EVALUATING ILLIQUIDITY AND SYSTEMIC CONTAGION IN SOUTH AFRICAN BANKS

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Abstract

A stress-testing model to evaluate liquidity and systemic risk in banks of developed and emerging economies has been assembled and tested. The Liquidity Stress Tester model (LST) was applied to Dutch and UK markets during crisis and non-crisis periods in previous research – here it is applied to South African banks. The flexibility and adaptability of the LST allows different banking systems and reactions of system participants to be evaluated comprehensively. Feedback effects arising from bank reactions to severely stressed haircuts and increases in systemic risk caused by reputation degradation are considered, as is the effect of enhanced contagion from other banks.

Keywords

Liquidity risk, systemic risk, contagion, buffers, bank, Liquidity Stress Tester, South Africa

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1. INTRODUCTION

Liquidity in financial markets diminished significantly before the 2008/9 financial crisis (van den End, 2009). In 2009, this dearth of liquidity was replaced by a severe credit crisis, which is still on-going (2014) albeit with much-reduced severity – although several countries, including Cyprus and Greece and much of the Eurozone, remain in severe financial distress. Cyprus was only recently (March 2013) granted a bailout of €15 billion, provided by the European Union (EU), European Central Bank (ECB) and the International Monetary Fund (IMF) albeit attached to certain austerity measures (Inman, 2013) and Greece continues (2014) to suffer the effects of a five-year-long recession and an economic contraction of 4.2% forecast for 2013 (Avent, 2012). These events were preceded by a period (2003–2008) in which the destructive ability of liquidity and systemic risk was profoundly underestimated (Van den End, 2009). The different dimensions of liquidity risk complicate quantification and contribute to this underestimation and the absence of effective liquidity risk management. The non-volatile pre-crisis period (early 2000s to 2007) – labelled as the most significant boom since post-World War II – set in motion the most severe financial crisis since the Great Depression of the 1930s (Kirkland, 2007). Events leading up to the crisis such as low interest rates and the relaxation of credit standards all slowly formed part of the economic boom prior to the crisis (FCIC, 2011). This saw most banks retain sufficient buffers relative to their set regulatory capital requirements. Financial markets were considered healthy with thriving liquidity flows and low risk premia (Borio, 2009).

Traditional ways through which banks expose themselves to liquidity risk are the interbank market and major deposit withdrawals also known as bank runs (Van den End, 2009). Although these exposures can severely punish banks thought to be illiquid, the crisis revealed how contagion through asset price changes can damage a bank's liquidity position (Adrian & Shin, 2008). Contagion would not only effect individual institutions, but would lead to a significant downward spiral of asset prices through fire sales of assets affecting all market participants (Alessandri et al., 2008). This process of market paralysation caused by a financial crisis might occur through several rounds. These rounds of a liquidity event may not be easy to quantify as data regarding these rounds and the reactions to them are scarce (Van Vuuren, 2011).

Since the crisis, several regulatory authorities and central banks have encouraged the stress testing of entire financial systems in terms of liquidity, as banks' stress-testing practices prior to the crisis did not effectively incorporate liquidity risk scenarios (FCIC, 2011). Stress testing liquidity risk across an entire financial system allows for the assessment of effects arising from liquidity stress events through multiple rounds which may affect a financial system. It would also contribute to assessing and comprehending the ability and danger of systemic risk spreading through liquidity risk.

The article proceeds as follows: section 2 presents the literature on liquidity risk models used in previous research. Section 3 describes the construction of the LST followed by a data description and calibration of the LST in Section 4. Section 5 presents and discusses the results estimated for both economies for both non-crisis and crisis periods and section 6 concludes.

2. LITERATURE SURVEY

The Basel Committee on Banking Supervision (BCBS), recognising the urgent need for coherent liquidity risk measurements, standards and monitoring, expressed its concern at the lack of attention and low priority assigned to liquidity risk in the years preceding the crisis (BCBS, 2010). However, liquidity risk and its ability to affect financial markets and their participants has received much-deserved attention in the early part of the 21st century, especially since the onset of the financial crisis of 2008/9 (Van Vuuren, 2011).

The ability of liquidity risk to affect the market and funding liquidity within financial markets and its participants was underestimated prior to the crisis. Market liquidity is defined as the ease of trading financial instruments at short notice with little effect on their underlying prices, something that became impossible in the crisis period. Funding liquidity is defined as the ability to raise cash or cash equivalents through the selling or borrowing of assets. This also became increasingly difficult, as participants were reluctant to participate in markets, which exacerbated the funding liquidity problem. The significant strain on these forms of liquidity gave rise to a financial crisis, defined as the sudden and prolonged evaporation of both market and funding liquidity (Brunnermeier & Pederson, 2009).

The relationship between market and funding liquidity has been explored by Brunnermeier and Pederson (2009). When funding liquidity is tight, market liquidity will also be pressured as traders provide liquidity to markets. If markets are not frictionless, asset prices will decrease, forcing banks to post higher margins, which increases their liquidity outflows. In order to remain liquid banks would be forced to further sell assets, further reducing funding liquidity (Brunnermeier & Pederson, 2009; Drehmann & Nikolaou, 2009).

Although a significant portion of research regarding liquidity and systemic risk focuses on the failure of single institutions, there are several studies on the stress testing of entire financial sectors (Upper, 2006). These studies include those of Avesani et al. (2006) and Basurto and Padilla (2006), which use market-based information to assess entire sectors via stress testing.

Aikman et al. (2008), by means of a Risk Assessment Model for Systemic Institutions (RAMSI), explore the effect of liability-side feedbacks on liquidity and systemic risk. The RAMSI model employed depends on balance information gleaned from UK banks and encompasses macro-credit risk, interest and non-interest income risk, network interactions and feedback effects, among other factors (Aikman et al*.,* 2008).

Further work focusing on the liabilities of banks and how liquidity shortages may arise from these liabilities includes that of Allen and Gale (2000) and Freixas et al. (2000). Liquidity shortages stemming from a bank's liabilities may be due to runs on deposits, but also panic withdrawals of interbank deposits, with the latter being the primary focus of Freixas et al. (2000).

The development of financial markets globally has increased demand for funding liquidity, and market-based systems have become increasingly funding liquidity thirsty (Borio, 2003). A liquidity crisis affecting liquidity thirsty financial systems can create significant feedback effects between funding liquidity, market liquidity and counterparty risk (Borio, 2009). Counterparty risk stemming from transaction withdrawals, funding and credit line cuts as well as increased haircuts and margins has the ability to trigger or amplify the initial effect of a liquidity crisis (Borio, 2009). These amplified effects may include the fire sales of instruments, further depleting market liquidity, and ultimately strangling funding liquidity supplies. Both forms of liquidity have the ability to vanish from financial systems and there is no set of rules indicating which should evaporate first, although market liquidity is usually the first to disappear (Borio, 2003). The crisis of 2008/9 is proof of how market liquidity can evaporate, ultimately leaving financial institutions scrambling for both forms of liquidity (FSF, 2008).

Liquidity crises which result in the evaporation of both funding and market liquidity are not unforeseen, sudden events, but rather the consequence of extended periods of risk taking and overextending balance sheets (Borio, 2003). These pre-crisis periods are characterised by buoyant asset prices, considerable leverage growths, low risk premia and low volatilities (Borio, 2009). These characteristics were also present in the period preceding the financial crisis of 2008.

The effects of liquidity crises may be mitigated or avoided through the use of buffers. Actual liquidity buffers may be employed, or capital adequacy standards may be increased. Increasing capital adequacy standards reduces liquidity risk due to the important role played by counterparty risk in liquidity risk. A report published by the BCBS addresses deficiencies in market practices of liquidity risk management (BCBS, 2010). Deficiencies identified include the inadequate treatment of individual products or business lines as well as the underestimation of funding requirements, albeit contractual or not associated with contingent obligations.

Markose et al. (2010) asserted that the root of the credit crisis stemmed from defaults on subprime loans, and the depth and duration of this crisis were due to bank contagion. Securitisation significantly contributed to bank contagion during the financial crisis, as securitisation spread exposures throughout financial systems in the pre-crisis period. This contagion had to be significant, as the subprime mortgage market was small compared to the entire financial system.

Understanding the contagion of the crisis period and how the relatively small size of the subprime mortgage markets created such a significant effect in the global financial system requires a grasp of the concept of contagion through asset price changes. Contagion spreading through price changes can significantly amplify the initial effects of a liquidity event, and defaults are necessary to induce contagion (Adrian & Shin, 2008).

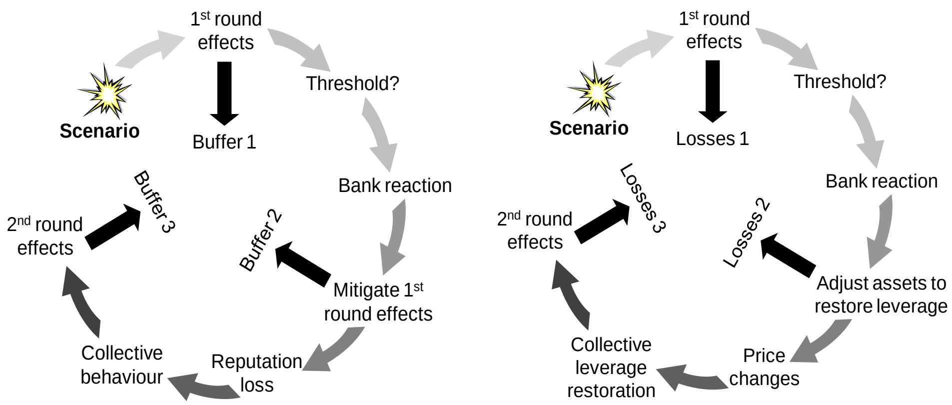
Van den End (2009) extended Brunnermeier and Pedersen's study (2009) and explored the role of banks in financial systems regarding the transmission and amplification of shocks. The role liquidity risk can play in interactions and contagion between banks in the interbank markets was also explored through a Liquidity Stress Tester (LST) model. The LST uses real data, while simulations account for the first- and second-round effects of a liquidity stress event, as well as mitigating actions by banks to first-round effects. This article reconstructs the LST and calibrates it to estimate possible liquidity buffer losses for both the emerging South African economy as well as the developed UK economy. The model is also adjusted to observe the effects of increased haircuts on balance sheet items as well as increased market stress.

3. MODEL CONSTRUCTION

The original LST developed by Van den End (2009) and employed by Van Vuuren (2011) applies Monte Carlo simulations of univariate shocks to several market and funding liquidity risk factors. The LST combines these factors into multi-factor scenarios illustrating the possible combined effects on the liquidity in a financial system. The LST estimates the effects of a liquidity event across three stages, with the first being the initial shock of an event. The first stage of the model is dependent on the haircuts and run-off rates of balance-sheet items used in the investigations. The weights attached to balance-sheet items are used in the industry and by rating agencies (Van den End, 2009; Van Vuuren, 2011).

It is assumed that banks affected by the initial shocks of a liquidity event react to these effects via mitigating actions if these effects exceed set reaction thresholds. The simulation of the mitigating actions, where reacting banks attempt to restore their liquidity buffers, is the second stage of the LST. Liquidity buffers comprise several balance-sheet items, which serve as provision for market and funding liquidity. These liquidity buffers can consists of securities which may be easily converted into cash or cash equivalents and eligible repo deposits at central banks. Furthermore, receivables from money market participants and available-on-demand interbank assets as well as central bank-eligible collateral can all form part of the liquidity buffers of banks. Losses stemming from the first-round effects in the LST are the haircut losses on balance-sheet items forming the liquidity buffer.

The third stage of the LST constitutes the simulation of second-round contagion effects stemming from the collective reactions of banks in the financial system. The reactions by institutions to initial effects of a liquidity event may induce severe effects on markets as increased haircuts on liquid assets and withdrawals of liquid liabilities take their effect on the liquidity positions of financial institutions. The effects of mitigating actions are positively correlated with the number of reacting banks and similarity of reactions by banks (Van den End, 2009). The whole process of the LST is illustrated in Figures 1 and 2, with the former using buffer restoration and the latter leverage targeting as mitigating actions. Note that leverage targeting as a mitigating action entails the restoration of the leverage ratio regardless of falling asset prices. The domino model of financial contagion assumes that the balance sheets of banks are affected only by defaults and not price changes, as assets are fixed at their book values.



FIGURES 1 (left) and 2 (right): Illustrations showing the cycle of a liquidity event and stages where liquidity buffers may be affected. Buffer restoration and leverage targeting used as mitigating actions respectively

Source: Adapted from Van Vuuren (2011)

The LST generates distributions of possible liquidity buffer losses at each stage of a liquidity event, with these distributions including tail outcomes and liquidity shortfall probabilities. Similar to Van Vuuren (2011) this article generates and displays possible losses of the liquidity buffer and not the remaining liquidity buffer. The original article of Van den End (2009) provides a full description of how the LST is constructed and calibrated for use with comprehensive data.

4. DATA AND MODEL CALIBRATION

The model is calibrated using data gleaned directly from the balance sheets of South African and UK banks. This data includes the appropriate haircuts and withdrawal rates for all relevant balance-sheet items used. The liquidity thresholds used in the LST for both economies were gathered from the UK and South African marketplaces respectively.

4.1 Liquidity horizon

This article allows for investigation using data limited to a one-month liquidity horizon only. This is due to the lack of data regarding the haircuts and run-off rates on balance-sheet items for investigations with extended liquidity horizons. Although banks usually allow for one- or two-month liquidity horizons, the flexibility of the LST allows it to investigate data for several liquidity horizons. However, the lack of data regarding haircuts on balance sheet items for extended time horizons limits investigation. The potential impact of a liquidity crisis can be underestimated with such short liquidity horizons, as losses might extend far beyond a one- or two-month liquidity horizon (FSF, 2008). The losses stemming from the credit crisis serve as evidence for this, and, if possible, work with extended liquidity horizons is encouraged.

4.2 Number and size of reacting banks

The LST results in this article are estimated using data from five principal South African and UK banks respectively. The specific banks used in the estimations are not explicitly disclosed. However, institutions used in the simulations form a significant part of the respective banking systems involved when assessing their market shares in their banking systems. Although the five banks in each economy form a significant part of their own banking systems, the South African banks used are significantly smaller than the UK banks, as is the South African banking system when compared to that of the UK. The diverse data used in this article emphasises the flexibility of the LST and its ability to assess different financial systems with regard to liquidity and systemic risk stemming from market and funding liquidity. Furthermore, the data provides banking system information in which one (UK) system hosts large banks labelled *too big to fail* as well as those banks considered significantly interconnected prior to the crisis period. The South African banking system, on the other hand, hosts smaller banks, which were not as interconnected prior to the crisis period. It is widely suggested that the South African economy did not suffer the effects of the financial crisis as severely as the UK economy and it further distinguishes the data used in the study (Moody's, 2011; Verster, 2012; The Banking Association South Africa (BASA), 2010).

A key characteristic distinguishing the two respective banking systems from each other is that the UK banking system hosts few independent banking institutions, as several were taken over through government intervention during the crisis period. All South African banks remain independent, i.e. they did not require government support and intervention during the crisis period.

Three important effects of liquidity risk are explored using the LST. These are the initial effects of a liquidity shock on the liquidity position of the banking systems of both developed and emerging economies; the reactions of institutions within these banking systems and the effectiveness of these reactions; and an illustration of how these collective reactions by banks can affect possible liquidity buffer losses through contagion stemming from the mitigating actions.

Van Vuuren (2011) addressed the possibility of sample selection bias by suggesting that the exclusion of smaller banks may amplify results, as sample selection bias would mean that only the most interconnected banks would be selected. However, for the purposes of the investigation it is more relevant to use the most interconnected banks, as results may shed light on the propensity for liquidity and systemic risks to cause contagion. This article however employs data from the five principal banks (according to market share) in the respective economies, regardless of their level of interconnectedness. This does not mean that the inclusion of other banks would not be insightful and may contribute to results. Further research may produce interesting results.

4.3 Indicators of market stress (s) and reputation ($\sqrt{s}$) and the adjustable haircut factor (f)

The market stress indicator, s, has a range derived using standardised, risk-aversion indicator distributions (namely the VIX index and corporate bond spreads). The range of s was and is determined in such a way as to represent normal (in the statistical sense) market conditions, namely, $-1 \leq s \leq +1$ (i.e. representing $\approx \frac{2}{3}$ of market conditions) and severe market stresses by $|s| \approx 3$ (i.e $\approx 0.05\%$ of adverse market situations).

The reputation effects the LST investigates are dependent on the stressed market conditions ($\boldsymbol{s}$) driving the second-round effects of a liquidity event. These reputation effects can be derived as $\sqrt{s}$, since the signals associated with the reactions of banks contribute to the feedback effects on banks. This is illustrated by the stigma attached to institutions accessing central bank funding facilities in times of stress (Van Vuuren, 2011).

The effects of increasing the market stress parameter and thus the reputation effects are investigated in this article. Values for these parameters are varied to estimate results for possible liquidity buffer losses in relatively stress-free markets to severely stressed markets. The values chosen for analytical purposes were relatively low, i.e. $|s| \approx 1$, hence $\sqrt{s} \approx 1$.

As with the Van den End (2009) and Van Vuuren (2011) studies, the VIX index was used as a proxy for the non-crisis period of 2005 and the crisis period of 2009. The market stress level used for simulations is varied between $1 < s < 3$. These values were more severe (with the benefit of hindsight) than values obtained for the original LST of Van den End (2009).

4.4 Thresholds

Two thresholds were used in the LST. The first is the reaction threshold defined by Van den End (2009). The second is the solvency threshold introduced by Van Vuuren (2011), which, if breached, indicates an institution's insolvency due to liquidity effects.

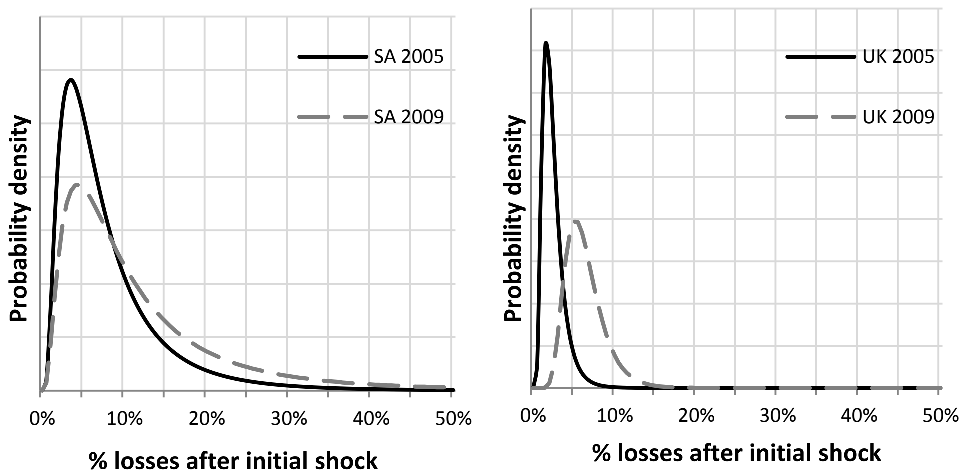
The reaction threshold defined by Van den End in the LST as θ indicates whether an institution would react to initial effects of a liquidity event given that initial losses exceed the derived reaction threshold. The reaction threshold is determined from the average correlation between balance-sheet item value changes and a one-month lagged liquidity buffer decrease. Reaction thresholds were calculated for the South African banking system at 12% for the non-crisis period and 3% for the crisis period respectively. For the UK banking system the reaction threshold in the non-crisis period of 2005 was calculated as 80%, while 2009 saw a significant decrease to 9%.

The solvency threshold depends on several factors, including the sensitivity of a financial system to liquidity shocks, research objectives and modeller input. For both the UK and South Africa in both the crisis and non-crisis periods, this value is 75%. This suggests that if the remainder of the liquidity buffer after the first-round effects is smaller than 75% of the original liquidity buffer, the bank would become insolvent. This threshold allows the modeller to investigate the sensitivity of specific institutions as well as the entire system to severe first-round effects of a liquidity stress event.

5. ANALYSIS

5.1 Initial effects of liquidity stress event (non-crisis and crisis period)

Reconstruction of the LST and calibrating it with non-crisis and crisis-period data for both economies delivers the results simulated for the initial effects of a liquidity event in FIGURES 3 and 4. These figures illustrate only the possible first-round effects of a liquidity event.



FIGURES 3 (left) and 4 (right): SA and UK buffer losses at original haircuts respectively

Source: Authors' analysis

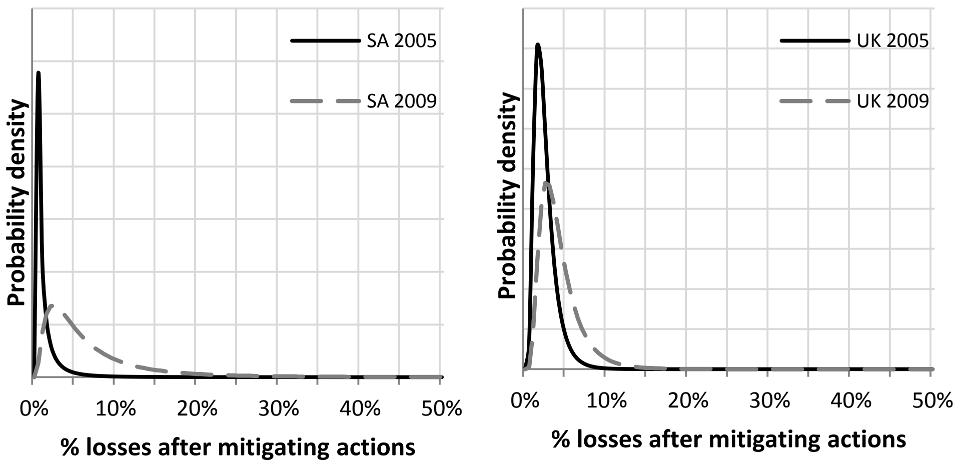
Both distributions in FIGURE 3 indicate that possible first-round losses could exceed 20% of the original liquidity buffer (i.e. the probability of this magnitude loss is > 5% in both cases) in the non-crisis and crisis periods in the South African banking system. Initial possible losses are not nearly as severe for the UK banking system; however, for both economies the possible losses during a crisis period would be most severe.

The distributions representing the crisis periods for both economies are flatter with longer tails, suggesting increased liquidity buffer losses in crisis periods. Several reasons can contribute to this effect, including that banks (which had already experienced the effects of the crisis) increased haircuts on balance-sheet items to compensate for the possibility of these losses realising and to fit their expectations for these items' performance in a stressed period. The South African banking sector haircuts were on average 4% and 6% in the non-crisis and crisis periods respectively. The UK banking sector haircuts were on average 1% and 4% in the non-crisis and crisis periods. This explains more severe initial effects in the crisis period, as the first stage of the LST is dependent on the haircuts linked to balance-sheet items. In the distribution representing the crisis period, losses would have been unavoidable in the UK banking system, as minimum losses start at approximately 2% of the liquidity buffer.

The South African economy would have been exposed to possible losses exceeding 30% of the liquidity buffer in both the non-crisis and crisis periods, while the UK economy would have been exposed to a maximum of only 15% losses of the original liquidity in the first stage. The second and third stages simulate mitigating actions by banks and subsequent second-round feedback to the initial effects of a liquidity event.

5.2 Mitigating actions and subsequent contagion to the initial effects of the liquidity events

This article investigates the effects of buffer restoration and leverage targeting as mitigating actions. FIGURES 5 and 6 show the effects of mitigating actions through buffer restoration within the emerging South African economy and the developed UK for both the non-crisis and crisis periods.



FIGURES 5 (left) and 6 (right): SA and UK losses after buffer restoration as a mitigating action

Source: Authors' analysis

Buffer restoration as a mitigating action is highly effective in restoring the liquidity buffer in the non-crisis period in the South African banking system. Possible liquidity buffer losses are reduced from 35% to approximately 5% through mitigating actions; however, these actions are not as effective in the crisis period of 2009. Although losses are reduced from above 40% to 20%, banks are still substantially more at risk in the crisis period. No mitigating actions occur in the UK banking system in the non-crisis period due to the significantly high reaction threshold of

80%. As possible losses do not exceed set reaction thresholds in the non-crisis period, mitigating action and contagion effects arising from these actions cannot be estimated. Possible losses illustrated for the non-crisis period are still only those of the initial shock simulated. The distribution representing the crisis period does, however, differ from that of representing the initial shock. This is due to possible losses exceeding the significantly lower reaction threshold. Through buffer restoration possible losses are slightly reduced as the mean of the distribution decreases; however, maximum losses remain approximately the same, as the tail of the distribution is almost unchanged.

The domino model of financial contagion assumes that the balance sheets of banks are affected only by defaults and are not due to price changes, as assets are fixed at their book values. However, Adrian and Shin (2008) contradict this by suggesting that these assumptions are unrealistic in modern financial markets and that price changes may be more effective than defaults in causing panic. Leverage targeting can thus be used as mitigating action in the LST when prices changes affect balance sheets and the original leverage ratio of a bank. FIGURES 7 and 8 illustrate the process of leverage targeting in both an economic boom and bust.

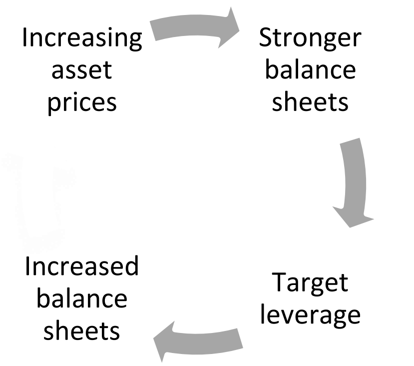


FIGURE 7: Leverage targeting during a financial boom

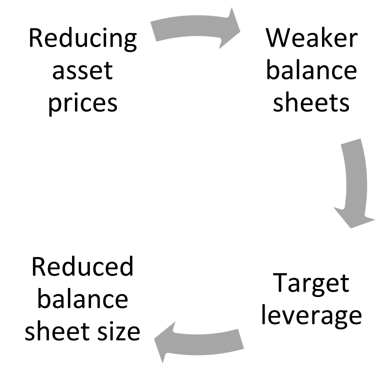


FIGURE 8: Leverage targeting during a financial bust

Source: *Authors' analysis*

FIGURES 7 and 8 illustrate how banks can effectively employ leverage targeting to actively manage their balance sheet and market exposures depending on the market situations. This form of mitigating action is introduced in the LST in FIGURE 2.

Using the balance sheet in TABLE 1 as an example to illustrate the process of leverage targeting, the institution holds 200 units of assets (assumed to be available-for-sale securities) funded by 180 units of debt and 20 units of equity. Leverage is the ratio of total assets to equity (Adrian & Shin, 2008):

$$\text{Leverage ratio } (L) = \frac{\text{Assets } (A)}{\text{Equity } (E)}$$

The leverage ratio throughout this example is thus:

TABLE 1: Balance sheet management through leverage targeting

Assets		*Liabilities*		*Leverage ratio*
Securities	200	Debt	180	10
		Equity	20	
2% Security price increase affecting leverage				
Securities	204	Debt	180	8.5
		Equity	24	
Leverage adjustment				
			216	10
			24	

Source: Authors' analysis

The original leverage ratio is estimated at L = 10. If there were an increase of example 2% in the value of securities, the leverage ratio would change to L = 8.5 as the value of securities increase but the value of debt remains constant. The balancing factor arises from equity. If the bank wishes to maintain an original leverage ratio of L = 10 more debt will have to be taken on and used to purchase additional securities to restore the leverage ratio. The additional debt is 36 units, used to purchase additional securities of 36 units. By doing this the leverage ratio is restored to L = 10.

This increase in security prices leads to increased holding of securities when leverage targeting is used as mitigating action and thus indicates upward-sloping demand curves and downward-sloping supply curves in the case of security price decreases (Adrian & Shin, 2008). Van Vuuren (2011) states that in order to use leverage targeting as a mitigating action in the LST, the assumption that banks have to restore their liquidity buffer back to the original level has to be relaxed. Instead an assumption that banks purchase additional assets (regardless of worsening prices) to restore their leverage ratio after the first round of a liquidity should be imposed.

Employing leverage targeting as a mitigating action produces similar results to that of buffer restoration. The initial shock of the liquidity stress event does not significantly affect institutional leverage ratios. TABLE 2 illustrates the effect of the initial shock on the leverage ratios of financial institutions in the non-crisis and crisis periods in the South African and UK banking systems.

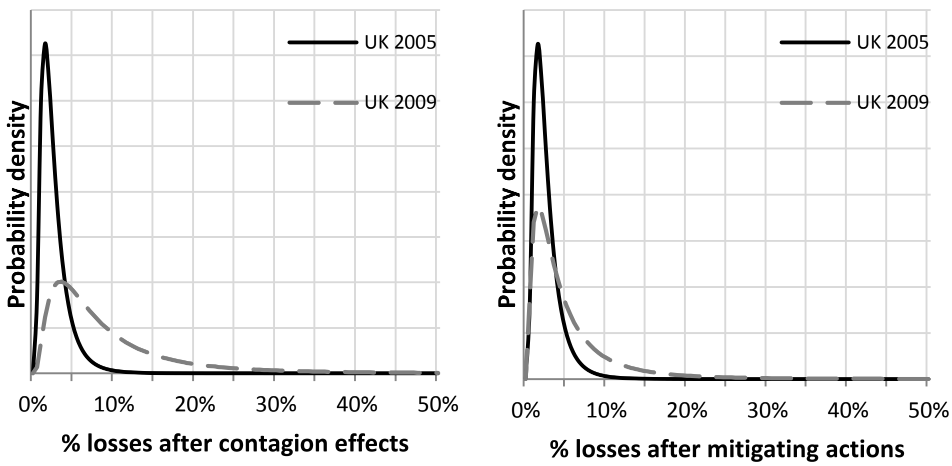
The leverage ratios are averaged for all institutions for both the non-crisis and crisis periods. In the SA system, the insignificant changes of leverage ratios cause the LST to produce similar distributions for possible losses when leverage targeting is used as a mitigating action. For the UK, leverage ratios are more severely affected by the initial shock of a liquidity event when compared to the emerging SA economy.

TABLE 2: Leverage ratios in SA and UK banking systems for leverage targeting

	South Africa		UK	
	Leverage targeting			
Leverage ratio	2005	2009	2005	2009
Original	16.10	16.78	24.35	21.36
After shock	15.61	15.09	23.27	18.38
Restored	16.10	16.78	24.35	21.36

Source: Authors' analysis

Leverage ratios are irrelevant for the non-crisis period, as no mitigating actions are simulated. As leverage ratios of UK banks are more severely affected by the initial shock of a liquidity event, the LST simulates a different loss distribution for leverage targeting as mitigating action as well as the feedback effects stemming from these actions in the crisis period. The effects of leverage targeting and subsequent contagion effects in the UK economy are shown in FIGURES 9 and 10.



FIGURES 9 (left) and 10 (right): UK buffer losses after leverage targeting as mitigating action and contagion effects stemming from these reactions respectively

Source: *Authors' analysis*

FIGURES 5 and 9 illustrate the respective effects of employing buffer restoration and leverage targeting as mitigating actions. Leverage targeting produces a loss distribution with a smaller mean but longer tail, increasing losses to exceed 20% of the liquidity buffer. Again, leverage targeting as mitigating action in the non-crisis period cannot be assessed, as reaction thresholds are not exceeded by first-round losses.

The third stage of the LST simulates contagion effects stemming from leverage targeting. The non-crisis period is irrelevant, as no contagion effects occur. Losses after contagion effects occurred are more severe compared to the first two stages of the LST (Van den End, 2009;

Nikolaou, 2009; Van Vuuren, 2011). Contagion effects for buffer restoration for both the South African and UK banking systems are shown in FIGURES 11 and 12.

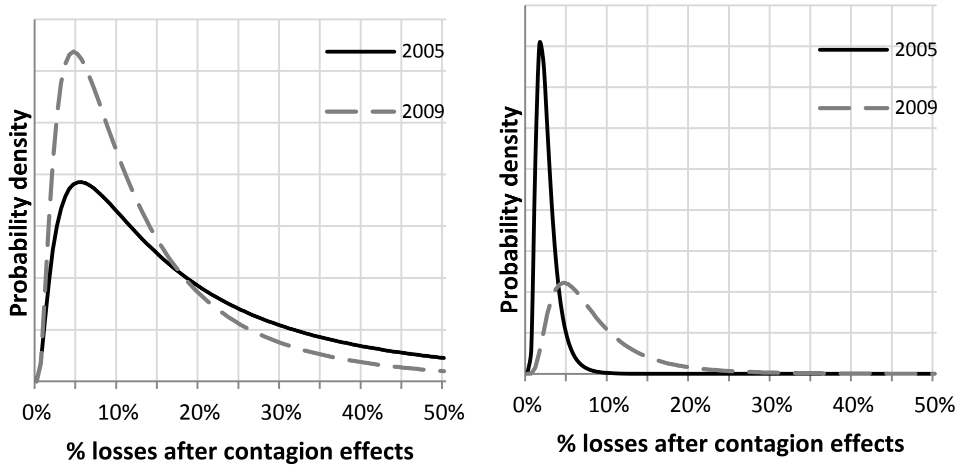


FIGURE 11 (left) and 12 (right): SA and UK buffer losses for buffer restoration models after contagion effects

Source: Authors' analysis

In the SA banking system losses after contagion comfortably exceed 50% of the original liquidity buffer for both the non-crisis and crisis periods and are most severe in the former. In the UK, 2005 losses are again only the initial effects; however, losses for the crisis period also exceed those of the initial shock and mitigating actions. This may be partly explained by the LST's third stage being dependent on reactions through mitigating actions. The significant mitigating actions in the SA non-crisis period may amplify contagion effects simulated in the third stage of the model. Loss statistics using original haircuts and market stress levels are given in TABLE 3.

TABLE 3: Loss statistics for original LSTs for both economies in both periods

Buffer restoration		*SA 2005*	*SA 2009*	*UK 2005*	*UK 2009*
Scenario	*Statistic*	*Loss (%)*			
Initial shock	Mean	5.65%	8.05%	2.07%	5.72%
	Mode	4.20%	6.00%	1.74%	5.20%
	95th percentile	17.58%	23.07%	5.53%	14.23%
	99th percentile	100%	100%	9.50%	21.65%
Buffer restoration	Mean	0.24%	5.79%	2.07%	4.61%
	Mode	0.05%	1.00%	1.74%	0.43%
	95th percentile	2.73%	11.79%	5.53%	8.34%
	99th percentile	100%	100%	9.50%	8.92%
2nd round losses	Mean	2.70%	6.47%	2.07%	4.71%

(feedback effects)	Mode	2.00%	5.00%	1.74%	5.20%
	95th percentile	22.99%	14.15%	5.53%	8.40%
	99th percentile	100%	100%	9.50%	8.96%

Leverage targeting

Scenario	*Statistic*		*Loss (%)*		
Leverage targeting	Mean	0.26%	5.76%	2.05%	4.61%
	Mode	0.06%	1%	2.12%	0.42%
	95th percentile	2.80%	11.81%	5.46%	8.33%
	99th percentile	100%	100%	8.85%	8.95%
2nd round losses (feedback effects)	Mean	2.72%	6.37%	2.05%	4.70%
	Mode	2.70%	5%	2.12%	0.50%
	95th percentile	22.05%	12.89%	5.46%	8.42%
	99th percentile	100%	100%	8.85%	9.00%

Source: Authors' analysis

Loss statistics for both economies show that initial liquidity-driven losses were more severe in the crisis. Identical loss statistics for all stages of the LST in the UK banking system in the non-crisis period confirm that no mitigating actions or contagion effects occur.

5.3 The effects of increased haircuts

As all three stages of the LST are interconnected, haircuts on balance-sheet items severely affect loss distributions for all model stages. The LST allows for the exploration of gradually increasing haircuts (f) to affect possible liquidity buffer losses. FIGURE 13 indicates liquidity buffer losses affected by increased haircuts in the SA economy pre-crisis.

The depth axis in FIGURE 13 illustrates how the haircuts on balance items are gradually increased to reach three times their original size. Possible losses illustrated are the effect of mitigating actions and contagion effects stemming from these actions after the onset of a liquidity event.

FIGURE 14 shows the loss distribution for South African banks during the crisis with buffer restoration used as mitigating action.

Again, the effect of increasing haircuts significantly flattens out the distribution and shifts it to the right, giving way to increased possible losses of the original liquidity buffer. This change in the distribution does not visibly look as drastic as that of the non-crisis period. This may possibly be due to South African banking system participants avoiding instruments linked to significant haircuts. Furthermore, there may be fewer of these instruments present in the balance sheet of banks due to the effects of the crisis and banks becoming more risk averse.

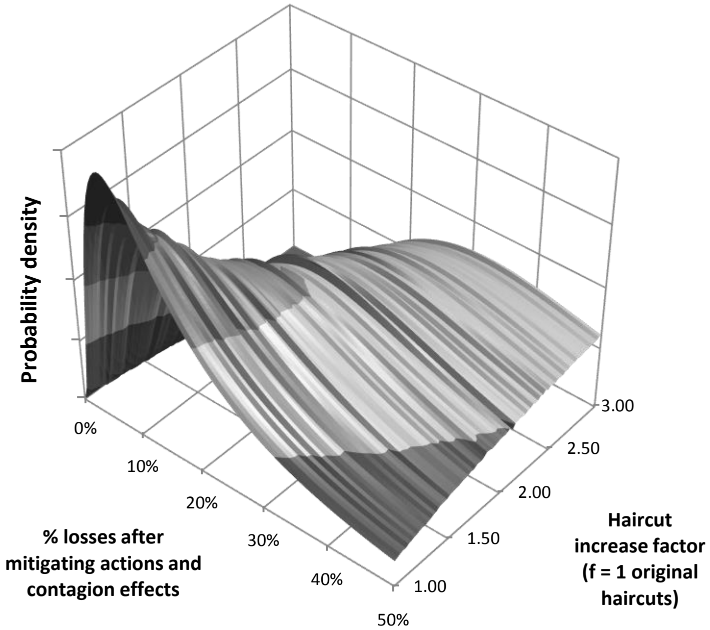


FIGURE 13: SA 2005, dependence of loss on haircut severity (buffer restoration)

Source: Authors' analysis

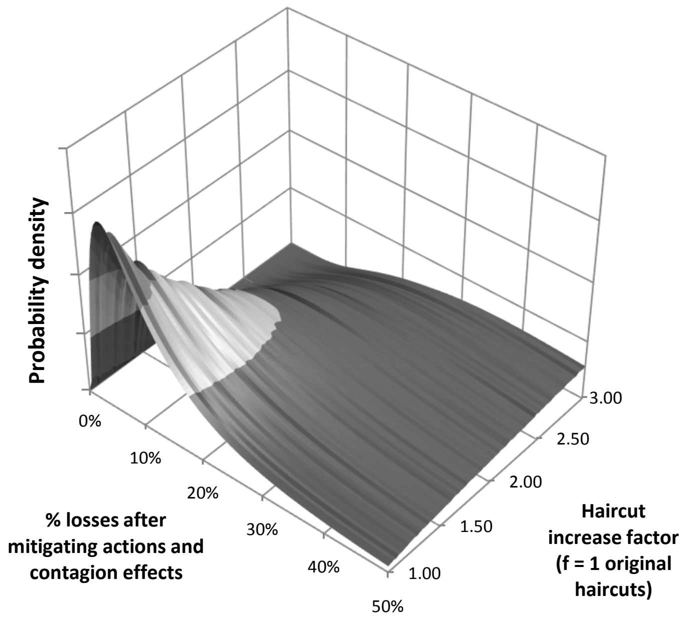


FIGURE 14: SA 2009, buffer restoration model output showing loss dependence on haircut severity

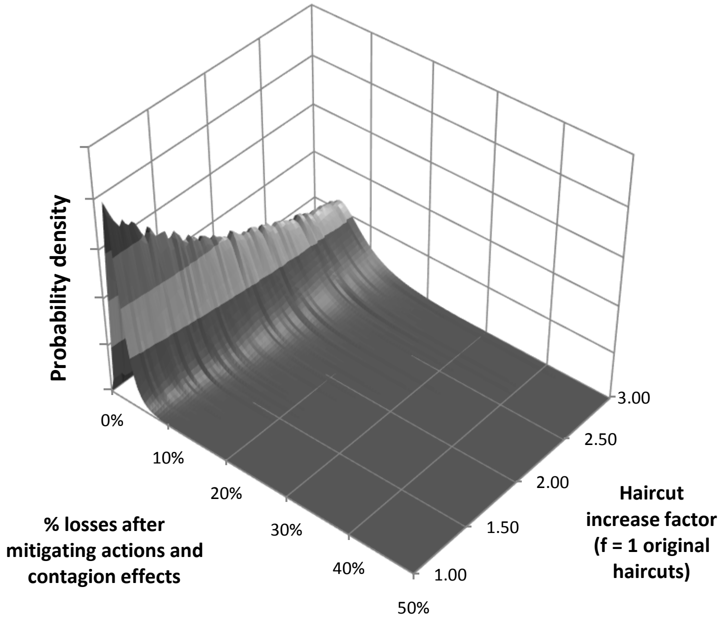


FIGURE 15: UK 2005, buffer restoration model illustrating haircut factors

Possible losses of the liquidity buffer stemming from the increased haircuts for the UK banking system in the non-crisis period are shown in FIGURE 15.

The loss distribution is dissimilar to the South African distribution for the non-crisis period: high reaction thresholds set by UK banks restrict the LST from estimating further phases of the liquidity event. This may have restricted banks from assessing market participation and contagion effects prior to the crisis. Liquidity buffer losses increase as haircuts on balance sheet items increase.

FIGURE 16 shows UK liquidity buffer losses from increased haircut factors in the crisis.

The loss probability distribution in Figure 16 is significantly different from that representing the non-crisis period in FIGURE 15. This is due to the significantly lower reaction thresholds set by UK banks, encouraging mitigating actions and the contagion effects stemming from these actions to occur. Similar to the South African crisis period, possible losses comfortably exceed 50% of the original liquidity at almost any level of set haircut factors.

Distributions in FIGURES 13 to 16 illustrate the severe effect haircut changes may have on possible losses of the original liquidity buffer throughout the LST. TABLE 4 illustrates losses for LSTs affected by increased haircut factors in both economies for both periods.

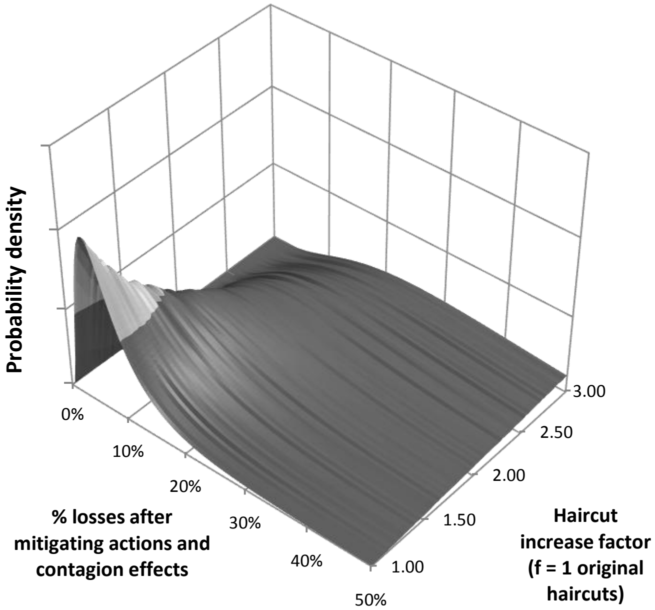


FIGURE 16: UK 2009, buffer restoration model illustrating haircut factors

Source: *Authors' analysis*

TABLE 4: Loss statistics for LST models affected by increased haircuts for both economies in both periods

Buffer restoration		*SA 2005*	*SA 2009*	*UK 2005*	*UK 2009*
Scenario	*Statistic*	*Loss (%)*			
Initial shock	Mean	11.72%	16.00%	4.04%	11.43%
	Mode	10.00%	10.00%	3.40%	8.00%
	95th percentile	100%	100%	10.81%	100%
	99th percentile	100%	100%	16.87%	100%
Buffer restoration	Mean	0.71%	6.97%	4.04%	1.57%
	Mode	0.00%	1.00%	3.40%	0.50%
	95th percentile	100%	100%	10.81%	100%
	99th percentile	100%	100%	16.87%	100%
2nd round losses (feedback effects)	Mean	36.44%	42.95%	4.04%	27.19%
	Mode	20.00%	10.00%	3.00%	8.00%
	95th percentile	100%	100%	10.81%	100%
	99th percentile	100%	100%	16.87%	100%

Leverage targeting

Scenario	Statistic	Loss (%)			
Leverage targeting	Mean	0.65%	5.82%	4.18%	1.43%
	Mode	0.00%	1.00%	2.95%	0.50%
	95th percentile	100%	100%	10.87%	100%
	99th percentile	100%	100%	17.66%	100%
2nd round losses (feedback effects)	Mean	34.90%	41.64%	4.18%	27.08%
	Mode	2.000%	10.00%	2.95%	8.00%
	95th percentile	100%	100%	10.87%	100%
	99th percentile	100%	100%	17.66%	100%

Source: Authors' analysis

Comparing loss statistics in TABLE 4 and TABLE 3 illustrates the effect of increased haircuts on all three stages of the LST. Loss statistics are significantly higher after the third stage of the LST, except for the UK banking system in the non-crisis period.

The effect of the market stress variable, which may also affect possible liquidity buffer losses in the third stage of the LST, is investigated in the following section.

5.4 The effects of enhanced contagion

The effects of increased contagion on possible liquidity buffer losses are explored through the market stress parameter (s), which also drives second-round effects. As reputation effects are dependent on the stressed market conditions they can be expressed as ($\sqrt{s}$). In this article s is gradually increased to explore the effects of increased market stress on liquidity buffer losses. A value of $s = 2$ represents stressed market conditions, so reputation effects are calculated as $\sqrt{s} = 1.41$. Van Vuuren (2011) suggests that although these values are more severe than those applied in the original LST by Van den End (2009) they may still underestimate the effects of the crisis experienced and estimates market stress to vary between $2.0 \leq s \leq 3.4$ when using a volatile period in the UK economy between September 2008 and March 2009.

The distributions presented in FIGURES 17 to 20 illustrate possible liquidity buffer losses for both economies involved for the non-crisis and crisis periods estimated varying the market stress factor between $1 < s < 3$, covering relatively calm markets to severely stressed markets. FIGURE 17 illustrates the effects of an increasing market stress factor on the loss probability distribution for the non-crisis period in the South African banking system.

An increased market stress variable in FIGURE 17 flattens the distribution, reducing the possibility of smaller buffer losses in the non-crisis period. This indicates the sensitivity of banks' balance sheets to market stress in this period, which might be caused by market exposure through risky assets present in their balance sheets and increased leverage exposure.

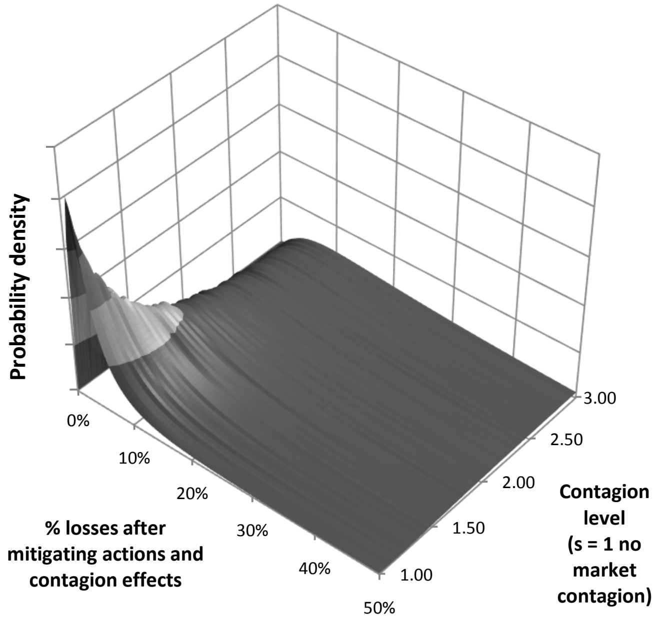


FIGURE 17: SA 2005, buffer restoration model output showing the dependence of loss probabilities on contagion level

Source: Authors' analysis

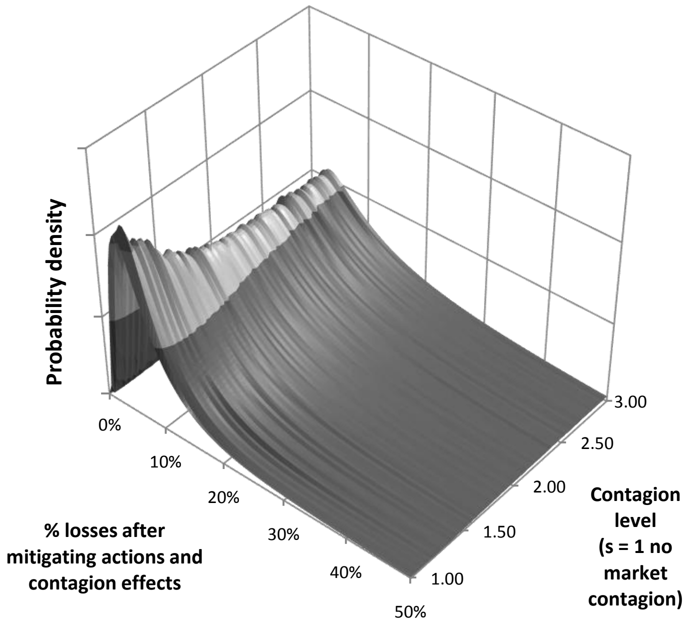


FIGURE 18: South African bank liquidity buffer losses affected by the crisis.

The loss probability distribution does not decrease as severely compared to the non-crisis period when effected by increased levels of market stress. It only flattens out slightly as market stress is gradually increased, with most possible loss distribution changes occurring between $1 < s < 2$. The less significant effects caused by market stress may be due to the balance sheet of banks being more risk averse in the crisis period or leverage being significantly reduced in unfavourable times, thus limiting their exposure to market conditions.

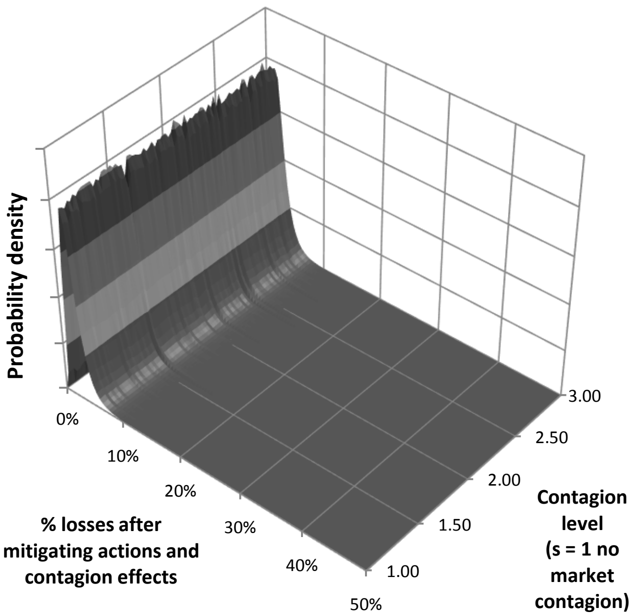


FIGURE 19: UK 2005, buffer restoration model illustrating contagion levels

Source: Authors' analysis

Losses for UK banks in the non-crisis period are unaffected by increased market stress: mitigating actions and contagion effects stemming from these actions were minimal. Losses illustrated are thus only the initial shock of the liquidity event, unaffected by contagion.

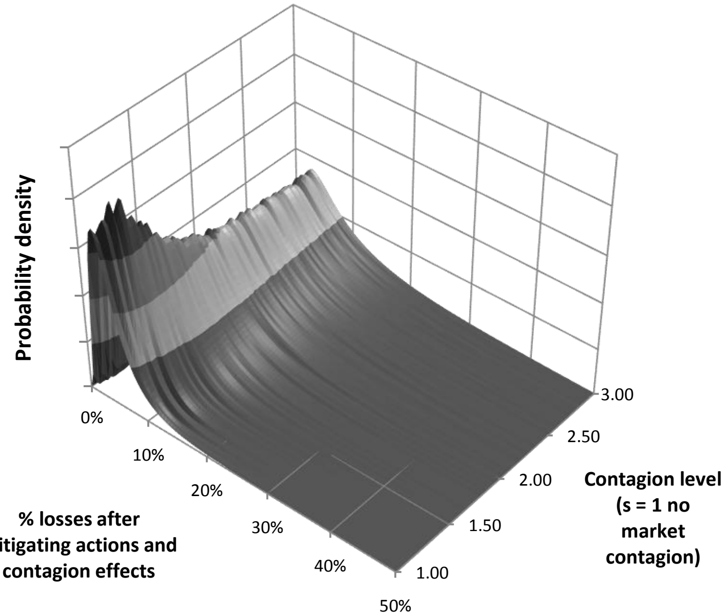


FIGURE 20: UK 2009, buffer restoration model output showing the dependence of loss probabilities on contagion level

Source: Authors' analysis

The lower reaction thresholds in the crisis period in the UK banking system allow for the loss distribution to be affected by contagion as the second and third stages of the LST are simulated. Figure 20 shows a flattening of the distribution and maximum losses increasing along with the level of market stress. Losses exceeding 50% of the liquidity buffer become likely as smaller losses become less likely. Loss statistics for all LSTs affected by increased levels of market stress are shown in TABLE 5.

TABLE 5: Loss statistics for increased market stress for both economies in both periods

Buffer restoration		*SA 2005*	*SA 2009*	*UK 2005*	*UK 2009*
Scenario	*Statistic*	*Loss (%)*			
Initial shock	Mean	5.81%	7.95%	2.06%	5.66%
	Mode	4.00%	6.00%	2.50%	4.10%
	95th percentile	18.79%	22%	5.58%	14.31%
	99th percentile	100%	100%	9.51%	23.78%
Buffer restoration	Mean	0.26%	5.87%	2.06%	4.58%
	Mode	0.05%	1.00%	2.50%	0.50%
	95th percentile	2.81%	11.45%	5.58%	8.23%

	99^{th} percentile	100%	100%	9.51%	8.94%
2^{nd} round losses (feedback effects)	Mean	18.03%	7.95%	2.06%	5.66%
	Mode	3.00%	6.00%	2.50%	4.10%
	95^{th} percentile	82.62%	61.82%	5.58%	32.43%
	99^{th} percentile	100%	100%	9.51%	49.13%

Leverage targeting

Scenario	Statistic	Loss (%)			
Leverage targeting	Mean	0.25%	5.99%	2.06%	4.56%
	Mode	0.05%	1%	2.08%	0.49%
	95^{th} percentile	2.77%	11.77%	5.39%	8.20%
	99^{th} percentile	100%	100%	9.30%	8.88%
2^{nd} round losses (feedback effects)	Mean	17.29%	7.86%	2.06%	5.66%
	Mode	2.00%	7%	2.08%	4.30%
	95^{th} percentile	81.79%	70.60%	5.39%	31.05%
	99^{th} percentile	100%	100%	9.30%	44.65%

Source: Authors' analysis

TABLE 5 illustrates how loss statistics significantly increase in the third stage of the LST. This is due to contagion affecting liquidity buffers only in the third stage of the LST.

6. CONCLUSIONS

Van den End (2009) suggested that the LST could be applied to any banking system and can be used by central banks to assess liquidity and systemic risk in the financial system. This article supports Van den End's assertion by simulating liquidity buffer losses for two different economies.

The LST provides a flexible tool to evaluate and compare the dangers of liquidity and systemic risk across financial systems. The model evaluates the impact of shocks to market and funding liquidity on banks. Parameters included in the LST seen as drivers of liquidity risk include: on- and off-balance-sheet contingencies, feedback effects induced by collective bank reactions and idiosyncratic reputation effects dependent on market stress levels. These are all adjustable to allow for the assessment of different scenarios. The LST assesses how collective bank reactions influence liquidity risk, market stress levels and the length of scenario horizons, all drivers of the financial crisis.

The flexibility of the LST is limited only by the requirement that data for liquid assets and liabilities be available at individual bank level. Other parameters used in the LST such as haircuts on balance sheet items, reaction thresholds to shocks and market stress factors can be tailored to fit the characteristics of the financial system investigated. The model's adaptability and flexibility is demonstrated by the fact that it has been applied to the Dutch banking system, twice to the UK banking system (different time periods) and now to the SA banking system. Results obtained from the LST may be used to support policy developments and initiatives attempting to enhance liquidity buffers and avoid reckless leverage activities.

Further research with the LST is encouraged, as it can significantly contribute to understanding the effect of several risk factors on the liquidity positions of banks and the research possibilities with the model are plentiful. Research with the US banking system may yield interesting results, as the US banking system was also considerably interconnected in the pre-crisis period (Markose et al., 2010).

LIST OF REFERENCES

Adrian, T. & Shin, H.S. (2008). *Liquidity and financial cycles. BIS working paper, No. 256.* [Online] Available: http://www.bis.org/publ/work256.pdf. (Accessed 22 March 2012).

Aikman, D., Alessandri, P., Eklund, B., Gai, P., Kapadia, S., Martin, E., Mora, N., Sterne, G. & Willison, M. (2008). *Funding liquidity risk in a quantitative model of systemic stability. Bank of England, Working Paper No. 372.* [Online] Available: http://www.bankofengland.co.uk/publications/workingpapers/wp372.pdf. (Accessed 23 March 2012).

Alessandri, P., Gai, P., Kapadia, S., Mora, N. & Puhr, C. (2008). *A framework for quantifying systemic stability.* Preliminary paper presented at the workshop Stress Testing of Credit Risk Portfolios, organised by the BCBS and DNB, Amsterdam, 7 Mar 2008.

Allen, F. & Gale, D.M. (2000). Financial Contagion. *Journal of Political Economy,* 108(1), pp. 1-33.

Avent, R. (2012). Greece, the skids. *The Economist*, 8 Nov [Online] Available: http://www.economist.com/blogs/freeexchange/2012/11/euro-crisis. (Accessed 7 March 2013).

Avesani, R., Pascual, A.G. & Li, J. (2006*). A new risk indicator and stress testing tool: A multi-factor nth-to-default CDS basket*. IMF Working Paper, No. [Online] Available: http://www.imf.org/external/pubs/ft/wp/2006/wp06105.pdf. (Accessed 22 March 2012).

Basurto, M.S. & Padilla, P. (2006). *Portfolio credit risk and macroeconomic shocks: Applications to stress testing under data-restricted environments*. IMF Working Paper, No.06/283. [Online] Available: www.imf.org/external/pubs/ft/wp/2006/wp06283.pdf. (Accessed 5 April 2012).

Basel Committee on Banking Supervision (BCBS), (2010). *Basel III: International framework for liquidity risk measurement, standards and monitoring*. [Online] Available: http://www.bis.org/publ/work188.pdf. (Accessed 12 March 2012).

Borio, C. (2003). *Market distress and vanishing liquidity: anatomy and policy options*. BIS Working Paper, No. 158. [Online] Available: http://www.bis.org/publ/work158.pdf. (Accessed 23 March 2012).

Borio, C. (2009). *Ten propositions about liquidity crises*. BIS Working Papers, No. 293. [Online] Available: http://www.bis.org/publ/work293.pdf. (Accessed 24 March 2012).

Brunnermeier, M.K. & Pedersen, L.H. (2009). Market liquidity and funding liquidity. *Review of Financial Studies,* 22(6), pp. 2201-2238.

Brunnermeier, M.K. (2009). Deciphering the liquidity and credit crunch 2007-2008. *Journal of Economic Perspectives,* 23(1), pp. 77-100.

Drehmann, M., & Nikolaou, K. (2009). *Funding liquidity risk definition and measurement.* ECB working papers, No. 1024, March. [Online] Available: https://www.ecb.de/pub/pdf/scpwps/ecbwp1024.pdf. (Accessed 3 April 2012).

Financial Crisis Inquiry Commission (FCIC), (2011). *The Financial Crisis Inquiry Report.* [Online] Available: http://www.gpo.gov/fdsys/pkg/GPO-FCIC/pdf/GPO-FCIC.pdf. (Accessed 2 December 2012).

Financial Stability Forum (FSF), (2008). Enhancing market and institutional resilience. *Report of the Financial Stability Forum.* [Online] Available: www.fsforum.org. (Accessed 13 November 2012).

Freixas, X., Parigi B.M. & Rochet, J.C. (2000). Systemic risk, interbank relations, and liquidity provision by the Central Bank. *Journal of Money, Credit and Banking,* 32(3), pp. 611-638.

Inman, P. (2013). IMF sets terms of Cyprus Bailout. *The Guardian,* 3 Apr 2013. [Online] Available: http//www.guardian.co.uk/business/2013/apr/03/imf-cyprus-bailout-terms. (Accessed 7 April 2013).

Kirkland, R. (2007). The greatest economic boom ever. *Fortune Global 500,* 12 Jul 2007. [Online] Available: http://money.cnn.com/magazines/fortune/fortune_archive/2007/07/23/100134937/index.htm?postversion=2007071209. (Accessed 14 April 2013).

Markose, S., Giansante, S., Gatkowski, M., & Shaghaghi, A.R. (2010). Too interconnected to fail: financial contagion and systemic risk in network model of CDS and other credit enhancement obligations of US banks. *Economics Discussion Papers No. 683, University of Essex, Department of Economics.*

Moody's Investor Service (2011). *The South African Market: Impact of the Crisis and the 2011-12 Prospects.* [Online] Available: http//www.moneyweb.co.za/mw/action/media/downloadfile?media_fileid=11276. (Accessed 15 January 2013).

Nikolaou, K. (2009). *Liquidity concepts, definitions and interactions.* (ECB Working Paper, No. 1008).

The Banking Association South Africa (BASA), (2010). *South African Banking Sector Overview.* [Online] Available: www.banking.org.za/getdoc/getdoc.aspx?docid=1130. (Accessed 15 January 2013).

Upper, C. (2006). Contagion due to interbank exposures: what do we know, why do we know it and what should we know? *Discussion Paper, Bank for International Settlements, Basel.* [Online] Available: http://qed.econ.queensu.ca/pub/faculty/milne/872/UpperSurvey_Interbank_-1.pdf. (Accessed 17 April 2012).

Van den End, J.W. (2009). Liquidity stress-tester: A model for stress-testing banks liquidity risk. *CESifo Economic Studies*, 56(1), pp. 38-69.

Van Vuuren, G.W. (2011). Modelling systemic liquidity risk with feedback effects in the UK banking sector. *Journal of Risk Management in Financial Institutions,* 5(1), pp. 36-59.

Verster, R. (2012). The Deloitte 2013 Banking Industry Outlook. *Deloitte.* [Online] Available: http://www.deloitte /assets/Dcom-SouthAfrica/Local%20Assets/Documents/Banking_industry_outlook_2013b.pdf. (Accessed 15 January 2013).