# How much capital does a bank need: A few points regarding the Basel accord

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**Abstract**

Basel framework for bank's capital adequacy has been criticized for its over reliance on external credit rating agencies [6]. Moreover, implementation of Minimum Capital Requirement (MCR) under Basel-III is often linked to a decrease in economic growth as it requires banks to maintain a higher capital base which raises their cost of fund [8]. In addition to these, here, we criticize the Basel accord for the capital requirement under this framework is not inspired by the essence of the basic accounting equation. Moreover, under Basel framework, capital requirement and liquidity parameters are discussed separately. Here, we argue that the capital requirement should arise as a by-product of the day to day liquidity management and hence both the requirements can be brought together under one umbrella which enables us to view the overall position of a bank from a more holistic point of view. Here, we attain all the above issues and provide a comprehensive framework regarding bank's capital adequacy and liquidity requirements which is claimed to settle all the aforementioned issues and reduces all the extensive paper works needed for the implementation of the Basel accord.

## 1 Introduction and History of the Basel Accord

Sudden collapse of Cologne-based Herstatt Bank in 1974 provoked the global community to formulate a set of rules regarding bank's capital adequacy. The quest for a voluntary regulatory framework regarding bank's capital adequacy resulted into the creation of the first Basel accord [1] which was prepared by the Basel Committee of Banking Supervision (BCBS) in Basel, Switzerland. Basel-I mainly focuses on credit risk ascribing different risk weights to different assets of a bank. The framework defines 5 (five) different risk weights for different categories of assets. Each asset's carrying value is multiplied by the corresponding risk weight in order to calculate total risk weighted assets of a bank.

The minimum capital required for a bank at any instance is defined to be 8% of its total risk weighted asset. However, apart from the credit risk, a bank may suffer from a comprehensive list of other risks e.g., market risk, operational risk, concentration risk, liquidity risk, strategic risk, settlement risk, reputation risk, residual risk, environmental risk etcetera which are not accounted for in the first Basel accord. The second Basel accord or Basel-II [2] comes into existence in 2006 which, in addition to credit risk, accounts for all the aforementioned risks. Apart from covering a comprehensive set of risks, Basel-II framework also circulates a disclosure requirement which enables market participants to look into the capital structure and capital adequacy of a bank more closely than before. However, the Basel-II framework has been proved to be inadequate during the 2007-2008 global financial crisis which culminated at the failure of some major global financial institutions. In response to it, the Basel Committee on Banking Supervision (BCBS) comes up with another set of rules namely, Basel-III regarding bank's capital adequacy, stress testing, liquidity and leverage requirement [3]. Aside from increasing Minimum Capital Requirement (MCR) for the bank, Basel-III accord introduces two new buffers namely, Capital Conservation Buffer and Counter Cyclical Buffer. Capital Conservation Buffer is supposed to be maintained at the rate of 2.5% of the total risk weighted asset of the bank while the counter cyclical buffer will act as a discretionary tool to combat business cycles by the regulatory authorities. Although, all the major economies are adopting Basel framework with a view to establishing a sound, resilient financial system, the Basel accord has recieved many criticisms. It has been criticized for its dependency on external credit rating of bank's investment clients. It is also said to impede economic growth by raising bank's capital requirement to an artificially higher base. Apart from these, here, we criticize the Basel accord as it can not be intuitively followed from the basic accounting equation. Moreover, the Basel accord tends to discuss bank's capital requirement and liquidity parameters from two distinct points of view. Under Basel framework, liquidity requirements and capital requirements evolve as two independent concepts and they can barely influence each other. Here, we criticize this view and make the link between the liquidity requirements and capital requirements in order to depict a more holistic picture of the bank's financial health. Here, we address all the above issues and provide a comprehensive risk management framework for the bank. The rest of the article is arranged as follows. Section: 2 describes the capital and liquidity requirements under the third Basel accord. Section: 3 provides the criticism of the Basel framework in greater detail. Section: 4 consolidates the capital requirement and liquidity requirement and provide our proposed framework to capture both capital requirement and liquidity parameters simultaneously. Section: 5, 6 and 7 extend the

framework in the presence of credit, market and operational risk. Section: 8 discusses Minimum Capital Requirement(MCR) of a bank in the presence of credit, market and operational risk. Finally, Section: 9 concludes the article.

# 2 Minimum Capital Requirement and Liquidity Parameters Under the Third Basel Accord

## 2.1 Minimum Capital Requirement

### 2.1.1 Capital Requirement for Credit Risk

Basel accord introduces the concept of Risk Weighted Assets (RWA) in relation to bank's capital. Under Basel framework, every asset in the balance sheet of a bank is assigned a specific risk weight depending upon the credit rating of the underlying party. Each of the asset's carrying value will then be multiplied by the corresponding risk weight and the multiplication results are then added together to calculate the total risk weighted asset for credit risk arising from the on balance sheet items. Mathematically, if a bank has $n$ number of different assets and the risk weight of asset $i$ is given by $RW_i$ then the total risk weighted asset for credit risk arising from the on balance sheet items is given by the following:

$$TRWA_{CR-BS} = \sum_{i=1}^{n} RW_i \times A_i$$

Apart from on balance sheet items, the bank has off balance sheet items like, Letter of Credit (LC), Bank Guarantee (BG) etcetera which may also become funded in course of time. Once the off balance sheet items become funded they should also be included into the calculation of risk weighted asset for credit risk. To do so, the Basel guideline defines some Credit Conversion Factor (CCF) for each of the off balance sheet items to (theoretically) convert them into an equivalent on balance sheet item. Once the carrying value of each of the off balance sheet items is multiplied by corresponding Credit Conversion Factor (CCF), we will get an equivalent on balance sheet item which carries credit risk like all other on balance sheet items and entails a specific risk weight. Then the converted off balance sheet item's equivalent balance sheet value will be multiplied by the corresponding risk weight and all the multiplication results will then be added together to calculate the total risk weighted asset for credit risk arising from the off balance sheet item. Let, the bank has $m$ number of off balance sheet items and CCF for item $j$ is given by $CCF_j$ where $1 \leq j \leq m$. After converting the off balance sheet

items into on balance sheet ones they will entail risk weight like all other on balance sheet items. If the risk weight for item $j$ is given by $RW_j$, we can calculate the total risk weighted asset for credit risk arising from the off balance sheet items as follows:

$$TRWA_{CR-OBS} = \sum_{j=1}^{m} RW_j \times CCF_j \times OBS_j$$

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So, the total risk weighted asset for credit risk arising from both on and off balance sheet item is given by the following:

$$TRWA_{CR} = \sum_{i=1}^{n} RW_i \times A_i + \sum_{j=1}^{m} RW_j \times CCF_j \times OBS_j \tag{1}$$

Once the risk weighted assets for credit risk is calculated, the banks are supposued to calculate risk weighted asset for market risk and operational risk.

### 2.1.2 Capital Requirement for Market Risk

Market risk is the risk of loss arising from the movements of market interest rate, currency exchange rate and other market parameters. Market risk affects all the Held For Trading (HFT) securities of a bank as well as its all assets denominated in foreign currency and its total foreign currency holding.

To calculate capital charge for interest rate risk, Basel accord has considered two distinct types of market risk. One type of risk arises from the movement of general market interest rate which will effect all the securities in the bank's trading book. Another type of risk arises from the condition of individual issuer and it will affect the value of that particular security leaving the market values of all other securities unchanged. Like capital charge for credit risk, the Basel-II has defined capital charge weight for different securities depending upon the residual maturity, coupon rate and the rating of individual issuer [2]. Capital charge for specific market risk under Basel framework can be calculated as follows:

$$CCMR = \sum_{i=1}^{s} CCW_i \times GP_i$$

Where CCW is the capital charge weigh for security $i$ and $GP_i$ is the gross position of the security at time $i$.

Capital charge for general market position is calculated as the weighted sum of net open positioin, vertical disallowance, horizontal disallowance and option position [2].

Weights thus assigned to different categories are still subject to debate.

### 2.1.3 Capital Requirement for Operational Risk

Operational risk is defined as the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events. The Basel guideline [2] has documented three methodologies for the calculation of capital charge arising from operational risk. Three approaches are named as 1) Basic Indicator Approach, 2) Standardized Approach and 3) Advanced Measurement Approach. The first approach is the most naive one while the last is the most sophisticated one. In Basic Indicator Approach, the capital charge for operational risk can be calculated as follows:

$$K_{BIA} = \frac{\sum_{i=1}^{3} G_i \times \alpha}{N}$$

Where, $K_{BIA}$ is the capital charge for operational risk under Basic Indicator Approach (BIA), $GI_i$ is annual positive gross income at year $i$, N is the number of previous three years where gross income is positive and $\alpha$ is taken to be 15%.

## 2.2 Liquidity Parameters

At the height of global financial crisis, many banks, inspite of having a strong capital base, experienced difficulties due to the liquidity crisis. The liquidity mismanagement of some banks with adequate capital provoked the global community to think about it beyond the rules and regulations of the second Basel accord. The Basel Committee on Banking Supervision (BCBS) rethinked their framework and amended it with two new liquidity restrictions [4], [5] for banks to follow in order to escape possible bank run. The two new ratios namely, Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR) are now an integral part of the third Basel accord along with the minimum and adequate capital requirement under Basel-II. The BCBS defines these two ratios and set their acceptable range in their consultative documents [4], [5].

### 2.2.1 Liquidity Coverage Ratio(LCR)

Liquidity Coverage Ratio (LCR) is defined as follows:

$$LCR = \frac{Stock\ of\ high\ quality\ liquid\ asset}{Total\ net\ cash\ outflow\ over\ the\ next\ 30\ days}$$

High Quality Liquid Assets(HQLA) are those assets that can be easily and immediately converted into cash at little or no loss of value. According to the consultative

document issued by BCBS [4], any asset which can be considered as HQLA is supposed to have a wide range of characteristics including low riks, ease and certainty of valuation, low correlation with risky assets, listed on a developed and recognized exchange, active and sizable market, low volatility and flight to quality.

Total net cash outflow [TNCO] over a 30 days calendar period is calculated by subtracting the minimum of total expected cash inflows [CIN] and 75% of total expected cash outflows [COUT] from the total expected cash outflows [COUT]. Symbolically,

$$TNCO = COUT \ - \ Minimum\,[CIN, 75\%\, of\, COUT]$$

Basel-III framework requires the value of LCR to be $\geq 100\%$.

### 2.2.2 Net Stable Funding Ratio (NSFR)

The Net Stable Funding Ratio (NSFR) is defined as follows:

$$NSFR = \frac{Available\ amount\ of\ stable\ funding}{Required\ amount\ of\ stable\ funding}$$

Available amount of stable funding is defined as the portion of capital and deposit of the bank that are supposed to be reliable and are expected to stay with the bank over time. Available amount of stable funding is calculated by multiplying the bank's capital and deposits by their corresponding ASF factor and then the multiplication results are added together. If a bank has $n$ number of capital components and $m$ number of liability components then its avaiable amount of stable funding can be calculated as follows.

$$ASF = \sum_{i=1}^{n} ASFF_i \times C_i + \sum_{j=1}^{m} ASFF_j \times L_i$$

$ASFF_i$ is the available stable funding factor for capital component $i$ and $ASFF_j$ is the available stable funding factor for liability item $j$.

Required amount of stable funding is needed to provide for the bank's assets and off balance sheet exposures. In order to calculate the required amount of stable funding, each of the assets and off balance sheet exposures of the concerned bank is multiplied by its corresponding RSF factor and then the multplication results are added together. Symbolically, if a bank has $p$ number of assets and $q$ number of off balance sheet exposures then the required amount of stable funding is calculated as follows:

$$RSF = \sum_{i=1}^{p} RSFF_i \times A_i + \sum_{i=1}^{q} RSFF_j \times OBSE_i$$

$RSFF_i$ is the required stable funding factor for asset $i$ and $RSFF_j$ is the required stable funding factor for off balance sheet item $j$.

Basel-III requires the Net Stable Funding Ratio (NSFR) of a bank to be $\geq 100\%$.

# 3 Criticism of the Basel Accord

Here, we argue that the Basel guideline for determining bank's capital adequacy is not inspired by the basic accounting equation. Basic accounting equation which explains the relationship between an entity's assets, liabilities and capital runs as follows:

$$Asset = Liability + Owner's\ Equity$$

The above equation is infact the single most important equation in accounting and is treated as the foundation of double entry accounting system which is predominantly used in the banking and other industries all over the world. Here, the capital is defined as difference between assets and liabilities of an economic entity. Whenever there is a change in company's asset and/or liability, a quantifiable change will simultaneously occur to its capital. The way Basel guideline defines adequate capital is far from the principles of basic accounting equation. Instead of defining the capital as the difference between assets and liabilities, the Basel accord introduces the hypothetical risk weights and assigns different risk weights to different assets according to individual borrower's creditworthiness. The assignment of risk weights is subject to debate and the banking supervisors are usually asked to set the risk weights according to the indigenous situation. After the total risk weighted assets are calculated for credit, market and operational risk, the Basel guideline insists the Minimum Capital Requirement (MCR) should be a certain percentage of the total risk weighted assets. Again, the percentage will be chosen by the jurisdictions and Basel guideline opt for 8 (eight) to be the selected percentage. Yet, the assignment of this percentage is somewhat arbitrary and its values are different in different jurisdictions and most importantly, this selection is, by no means, tied to the definition of capital. So, in defining Minimum Capital Requirement (MCR) for banks, the Basel committee has gone far beyond the definition of capital being an absorbent of profit and loss of a company.

Moreover, the Basel guideline defines the capital requirement and liquidity require-

ment separately in such a way as if they were two unrelated quantities. But, here we argue, the capital requirement, among other things, arises as a by-product of day to day liquidity management. Whenever a bank has a liquidity cirisis it goes to the inter-bank money market to borrow fund. When this borrowing takes place, the borrowing bank is supposed to pay interest on the borrowed fund. Interest expense thus incurred will reduce the bank's profitability which, in turn, will hit bank's capital. On the other hand, when the bank has extra liquidity, it will lend the extra fund to the inter-bank money market and earns interest from it. Interest earning will add to the bank's profitability which eventually adds to the bank's capital. And hence, the liquidity requirement and capital requirement are not the concepts to be discussed independently. Rather they should have close ties with one another.

Moreover, as most of the banks nowadays follow the accrual basis of accounting, interest income is earned and interest expense is accrued on periodic interval irrespective of any cash transaction being taken place. Interest income earned will add up to bank's profit while the interest expense will reduce the bank's profit. At the year end, net profit will be transferred to bank's retained earning which is a part of bank's core capital. Hence, interest income and interest expense have substantial impact on bank's capital base and this impact of interest income/expense is not visibly represented in the Basel guideline.

Apart from the above criticisms, modern literatures have also criticized Basel accord for being overly dependent on the credit ratings provided by the external credit rating agencies [6]. These credit ratings are usually provided by two private sector agencies namely, Moody's and S&P. Thus Basel guideline is often accused for being nurturing anti-competitive duo-polistic practices [6] through public policies. The unreliable credit ratings provided by these two rating agencies are often seen as a major contributor to US housing bubble back in 2007.

Other studies suggest the Basel framework for bank's capital adequacy encourages banks to develop unconventional business practices to circumvent regulatory requirements and shifts banks' focus away from their core economic functions [7]. Meanwhile, Institute of International Finance, a Washington based banking trade association accused Basel accords for being impeding economic growth. Some studies posits that the implementation of Basel-III, will be accompanied by a decrease in annual GDP growth [8]. The study suggests that the banks' funding cost will rise due to higher capital requirement which will result into a $0.05 - 0.15\%$ percentage point decrease in annual economic growth. Some studies [9] claim that the implementation of Basel-III framework would affect small banks by raising their regulatory capital requirement and thereby impeding

growth.

# 4 Consolidation of the Capital Requirement with the Liquidity Parameters

At the beginning of the analysis, let us make two simplistic assumptions:

- Any surplus fund the bank has at any day will be invested into the overnight inter-bank money market.
- Any shortage in fund the bank has at any day will be met up by borrowing from the overnight inter-bank money market.
- All the assets of the bank tend to stay with it till their maturity and no such assets with a pre-fixed maturity will be sold prematurely by the bank in the period under investigation.

Let us assume that all the assets and liabilities that will mature at day $n$, $n \in N$ are given by $A_n$ and $L_n$ respectively. Moreover, like the balance sheet items, the off balance sheet items or contingent items also have a specific maturity and on maturity or the time when a contingent event takes place, the off balance sheet items become balance sheet items and they will affect the bank's liquidity scenario like the balance sheet items. Let us assume that the off balance sheet assets and liabilities that will mature at day $n$, $n \in N$ are given by $OBSA_n$ and $OBSL_n$ respectively. However, not all the off balance sheet items will become funded at their designated maturity. They will become funded only at a certain probability and this probability can be empirically calculated using the behavior of similar items previously. Let the probability that $OBSA_n$ and $OBSL_n$ will become funded at day $n$ be given by $PA_n$ and $PL_n$ respectively. So, if the cash position of the bank at day $n$ is given by $f_n$ then we have:

$$f_n = f_{n-1} + (A_n - L_n) + (PA_n \times OBSA_n - PL_n \times OBSL_n)$$

$$f_n = f_{n-1} + (A_n + PA_n \times OBSA_n) - (L_n + PL_n \times OBSL_n) \tag{2}$$

If $f_n > 0$ then it means the bank has access liquidity on day $n$ and according to the first assumption made at the beginning of the section, this surplus fund will be invested into the inter-bank overnight money market. If the money market rate at day $n$ is given

by $m_n$ then interest earned through the process will be given by $f_n \times m_n$. This $f_n \times m_n$ will add to the bank's capital. But, if $f_n < 0$ then it means the bank has shortage of fund on day $n$ and thus can not meet the maturing liabilities on that day from its own sources. The bank therefore borrow the amount $f_n$ from the inter-bank money market and eventually pay $f_n \times m_n$ as interest expense. Interest paid on borrowing from the money market will be adjusted from the bank's capital and the capital decreases by $f_n \times m_n$. If the bank's capital at day $n$ is given by $C_n$ then,

$$C_n = C_0 + \sum_{i=1}^{n} f_i \times m_i \tag{3}$$

However, this is not the only way the bank's capital is affected. As all the banks nowadays follow the accrual basis accounting, the bank's assets and liabilities will bring about periodic interest income and interest expense regardless of any cash transaction being taken place or not. In other words, cash transactions do not effect bank's capital base but, accrued income and accured expense do. As, we have already accounted for the accrued interest income and accrued interest expense in the money market activity in equation: 3, we will consider all other accrued interests in the remaining part of this section. If the interest income and interest expense accrued on day $n$ apart from those arising from money market transactions are given by $I_n$ and $E_n$ repectively then the bank's capital will be effected by the amount $I_n - E_n$ on day $n$. If $I_n > E_n$ then at the $n$-th day, the bank's capital will be increased by the amount $(I_n - E_n)$. Otherwise, the bank's capital will decrease by the amount $(E_n - I_n)$. If we consider the cumulative impact of accrued interest income and accrued interest expense on bank's capital then equation: 3 turns out to be:

$$C_n = C_0 + \sum_{i=1}^{n} f_i \times m_i + \sum_{i=1}^{n} (I_i - E_i) \tag{4}$$

If for any $n \in N$, $C_n$ becomes lower than the statutory minimum capital requirement which is often enforced through a parliamentary law then the bank needs to inject capital on day $n$. If the statutory minimum capital requirement is given by $C_s$ then amount of capital injection required on day $n$ will be given by $C_s - C_n$. Total amount of capital that needs to be injected upto day $n$ is given by the following construct:

$$\Delta C = \sum_{i=1}^{n} (C_s - C_i) \tag{5}$$

Moreover, $\forall n \in N$, $f_n$ denotes the amount of surplus/shortage fund the bank has

at day $n$. When $f_n$ is negative, it means the bank will have shortage of fund at day $n$. Hence, in order to meet up with the day to day liquidity requirements, the absolute value of $f_n$, $\forall f_n < 0$ must be within the bank's wholesale borrowing capacity ($WB_{cap}$).

$$|f_n| \leq WB_{cap}, \forall f_n < 0$$

$$\frac{|f_n|}{WB_{cap}} \leq 100\%, \forall f_n < 0 \tag{6}$$

where $WB$ denotes the bank's wholesale borrowing capacity.

# 5 Consolidated Capital and Liquidity Requirement in the Presence of Credit Risk

So far, no risk is assumed in the derivation of the liquidity parameter $f_n$ in equation: 2 and bank's capital holding ($C_n$) in equation: 4. However, in practical cases, credit risk exists and all the balance sheet and off balance sheet assets maturing on day $n$ will not be converted into cash in due time. In order to incorporate the concept of credit risk into the liquidity parameter $f_n$ and eventually, in bank's capital holding ($C_n$), let us assume the percentage of non-performing loan of the bank be given by $w$. Percentage of non-performing loan ($w$) is a population parameter and in case of large sample, this population parameter $w$ can be used to approximate sample parameter. So, for now on, we assume a substantial number of loans and off balance sheet long positions of different rating grades will mature in any particular day $n$. Hence, amongst all the loans and off balance sheet positions maturing at day $n$, only $(1 - w)$ portion will generate cash flow and the remaining portion will be non-performing. Hence, equation: 2 turns out to be:

$$f_n = f_{n-1} + (1 - w)(A_n + PA_i \times OBSA_n) - (L_n + PL_n \times OBSL_n) \tag{7}$$

Using the modified value of $f_n$ as given by 7 we can calculate bank's capital holding at time $n$ using equation: 4.

# 6 Consolidated Capital and Liquidity Requirement in the Presence of Market Risk

Market risk arises due to the adverse movements in interest rate, exchange rate, commodity prices, equity prices etcetera. Market risk that arises from the adverse movement

in the interest rate of one particular security/equity is termed as specific market risk. Specific market risk will affect the value of that particular security. On the other hand, market risk arising from the adverse movement of general market interest rate and/or general equity price index and/or exchange rate of local currency against the foreign one is termed as general market risk and it will affect the bank's entire trading book. For the sake of simplicity here we restrict ourselves to general market risk owing to the change in genral market interest rate only.

To start our analysis, let us assume that at day $n$, the bank's trading book consists of $p$ number of assets. If the market interest rate rises then the market value of all the assets in the bank's trading book decreases due to a higher discounting factor. So, if the market value of asset $i$, $1 \leq i \leq p$ at day $n$ is given by $MV_i$ and its amortized cost is given by $AC_i$ then bank's unrealized gain/loss (UGL) due to the revaluation of its trading portfolio at day $n$ is given by the following construct:

$$UGL = \sum_{i=1}^{p} MV_i - AC_i$$

If $UGL$ is positive then it implies that the bank has made unrealized gain in its trading portfolio due to a decrease in general market interest rate. On the other hand, if $UGL$ is negative then it implies that the bank has made unrealized loss in its trading book due to an increase in general market interest rate. Unrealized gain will be credited to the bank's revaluation reserve while unrealized loss will be debited from it. So, assuming the presence of general market interest rate risk only, we modify equation: 4 only to get modified capital position:

$$C_n = C_0 + \sum_{i=1}^{n} f_i \times m_i + \sum_{i=1}^{n} (I_i - E_i) + \sum_{i=1}^{p} (MV_i - AC_i) \tag{8}$$

The value of $f_i$ will be determined by equation: 7 in the presence of credit risk or by equation: 2 in the absence of credit risk.

The extent of capital charge for general market risk will depend upon the magnitude of change in general market interest rate which can be inferred from the recent and upcoming monetary policy stance. If the monetary authority approves a contractionary monetary policy then it will reduce the money supply and as a direct consequence of it, interest rate will rise. On the other hand, if the monetary authority pursues an expansionary monetary policy then the money supply will increase and eventually market interest rate will decline. Hence, in order to quantify the extent of capital charge for general market interest rate risk, the bank may interprete the monetary policy stance to forecast interest

rate or the supervisory authority may provide specific, explicit interest rate (based upon the monetary policy stance) to be used to discount bank's trading portfolio at any day $n$.

# 7 Consolidated Capital and Liquidity Requirement in the Presence of Operational Risk

The Basel guideline defines operational risk as the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events. It is the risk remaining after determining financing and systematic risk and includes risks resulting from breakdowns in internal procedures, people and systems. The Basel accord has defined three approaches to calculate operational risk namely, 1) Basic Indicator Approach, 2) The Standardized Approach and 3) Advanced Measurement Approach. We can measure operational risk by using any of the approaches. We can also calculate operational risk from a bottom-up approach. In this case, we try to quantify the impact of each of the operational risk in monetary terms and calculate the probability of the lapse to occur. Let us assume, we have identified $q$ number of risk. Let, the probability of risk $k$, $1 \leq k \leq q$ to occur be given by $p(k)$ and the extent of financial loss involved in the process be given by $Im(k)$. Hence, the total amount of expected loss arising from operational risk is given by the following:

$$\textit{Expected Loss Due to Operational Risk } = \sum_{k=1}^{q} p(k) \times Im(k)$$

In many cases, operational risk arises abruptly and calls for immediate action. For example, a cheque fraud may take place at any time and it will hamper bank's liquidity position instantly. So, incorporating the impact of operational risk into the bank's liquidity position, we get the following construct:

$$f_n = f_{n-1} + (A_n + PA_n \times OBSA_n) - (L_n + PL_n \times OBSL_n) - \sum_{k=1}^{q} p(k) \times Im(k) \quad (9)$$

Capital holding of the bank at day $n$ in the presence of operational risk only (ignoring

credit and market risk) will be given by the following:

$$C_n = C_0 + \sum_{i=1}^{n} f_i \times m_i + \sum_{i=1}^{n} (I_i - E_i) \tag{10}$$

# 8 Minimum Capital Requirement in the Presence of Credit, Market and Operational Risk

Like the Basel accord, we define the Minimum Capital Requirement (MCR) for a bank to be the amount of capital which will be sufficent to cover the expected losses arising from credit, market and operational risk. In the previous three sections, we have investigated the impact of credit, market and operational risk on bank's capital individually and here we will depict a consolidated capital and liquidity requirement in the presence of all three risks. Liquidity position $f_n$ of the bank for any day $n$ in the presence of all three types of risks will be given by the following expression:

$$f_n = f_{n-1} + (1-w)(A_n + PA_n \times OBSA_n) - (L_n - PL_n \times OBSL_i) - \sum_{k=1}^{q} p(k) \times Im(k) \tag{11}$$

If for any day $n$, bank's liquidity position becomes negative and less than the bank's wholesale borrowing capacity then the bank will be in liquidity crisis at that day. For all the negative value of $f_n$, liquidity restriction is given by the following:

$$\frac{f_n}{WB_{capacity}} \leq 100\%, \forall f_n < 0$$

Capital holding of the bank at any day $n$ in the presence of credit, market and operational risk will be given by the following:

$$C_n = C_0 + \sum_{i=1}^{n} f_i \times m_i + \sum_{i=1}^{n} (I_i - E_i) + \sum_{i=1}^{p} (MV_i - AC_i) \tag{12}$$

If for any day $n$ bank's capital holding $C_n$ becomes less than the statutory minimum $C_s$ then the bank needs to inject additional capital by an amount equal to $C_s - C_n$. So, the total amount of capital to be injected upto day $n$ is given by:

$$\Delta C = \sum_{i=1}^{n} (C_s - C_i) \tag{13}$$

Then equation: 11, 12 and 13 will be our final set of equations which captures the dynamics of bank's capital holding and liquidity over the course of time. The above three equations can also be used as the basis for stress testing also.

## 9 Conclusion

Here, we have derived three simple equations that shows the dynamic relationship between bank's liquidity position and capital holding over the course of time. All the equations are inspired by the principles of the basic accounting equation and can be intuitively followed. To define capital adequacy of a bank, the Basel freamework resort to the *artifical* concept of risk weighted asset and defines a comprehensive set of risk weights which should be used in the calculation of minimum capital requirement of a bank. In defining capital adequacy, the Basel framework goes far beyond the accounting concept of capital and introduces the artifical concept of risk weighted asset. Moreover, the assignment of risk weights and pre-fixed capital adequacy ratio are somewhat subjective and can not be intuitively followed and unanimously accepted. Last but not the least, Basel describes bank's liquidity restrictions and capital holding as two distinct concpepts. But, here, we argue that bank's liquidity position should affect bank's capital holding and establish the link between the two. Our final set of equations namely, equation: 11, 12 and 13 can be used to determine bank's liquidity position, measure capital adequacy and to perform stress testing on the bank's balance sheet easing from the extensive paper work needed to do the same under Basel accord.

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