Liquidity-The Intriguing Reality Game

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Liquidity: The Global Scenario

The global market is slowly witnessing waves of the turmoil which began since mid-2007 in the US markets. This emergence has highlighted the importance of the liquidity in the banking industry than ever before.

In case of certain structured products as well as in the inter-bank markets, the overall tightening of liquidity along with the probability of off-balance sheet commitments are now getting reflected in banks' balance sheet, leading to severe liquidity funding strains for some banks. This also means intervention of the central bank in some of these cases.

Actually the happenings in the global scenario have accentuated the line of connectivity that exists in the funding and market liquidity risk, the interrelationship of funding liquidity risk and credit risk, and above all the bible fact that liquidity is a key determinant of the soundness of the banking sector.

Liquidity *can be defined as the ability to fund the rise in the assets and the capability to meet the obligation as they become due in the course of time.*

Common definitions:

Liquidity *of any financial instruments reflects the ease with which it can be traded of for money with the loss of its value*
Or
The market's ability to trade a given volume of assets and securities without considerably affecting their prices.
Or
Monetary liquidity explains the quantity of fully liquid assets circulating in the present economy.

The basic role of banks in assisting the maturity transformation of short-term deposits into long-term loans actually makes the banks naturally vulnerable to liquidity risk, the risk that demands for repayment outstrip the capacity to raise new liabilities or liquefy assets

Banks are subjected to stress due to various market conditions, this liquidity risk could have profound impact due to changes in the counterparty behavior and the inherent liquidity of financial instruments.

Such conditions have led to innovations in the global market and have transformed the nature of liquidity risk in the recent years.

Payments Systems and Challenges

In the present scenario, most of the banks are facing a lot of challenges w.r.t intraday liquidity management in relation to Payments Systems.

These challenges have emerged from recent improvements to the design of payment and settlement systems, such as the adoption of large-value payment systems with intraday finality (e.g. real-time gross settlement-RTGS systems), delivery-versus-payment (DVP), securities settlement systems, the development of CLS to settle foreign exchange trades, and the increasing use of central counterparties. Nevertheless, these improvements have reduced certain inter-bank credit risks, as well as operational risks. Also, some profound changes for the banks can be acknowledged, for example these changes have increased the collateral needs and increased the time-criticality of certain payments, due to which many banks are facing the new forms of intraday liquidity risks. As cascading impacts, the failure of an institution to meet time critical payments could actually transmit a major liquidity shock to other firms domestically or even internationally. It may even impair the functioning of short-term money markets in multiple jurisdictions.

To ensure the smooth functioning of systems, central banks generally offer intraday credit to the participants of RTGS-type systems. However, collateral is almost always required to obtain this credit. As such, institutions must have some form of liquidity available to meet their obligations on a timely basis throughout the business day.

Taking a leaf out the same concept, here we have focused on the Liquidity and its further segmentations i.e. Intraday Liquidity Management from the banks' perspective to the payments systems (RTGS).

The paper highlights various analysis, simulation runs, game theory from the liquidity angle, in the order of Intra-day Liquidity, Liquidity Algorithms, and Simulation run on Just in Time and Opening Balance Liquidity Funding

Intraday Liquidity Management

Due to increase in the volumes of payments effected via the payments and settlement system, it has become imperative for the banks to efficiently maintain the liquidity across various payments systems during the operating day.

In a nut shell, the management of the liquidity needs across various payments and settlement system by the bank is defined as Intra-day liquidity management

Sources of Finance

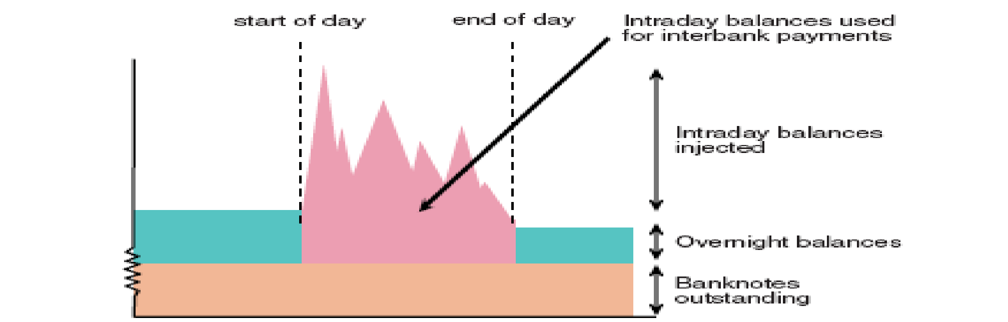
The two of the main sources of financing the Intra-day Liquidity can be –

1. Central bank money
2. Commercial bank money.

The development of various collateral policies also effects the intra-day liquidity management.

The Inter-relation between CENTRAL BANK MONEY and COMMERCIAL BANK MONEY

Any payment and settlement system can settle either in central bank money or in commercial bank money. When the central bank money is used as the settlement asset, the first component of the intraday liquidity will take in the form of the deposits with the central bank, which would be applied to make the payments during the day.



Stylized diagram of central bank money

Source: BIS (2003): The role of central bank money in payment systems, August.

The intra-day balance is actually impacted by the proceeds of the settlement of payments with other participants all through-out the operating day. Incase the balance available is very small compared to the value of payments to be made; it could lead to a gridlock, eventually leading to prevention of payments being executed.

Most of the central banks provide an intra-day credit to banks and other eligible account holder and with the decline in importance of reserve requirements in many economies, balance held by the settlement banks in their respective accounts, during the operating day is often substantially larger than those held overnight.

In the present era of financial globalization, global players, active in multiple currencies, are now-a-days being confronted with the fact that as settlement asset each central bank provides only the currency it issues. This being the main reason of various systems, the multi-currency settlement services use the commercial banks' money as settlement asset. Thus, the International Central Securities Depositories, Euroclear Bank and Clearstream Banking Luxembourg which service across international markets and participants, provide settlement in multiple currencies in commercial banks money.

Although the use of the commercial bank money raises a few concerns pertaining to liquidity risks, in terms of transferability of the private settlement asset in claims denominated in central bank money, the issue has been addressed in the case of settlement bank CLS, with the support of the international central banking community, whereby the CLS system provides payment-versus- payment (PVP) settlement in 15 major currencies eligible in the system. CLS Bank is the settlement institution for CLS not using central bank money for settlement. CLS displays an illustrative example towards the development of commercial money settlement backed by funding in the central bank money. CHIPS is another good example whereby the initial and final funding done in central bank money. There are few other innovative arrangements aimed at limiting the use of central bank money to a net funding (e.g. Clearstream settlement model or Euroclear future alternative payment model).

In these settlement models, the level of intra-day liquidity has a high level of complexity such as –

1. The level of funding in the central bank money is limited in the total quantitative terms, compared to the payment obligations that are settled in the commercial bank money.

2. There exists a strong settlement interdependency between the settlement system in commercial bank money and the payment system(s) used to fund the net obligations in central bank money

3. This also requires a very close monitoring of the completion of the funding obligations, typically within tight intraday deadlines.

CENTRAL BANK INTRADAY CREDIT AND COLLATERAL POLICIES

Intraday credit policies

There exist some variations in the central bank policies w.r.t. the institutions which are eligible to be provided with intraday credit in RTGS systems.

Apart from the resident banks, which are eligible to intra-day and overnight credit, there is always less uniformity about providing credit to non-banking financial institutions (e.g. clearing houses or other settlement systems operators, investment firms and brokers…). Intra-day credit is generally given to account holders at the central banks, in order to support the orderly flow of the payments.

This sets the level of tiering in the systems, since many of the major banks who have a direct access to the liquidity limit, use little or don't use the assigned limit. Hence, a central bank provide credit limits to the next tier level of banks. But since the central bank would be at credit risk, collateral, set limits and/or charge fees is sought as means to mitigate the risk..

In practice, the monetary policy considerations are quite instrumental in designing a central bank policy w.r.t. intraday credit. The failure to repay intraday credit by close of business will lead to "spillover" into overnight credit, which might threaten the implementation of monetary policy. A massive spillover of intra-day credit into overnight credit may create short term disturbances in the conduct of monetary policy operations.

The flow of discussion in this paper is as follows –

1. Intraday Liquidity Management in terms of Game Theory of John Nash
2. Liquidity Algothrims in RTGS /ACH/DNS
3. Simulation Runs on the Delay of Liquidity
4. Gridlock and Deadlock Equation Derivation

Intraday Liquidity Management: Games Theory

Principle Model

Around the world, some 93 central banks have implemented RTGS systems by the end of 2006. The volumes and the numerical values of inter-bank payments have gradually increased over the last decade.

This eventually has led to central bank of many countries to shift themselves from the inter-bank payments model of deferred (end of day) netting to the Real- time gross settlement model.

The main cause of worry being for the central bank being , since the volumes were high , the subsequent settlement risks inherent in netting systems were also increasing Central banks main concern about the potential for Contagion,/ "knock-on," effects attributable to the unwinding of net positions that would impact drastically if a participant was not able to fulfill its end-of-day obligations.

Intraday liquidity management has become an important competitive parameter in commercial banking and a policy concern of central banks.

Intraday credit policies can be categorized as ***Collaterized Credit and Priced Credit***

While *Collaterized Credit* usually takes the form of pledging collateral to the central bank or entering into an intraday repurchase agreement with the central bank, the *Priced Credit* involves charging a fee for intra-day credit overdraft.

In any case, the intraday credit is not cheap; irrespective of the form of credit it is availed.

Though there are various models have been elaborated globally, we have confined the discussion on few models in this paper.

This is a stylized game-theoretical model to analyze the behavior of banks' intraday liquidity management in an RTGS environment, popularly known as "*Nash equilibrium of the game theory*" which is based upon various cost parameters and highlights the efficiency implications, under different outcomes. The two classic paradigms in the game theory are the "prisoner dilemma" and the "stag hunt".

The Game theory has been shown with various scenarios under the Liquidity Management, which are listed below:-

Game 1 - Intraday Liquidity Game

Assume a scenario where there are two identical banks using the RTGS system operated by the Central Bank which settles the inter-bank claims.

The banks in the game are BANK A and BANK B and the time period under consideration is morning and afternoon. Both of the banks seek to minimize the cost of making their payments in the most cost effective manners.

At the start of clearing day, both the banks receive a request from their customers to pay $1000 to a customer of the other bank within the same business day.

For the sake of simplicity, we assume that both the banks can process the transaction immediately or defer it till afternoon. Preferably, they take the second decision on the basis of the dependency on their reserve requirements and as a precautionary move to hold balances with the Central Bank. Thus, each bank has a zero balance on its settlement account at start of the clearing day.

if the amounts for payment exceed the available balance, banks avoid sending the payments from their respective account with the Central Banks., However the banks have an option to borrow the same from the central banks but that is going to come at a price, which the bank prefers to avoid.

Under the normal circumstances, each bank prefers to make its payments with the use of the funds received from the incoming payments from the other bank to cover its own outgoing payments.

In a normal scenario the *cost of the intraday delay* is normally a small amount, as the underlying contractual obligation of the customer only specifies payment, within a business day.

But with the increasing number of financial transactions, the *cost of delay* at time could be quite substantial, given that the said underlying contract stipulates payment prior to the cut-off time specified by the clearing system.

Moreover, postponing payments until the next day can be an extremely expansive proposition to the bank in terms of its reputation or direct compensation to customers, so banks always submit any remaining payments in the afternoon.

Assuming the *cost of delay* is denoted as “D” PER DOLLAR PER PERIOD WITHIN., the associated cost with reference to the Bank A and Bank B can be shown in the 2&2 game as follows –

GAME 1

Intraday Liquidity Management Game

		Bank B	
		morning	*afternoon*
Bank A	*morning*	$c^A(m,m), c^B(m,m)$	$c^A(m,a), c^B(a,m)$
	afternoon	$c^A(a,m), c^B(m,a)$	$c^A(a,a), c^B(a,a)$

As per the above metrics, each bank has one of the two strategies to play: either morning or afternoon. The first element in each cell highlights the settlement cost to Bank A, whereas the second element highlights the cost associated with B.

The game is planned on the basis of the famous game theory by Nash as the Nash Equilibrium – it presupposes that neither bank would wish to change its strategy on the assumption that the other bank will not change its strategy either.

We will be actually showcasing the Nash equilibrium in pure strategies, wherein the player, will choose to take one action with probability 1, which is in contrast to a mixed strategy, where Individual players choose a probability distribution over several actions.

Game 2 - Free Intraday Credit Regime

In the said situation used here is that RTGS systems provided intraday credit for free, and we use this intraday credit policy regime as a benchmark. There is a facility of free credit within the day with no incentive to postpone payments

It is best for both the banks to play the morning strategy because they incur no costs. But they will incur the *cost of delay* if they postpone to the afternoon.

The morning strategy dominates the afternoon strategy, and the strategy profile (morning, morning) is said to be equilibrium in dominating strategies. A pair of dominating strategies is a unique Nash equilibrium.

GAME 2

Free Intraday Credit Game

		Bank B	
		morning	*afternoon*
Bank A	*morning*	0, 0	0, *D*
	afternoon	*D*, 0	*D*, *D*

Note: We underline the cost associated with the strategy that is the best response of a bank given the strategy played by the other.

In the real time scenarios of the payments system, the payment is not perfectly symmetric as they are in the model. The imbalances frequently occur and the zero price for intraday credit creates no incentives to economize on overdrafts. Infact, the size of overdraft allowed to bank by the central bank is based on the bank's capital base in an RTGS environment

Game 3 - Collateralized Intraday Credit Regime

Presently, many of the central banks globally provide commercial banks with intraday credit against collateral. Under the intraday repo-agreement, the central bank provides the bank with $1000 in its account at the beginning of the period, which in-return is supported for eligible collateral worth the same amount plus a "haircut" to cover out for any market and credit risk associated with the collateral.

At the end of stipulated period, the said transaction is reversed. The central bank does not charge explicit interest on this service, but then the collateral subject to repo entails an opportunity cost for the banks, as this collateral cannot be used for other purposes.

We assume that opportunity cost of collateral to be C per period per dollar.

The *cost of delay* could be expressed in several forms of financial penalties which may be due to the failure to make time-critical payments by specified deadlines or even it could be repayments of interbank loans.

This can also be translated as a case where-in the failure to make customer payment /payments on time i.e. the intended settlement date may result in reputational costs and a loss of future business for the bank.

If Bank A and Bank B both decide to process their requests early during the day, they each will have to engage in an intraday repo with the central bank in order to obtain liquidity, and consequently, they will each have to incur the cost C.

But, say, Bank A plans to delay while Bank B decides to go on the processing; Bank A will incur the *cost of delay* D in the morning period. However, later in the afternoon period, it can comfortably use the incoming liquidity from Bank B to support the funding with its own outgoing payment in the next period.

Conversely, Bank B receives no liquidity and it has forced to roll over the repo with the central bank for an additional period and incur an additional cost C one more time for a total of 2C.

Finally, if both banks decide to postpone, they both will have to incur the *cost of delay* D.

Meanwhile, at noon they still do not have any liquidity available, and both have to engage in an intraday repo in the afternoon period for which they will have to incur the opportunity cost of collateral C. The settlement costs are summarized in the following illustration for this Game 3 also referred to as the Collateralized Credit Game –.

GAME 3

Collateralized Credit Game

		Bank B	
		morning	*afternoon*
Bank A	*morning*	C, C	$2C, D$
	afternoon	$D, 2C$	$C + D, C + D$

In this game, the equilibrium actually is based on the relative size of the opportunity cost of collateral and the cost of postponing a payment request.

If the *cost of delay* is larger than the cost of obtaining liquidity – i.e. if D > C, the banks have no reason to delay and the strategy profile (morning, morning) is the best choice (Nash equilibrium).

If Bank B plays in the morning, the best strategy for Bank A is to play in morning as well.

However, incase Bank B chooses to postpone; the best strategy for Bank A is still morning.

This can be easily summed up that the morning is a dominating strategy for Bank A and, by symmetry, for Bank B as well. However, incase the cost of liquidity is higher than the *cost of delay*, i.e. C > D, then the strategy profile (afternoon, afternoon) is the only Nash equilibrium.

This scenario is a unique Nash equilibrium, since neither of the banks wishes to switch to morning, if the other bank keeps playing afternoon because the switch would infact be a costly affair and shall increase the overall settlement cost. However, it is evident that the banks would be better off if they both chose to process payments in the morning.

Though it is fact that (morning, morning) are not in equilibrium in this one-shot game. Since from the starting (morning, morning), each bank will actually wish to postpone payment in order to lower its settlement cost.

This fact can further be understood more clearly as depicted in the Classic Paradigm Game Theory called the Prisoner's Dilemma.

Prisoner's Dilemma

The "Prisoner's Dilemma" is the most famous paradigm in game theory. Suppose that the police have arrested two former criminals who are well aware of, who has committed an armed robbery together. Unfortunately, they lack enough admissible evidence to get a jury to convict them of armed robbery. They do, however, have enough evidence to send each prisoner away for two years for theft of the getaway car.

The chief inspector now makes the following offer to each prisoner: "If you will confess to the robbery, implicating your partner, and he does not also confess, then you'll go free and he will get ten years. If you both confess, you'll each get five years. If neither of you confesses, then you'll each get two years for the auto theft." It is Nash equilibrium for each prisoner to confess; yet they would both be better off if they both chose to remain silent.

Prisoner's Dilemma

		Prisoner 2	
		Confess	Silence
Prisoner 1	Confess	5, 5	0, 10
	Silence	10, 0	2, 2

Ref Note-1 in the References

Banks are well aware of the fact that the inter-bank payments systems are keenly aware that costly liquidity may lead to situations where the settlement of payments actually will await the settlement of other payments. This situation is called as gridlock and the case of prisoner's dilemma above is a form of gridlock.

Gridlock is defined as a stage in the payments systems, when two or more payments queues are blocked due to shortage of funds and can occur even if throughout the system as a whole there is no such shortage.

Some of the Central Banks and industry groups have a set of guidelines under which plan, the banks are to process certain percentages or types of traffic by predetermined times over whole period of time during any business day.

For Example – In UK, the various member banks of the RTGS system are required to manage their payment flows in such a way that, on average, 50 percent of the value throughput is sent by noon and 75 percent is sent by 2:30 p.m. In Japan, banks are encouraged to return call money market loans within the first hour of operations. Swiss National Bank charges higher prices for payments sent later in the day, thereby giving banks a direct incentive to process early. Moreover, the transaction fee increases more steeply for payments of larger value.

Under the model of our context, we have assumed if an offsetting payment is submitted to the system in the same period, the offsetting mechanism allows the payments to be processed in a given period without the need of collateral,. However it is a clear stated fact that if no offsetting payments come, then collateral needs to be recorded.

Game 4 - Offsetting in the Morning Game (C>D)

Now we take a scenario where an offsetting mechanism is running only in the morning period.

The prisoner's dilemma changes into a coordination game. Coordination games are a class of games with multiple (pure strategy) Nash equilibria in which players choose the same or corresponding strategies.

GAME 4
Offsetting in the Morning Game ($C > D$)

		Bank B	
		morning	*afternoon*
Bank A	*morning*	<u>0</u>, <u>0</u>	2C, D
	afternoon	D, 2C	<u>C + D</u>, <u>C + D</u>

Note: We underline the cost associated with the strategy that is the best response of a bank given the strategy played by the other.

The various scenes could be as follows –

1. if Bank A submits in the morning, then the best response of Bank B is to do the same
2. if Bank A postpones to the afternoon, then the best response of Bank B is to follow the same

This game is called a pure coordination game, or the game of common interest, in which both banks prefer the (morning, morning) equilibrium to the (afternoon, afternoon) equilibrium.

Game 5 - Priced Intraday Credit Regime

Under this scenario the priced credit regime, banks will be charged a particular amount of fee "F" per dollar if their settlement account is overdrawn at the end of a period.

The different possible strategies in the price credit game are –

- <u>Both Banks Play in Morning</u> - then payments net out and both the banks incur no costs. The same logic will apply in case, both the banks play in the afternoon, but then both of them will incur a *cost of delay*.
- <u>One Bank Pays and Other One Delays</u> - then the bank paying first will incur an overdraft at noon while the other can use the incoming payment received from the other bank in the morning period to fund its outgoing payment in the afternoon. However, the bank that delays will incur the cost D.

GAME 5
Priced Credit Game

		Bank B	
		morning	*afternoon*
Bank A	*morning*	0, 0	F, D
	afternoon	D, F	D, D

Game 6 - Stag Hunt

Following the same steps as in the case of collateralized credit regime, the outcome shall always depend on the relative size of the cost of liquidity and the cost of delaying the processing of the request.

Again, the strategy profile (morning, morning) is a unique Nash equilibrium if the cost of liquidity is less than the cost of delaying the payment request i.e. $F < D$.

Nash Equilibria is achieved by the strategy profiles (morning, morning) and (afternoon, afternoon).

Let us assign values to F and D as 5 cents and 2 cents respectively and showcase in this game.

If both bank pay in the morning, neither of them will want to change the condition because of the settlement cost payable from 0 cents to 5 cents. However, if both banks decide to make an afternoon strategy, they will never deviate from this action as they will incur increased cost from the existing 2 cents to 5 cents i.e. additional 3 cents.

GAME 6

Priced Credit as the Stag Hunt Game

		Bank B	
		morning	*afternoon*
Bank A	*morning*	<u>0</u>, <u>0</u>	5, 2
	afternoon	2, 5	<u>2</u>, <u>2</u>

Note: We underline the cost associated with the strategy that is the best response of a bank given the strategy played by the other.

This is a classic Case under the *Famous Coordination Game* called Stag Hunt. The key feature of the stag hunt game is while the (morning, morning) equilibrium is preferred by both players in terms of lowest cost, the other (afternoon, afternoon) is preferred in terms of strategic risk.

Conclusion - Choice of Intraday Credit Policy

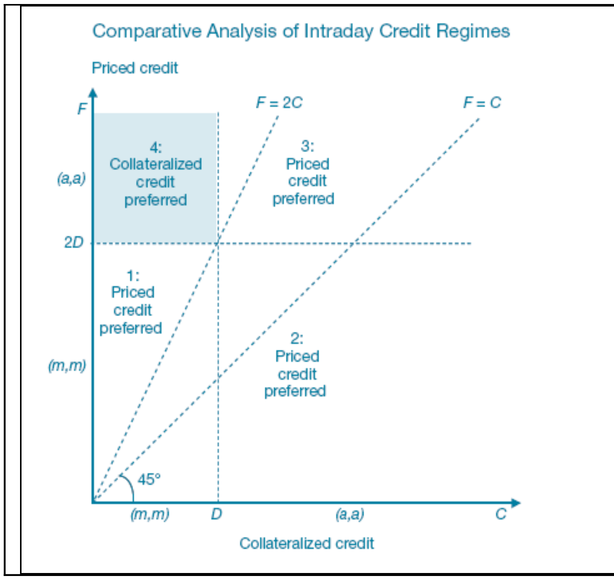
Central bank is a benevolent provider of the RTGS system and works on the principle to secure the lowest possible aggregate settlement costs for the economy.

The central bank has the option to choose between a collateralized credit and a priced credit regime. Additionally, for the purposes of this analysis, we take into consideration that the central bank cannot (further) influence the cost of liquidity or the cost of delay under either regime. The preferred regime will actually depend on the equilibrium outcome which in turn depends on the relative magnitudes of F, C, and D.

The aggregate of the settlement cost under the equilbria of the two intra-day credit regime can be easily calculated by summing the entries in each cell in Game 3 and Game 5 respectively. The aggregate cost, when one bank is playing in the morning and other in the afternoon are 2C + D and F + D, respectively, under the two regimes.

With two possible (risk-dominant) Nash equilibria under each regime, there are four different scenarios to be considered as depicted in each metrics.

In the priced credit regime, aggregate settlement costs are zero if the equilibrium is (morning, morning), whereas the collateralized credit regime always implies positive settlement costs. Consequently, priced credit is the preferred regime if F < 2D as referred to in the following chart.



X –Axis in the Nash Equilibrium, a collateral credit regime as a function of opportunity cost of collateral.

Y-axis shows the risk-dominant Nash equilibrium under a priced credit regime as a function of the overdraft fee.

Incase the payments are delayed, then in that case under both the said regime i.e. 2D < F and D < C— and the aggregate settlement costs are 2D + 2C and 2D, respectively.

Priced Credit is the preferred regime C in (scenario 3), whereas the collateralized credit is the preferred regime if banks do not delay payments under such a regime but they do under a priced credit regime—that is, C < D < 2D < F (scenario 4).

<u>The overall findings showcase that the Priced Credit is a preferred option to Collateralize Credit except when Collateralized Credit leads to quicker settlement of payments.</u>

However, this assumption is not free from certain limitations –

- The overall analysis doesn't account for the default risk, against which the collateral provide protection
- Since the actual cost of delay incurred by banks is not supported with facts and figures, the comparative analysis has been of less informative nature
- To prefer Collateralized Credit over Priced Cost, one of the most important condition is the opportunity cost of collaterals which need to be lower (say, literally half) than the overdraft fee charged under Priced Credit

It may be also stated that the opportunity cost of collateral cannot be the only and direct factor to decide preference over the Priced Cost. For this reason, it has been estimated that the rate differential for opportunity cost between federal funds loans and loans through repurchase agreements is in the range of 12 to 15 basis points per annum, while the former is classified as uncollateralized and the latter as collateralized one.

The overdraft fee is readily observable because it is set by the central bank with the overall view to managing credit exposure from overdrafts. In the present day scenario the daylight overdraft fees in the Fedwire Funds Service is being calculated using an annual rate of 36 basis points, quoted on the basis of a 21.5-hour day.

This simple "back-of-the-envelope" comparison suggests that there may be scope for investigating an increased role for collateral in a payments mechanism like Fedwire system.

ALGORITHMS

Algorithms in the RTGS / ACH / DNS system are one of the most important parts, as they are the heart of the management of the various operations and the queues.

They are instrumental in the avoiding of various gridlock scenarios, which may happen due to insufficient liquidity by the bank.

There are various groups under which algorithms can be classified –

- Injection algorithms (INJ) transfer liquidity between the ancillary and main systems
- Submission algorithms (SUB) for fetching the next transaction to be submitted for processing. This Algorithm works on the transaction level only, whereas all the other Algorithm work at the system level
- Entry algorithms (ENT) conduct the initial processing of each and individual payment transaction
- Settlement algorithms (SET) process queued payment transactions
- End-of-day algorithms (END) process the final steps during a day or settlement cycle
- Queue release algorithms (QUE) are principally accountable for checking and fetching the transactions from the waiting queue in the given order once an account or participant has received more liquidity
- Bilateral off-setting (BOS) are responsible for checking and fetching the transactions from the waiting queues that can be bilaterally off-set
- Splitting algorithms (SPL) split a large transaction into sub-transactions according to specific rules

  Example: In the case of Swiss Inter-bank Clearing, it is a perquisite that the SIC participants split payments of over 100 million CHF into several smaller chunks to successfully reduce the liquidity requirements of the clearing system. The risk of gridlocks occurring in SIC is indeed very small.

- Partial netting algorithms (PNS) hunt to settle part of the queued transactions
- Multilateral netting algorithms (MNS) basically focus on the attempt to settle all the queued transactions in one netting event

Example of the Liquidity saving features that is present in the Target2 system

TARGET2 is one of the most relevant examples of a system providing its users with the most up-to-date liquidity management tools that are offered currently in RTGS systems.

It has the following set of wing liquidity-saving patterns:

Consolidated monitoring of the liquidity position in all RTGS accounts
Due to the shared single architecture, which consist of the a single shared platform, Multi-country banks are able to manage from a single point, the various activities of their branches and are able to centralize their cash management, which shall also include the liquidity involved in the settlement of ancillary systems .

Liquidity pooling functionality

This liquidity pooling Functionality is based on the concept of the virtual account, where-in the purpose of intra-day aggregation of the liquidity available on all the single accounts belonging to a group of accounts of a said banking group. Hence in this way the liquidity can be managed in a consolidated way.

Different priority levels

Each Payments could be assigned a Priority level based on the level of the its criticality.

Possibility to use a liquidity reservation feature

In order to support the settlement of participants' operations, that also includes the ability to set aside liquidity on specific sub-accounts. This scenario will be applicable in the case of the settlement of transactions stemming from ancillary systems.

Bilateral and Multilateral sending limit features

This Facility is available on the offer to avoid the need of some of the participants to wait for receiving payments from their counterparties before issuing their own payments.

This will call for the need of setting of the following limits –

Bilateral limit vis-à-vis a participant can prevent the settlement of payments that would cause the bilateral balance with this participant to breach this limit.

Multilateral limit will actually prevents the settlement of payments which will cause the balance vis-à-vis all the participants towards whom no bilateral limit was set to breach this multilateral limit.

The main advantage of this multilateral limit feature is that, there is no need for participants to manage bilateral limits towards each other (TARGET2 should have around 1,000 direct participants)

Optimization mechanisms

The sole purpose of this mechanism is to reduce participants' liquidity needs while improving the fluidity of settlements.

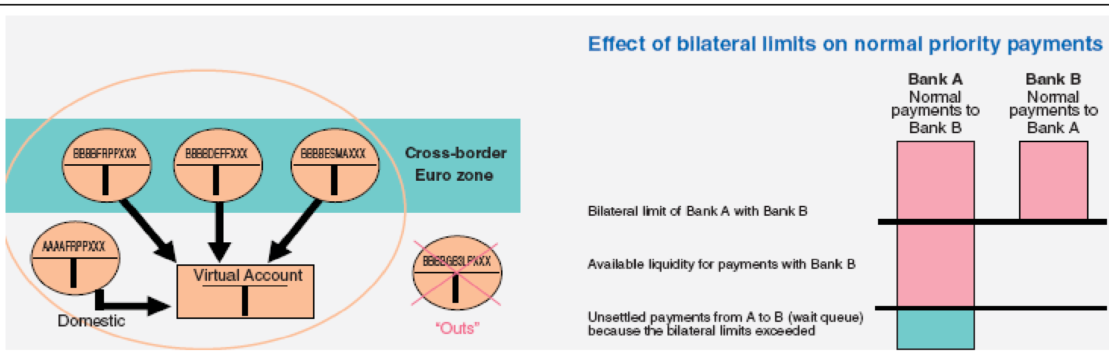
Offsetting processes

This process is actually triggered by the arrival of a transaction in the system. It endeavors to immediately settle this transaction, in combination with those transactions which are already queued transactions.

Five Optimization processes

This is one of the methods, which is available in the Target2 system, where-in the optimization method is applied on the first three payments, that area available in the queue (under the category of normal priority and are sequentially triggered throughout the day.

The other two correspond to specific settlement methods for ancillary systems.



A Simulation Model of the RTGS Payment System

This simulation model basically highlights the focus on the *cost of liquidity* and *cost of delay* in funding with reference to the RTGS system.

> The *cost of liquidity* varies according to regime employed by the central bank. When the credit is supplied unsecured, the cost typically is in the form of an explicit overdraft fee.
>
> The *cost of delay* could be expressed in several forms of financial penalties which may be due to the failure to make time-critical payments by specified deadlines or even it could be repayments of interbank loans.
>
> This can also be translated as a case where-in the failure to make customer payment /payments on time,i.e. the intended settlement date may result in reputational costs and a loss of future business for the bank.

The model of payments system will have the following ingredients –

- Centralized processor for the payment system
- Central bank which will offers settlement accounts to a group of settlement banks; which actually means that the payments within the payment system are settled across these settlement accounts
- A set of settlement banks which have a direct access to the payment system and have settlement accounts at the central bank
- Customers (who could be customer of the settlement banks) submitting payment requests at random times

In code of operation, there will be three arrival times that need to be stipulated for payments:

- t_R is defined as the time when the customer of bank i has made the request for a payment,
- t_C will be the time when the payment request arrives at the central processor , (it could be either settled immediately or put in the central queue (if this facility exists)
- t_E Defines the actual time when the system settles the payment with finality.

Assume that

- $X_{t_R}^{ij}$ denotes the payment request made by a customer from bank i to bank j at time tR and is known only be know to his bank I,
- $X_{t_C}^{ij}$ reflects that the payment from bank i has been submitted to the central processor for settlement , which will now be known available to the central bank and to bank j.
- In the case the facility of the central queue is not present for the said system, and then in that case the time between tC and tE would be zero as only payments capable of being executed are submitted to the central processor. Incase these payments are timed for a particular time t_R , but are forwarded well in advance of schedule time for final execution at tC = tE, tC > tR , banks have effectively maintained 'hidden queues' denoted by XiHQ(0, t), which can be defined as the vector of time stamped non-settled payment requests being held at each bank i.

If the opening time is t=0, a bank's settlement account balance at the central bank at t-1is denoted by B_{it-1}

$$B_{i,t-1} = \sum_{s=0}^{t-1} LP_{i,s} + \sum_{s=1}^{t} \sum_{j} X_{t_C - s}{}^{ji} - \sum_{s=1}^{t} \sum_{j} X_{t_C - s}{}^{ij}$$

(A)

Where in the following variables in the above mentioned equation will be defined as –

- $LP_{i,s}$ denotes the liquidity generated by bank i (by depositing collateral with the central bank) at time s;
- Second term is the sum of all payments made to bank i by all other banks j;
- Third term is bank i's payments to all other banks.

Going further towards the improvements in the above equation is that we have only considered the time of the payments were submitted to the central processor, tC, and not tR.

An alternative would come into the scenario will be the warehousing principle, which for the moment we have not considered.

For the moment we are assuming that the that the arrival times are drawn from independent uniform distributions, $t_R \sim U(0, t_C)$.

The other important issue to be taken into consideration has been the issue of the queuing principle. The banks shall have to take care of the balance available in the settlement accounts with the Central Bank and generate additional liquidity if the balance in below the required balance as defined in the equation (A)

The bank will have to work out a strategy, where-in they will forward the payments request to the Central Processor, start by noting that, since delaying payments is costly, banks will always settle payments when they have the liquidity to do it.

In that case, if $B_{i,t-1} > 0$ and greater than any of its payment requests in its hidden queue, $X_i^{HQ}(0,t)$, the bank will select such payments for settlement without delay. It can be well defined that the payments with a higher delay cost (e.g., time-critical payments) shall be made first and cleared off by assigning equal priority are 'first-in-first-out' (FIFO) and by value.

Hence it can be said the total costs incurred for initiating any given payments will be the sum of two components: a delay cost and a liquidity cost. Delay cost will always increase in the length of time the payment is delayed, $t_E - t_R$, which will tend towards infinity as the execution time approaches the end of the day. This actually means that the cost of payment failed can be very large – as the reputation risk exists.

Different payments have different payment priorities assigned, β, with high priority payments; hence it will carry a larger delay cost than low priority payments for a given delay.

We now consolidate all this together and together suggest the following specification of delay costs:

$$\text{Delay Cost} = \frac{b\beta X(t_E - t_R)}{T - t_E}$$

(B)

Although there could a few alternative assumptions for the liquidity cost –

- It may be constant throughout the day (though it may not need to be the same as that of generating liquidity at the central bank first thing in the morning)
- Depends on the length of time for which the bank expects to need it

In both of the above mentioned scenarios, they will always create an incentive for the bank to 'free ride' off the liquidity provided by its incoming payments, though it will be impossible to generate analytically an 'optimal' decision rule for how long to delay a payment.

The general analysis under such said conditions suggests that using the 'rule of thumb' which links the length of time a bank is prepared to delay in making a payment, cumulative of the all the outgoing payments and the incoming payments, all the expected payment requests (in and out) for the rest of the day, with any other related variable.

Applying the rule of the thumb, we assume the cost of liquidity to equal γ (where γ is independent of the length of time the liquidity is required).

Such a scenario will exist in UK, where there is no intraday money market and the banks have to enter into two overnight transactions in order to raise the liquidity they need. The banks always take into account the possibility of receiving incoming payments.

Going further on the same factor, the bank need to calculate the difference between the value of payments they expect to receive and the value of payments they need to pay out over all time periods between now and the end of the day, which we denote by the variable V.

Incase we are forced to assume a scenario that they are well aware of the total value of payments they shall need to make and expect to receive over the whole day, but they do not know the timing of any of them we can calculate V as:

$$V_{i,t} = \frac{\sum_{s=t}^{T}\sum_{j} X_t^{ji} - \sum_{s=t}^{T}\sum_{j} X_t^{ij} - \sum_{s=1}^{t}\sum_{j} X_t^{ji} + \sum_{s=1}^{t}\sum_{j} X_t^{ij}}{T - t}$$

(C)

Hence the cost function of the bank will be as follows:

$$Cost = \frac{b\beta X(t_E - t_R)}{T - t_E} + \max(\gamma((X - B) - V(t_E - t_R)), 0)$$

(D)

Now we try to arrive the cost by Differentiating with respect to t_E (time of execution) implies:

$$\frac{\partial Cost}{\partial t_E} = \frac{b\beta X(T - t_R)}{(T - t_E)^2} - \gamma V$$

(E)

Applying the above mentioned principle, the bank will be forced to follow the strategy as follows:

If $B > X$ and/or $\frac{b\beta X}{(T - t_R)} - \gamma V \geq 0$, then the bank will effect the payment immediately.

Otherwise, it will in the betterment of the bank to delay the payment. Now we are assuming at this stage that the bank's expectation of V turned out to be realised, the optimal execution time will be given by:

$$t_E = T - \sqrt{\frac{b\beta X(T - t_R)}{\gamma V}}$$

(F)

However it can be easily stated that this will not as smooth in the real time calculating the V, as the overall pattern of the outgoing and incoming payments cannot be pre-defined as per time.

It is likely that the pattern of incoming and outgoing payments would not be as smooth as assumed in calculating V. In that case, the bank would need to re-optimise each time it received a new payment request or a payment from another bank.

It will apply on the payments in its internal queue; part of the rule of thumb shall involve specifying an ordering for payments within the queue, say, first-in-first-out or by value from lowest to highest.

The parameter b is defined on the line of thinking that the banks will decide whether or not to delay payments based on their priority. Example – Relatively low priority (low β) payments, banks will be happy to delay them a while, whereas in the case of relatively high priority (high β) payments, banks will want to make them immediately.

Let β^* can be defined as the cut-off point at which all payments of priority higher than or equal to β^* are made immediately. Then different values of b will imply different values of β^*. So b can be thought of as parameterize a rule of thumb along the lines of 'Make any payment immediately if it is of high enough priority; otherwise, delay until incoming payments provide the liquidity needed to make it or we are getting close to the end of the day'.

If the banks are under the impression that they will delay the outgoing payments based on the fundamental to use the liquidity of the incoming messages than in that case the for the derivation of equation (F), we could think of a lower b as proxying for more regular and larger incoming payments since this would lead to an increase in the value of delaying payments (reduction in delay costs).

In any case, varying b shall lead to changes in the amount of liquidity used and numbers of delayed payments in a system., where-in the banks are obtaining the liquidity through the day, it will have the same effect as varying the amount of liquidity inserted in a in a system compare to the banks that obtain all their liquidity at the start of the day.

With the help of the equation below, we shall vary b in order to achieve different levels for the liquidity-delay trade-off in our system where liquidity was raised 'just-in-time'.

Minimizing the total cost implies an optimal time to execute the payment that will be given by:

$$t_E{}^* = \max\left(T - \sqrt{\frac{b\beta X(T - t_R)}{i(X - B)}}, t_R\right)$$

(G)

With the overall analysis we suggest that the banks: execute payments immediately if the liquidity is available and otherwise execute the payment at the time suggested by equation (G).

It can be cleared stated that higher the liquidity needed to make the payment and/or the cost of liquidity, the longer it will be delayed whereas the higher its priority the less time it will be delayed.

Liquidity Funding

We can assume two scenarios in this model as under –

1. The liquidity funding at the beginning of the day – enough to meet the day's requirement
2. The Just-In-Time (JIT) concept - liquidity is arranged during the course of time needed

To analyze the liquidity delay within the different systems, it is imperative to calculate the absolute values of liquidity posted and the number and value of delayed payments. This can be also supported by the time-weighted values for these payments in order to see what proportion of the day payments were delayed or settlement balances were positive.

All the time delays on the payments will be time stamps and these will be converted to the closet numbers of minutes from opening for payment requests, t_{isR}, and payment execution, t_{isE}, for each payment indexed by s for bank i such that when $(t_{isE} - t_{isR}) > 0$. The time weighted delay is given by dividing each of these numbers by T where T is total time in minutes from opening to closing. **- Where X will denote the payment**

The aggregate time weighted value of payments for N banks is given by

$$X^{TWD}(£) = \sum_{i=1}^{N} \sum_{s} X_{is} \left[\frac{t_{isE} - t_{isR}}{T} \right]$$

(H)

In case all the payments are delayed till the last minute of settlement, the , $X^{TWD}(£)$ will equal the total value of payments requested in the day and, in percentage terms will be 100%

The aggregate time weighted value of liquidity (L^{TW}) used is a useful measure to be contrasted with the total absolute value of payments made and the liquidity used in so doing. This is defined as

$$L^{TW} = \sum_{i=1}^{N} \sum_{s} L_{is} \left[\frac{T - t_{isL}}{T} \right]$$

(I)

Liquidity posted at opening (OL)

Now in this model we have taken in that case the six liquidity levels are operated for simulation purposes. These levels actually lie between the upper bound *(UB)* and lower bound *(LB)* levels of liquidity for each bank. The six levels of liquidity are calculated as follows

$$L(\alpha) = UB - \alpha(UB - LB)$$

(J)

where $\alpha = \{0, 0.2, 0.4, 0.6, 0.8, 1\}$

If sufficient liquidity is available, the payments will be effected else will be shifted to the queue.

Liquidity is raised just in time (JIT)

In a scenario where no liquidity provided at the beginning of the day, the banks raise their liquidity based on the principle of 'just-in-time' by borrowing from central bank, the moment they need to make payments. If it is not possible, the payment will be put in the queue to be paid off as and when the liquidity comes in. from various incoming payments.

Results: Based on the Time- Liquidity- Delay trade off in RTGS

The overall result of the simulation expert for both the system on base of 24 simulations, for each system on the base of the six value of the parameters and two alternative methods of the ordering queue payments are listed as follows

This simulation has been planned on the bases of the equation (J) for determining the liquidity-delay trade off in RTGS where –in all the liquidity is inserted in to the settlement account at the opening and delayed payments are settled on a FIFO basis.

Upon running the simulation of the OL system based the six values of (α). Table A gives the results of these simulations in contrast the Table B the reports are based on the principle that the banks submit the payments for settlement smallest in value first.

The most interesting result derived from the said equation is as follows

- When the lower value payments were send first there were some 10 unsettled payments of about £7.8 billion. The scenario leads towards a gridlock. (Table B)
- Where the system, which supported the FIFO scenario was able to comply without any gridlock problem. Another result being that the time –weighted delayed timed payments value were lower than the previous system (Table A)

Table A: Liquidity-delay statistics for Opening Liquidity, FIFO

Alpha	Liquidity (£ billion)	TW Liquidity (£ billion)	Number of delays	Number of delays (%)	Value of delayed payments (£ billion)	TW value of delayed payments (£ million)	TW value of delayed payments (%)
0.0	17.6	17.6	0	0.00	0.0	0	0.00
0.2	15.2	15.2	60	0.07	4.7	68	0.03
0.4	12.8	12.8	303	0.36	12.3	229	0.11
0.6	10.4	10.4	796	0.94	23.2	503	0.24
0.8	8.0	8.0	3370	3.98	49.2	1,279	0.61
1.0	5.6	5.6	12319	14.54	87.6	3,804	1.80

Table B: Liquidity-delay statistics for Opening Liquidity, Order by size, smallest first

Alpha	Liquidity (£ billion)	TW Liquidity (£ billion)	Number of delays	Number of delays (%)	Value of delayed payments (£ billion)	TW value of delayed payments (£ million)	TW value of delayed payments (%)
0.0	17.6	17.6	0	0.00	0.0	0	0.00

0.2	15.2	15.2	33	0.04	4.5	72	0.03
0.4	12.8	12.8	79	0.09	10.9	300	0.12
0.6	10.4	10.4	188	0.22	20.5	500	0.25
0.8	8.0	8.0	314	0.37	38.3	1,800	0.86
1.0[(a)]	5.6	5.6	848	1.00	65.2[(a)]	8,500[(a)]	4.04[(a)]

(a) Includes value of the 10 failed payments totaling £7.8 bn.

By analyzing above tables, an inference can be drawn if the banks are able to prioritize the payments in the FIFO method; it will be beneficial as the overall operational risk will be reduced comparatively as that under 'order by size, smallest first'.

Results: Tables C and D report the liquidity-delay trade offs for the JIT system

Going through the second simulation runs, it can be said that using the principle of the JIT system conditional on different threshold values for b. With $b = 6*10^{-5}$, banks will make all payments without delay. To do this, they need to use a total of £17.6 billion, the 'upper bound' value of liquidity needed by the system. With $b = 0.97*10^{-5}$ (at which point liquidity used is minimized), banks use a total of £11.9 billion if they order their queues by FIFO and £11.6 billion if they order their queues by value.

At any level of the liquidity, lesser number of payments is delayed when the queues are ordered by value compare to when order by the FIFO, but the value of delayed payments is always on the higher side compare to FIFO.

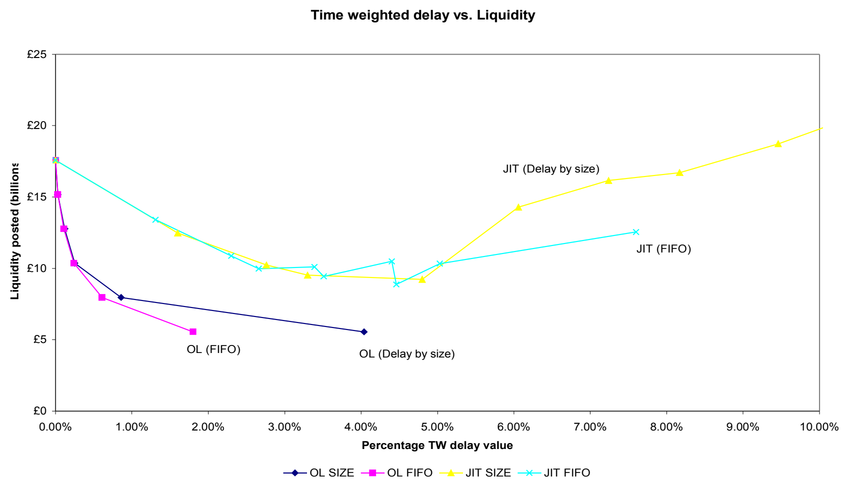
Table C: Liquidity-delay statistics for Just in time, FIFO

b	Liquidity (£ billion)	TW Liquidity (£ billion)	Number of delays	Number of delays (%)	Value of delayed payments (£ billion)	TW value of delayed payments (£ billion)	TW value of delayed payments (%)
$10*10^{-6}$	17.6	15.3	0	0.00	0.00	0.00	0.00
$5*10^{-6}$	17.5	15.2	102	0.12	0.97	0.10	0.05
$4*10^{-6}$	17.3	15.0	155	0.18	1.33	0.20	0.09
$3*10^{-6}$	16.8	14.4	258	0.30	2.81	0.44	0.21
$2*10^{-6}$	15.8	13.4	470	0.55	8.56	1.50	0.71
$1*10^{-6}$	12.5	9.5	2845	3.36	43.90	10.01	4.74
$0.97*10^{-6}$	11.9	9.1	6089	7.19	52.29	11.93	5.65

Table D: Liquidity-delay statistics for Just in time, Order by size, smallest first

b	Liquidity (£ billion)	TW Liquidity (£ billion)	Number of delays	Number of delays (%)	Value of delayed payments (£ billion)	TW value of delayed payments (£ billion)	TW value of delayed payments (%)
$10*10^{-6}$	17.6	15.3	0	0	0.0	0.0	0.00
$5*10^{-6}$	17.4	15.2	93	0.11	1.0	0.1	0.05
$4*10^{-6}$	17.3	14.9	137	0.16	1.7	0.2	0.11
$3*10^{-6}$	16.7	14.4	226	0.27	3.1	0.5	0.24
$2*10^{-6}$	15.9	13.4	403	0.48	9.0	1.7	0.80
$1*10^{-6}$	12.3	9.4	2119	2.50	44.3	10.2	4.84
$0.97*10^{-6}$	11.8	8.9	5447	6.43	53.8	12.4	5.89

The Figure below graphs the percentage time weighted value of delayed payments against the liquidity posted in the OL and JIT systems.



Concluding remarks

In the above mentioned model we have showcased the experiment based on the two mechanisms –

- Liquidity was posted at the beginning of the day
- Liquidity could be borrowed 'just-in-time'

The efficiency in recycling the liquidity posted by banks is the key to the design of RTGS system.

Observations from various simulation runs are as follows:-

- The delay of large payments (with low priority) leads to a deterioration in the collective performance of the RTGS system whether in the OL case or the JIT variant.
- It has been observed that the JIT system is more prone to rapid deterioration of its liquidity recycling capabilities than the OL system, which implies that the JIT system will generate more delayed payments, than any other identical system in which banks insert liquidity in the beginning of the day and this would be bad from an operational risk point of view.

Limitation of these simulation runs are as follows:-

- These simulations are based on a single stochastic simulation of data on one day's worth of actual payments. Simulations run on multiple sample data with larger number of payments days would fetch more authentic results for further analysis
- To get a real feel of the system, behavioural hypothesis also would be required to be incorporated in the simulation to explain the decision of how much liquidity to post at opening and allow the hypothetical parameters to get the outcomes of previous days
- For the JIT system, we assumed that banks did not take into account the possibility of using liquidity from incoming payments to make their own future payments when they choose how long to delay payments

The few issues, which need to considered relating to mechanism design in real time interbank settlement systems are as follows

- At what levels of liquidity and delay each system can operate in equilibrium?

- How the socially efficient outcome can be achieved by design?

Further, unless autonomous behaviour for banks can be robustly established, it is not possible to analyze how bank strategy may change in response to changes in policy rules.

Gridlock vs Deadlock

None of the RTGS will have the capacity to fully eliminate systemic risk. A failure by a large participant in the system to effect its payments may have knocking effects on other participants, ultimately leading to gridlock with potential systemic risk.

Insufficient balances in the settlement accounts of the participant banks can eventually lead to the system gridlock.

A dead-weight losses scenario will occur, when the payments are delayed, either in a central queue at the payments system or the bank's internal systems for the purpose of saving the liquidity. When the payments are delayed, the system faces the risk of the gridlock, which can eventually lead to the dead-weight losses experienced by the system. There is a real cost associated with actual time spent waiting for payments to be settled and the delays in getting funds to their ultimate destination.

This particular cost can be reduced by sending very large value payments in smaller value by breaking them. Central banks also might have a limit on the queuing time for payments temporarily without cover or they could provide an incentive for entry and settlement of payments in the early part of the operational day (e.g. cost penalties might be imposed on afternoon settlements).

Based on the above mentioned problem of gridlock, the Department of Informatics and Mathematical Modeling at the Technical University of Denmark did work along with the Danmarks Nationalbank in conceptualizing and developing this simple algorithm to resolve this problem given below under definition 3.

Definition of Gridlock and Deadlock

The terms gridlock, deadlock and gridlock resolutions problem are best defined with the help of mathematical equations as follows –

Let us take for a moment that there are a number of banks (n) and let's define the queue of the bank i' as Q_i, which compasses the set of payments. The total queue will be defined in the RTGS as $Q = \bigcup_{i=1}^{n} Q_i$.. Following the same principle, the subset of the payments to be settled simultaneously can be defined as $X = \bigcup_{i=1}^{n} X_i$, where X_i is the contribution from the individual bank's queue. In the individual bank's settlement account, the ex ante and ex post balance in the settlement account are expressed as B and B_i, respectively.

Going Further, the value of the payments sent and received by the bank i will be expressed as $S(X_i)$ and $R(X_{-i})$. The relative preference relation for the bank i in terms of the order in which payments need to settle at its account with the central bank will be defined as $\succ_i$., (it can be defined as the ranking of the payments in terms of sequence of settlement.

Definition 1 (Gridlock)

The gridlock is a scenario wherein the $Q \neq \emptyset$ and there is a non-empty subset X Q, and in such case that if the payments in X are settled simultaneously, then

$$B\,(B_i, \mathrm{X}) = B_i - S\,(X_i) + R\,(X_{-i}) \geq 0, \text{ for} = 1 \ldots n \qquad (2)$$

$$\forall\, x \in X_i\ \exists \in Q_i \setminus X\,, \text{ such that } q \succ_i x, \text{ for} = 1, \ldots n \qquad (3)$$

The first equation *(2)* states if the liquidity balance is available in the settlement account, the payments would be settled immediately.

The second equation *(3)* is used to assigned the priority to the payment messages to be settled in the payment system.

Definition 2 (Deadlock)

This scenario will be happening at the point, where the $Q \neq \emptyset$, and X, and when there not sufficient amount of liquidity as defined i.e. $X \neq \emptyset$

To resolve this grid lock, the largest possible subset of payments in queue would be selected to be settled simultaneously (using the bilateral – multilateral limit usage) without breaking the two equations (2) and (3).

Definition 3 (Gridlock Resolution)

Now let's define V(X) as the value or number of transactions in X. This gridlock resolution problem is $\max_{X\, Q} V(X)$, subject to the liquidity condition stated in (2) and the priority condition stated in (3).

Solution Algorithm Applied

The various series of steps applied by researchers to get the algorithm moving were –

1. Include all the queued payments in the said solutions
2. Calculate the virtual balances after the simultaneous settlement of all payments in the solutions
3. If the virtual balances in the all the accounts are positive, the settlement could take place, else start moving from the desired solution, payment of the lowest priority from a deficient bank and repeat back to step 2.

FINDING OF THIS ALGORITHIMS

The solutions is unique and optimal in nature and possesses two surprising properties such as –

- The solutions arrived is independent of the selection of that deficient bank which has removed its payment of lowest priority in each iteration
- The said algorithm is very fair in totality since it doesn't favor any particular bank and works on the "Fair Game Principle"

ACTION OF THE FEDERAL RESERVE ON 9/11 TO AVOID GRIDLOCK

During aftermath of *September 11*, the Fed provided liquidity to banks, in order to support the overall functioning of the banking activities, despite the horrendous attack which otherwise would have caused a massive deadlock in the payment systems.

This had a severe impact on the banking and financial institutions in Lower Manhattan. The markets were closed, participant banks/FIs relocated to backup sites, communication links failed or were in an unreliable stage, settlement instructions were lost, payments were delayed, and the Federal Reserve at one point had to inject more than $100 billion in additional liquidity, as an unprecedented sum.

Fed Reserve initiated the discount window loans in-order to inject a high level of liquidity for the banks to effect payments; this was also supported by the waiving daylight overdraft fees and penalty fees on overnight overdrafts and also assured that and assured banks that liquidity was available from the discount window with providing liquidity at rates that take into account the social benefits of payments coordination.

Table 1. Factors Affecting Account Balances of Depository Institutions, September 10-21, 2001

End of day balances, billion $

	Repos						Overnight credit		
Date	Term	Overnight	Check float	Swap draws	Currency	Other	Discount	Overdrafts	Balances
Sep 10	23	0	1	0	-611	601	0	0	13
Sep 11	23	0	4	0	-613	595	37	2	47
Sep 12	23	38	23	5	-616	585	46	4	109
Sep 13	14	70	47	20	-615	577	8	0	121
Sep 14	14	81	44	9	-615	578	0	0	111
Sep 17	12	57	12	0	-615	579	0	0	45
Sep 18	12	36	9	0	-616	578	0	0	19
Sep 19	12	28	4	0	-615	584	3	0	15
Sep 20	33	7	3	0	-614	583	1	0	13
Sep 21	33	1	1	0	-612	588	2	0	12

The above table evidences how overnight credit funding provided by the Fed Reserve to participants banks invariably avoided the gridlock, which otherwise could have converted to a deadlock scenario.

CONCLUSION

The second half of 2007 and the first half of 2008 have provided important learning about the role of liquidity for financial stability.

The problems arisen out of sub-prime mortgage crisis in US have led to drying up of liquidity in a range of markets at different points of time, though many of them are not directly related to the mortgage sector.

Indeed, the loss of liquidity has led to steep falls in the asset values causing further havoc at certain financial institutions and turmoil in the credit market globally.

Wonder still prevails about the quantum of total losses that would have inflicted deteriorating effect on the finance markets on the global horizon. The repercussions, nevertheless, would be reflected from the US markets across to the European Markets and eventually the Asia-Pacific.

The erosion of Liquidity actually recalls earlier episodes during the year 1998 and 2003, when the market “seized up“ resulted in the general unwillingness of the crowds to play in the markets.

To sum up, the various characteristics of the liquidity that have not be appreciated by the market financial are as follows –

- Liquidity, as a whole and at any point of time, is not dependent simply on objective factors, but also critically persuaded by various endogenous forces, especially the stringent dynamic reactions of market participants in the face of uncertainty and changes in asset values.

- In the global markets, liquidity works on the dual equilibrium phenomenon, which implies that liquidity is easily available and "cheap". But under stress conditions, liquidity becomes very scarce and expensive. It may become effectively unavailable.

- There is a strange correlation of interdependent between the liquidity in markets and individual intermediaries. Markets are virtually dependent on back-up liquidity lines from various global financial institutions and institutions are dependent on continuous market liquidity to execute their risk management strategies.

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