulations will be covered in a forthcoming study.

12 Bank D's results are shown for illustrative purposes as the shock would not prompt a bank's reaction given that the shock does not reduce its baseline buffer beyond the 30 percent threshold.

Yet, even before considering the simulations for second round effects, the results indicate the importance of system-wide measures to minimize the systemic effects of liquidity shocks, both ex-ante and ex-post, such as sound liquidity management frameworks and contingency plans, robust liquidity buffers, and deposit insurance. This study is, therefore, one more important macroprudential tool which Luxembourg can use to incorporate financial stability considerations into monetary policy decision-making. It provides a framework to produce quantitative judgments on systemic risk and financial stability.

References

Basel Committee on Banking Supervision (2008), "*Principles for Sound Liquidity Risk Management and Supervision*", Bank for International Settlements.

Basel Committee on Banking Supervision (2009a), "*Principles for Sound Stress Testing Practices and Supervision*", Bank for International Settlements.

Basel Committee on Banking Supervision (2009b), "*International Framework for Liquidity Risk Measurement, Standards and Monitoring*", Bank for International Settlements.

Borio, C. and M. Drehmann (2009), "*Toward an Operational Framework for Financial Stability: "Fuzzy" Measurement and its Consequences*", Bank for International Settlements WP, No. 284.

Brunnermeier, M. and L. H. Pedersen (2009), "*Market Liquidity and Funding Liquidity*", Review of Financial Studies vol. 22, pp. 2201-2238.

Drehmann, M. (2009), "*Macroeconomic Stress Testing Banks: a Survey of Methodologies*", in Stress Testing the Banking System: Methodologies and Applications, ed. M. Quagliariello, Cambridge University Press, Cambridge.

ECB (2006), "*The Implementation of Monetary Policy in the Euro Area*", European Central Bank.

ECB (2008), "*EU Banks' Liquidity stress Testing and Contingency Funding Plans*", European Central Bank.

IMF (2008), *Global Financial Stability Report*, April 2008.

Moretti, M., S. Stolz and M. Swinburne (2008), "*Stress Testing at the IMF*", IMF WP/08/206.

Rychtarik, S. (2009), "*Liquidity Scenario Analysis in the Luxembourg Banking Sector*", BCL WP No. 41.

Standard & Poor's (2007), "*Liquidity Risk Analysis: Canadian Banks*".

F. Stragiotti (2009), "*Stress Testing and Contingency Funding Plans: An Analysis of Current Practices in the Luxembourg Banking Sector*", BCL WP No. 42.

F. Stragiotti and S. Rychtarik (2009), "*Liquidity Risk Monitoring Framework: A Superviory tool*", BCL WP No. 43.

Van den End, J. W. (2008), "*Liquidity Stress-Tester. A Macro Model for Stress-Testing Banks' Liquidity Risk*", De Nederlandsche Bank WP No. 175.

5 AN OFF-SITE LIQUIDITY SUPERVISION TOOL

By
Štefan Rychtárik*
Franco Stragiotti†

1 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 testing exercises [Van den End 2008, Boss and Altera 2007]. Nevertheless, the literature on frameworks adopted by central banks and financial regulators for monitoring liquidity risk of single banks is scarce. In this context, a paper published by the Bank of Japan [2009] tackles the issue of liquidity monitoring in the banking sector. In this analysis, the central bank point of view, the complexity of measuring liquidity risk, and as a consequence, the difficulties embedded in monitoring the process, are highlighted. The 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. The FSA also proposes a set of metrics for liquidity risk monitoring. In these consultation papers, several issues arise regarding comparability across different banks as well as problems related to the intrinsic value of such liquidity metrics when they are extrapolated from their economic and financial context.

Recent market developments have also reminded us of the complex 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.[1] 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 drivers (defined by our ratios) regarding two aspects. On one hand, the liquidity ratios of a bank are compared to the liquidity ratios of similar banks. On the other hand, these ratios are compared to the liquidity ratios 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 own past liquidity position. 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 the sources of liquidity risk each one faces. Similar ratios may imply different liquidity risk levels across diverse business lines. 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

* National Bank of Slovakia

† BCL – Prudential Surveillance Department

1 This approach is decribed in detail in the BCL Working paper No. 43

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 the macro variables, we integrate the 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.

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 a database with financial market and economic indicators from 2003q1 to 2009q3 and on- and off-balance sheet data from 2005q5 to 2009q3. The methodology consists of a foundation and two core pillars:

- The foundation consists of a risk factor matrix that allocates a set of liquidity risk factors with respective weights to each bank based on its business

- 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 data compared to the other banks' for different time periods

- The second pillar assesses the current liquidity position of a selected bank over time vis-à-vis its own historical data. It defines a "time score" for each bank, which integrates both a micro- and a macro-component.

These scores can be further analysed bank by bank as they change over time. They can also be decomposed to identify the main liquidity risk factors for every bank. Moreover, the framework can be used as a tool in general banking sector analysis, e.g. for financial stability purposes.

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. Previous research at the Central Bank of Luxembourg (BCL) [Stragiotti, F., 2009] showed that Luxembourg's 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 or covered bond issuance banks. The average number of activities is often characterized by more than two business activities per bank. This implies that banks may not be merely classified by allocating a bank to one 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 uses a matrix of weighted liquidity risk factors translated into indicators and mapped to 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 a different degree of importance, a large spectrum of the potential sources of liquidity stress relevant for the banks active in Luxembourg.

2.1 Balance sheet risk factors

Since the nature of liquidity risk depends importantly on the type of business conducted by the bank, it is necessary to identify the main banking activities located in Luxembourg. For that purpose, we used several sources of information. The main ones were: (i) regulatory reporting data (also treated by a principal component analysis); (ii) annual reports of the banks; (iii) questionnaires[2]; (iv) meetings with banks; (v) on-site visits and; (vi) other sources such The Luxembourg Bankers' Association.[3] We 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 security prices, which results in a decrease in the value of liquid assets.
Retail run in Luxembourg	Idiosyncratic	Withdrawal of household deposits triggered by rumours.
Private run	Idiosyncratic	Withdrawal of private deposits triggered by rumours.
Corporate run	Idiosyncratic	Withdrawal of corporate deposits triggered by rumours.
Withdrawals by funds	Idiosyncratic	Withdrawal of investment fund deposits triggered by banks' rating downgrade, or as a result of fund redemptions
Issuance problems	Macro/ Idiosyncratic	Problems to raise funding by new debt 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 for accessing Eurosystem liquidity become stricter (e.g. stricter collateral criteria and larger haircuts)
Group liquidity	Group idiosyncratic	Netting of the liquidity position with banks from the parent banking group

2.2 Market risk factors

The market risk factors are included in our framework for three main reasons. First, according to the Principles for Sound Liquidity Risk Management and Supervision (BIS 2008), supervisors should also use the market information in the process of liquidity risk assessment.[4]

Second, the host character of the Luxembourg banking sector implies a rather high dependence of the local entities on the overall situation of the parent banking group[5]. 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 obtain a complete 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 that act as predictors of financial crises which could potentially hit the banking sector.[6] In this context, the integration of the risk factors in our

2 See Stragiotti (2009)

3 For more information on this organization, please visit: www.abbl.lu

4 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.

5 These specific characteristics of each local banking sector should be taken into consideration according to, e.g. Kaminsky and Reinhardt (1999) and Hermosillo (1999).

6 For a review of early warning indicators in banking crises, see Gaytán and Johnson (2002).

framework 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 stress situation in a specific banking group/country. Based on the literature and data availability, we have defined four main categories of indicators of market risk: financial markets, interbank market, macroeconomic conditions and currency issues.

Like the balance sheet part of our framework, the market risk factors need to be translated into indicators; we use three levels of specificity. While the first two indicators (namely Euribor/ Eurepo spread and Luxembourg consumer confidence indicator) are applied to all the banks; the next three indicators (economic sentiment, stock exchange index and special drawing rights) are common for banks whose mother company is located in the same country. The final two indicators (stock price and stock price volatility) relate to the parent banking group. The set of market risk factors is translated into a set of market variables, which could be classified according to the following matrix (Table 2). The table displays the components of market risk factors, their coverage (market-wide, country specific and idiosyncratic) and their type (financial vs. macroeconomic).

Table 2:
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

2.3 Risk factor weights determination

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

The balance sheet risk factor weight $(w_i^{b,t})$ is a normalised intermediate risk weight that sums up to 1, and depends on how many risk factors are relevant for each individual bank. Intermediate risk weights are a function of the relative share of the risk parameters over the liquid assets and the volatility of these parameters over time. As a general rule, the higher the importance and the volatility of a risk parameter, the higher the balance sheet risk factor weight associated with it. This allows us to integrate the effect of changes in banking activity into the balance sheet of the banks over time.

Unlike balance sheet risk factor weights, the market risk factor 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 factors. As a result, the market risk factor weights are calculated as a function of the number of market risk indicators available for each bank in different periods. The weights are 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.[7]

7 The market factor weights can be further calibrated according to characteristics of the local banking sector.

3 CALCULATION OF THE SCORES

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

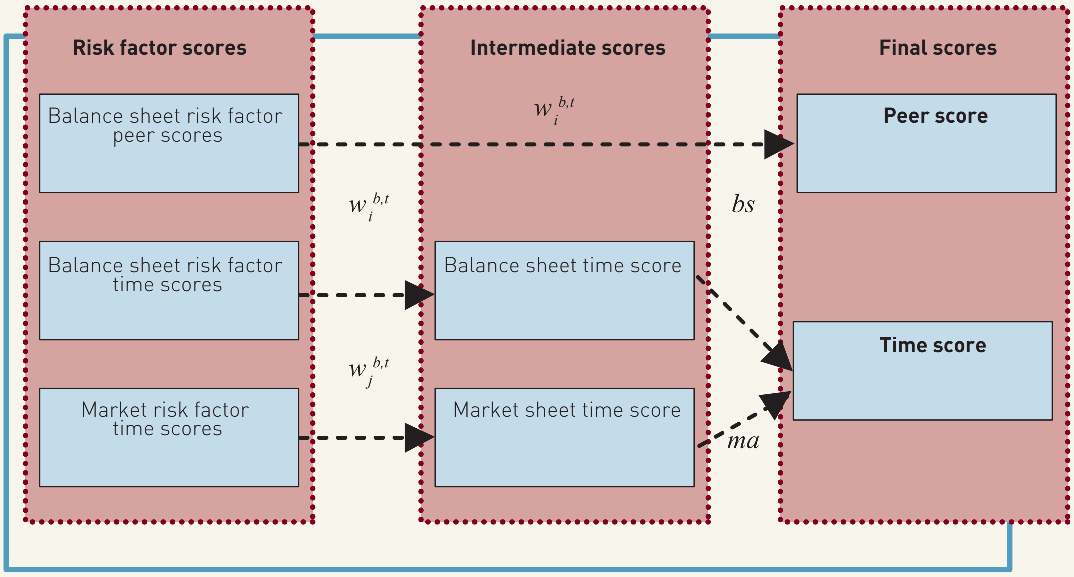
A distribution of every balance sheet risk indicator is calculated taking into consideration only those banks for which that indicator is relevant. Based on the relative position of the bank's risk indicator in the distribution, a score is assigned. This is done separately for each of the 14 balance sheet risk factors. A bank receives a balance sheet risk factor peer score, unless its corresponding weight is below a threshold, which, in our case, is equal to 0.1. According to the position of the risk indicator in the different percentiles of the distribution, this risk balance sheet factor peer score can span from 1 to 9. The final peer score is an average of the balance sheet risk factor peer scores obtained for different risk factors weighted by their relative importance and volatility (Figure 1).

As a result, the peer score depends only on a bank's relative liquidity position within the banking sector as measured by the balance sheet risk factors, and does not reflect possible shifts in the liquidity position of the banking sector as a whole. 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 trends in the banks in the sample. This is, instead, captured by the second pillar, namely the time score.

The objective of the second pillar is to provide a score relative to the bank's previous experience (the time score). In this exercise, we do not compare the banks among themselves but we confront the bank with its past liquidity positions. For the time score, we have added 7 external market variables to take into consideration developments in financial markets, the situation of the parent banking group and the general macroeconomic outlook for the relevant countries (Table 2). The introduction of these 7 external variables reduces the degree of interdependence between the peer score and the time score. As a result, the difference between the two pillars lies not only in the different methodology followed (peer comparison vs. comparison over time), but also in the variables considered. 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 depends on the positions of a bank's risk indicators in the distribution of the respective risk indicators calculated for previous periods. This is done separately for balance sheet and market components to calculate risk factor specific scores within both components. As a result, two intermediate scores are assigned to every bank, i.e. the balance sheet time score and the market time score. The final time score is a weighted average of the intermediary scores (Figure 1).

As a result, at every moment in time, each bank is characterised by two scores. On the one hand, we can see the bank's liquidity position described by reporting data, which depends primarily on comparisons among different banks in the 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 contingent on the general soundness of its parent banking group.

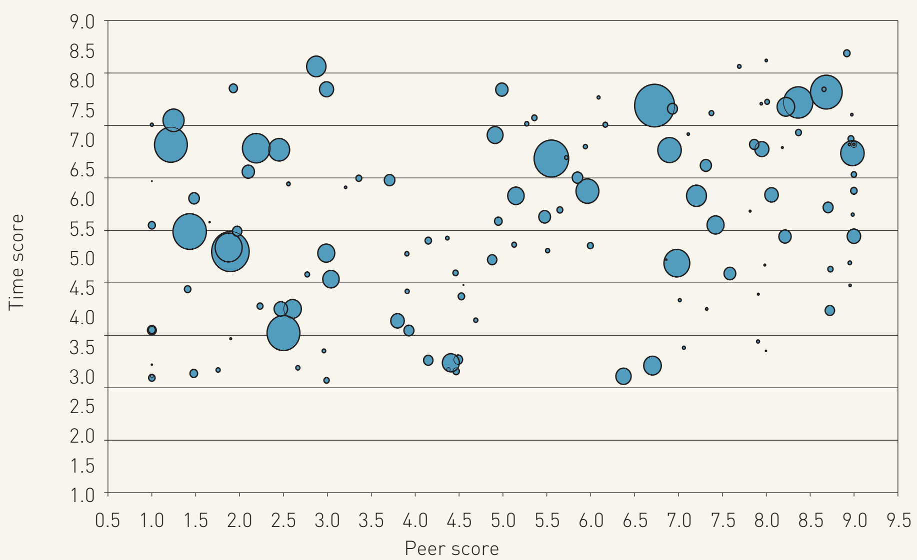
Figure 1
Sequence of scores



4 RESULTS

This section demonstrates how 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.

Figure 2
Example of a liquidity matrix (September 2009)



The size of the bubble represents the size of the balance sheet.
Source: BCL, authors' calculations

4.1 Liquidity matrix

In every time period, the liquidity situation of banks can be displayed in a liquidity matrix that shows both the peer scores and the time scores (Figure 2). If such analysis is done for time 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.

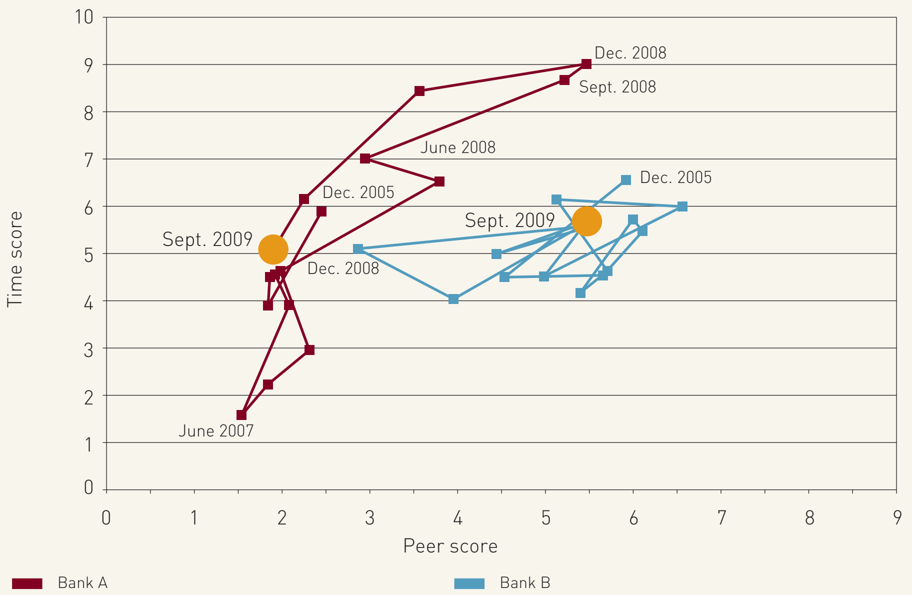
As the size of a bank could be correlated with its systemic importance, such information can be useful in the field of financial stability as well.

To give a practical example, the results for September 2009 displayed on Figure 2 could be analysed in the following way. Although the bigger banks are spread all over the matrix, 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 a relatively more difficult liquidity position than their historical benchmark provided by four years of data. The biggest banks dominate the score bands from 4 to 8. From a supervisory point of view, therefore, attention should be focused on the banks in the upper right hand corner to analyse and understand the reason behind their relative liquidity positions.

4.2 Evolution of the scores over time

The liquidity matrix can be analysed by studying the liquidity position of a bank over time. On Figure 3 we can observe the trajectory of the positions of two of the banks in the liquidity matrix.

Figure 3
Examples of changes of two banks' position in the liquidity matrix



The bubbles represent the last available observation.
Source: BCL, authors' calculations

4.3 Decomposition of the scores

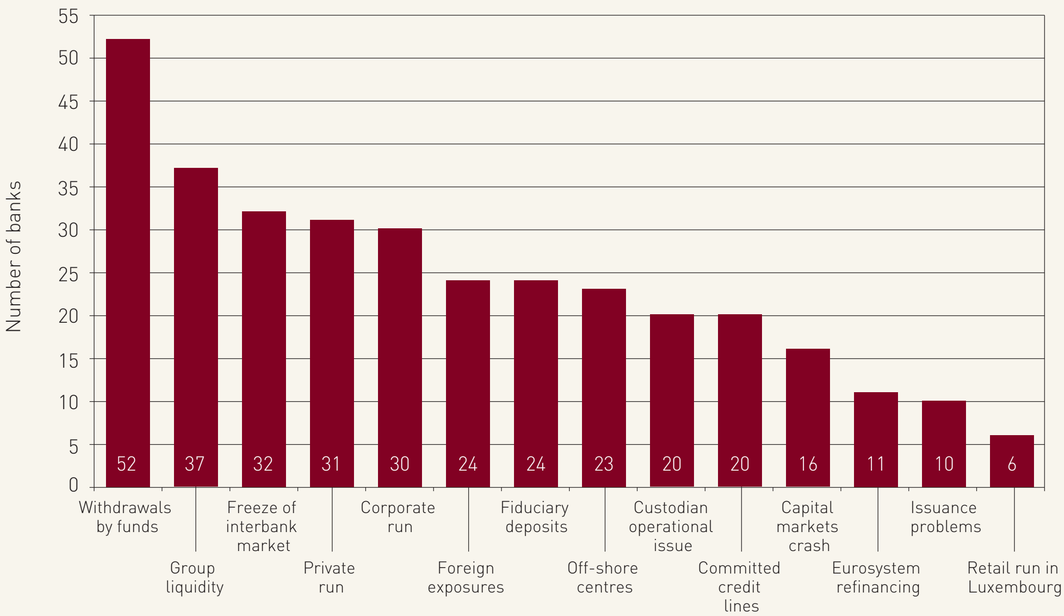
Since the final scores are weighted averages of scores calculated for different risk factors, we can calculate the contribution of each risk factor to the final scores. In the case of the peer score, such decomposition identifies the main balance sheet risk factors. As regards the time score, we can distinguish between the market and the balance sheet risk factors.

The decomposition of the scores helps us in understanding the main driving forces of liquidity risk of 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, the composition of the score of these banks changed significantly, while the value of the score usually remained rather stable at high levels.

One further possible application of this off-site supervisory tool is the assessment of the most relevant risk factor at t_0. The number of banks with $c_i^{b,t}$ larger than 0.05 for different risk factors is shown on Figure 4 For every risk factor, we count the number of banks for which this factor contributes to the final peer score by more than 5%.

Figure 4

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



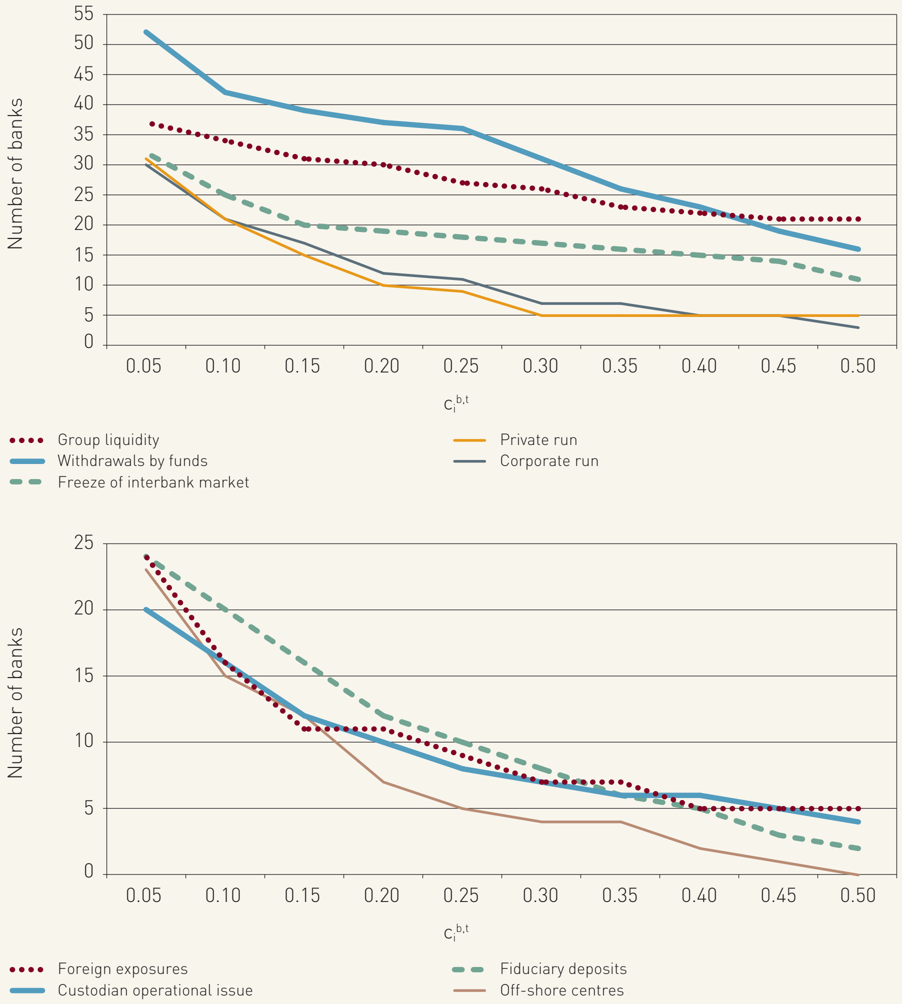
Source: BCL, authors' calculations

With this threshold of contribution of 5%, the most relevant risk scenarios are: withdrawal of deposits by investment funds (52 banks), netting of the position with the parent banking group (37 banks), interbank market (32 banks), and 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. 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 risk.

In Figure 4, 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 $c_i^{b,t}$ (Figure 5). In this context, sensitivity to deposit withdrawals by investment funds and dependence on the parent banking group seems 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 significantly as $c_i^{b,t}$ increases (5 banks with a contribution of more than 50%). This implies that, even if many banks located in Luxembourg are involved in private banking, this scenario is the most important risk factor for only a few of them.

Figure 5

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



Source: BCL, authors' calculations

4.4 Evolution of the risk factor relevance over time

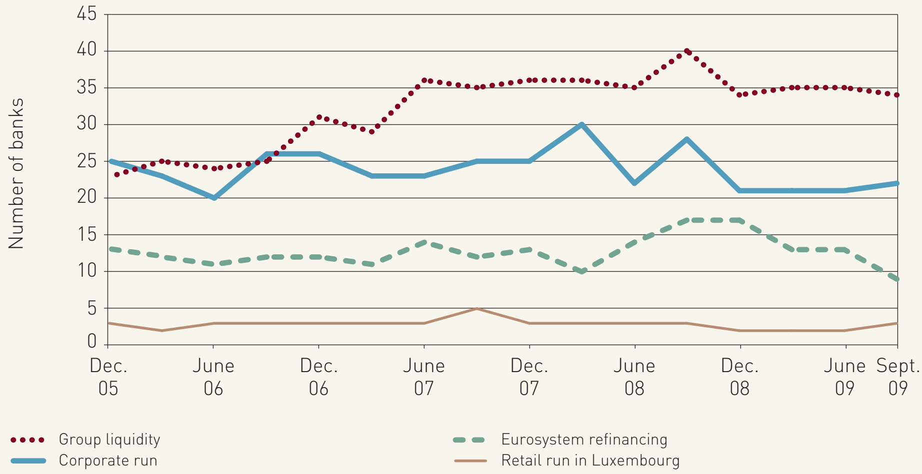
With a constant $c_i^{b,t}$[8], we can observe the evolution of the risk factor relevance over time (Figure 6). As a result, we can analyse the potential influence of the financial crisis on the general risk profile of the Luxembourg banking sector.

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

8 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

Figure 6

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



Source: BCL, authors' calculations

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

5 CONCLUSIONS

In this paper, we described the off-site liquidity risk monitoring framework used by the BCL. Our framework integrates several types of data (regulatory reporting, financial markets, macroeconomic data) 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 each bank 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 the 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 could discriminate between structural illiquid banks and those whose liquidity position deteriorated recently.

Thirdly, using one bank as an example, we have shown the potential benefits of a thorough 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 their scores and in terms of their evolution before the recent crisis.

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 a rather constant contribution (e.g. the retail business), and risk factors whose contribution depended more on recent market developments (e.g. dependence on the refinancing operations with the Eurosystem).

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

References

Bank of Japan [2009] "*The Bank of Japan's Approach to Liquidity Risk Management in Financial Institutions*", available at: http://www.boj.or.jp/en/type/release/adhoc09/data/fss0906a.pdf

Bank of England [2009] "*Special liquidity scheme: information*" and "*Special liquidity scheme: market notice*", available at: http://www.bankofengland.co.uk/publications/news/2008/029.htm

Bank for International Settlement [2008] "*Principles for Sound Liquidity Risk Management and Supervision*", BCBS, September 2008, available at: http://www.bis.org/publ/bcbs144.pdf

Bank for International Settlement [2000] "*Sound Practices for Managing Liquidity in Banking Organisations*", BCBS, February 2000, available at: http://www.bis.org/publ/bcbs69.htm

Banque centrale du Luxembourg [2009] "*Revue de stabilité financière 2008*", available at http://www.bcl.lu/fr/publications/bulletins_bcl/Revue_de_stabilit___financiere_2008/index.html

Boss, M., G. Krenn, M. Schwaiger and W. Wegschaider [2004] "*Stress Testing the Austrian Banking System*" Öesterreich National Bank, 11/04, 841–852, also available on http://www.oenb.at/de/img/artikel_9_841852_boss_et_al_11_tcm14-27296.pdf

Committee of European Banking Supervisors [2009] Interim Report on Liquidity Buffers & Survival Periods. 2009, also available on http://www.c-ebs.org/News--Communications/Latest-news/CEBS-is-today-publishing-an-interim-report-on-liqu.aspx

European Central Bank [2008] "*The Implementation of Monetary Policy in the Euro Area. General Documentation*", Eurosystem monetary policy instruments and procedures.

Financial Services Authority [2009-a] "*Strengthening liquidity standards 2: liquidity reporting*" consultation paper 09/13, also available at: http://www.fsa.gov.uk/pubs/cp/cp09_13.pdf

Financial Services Authority [2009-b] "*Strengthening liquidity standards 2: liquidity reporting*" consultation paper 08/22, also available at: http://www.fsa.gov.uk/pubs/cp/cp08_22.pdf

Frankel, J., and Shang-Jin W. [2004], "*Managing Macroeconomic Crises: Policy Lessons*", Chapter 7, in Economic Volatility and Crises: A Policy-Oriented Guide, edited by Joshua Aizenman and Brian Pinto, World Bank, Washington DC.

Gaytán, A. and Johnson C. A. [2002], "*A review of the literature on early warning systems for banking crises*", Working Papers No. 183 October, Central Bank of Chile.

González-Hermosillo B. [1999] "*Developing Indicators to Provide Early Warnings of Banking Crises*" Finance & Development, IMF quarterly magazine, Volume 36, Number 2, June, available at http://www.imf.org/external/pubs/ft/fandd/1999/06/gonzalez.htm

Jurča, P. and Rychtárik, Š. [2006] "*Stress testing of the Slovak banking sector*", Biatec Volume XIV, 4/2006

Kaminsky G. L., [1998] "*Currency and banking crises: the early warnings of distress*" International Finance Discussion Papers 629, Board of Governors of the Federal Reserve System (U.S.).

Kaminsky, G. and al. [1998] "*Leading Indicators of Currency Crises*" IMF Staff Papers, 5 (1):1-48.

Kaminsky, G. and Reinhardt, C. [1999] "*The twin crises: the causes of banking and balance-of-payment problems*" American Economic Review 89: 473-500.

Rychtárik, Š. [2009] "*Liquidity scenario analysis in the Luxembourg banking sector*" Banque centrale du Luxembourg, Working paper n. 41/ September.

Stragiotti, F. [2009] "*Stress testing and contingency funding plans: an analysis of current practices in the Luxembourg banking sector*" Banque centrale du Luxembourg, Working paper n. 42/ December 2009

Van den End, J.W. [2008] "*Liquidity stress-tester: a macro model for stress testing banks' liquidity risk*" DNB working paper No. 175, May 2008.

6 LA TRANSMISSION DES CHOCS EXTERNES À L'ÉCONOMIE LUXEMBOURGEOISE : UNE APPROCHE VAR[1]

Par
Romuald Morhs*

1 INTRODUCTION

La méthodologie VAR constitue un outil économétrique particulièrement adapté pour modéliser les interactions dynamiques entre variables macroéconomiques à partir d'une représentation sommaire de l'économie. L'objectif de cette contribution est d'estimer un modèle VAR pour le Luxembourg de manière à étudier l'influence des chocs externes sur les développements économiques au Grand-Duché. Ce modèle, qui est estimé à partir de données trimestrielles couvrant la période 1986 à 2007, s'attache à prendre en compte les spécificités de l'économie luxembourgeoise à travers, notamment, l'incorporation d'un ensemble de variables spécifiques comprenant le taux d'intérêt nominal de court terme, le PIB réel et l'indice du prix des actions de la zone euro.

Les principaux résultats obtenus dans cette étude sont les suivants. L'économie luxembourgeoise apparaît très sensible à l'évolution de l'environnement international, les fluctuations à long terme de l'activité économique provenant à plus de 65% des chocs sur les variables de la zone euro. Plus précisément, l'impact d'un choc de taux d'intérêt sur le PIB réel luxembourgeois est relativement élevé, une hausse du taux d'intérêt nominal de court terme de 35 points de base se traduisant par une contraction du PIB réel de 0,45% après deux ans, un résultat qui pourrait notamment s'expliquer par la structure à taux variable des crédits au secteur privé, mais aussi par les effets indirects des changements de taux d'intérêt qui s'exercent par le biais du PIB réel et du prix des actions de la zone euro. Un choc de 0,4% sur le PIB réel de la zone euro exerce en effet un impact de même ampleur sur le PIB réel luxembourgeois après 2 à 3 trimestres, tandis qu'un choc de 9% sur le Dow Jones EURO STOXX exerce une influence quasi immédiate sur l'activité économique pour une hausse maximale de 0.6% du PIB réel luxembourgeois.

Cette contribution est organisée comme suit. Les principales caractéristiques du modèle VAR estimé pour le Luxembourg sont tout d'abord brièvement exposées dans la première section. La deuxième section s'attache quant à elle à présenter les principaux résultats empiriques obtenus à partir de ce modèle, en focalisant sur l'influence des chocs externes sur l'économie luxembourgeoise. Enfin, la dernière section conclut en avançant certaines pistes de réflexion relatives à de futurs travaux autour de cette problématique.

2 LE MODÈLE VAR POUR LE LUXEMBOURG

Un VAR est un système dynamique dans lequel chaque variable est régressée sur ses propres valeurs et sur les valeurs présentes et passées des autres variables. De manière générale, un processus VAR est décrit par:

(1) $$Y_t = A_0 + A_1(L)Y_t + \varepsilon_t,$$

avec Y_t, un vecteur de variables endogènes, A_0, un vecteur de constantes, et ε_t, un vecteur de résidus identiquement et indépendamment distribués.

Dans le cadre du modèle estimé dans cette étude, le vecteur de variables endogènes Y_t, comprend un ensemble de variables domestiques et étrangères. L'ensemble de variables domestiques (Y_t^{LUX}) contient

1 Cette contribution est un résumé non-technique d'un cahier d'études de la BCL à paraître prochainement.

* BCL – Département Economie et Recherche

le PIB réel (y_t^{LUX}), l'indice des prix à la consommation (p_t^{LUX}), le crédit nominal au secteur privé $(credit_t^{LUX})$, et l'indice du prix nominal de l'immobilier résidentiel $(prop_t^{LUX})$ pour le Luxembourg. L'ensemble de variables étrangères (Y_t^{EA}) contient quant à lui le PIB réel (y_t^{EA}), l'indice des prix à la consommation (p_t^{EA}), l'indice du prix des actions $(shares_t^{EA})$, et le taux d'intérêt nominal de court terme (sri_t^{EA}) pour la zone euro. Toutes les variables sont exprimées en logarithme, hormis le taux d'intérêt qui est exprimé en niveau.

Afin de prendre en compte de manière appropriée les interactions entre le Luxembourg et la zone euro, le cadre d'analyse retenu décrit par ailleurs une petite économie ouverte dans laquelle les variables domestiques n'exercent pas d'influence sur la détermination des variables étrangères:

(2) $$\begin{pmatrix} Y_t^{LUX} \\ Y_t^{EA} \end{pmatrix} = \begin{pmatrix} A_{10} \\ A_{20} \end{pmatrix} + \begin{pmatrix} A_{11}(L) & A_{12}(L) \\ 0 & A_{22}(L) \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix}$$

Dans le cadre de cette étude, le modèle VAR représenté par les équations (1) et (2) est estimé en niveau à partir de données trimestrielles couvrant la période 1986-2007. Les critères standard de sélection des décalages conduisent par ailleurs à retenir un processus VAR(3). Deux variables muettes pour les trimestres 1992:3 et 1999:1 sont également introduites dans la composante déterministique du système de manière à améliorer le comportement des résidus. Enfin, les chocs structurels sont identifiés à partir d'une décomposition de Choleski avec les variables ordonnées de la manière suivante:

(3) $$Y_t' = [\, p_t^{EA} \quad y_t^{EA} \quad sri_t^{EA} \quad shares_t^{EA} \quad p_t^{LUX} \quad y_t^{LUX} \quad credit_t^{LUX} \quad prop_t^{LUX} \,]$$

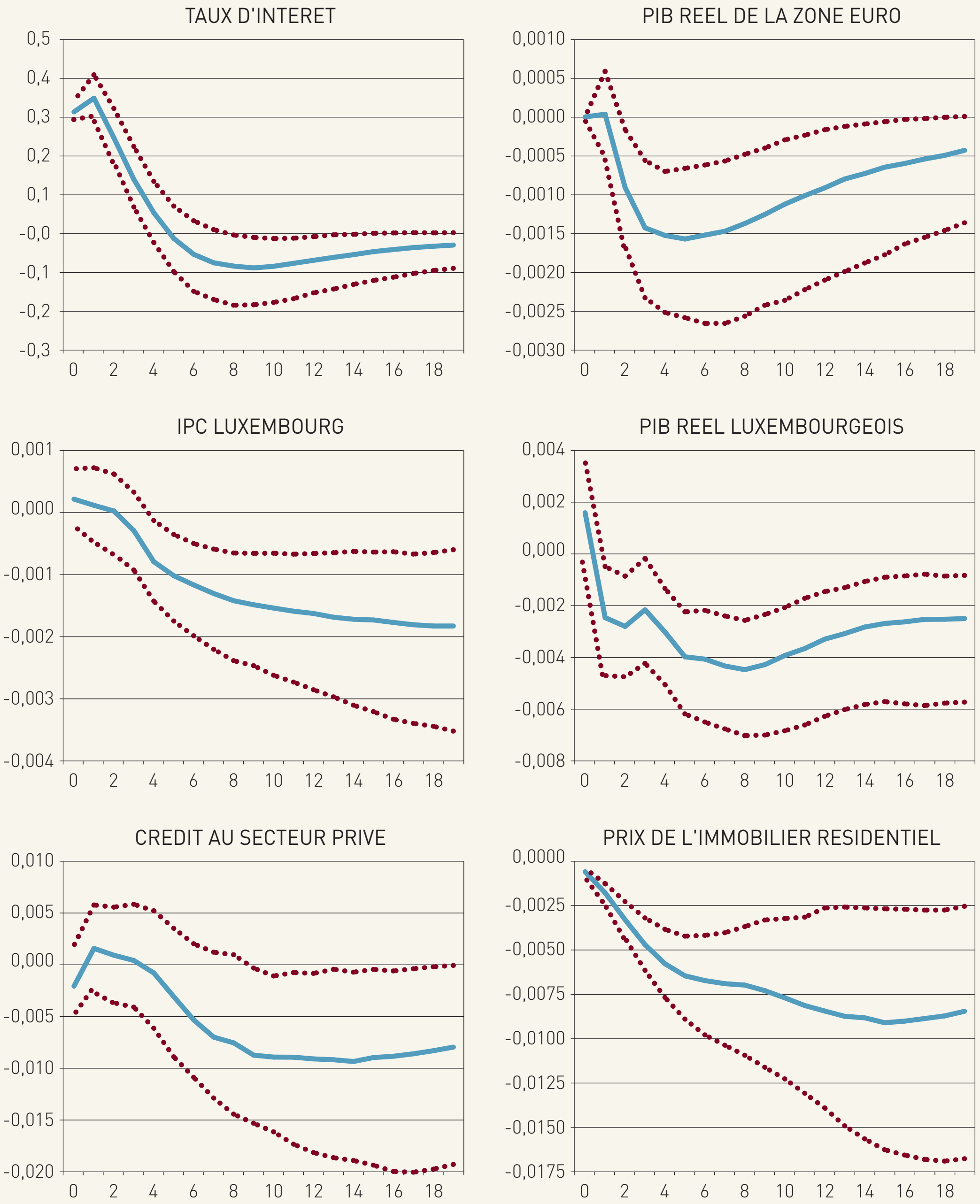
La robustesse des résultats de l'estimation obtenus à partir du modèle VAR décrit ci-dessus a été explorée à partir de différentes spécifications du modèle. En particulier, les résultats de l'analyse structurelle se sont avérés quantitativement et qualitativement identiques à un changement dans l'ordre des variables, dans le nombre de décalages et dans la date de départ de l'échantillon, ainsi qu'à l'introduction d'un terme de tendance dans la composante déterministique du modèle.

3 L'EFFET DES CHOCS EXTERNES SUR L'ÉCONOMIE LUXEMBOURGEOISE

Le graphique 1 relate l'effet d'un choc de taux d'intérêt sur l'activité économique, le niveau des prix, le crédit au secteur privé et le prix de l'immobilier résidentiel au Luxembourg. Les lignes en pointillé représentent les intervalles de confiance à 68% des fonctions de réponse impulsionnelles associées à ce choc.

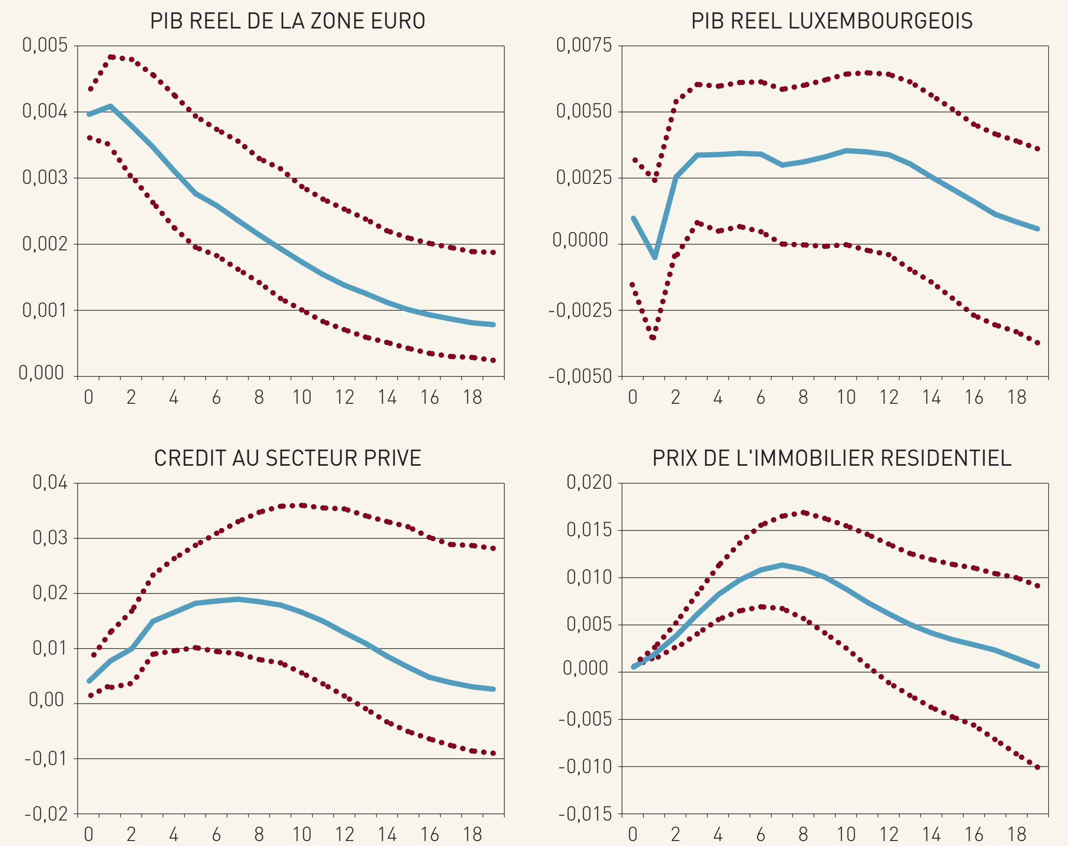
Après un choc de taux d'intérêt, la baisse des prix devient statistiquement significative après quatre trimestres et exhibe une forte persistance, alors que la baisse du PIB réel se produit plus rapidement pour atteindre un maximum après huit trimestres. Eu égard au point d'estimation, une hausse temporaire de 35 points de base du taux d'intérêt nominal de court terme engendre une baisse du PIB réel de 0,45% après deux ans et une baisse de l'IPC de 0,16% après trois ans. Concernant les autres variables domestiques, le crédit au secteur privé commence à baisser à partir d'un an pour atteindre un creux de 0,90% environ dix trimestres après le choc, tandis que le prix de l'immobilier résidentiel entame une baisse graduelle dès la première année pour atteindre un maximum d'environ 0,90% après quatorze trimestres (0,70% après deux ans).

Graphique 1
Les fonctions de réponse impulsionnelles associées à un choc de taux d'intérêt



Ces résultats suggèrent globalement que la transmission des chocs de taux d'intérêt à l'économie luxembourgeoise est relativement importante. En comparaison avec les résultats obtenus pour la zone euro, la baisse du PIB réel luxembourgeois intervient avec un décalage de trois à quatre trimestres, alors que dans le même temps, l'ampleur de la réaction est environ trois fois plus élevée. La structure à taux variable des crédits octroyés aux entreprises et aux ménages représente un premier facteur explicatif à ce résultat. En effet, cette particularité du système financier luxembourgeois implique que les changements de taux d'intérêt sur le marché monétaire se transmettent rapidement et de manière quasiment intégrale aux taux d'intérêt pratiqués par les banques commerciales, ce qui exerce en retour un impact substantiel sur l'activité économique. D'un côté, le coût des financements constitue un déterminant essentiel dans les décisions d'endettement et d'investissement (résidentiel) des emprunteurs, et de l'autre côté, les changements de taux d'intérêt se transmettent plus rapidement sur le coût du service de la dette et, par voie de conséquence, sur la trésorerie des entreprises et le revenu disponible des ménages, établissant ainsi un canal important à travers lequel les changements de taux d'intérêt affectent les décisions d'investissement et de consommation des agents économiques. Le degré élevé d'ouverture de l'économie et le rôle moteur des services financiers dans le processus de croissance représentent un deuxième facteur explicatif à ce résultat. En effet, dans le cadre du processus VAR estimé dans cette étude, l'impact du taux d'intérêt nominal de court terme sur le PIB réel luxembourgeois transite également par le biais du PIB réel et du prix des actions de la zone euro, indiquant par là que la transmission d'un choc de taux d'intérêt s'exerce également de manière indirecte, par le biais de son impact sur les variables étrangères présentes dans le modèle, tel que suggéré par les résultats présentés dans les graphiques 2 et 3.

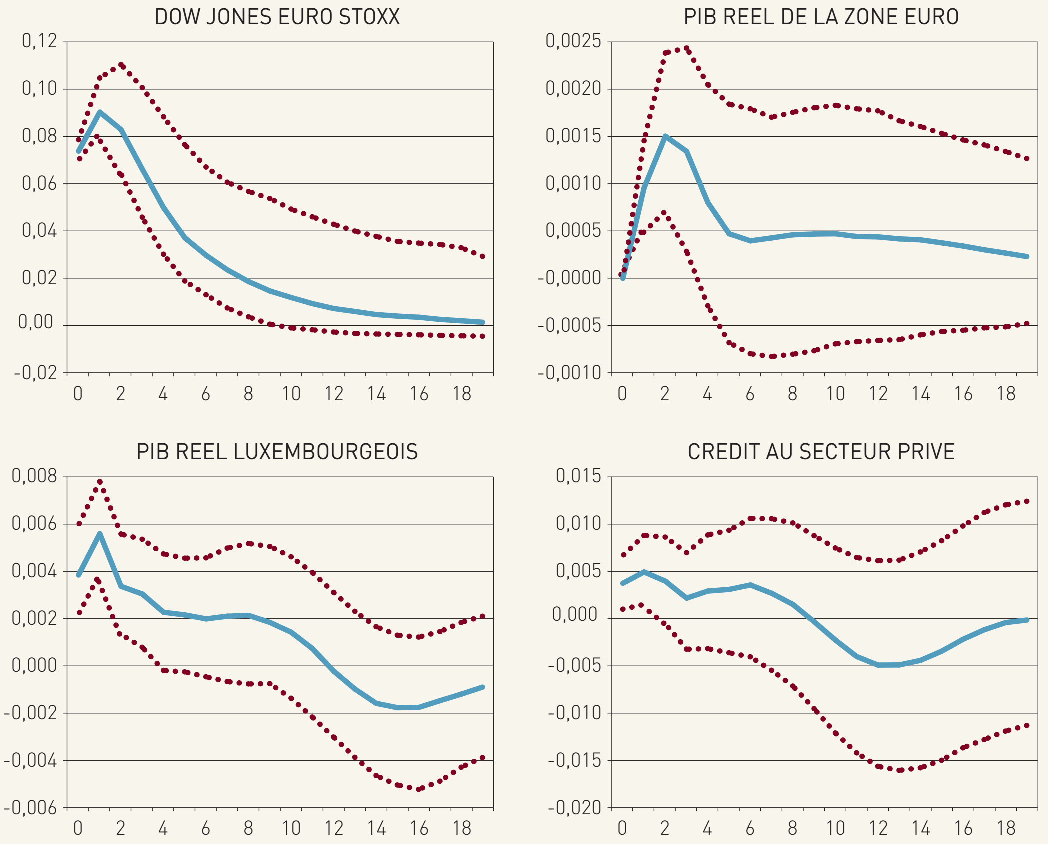
Graphique 2
Les fonctions de réponse impulsionnelles associées à un choc sur le PIB réel de la zone euro



Le graphique 2 indique que la réaction de l'activité économique au Luxembourg à la suite d'un choc sur le PIB réel de la zone euro (qui constitue une proxy de la demande étrangère) est significativement positive à moyen terme. L'impact maximal, qui est atteint après trois trimestres, est d'une ampleur similaire à la taille du choc initial, reflétant ainsi le degré d'ouverture élevé de l'économie luxembourgeoise vis-à-vis de la zone euro, près des ¾ des échanges externes du Grand-Duché étant en effet réalisés avec les pays membres de l'Union monétaire[2]. La réaction du crédit au secteur privé et du prix de l'immobilier résidentiel au Luxembourg consécutive à ce choc est également significativement positive, ce qui permet ainsi clairement d'identifier les chocs sur le PIB réel de la zone euro comme des chocs de demande agrégée.

2 Un résultat similaire est obtenu à partir du modèle du STATEC, Modux. Pour une présentation de la méthodologie utilisée pour parvenir à ce résultat, voir Adam (2007) "Cahier de variantes Modux", STATEC, Cahier économique No. 104.

Graphique 3
Les fonctions de réponse impulsionnelles associées à un choc sur l'indice du prix des actions européen



Le graphique 3 indique quant à lui que la réponse du PIB réel luxembourgeois à la suite d'un choc sur l'indice du prix des actions de la zone euro est quasiment instantanée et significativement positive pour la première année suivant le choc. Une hausse temporaire de 9% du Dow Jones EURO STOXX se traduit en effet par une hausse d'environ 0,6% du PIB réel luxembourgeois, ce qui représente un impact quatre fois plus important en comparaison avec la réaction du PIB réel de la zone euro[3]. Etant donné l'évolution structurelle de l'économie luxembourgeoise au cours de la dernière décennie, marquée par le développement substantiel de l'industrie des fonds d'investissement, cet effet pourrait même s'avérer encore davantage supérieur dans la seconde partie de l'échantillon. A noter en outre que la réaction du crédit consécutive à une innovation sur le prix des actions européen est également significative à très court terme pour atteindre un pic de 0,5% dans le trimestre suivant le choc.

Enfin, pour compléter cette analyse, la décomposition de la variance de l'erreur de prévision pour le PIB réel luxembourgeois est présentée dans le tableau 1 ci-contre, relatant ainsi les sources de fluctuations de l'économie luxembourgeoise sur différents horizons.

3 Adam (2007) prend en considération l'influence de l'indice du prix des actions européen sur l'économie luxembourgeoise dans le cadre d'une simulation basée sur une hausse de 1% du PIB de la zone euro. Une élasticité de 5,2 (2,6) entre le PIB de la zone euro et le Dow Jones Euro STOXX donne alors lieu à une hausse additionnelle du PIB luxembourgeois de 0,2% (0,1%) au cours de la première année et 0,3-0,4% (0,1-0,2%) au cours de la deuxième et de la troisième année.

Tableau 1 :
Décomposition de la variance de l'erreur de prévision du PIB réel luxembourgeois

Horizon trimestriel	PIB réel	variables domestiques	variables étrangères
1	90,2	0,79	9,01
4	62,8	1,93	35,3
8	44,2	4,22	51,6
12	34,3	6,13	59,6
20	27,8	6,10	66,1

Les fluctuations du PIB réel luxembourgeois dépendent, dans un premier temps, de leurs propres innovations (un résultat typique dans la littérature VAR), et, à partir de la deuxième année, des innovations sur les variables étrangères, les chocs externes devenant une source dominante de variabilité pour l'activité économique au Grand-Duché. Plus précisément, pour le 20ème trimestre, la variance de l'erreur de prévision du PIB luxembourgeois est due à 16,8% aux innovations sur le Dow Jones EURO STOXX index, à 27,7% aux innovations sur le taux d'intérêt nominal de court terme, et à 19,1% aux innovations sur le PIB réel de la zone euro.

4 CONCLUSION

Pour conclure, les résultats obtenus à partir du modèle VAR estimé dans le cadre de cette étude ont permis d'apporter un éclairage concernant l'influence des chocs externes sur les développements économiques au Luxembourg. Les faits stylisés qui ont été ainsi dégagés ont par ailleurs été analysés à la lumière des spécificités économiques et financières du Grand-Duché. Cet exercice, qui a permis de mettre en exergue la vulnérabilité de l'économie luxembourgeoise aux chocs extérieurs, devrait néanmoins faire l'objet d'un approfondissement dans un avenir proche. D'une part, il apparaît nécessaire de réestimer le modèle sur une période plus courte, étant donné les changements structurels que l'économie luxembourgeoise a connu au cours des deux dernières décennies, et d'autre part, l'utilisation de techniques plus récentes telles que le FAVAR (*Factor Augmented VAR*) semble davantage féconde puisqu'elle permettrait d'appréhender la transmission de ces chocs à travers un ensemble de variables économiques et financières beaucoup plus large.

7 COLLATERAL REQUIREMENTS AND THE MONETARY TRANSMISSION MECHANISM[1]

By
Paolo Fegatelli*

1 INTRODUCTION

Until 2008, central bank collateral eligibility criteria were mostly viewed as an administrative instrument used for operational purposes, whereas their implications for the monetary policy transmission mechanism and the working of the money market were considered irrelevant. However, these implications have become much more prominent after the rise of the recent financial crisis. As liquidity vanished in the money market, banks used and, according to some commentators, abused central bank funding with greater intensity, in order to cover their financing needs. As a result, collateral eligibility criteria have become an important driver of liquidity in the interbank market as well as a binding factor in the transmission of monetary policy.

After Lehman's collapse, one major problem related to central bank collateral requirements concerned their use for two potentially conflicting objectives: 1) the protection against the counterparty risk implicit in monetary policy operations (implying a microeconomic dimension), and 2) the transmission of the monetary policy input to the banking sector (implying a macroeconomic dimension). Achieving a balance between these two goals is at the heart of the current debate surrounding the choice of optimal collateral eligibility criteria. Indeed, the crisis has clearly shown that collateral availability might place significant constraints on banks' access to liquidity. Central banks became much more conscious of the importance of this issue during the turmoil: in 2008 the Fed (in March), followed by the Bank of England (in April), and finally the ECB (in October, after a U-turn decision) each adopted softer collateral policy stances.

2 A CORRECT FRAMEWORK TO MODEL THE IMPLEMENTATION OF MONETARY POLICY

In order to illustrate the role of collateral in monetary policy, and how such a role has evolved over the course of the crisis, we need to reconsider the monetary transmission mechanism. In fact, the traditional view of the channels through which monetary policy achieves its targets is overly simplified and generally inadequate in capturing the significance of the events which have taken place since the summer of 2007[2]. Moreover, in the traditional representation of monetary policy, collateral as a discriminatory factor for banks' access to funding, via central banks or interbank markets, does not play a role. This is in apparent contrast with what has been observed in reality over the last two years.

According to Disyatat (2008)[3], a properly specified model of the implementation of monetary policy should not interpret the amount of credit granted to the banking sector as a tool for interest rate setting. Indeed, the link between policy rate(s) and central bank balances is only indirect, while the mechanism used by central banks for implementing monetary policy is the opposite of what is usually assumed in neo-classical monetary theories[4]. In truth, this criticism is not new. In the academic debate on monetary policy, all the post-Keynesian schools start their analyses from this point, namely, from the assumption of an endogenous money supply function. The critical point here concerns the role of credit for the money supply formation. Post-Keynesian endogenous money theory emphasizes that the link between the financial and the real

1 This contribution is based on the BCL Working Paper No. 44 : "The role of collateral requirements in the crisis : one tool for two objectives ?", by P. Fegatelli (February 2010).

* BCL – Prudential Surveillance Department

2 E.g., 'unconventional' monetary policy measures are inexplicable on the basis of such models.

3 P. Disyatat, "Monetary policy implementation: Misconceptions and their consequences", BIS Working Paper, No. 269, December 2008.

4 Based on the observation of current central bank practice, Disyatat (2008) focuses on the link between key interest rate (the 'policy signal') and central bank balances as the result of using various 'instruments' (open market operations, standing facilities, reserve requirements, etc.).

sectors runs predominantly from credit to money to economic activity. The important feature is that credit is placed at the beginning of this sequence. This contrasts with conventional representations that place money first, as reflected in the typical money multiplier story in which bank deposits are said to create loans"[5].

The origins of the post-Keynesian endogenous money theory go back to Kaldor's (1970, 1982)[6] critique of monetarism. It is significant, however, that as early as 1959 the conclusions of the second Radcliffe Report[7] indicated that the velocity of circulation of money is unstable, so that a) central banks control interest rates, but have only a very indirect control of money aggregates, and b) overall, monetary policy has only a moderate effect on inflation, which depends on many other factors[8].

Given this theoretical background, the analysis developed here is based on the following representation of the monetary transmission mechanism.

a. As in Disyatat (2008), the central bank selects a 'policy signal' (to formally express the stance of monetary policy) by fixing a reference rate, or a system of reference rates; e.g., for the ECB the main reference rate is linked to a) the marginal lending facility rate (equal to the main reference rate *plus* a spread), and b) the marginal deposit facility (equal to the main reference rate *minus* a spread).

b. The reference rate(s) affects the whole system of multiple rates that are used by banks to a) lend to the rest of the economy (corporate borrowers, individuals etc.), and b) borrow/lend in the interbank sector (e.g. money-market, repo, security lending etc.). Such a system of multiple rates is critically related to the degree of reliance by banks on the lender of last resort, namely, the central bank.

c. Adrian and Shin (2008)[9] have shown that a major source of funding for banks is represented by the interbank market, in particular via repo trades. In normal times, the interbank short-term rates closely follow the pattern of the reference rate. This occurs because banks know that the supply of central bank funds is always sufficient to satisfy their demand, *at the reference rate*[10]. When this is not the case, however, tensions in the interbank market (e.g. due to an excess of demand for funds) determine an increased differential between money market rates and the policy rate (e.g. between the EONIA rate and the main reference rate of the ECB).

d. Thus, as Disyatat (2008) correctly affirms, open market operations are not used to set interest rates. Instead, *the main function of central bank's open market operations is to satisfy the banks' demand for liquidity, given a certain level of the reference rate, so to avoid any turbulence in the interbank market (by smoothing money market rate volatility).* In the words of Disyatat, "somewhat paradoxically, the ability to detect a liquidity effect [by monetary policy operations] is greater the less effective is the central bank's liquidity management" (p. 12).

5 T. Palley, "Endogenous money: implications for the money supply process, interest rates, and macroeconomics", P.E.R.I., University of Massachusetts Amherst, WP 178, August 2008, p. 2.

6 N. Kaldor: "The new monetarism", Lloyds Bank Review, 97, 1970, 1-17; and "The scourge of monetarism", Oxford University Press, 1982.

7 In May 1957 a committee chaired by Lord Radcliffe was set up in the U.K. to make recommendations to the government about the working of the British monetary and credit system.

8 M. Lavoie, "Money, Credit and Finance", Lecture at the Summer School on "Keynesian Macroeconomics and European Economic Policies" of the Research Network Macroeconomics and Macroeconomic Policies, Berlin, 28 July 2008.

9 T. Adrian and H. S. Shin, "Liquidity, Monetary Policy, and Financial Cycles", Current Issues in Economics and Finance, Vol. 14, No. 1, Federal Reserve Bank of New York, Jan./Feb. 2008.

10 This is not the same as saying that banks could borrow ***whatever amount*** from the central bank at the reference rate: rather, it means that individual banks' demand for central bank funds is relatively small, so that it can always be fully satisfied, in spite of the limits imposed to the overall supply of central bank balances.

Schematically, our model considers three markets:

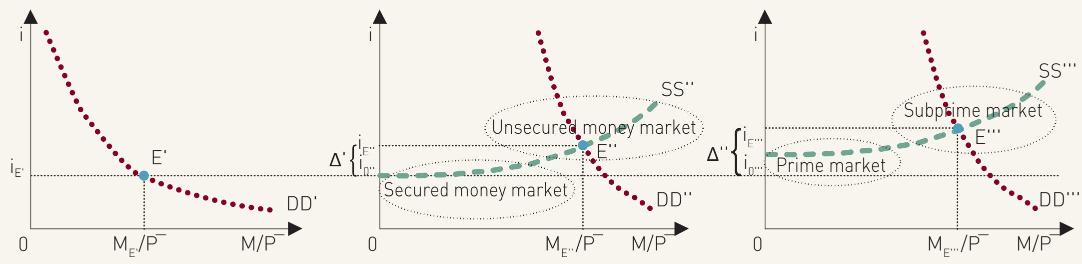
1. a market for central banks funds or balances;

2. a market for interbank funds (money market);

3. a market for bank lending to all the other non-bank sectors.

Figure 1 below describes their mutual relationships in terms of interest rate links and related spreads.

Figure 1
The relationship between the central bank fund market, the interbank market, and the bank lending market



The first figure on the left represents the market for central bank funds, which is where open market operations take place. This market is strictly linked to the money market (or interbank market), here represented in the middle. We can suppose that under normal market conditions the spread differential, Δ', between the rates of the two equilibrium points, E' and E'', is relatively stable (i.e. its volatility is low) and small. The third market, the one on the right side, is the bank lending market. We suppose that under normal conditions also the spread differential, Δ'', between the reference rate, E', and the subprime lending rate, E''', is relatively stable and not excessively large.

We assume that the transmission mechanism between the bank lending market and the previous two markets is given by the provision of money/credit. That is, banks finance their day-to-day changes to the provision of credit in the bank lending market via two alternative short-term funding channels: central bank funds and interbank (money market) funds. In this way, two further underlying assumptions are the following:

i. Banks are liable to a maturity mismatch between the average duration of their long-term assets in the bank lending market and the average duration of their short-term liabilities in the two funding markets;

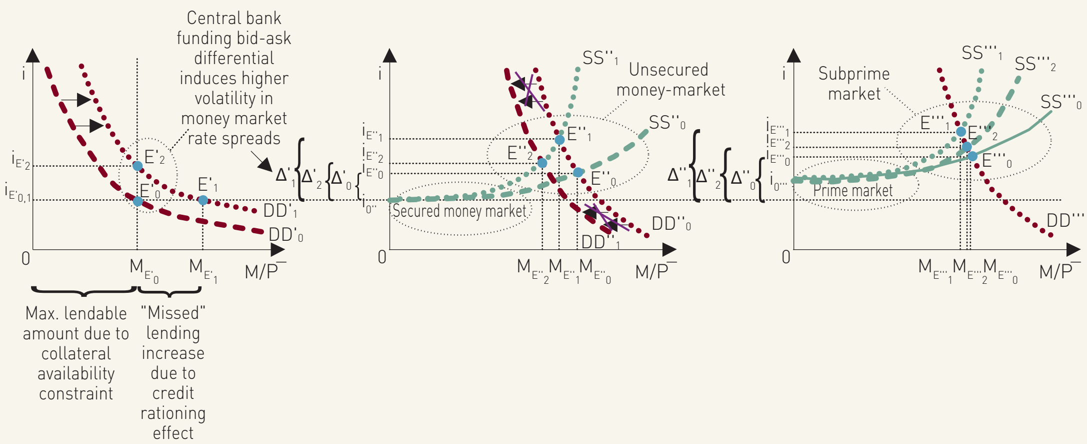
ii. Deposits are not considered as a viable source for banks to adjust the volume of their liabilities to the volume of their assets in the very short-term, given a certain level of deposit resiliency. This is because depositors do not suddenly move their funds from one bank to another, except under very special circumstances like a bank run.

As a consequence, taking deposits as fixed, in our scheme the quantity of money/credit supplied in the bank lending market, $M_{E'''}/\bar{P}$, is the sum of the quantities of money/credit collected in the previous two markets, $M_{E'}/\bar{P}$ and $M_{E''}/\bar{P}$. That is, we suppose that funds obtained from the central bank can substitute for funds achieved in the interbank market, and vice versa. As for point d) above, we assume that the main function of central bank open market operations is to ensure the effectiveness of the use of the reference rate as a monetary policy tool or, in other words, to ensure that the operational targets, Δ' and Δ'', have relatively low size and volatility. In fact, these two conditions are required for the central bank to pass its interest rate stimuli to the financial and real sectors in an effective way. In statistical terms, this means that even in the presence of a change of the policy rate, $i_{E'}$, the first two moments of the distributions of Δ' and Δ'' should remain relatively small and stable[11].

3 THE ROLE OF COLLATERAL ELIGIBILITY CRITERIA

This theoretical framework can be used to explain the rationale of the monetary and collateral policy measures taken by the ECB in the aftermath of Lehman's failure[12]. Among such measures[13], the enlargement of collateral eligibility criteria for monetary policy operations was probably a *condition sine qua non* to make the ECB's course of action really effective. Thus, to ensure that collateral did not constitute a constraint after the provision of unlimited liquidity through fixed rate tenders with full allotment, the first element of the measures announced on 15 October 2008 was a temporary expansion of the list of assets eligible as collateral[14]. The ECB has publicly acknowledged that this enlargement was a necessary condition to ensure the effectiveness of other monetary policy actions taken in the aftermath of Lehman's default[15]. Indeed, excessively binding collateral eligibility criteria could have represented a serious bottleneck vis-à-vis the central bank's attempt to pump considerable volumes of liquidity into the banking system in a very short time frame. Figure 2 below illustrates the reason.

Figure 2
Monetary policy effects of a collateral bottleneck



Following the ECB's introduction of the fixed rate procedure with full allotment, the adjustment of the equilibrium quantity from $M_{E'_0}$ to $M_{E'_1}$ in the central bank funding market helped to reduce the pressure in the interbank market by pushing the demand curve backward from DD''_0 to DD''_1. A new equilibrium in the interbank market was finally achieved at E''_2, given by the combination ($M_{E''_2}$, $i_{E''_2}$), this equilibrium corresponds to a level of the secured-unsecured lending spread, Δ'_2, which is still above the original spread,

11 Notice that in our model the macroeconomic effects of a change in the reference rate are not taken into consideration. Such effects are supposed to fully deploy over a period longer in comparison to the very short-term horizon assumed in our analysis.

12 Cf. Fegatelli (2010) for an extensive discussion.

13 For a summary of the measures included in the ECB's policy of 'enhanced credit support', cf. "The implementation of monetary policy since August 2007", in ECB Monthly Bulletin, July 2009, pp. 75-89.

14 For a detailed list of changes to the Eurosystem collateral framework, cf. European Central Bank, "EU banks' funding structures and policies", May 2009, p. 25.

15 ECB (July 2009).

Δ'_0, but much lower than the crisis level, Δ'_1[16]. This 'normalization' of the secured unsecured lending spread was achieved by the ECB at the cost of a further contraction of credit volumes in the interbank market: the shift from $M_{E''_1}$ to $M_{E''_2}$ in our model. That is, in the attempt of minimizing the impact of the financial crisis on the real sector, the Eurosystem's provision of refinancing has *de facto* largely substituted market-based borrowing in the interbank market, thereby crowding out further interbank activity in order to reduce money market spreads[17]. The prominent role of the Eurosystem as a major funding source for euro area credit institutions in Q4 2008 is clearly evidenced by both public and private sector data[18].

Consider the case of a monetary bottleneck, due to a limited endowment of collateral by borrowing banks. In the figure on the left (central bank funding market), we suppose that the collateral held by banks for central bank refinancing operations is just sufficient to cover an amount of borrowing equal to $M_{E'_0}$. This means that, in the presence of an incremental shift of the demand from DD'_0 to DD'_1, even with an unlimited provision of central bank refinancing through fixed rate tenders with full allotment, banks would never be able to borrow more than the quantity $M_{E'_0}$, due to the lack of proper collateral. Notice that, for $M_{E'_0}$, banks would be willing to pay, at the margin, a much higher interest rate, $i_{E'_2}$, than the fixed-rate offered by the central bank, $i_{E'_{0,1}}$. A typical case of credit rationing would follow, whereas the distribution of liquidity among individual banks would depend on their access to central bank refinancing. This, in turn, would depend on each bank's availability of proper collateral. The abnormal bid ask spread in the central bank fund market would immediately translate into a rising demand in the money market by those banks having limited or even no access at all to central bank refinancing; ultimately, this would entail a credit crunch for the real sector.

In graphical terms, this is visible in the second and third sections of Diagram 2. In the second section (interbank market), the demand curve would not shift to the left, from DD''_0 to DD''_1, in spite of the unlimited provision of central bank liquidity with full allotment. The disparity in the distribution of liquidity among banks would exacerbate money market spreads both in terms of average values (rising up to Δ'_1) and in terms of their dispersion across different transactions (volatility). *That is, the benign impact of central bank's unlimited provision of liquidity through fixed rate tenders with full allotment, would be, at the limit, completely impaired by excessively binding access conditions (due to a compelling collateral constraint) for certain banks*. Even worse, such banks might probably be the same ones needing liquidity most urgently, as the bad quality of their balance sheet and, in particular, of their asset (i.e. collateral) portfolio might have already prevented them from having recourse to other funding sources. These problems in the banking sector would finally pass to the real sector, as the money/credit supply curve would not recover from its acute-stress position, SS'''_1, in the right-hand chart (bank lending market), so that a credit crunch could not finally be averted.

As for the crowding-out effect mentioned above, our analysis implies that, in spite of the ECB's adoption of softer collateral criteria, the substitution of interbank funding with central bank funding does not leave banks indifferent in terms of collateral needs. In the unsecured money market, collateral requirements are zero: having to replace this funding source with central bank refinancing certainly exacerbates banks'"hunger" for central bank-eligible collateral. The ECB's outright purchases of covered bonds as an additional measure of enhanced credit support could then be interpreted as an effort to stimulate new issues in an asset class which provides an important source of collateral in the (interbank) repo market (Fegatelli (2010)).

16 See again ECB (July 2009) for data and charts supporting this view.

17 The existence of a crowding-out effect vis-à-vis the interbank market, linked to the central bank's direct provision of liquidity, is proved both theoretically (F. Heider, M. Hoerova, and C. Holthausen, "Liquidity hoarding and interbank market spreads: the role of counterparty risk", working paper, April 2009), and from an empirical point of view (C. Brunetti, M. di Filippo and J. H. Harris, "Effects of central bank intervention on the interbank market during the subprime crisis", working paper, June 2009).

18 ECB (July 2009), and Fegatelli (2010).

In conclusion, it is opportune to note the use that the ECB and other central banks have made of collateral eligibility criteria at the apex of the financial crisis. Indeed, central banks actions in this area have been driven primarily by concerns about monetary policy, besides financial stability. In the first instance, the ECB adopted wider collateral requirements with the main objective of ensuring the effectiveness of other, both conventional and unconventional, monetary policy actions. Thus, c*ollateral requirements were essentially used as an instrument of monetary policy, as a necessary condition to preserve the monetary policy transmission mechanism in the presence of a steep money/credit supply curve in the interbank market*. Notice that this factual role of collateral requirements as monetary policy enabler goes somewhat beyond their original nature of "administrative" tool to manage counterparty risk in monetary policy operations. A major implication is that, *ultimately, central bank's collateral eligibility criteria are at least as important as the short-term rate when we want to define the degree of ease of a given monetary policy*. This is true today, in the presence of a steep money/credit supply curve in the interbank market combined with a horizontal supply curve in the central bank funds market, but it was also true in the post-Keynesian world that came to an end in September 2008[19].

On the other hand, from a financial stability point of view, broader collateral eligibility criteria certainly contributed to facilitate the access to short-term credit and to alleviate the liquidity needs of those banks that were most struck by the turmoil, therefore lessening the risk of possible bank defaults with a potential impact also in terms of systemic risk. It was a fortunate occurrence that, in the harsh contingency of October 2008, both monetary policy and financial stability were required to maneuver the collateral requirements tool into the same direction.

4 CONCLUSIONS

In terms of policy recommendations, this analysis proves that *in a neoclassical framework (i.e. with a steep interbank money/credit supply curve), broader collateral eligibility criteria may be necessary for a more expansive monetary policy. Depending on the banks' effective endowment of collateral assets, collateral requirements may then be crucial for a smooth working of the monetary transmission mechanism, as their correct configuration may be a necessary condition for the efficacy of a lower policy rate*. Likewise, there may exist some binding constraints on the ECB's ability to "choose the way in which interest rate action could be combined with the unwinding of the non-standard measures"[20] more specifically, with the re-tightening of collateral requirements. Indeed, *from a monetary policy perspective, unwinding the current collateral policy measures should require the occurrence of at least one of the three following preconditions (compared to the situation at the end of 2008)*: i) *a recovery of the unsecured money market, thanks to a less steep interbank money/credit supply curve;* ii) *a broadening of banks' endowment of collateral for secured central bank and/or interbank borrowing;* iii) *a widening of the standing facilities rates corridor – to stimulate the interbank money/credit supply – and/or a rise in the policy rate*, thereby reversing the analogous actions taken by the ECB in October 2008.

Nonetheless, from a financial stability point of view, central banks should consider that a relaxation of collateral eligibility criteria always implies a sacrifice of the major *raison d'être* of collateral in monetary policy operations: to protect the central bank against the default risk of its counterparties. *This sacrifice might be the lesser evil in times of crisis, but in the long term, it is certainly questionable from many points of view:* in primis, *because a higher risk profile may compromise the consistency of the monetary policy target as well as the same central bank financial independence;* in secundis, *because it may push the central bank outside its legal mandate (besides being morally unacceptable and politically inopportune);* in tertiis, *because it may raise moral hazard issues in terms of bank managers' behavior, without really solving banks' most structural problems.*

19 …namely, in the presence of an endogenous (nearly-flat) money/credit supply curve in the interbank market. Again, cf. Fegatelli (2010) for a discussion.

20 J.-C. Trichet, "The ECB's exit strategy", Speech at the CFS conference "The ECB and Its Watchers XI", Frankfurt am Main, 4 September 2009.

From a long-term perspective, central banks should consider the possible use of their collateral eligibility criteria as a countercyclical instrument, either by lending against a broader range of assets (provided that they are effectively able to properly estimate and 'charge' the risks incurred by accepting lower-quality assets), or by adopting 'cycle-neutral' haircuts, or – *in fine* – by using haircut changes as a tool to target asset price bubbles. Central banks should also take into account that their collateral requirements tend to influence collateral eligibility criteria in secured money-market trades and, down the trade processing chain, in clearing and settlement systems[21]. As a consequence, another major issue arises when such criteria are softened: central banks should ponder not only the counterparty risk they directly take on, but also the higher level of systemic risk likely endorsed in such circumstances by central counterparties and securities settlement systems. Due to a lower buffer in terms of protection and recovery against counterparty risk when collateral requirements are more relaxed, during these periods it becomes, therefore, even more important to strengthen the oversight activities aimed at an early detection of potential credit and liquidity problems in market infrastructures.

21 Indeed, even the business growth of infrastructures offering added-value services to the interbank market, like the 'international central securities depositories', might have been, in someway, affected by the impact of the ECB's collateral eligibility criteria on the secured money market standards (Fegatelli, 2010).