WHAT IS THE BEST WAY TO HELP? CENTRAL BANK STRATEGIES AND THE INTERBANK MARKET

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ABSTRACT
The paper proposes an analytical framework for addressing liquidity problems in cases where the expected value of the liquidity flow is zero, but negative deviations from the normal liquidity stance can trigger crises. Crises can be avoided by effectively signalling the temporary nature of the problem with the help of a central counterparty. The theoretical models and the numerical evaluations apply to the interbank market; however, the framework can also support the analysis of similar problems such as international payments or corporate liquidity.

INTRODUCTION
Every family, company, municipality, bank, and country has a liquidity situation, even if they do not monitor it. The specific reasons that change a liquidity position may be so varied and complex that it is advisable to treat liquidity developments as a random process for certain types of analysis. However, this is only for the convenience of modeling, and it is not a matter of general rule that blind luck controls the ability to meet instantaneous obligations.

Three things can happen to the liquidity situation of a person or institution: it improves, worsens, or does not change. We will not complicate this in the first step. It does not matter if it gets a little better or significantly better if it gets better. The analysis is radically simplified by the assumption that successive changes are always caused by new impulses, that is, these changes are independent in time.

Therefore, the tool of our study will be a trinomial tree, a well-known species of Markov chains. Let 0 denote the state in which we have the required liquidity and categorize the liquidity surplus and deficit states into discrete classes. In the simplest case, the liquidity position remains unchanged with probability $pm = 1/2$, improves with $pu = 1/4$ and worsens with $pd = 1/4$. We cannot go beyond the edges, hence, there is a ½ chance of turning back or staying there.

It is more exciting to assume that the evolution of liquidity is a mean-reverting process. That is, increasing liquidity surpluses (deficits) increase the probability of a downward (upward) movement. Furthermore, let us suppose that if we do not have the liquidity needed, we can get in trouble; the higher the liquidity shortage, the higher the probability of this trouble.

With all these assumptions, the random walk between liquidity states becomes not only mean-reverting but asymmetric as well. And now we can start asking the real questions. Should A give a liquidity loan to B at the expense of its own liquidity? Does the network of mutual assistance improve the average liquidity situation in the system? Another interesting question in this framework is, if there is a central counterparty (CCP) with a limited rescue power, are the big ones or the small ones worth saving? Are those in big trouble (who need more money) worth leaving to their fate? On which parameters depends the effectiveness of the rescue strategies?

Let us examine a place where liquidity surpluses and deficits meet literally every day. This is the interbank market. Let us model this much-studied market through the glasses of the analytical framework outlined above.

HISTORICAL BACKGROUND
It has been long known that central banks can contribute to financial stability by lending to banks that lack liquidity. When the Overend-Gurney Bank got into a liquidity crisis in 1866, the Bank of England (BoE), despite being asked to do so, was in no hurry to help. The consequence was a general, systemic liquidity crisis on the London money market. The lessons of the case were summarized by Walter Bagehot, offering a recipe to avoid similar future situations: the central bank should immediately provide a liquidity loan to a bank in need, with adequate collateral and high interest rate (Bagehot 1873). BoE, that had been existing for almost 200 years by that time, became a real central bank by embracing the Bagehot proposals.

In contrast, the foundation of the Fed was based precisely on the idea that situations of liquidity shortage and crisis, which were frequent due to the geographic structure and cyclicality of the economy and the banking system, could be prevented if there was a bank that could provide credit in time (Mehrling 2002).

A bank’s liquidity crisis is particularly dangerous because it can cause an infection. Therefore, it is worth examining, on the one hand, what leads to a bank run, that is to say, depositors withdraw too much liquidity...
from a particular bank, and, on the other hand, how it becomes a general panic when several players in the banking system are attacked simultaneously. The decision of depositors depends on several factors according to the classical DD model (Diamond-Dybvig, 1983) and to its later versions (Bhattacharya-Gale 1987, Diamond-Rajan 2001, Freixas-Holthausen 2005). One such factor is what the depositor thinks about the quality of the bank's illiquid assets. If he suspects (or may know) that the market value of the assets is declining, he will withdraw the deposit. However, it is not only individual belief that counts. The depositor may know for sure that the bank's assets are excellent, if others do not think so, it is worth joining the crowd and deciding to liquidate. These considerations can lead to an extremely unfavorable Nash-equilibrium where the optimum strategy for all depositors is liquidation. Regardless of the quality of the bank's assets, a crisis may occur. This happens when the number of impatient depositors (who want to consume earlier) increases. Here, too, the above equilibrium situation may occur: the choice of the time path of consumption is influenced by what the depositor thinks of the consumption decision of the others. If he believes that too many market players have become impatient, then he should not hesitate, because in this case, postponing the consumption may lead to the inability to consume at all because of the bank's crisis. One of the suggestions to avoid similar situations is the introduction of deposit insurance. However, this raises several problems: on the one hand, with deposit insurance, depositors do not control the bank, and on the other, the bank tends to finance riskier projects (Anginer-Demirguc 2018). In addition, deposit insurance is in practice confined to retail depositors, while the onset of a bank crisis may be the result of decisions made by large investors such as money market funds. That is, the behavior of institutional investors can still lead to the unfavourable equilibrium of the DD model. DD-like models have some critical assumptions that in practice may not be valid. Depositors, especially the small ones, are unable to value the bank's assets. The processes leading up to the 2008 crisis prove that even the official institutions (supervisors, credit rating agencies), the interbank market, and sometimes even the bank managers themselves are unable to do so. Given the decision already made by other players, the depositor can easily decide on liquidation, but an ex-ante strategic game between retail depositors is hardly imaginable. If something is easily observable for depositors, it is the size of the bank's liquidity. The magnitude or proportion of this relative to the bank's liabilities may indicate to the depositor the likelihood of a crisis. However, since the depositor is unfamiliar with the operation of the bank, misinterpretation of the temporary liquidity shortage and the consequent withdrawal of the deposit may create a self-fulfilling liquidity problem. To prevent such situations, the bank must credibly signal to depositors that the deficit is only temporary. The liquidity situation of depositors or of the bank can be modeled in several ways. The solution we have chosen, according to which we describe the development of liquidity using a Markov process, is rare in the literature. In Deaton's (1991) model, consumers' labor income, and thus their current liquidity, is a Markov process. This can be used to explain the aggregate savings rate, but the model does not examine the impact on the liquidity situation of the banking system. Temzelides (1997) examines banking systems with different structures, where the strategy choice of clients - as a repeated game - results in a Markov process of the liquidity of banks. The model has the ability to reflect the liquidity crises experienced in U.S. banking history. In Csucsik and Kiss's (2018) study, the liquidity situation of depositors follows a Markov process, for which banks need to come up with an optimal strategy that keeps the probability of a bank run below a certain level. The literature on the subject does not take into account that the central bank as an institution is not only a monetary authority but also a financial supervisor. This is not the case everywhere, but, especially since the 2008 crisis, on the one hand, the two institutions have been merged in several countries, and on the other hand, even if they have not been merged, there is much closer cooperation than before. This, in addition to mitigating systemic risks (Borio - White 2004), can help the central bank, as a lender of last resort (LLR), provide liquidity loans to solvent banks only. This has been for long a prerequisite for the LLR function (Bagehot 1873, Mehrling 2011), but it lacked the institutional background. Even if the bank is solvent, it does not need to be rescued immediately and at all costs from a liquidity shortage (when there is no liquidity crisis yet, but there is a good chance for it) or from the crisis. That is, the central bank may adjust the decision to provide banks with liquidity to some strategy and not necessarily to the price offered (interest rate). The question is what should be this strategy if the central bank wants to discipline the market (constrained liquidity supply) and, at the same time, also wants to minimise the portion of banks in liquidity shortage and/or in a liquidity crisis.

**MODELING ASSUMPTIONS**

Other than those listed in the previous section, we are not aware of approaches that describe bank liquidity as a random walk. Thus, the assumptions below are arbitrary and will obviously need to be refined later. Let the market size of the bank-accounts be \(1\), the share of the observed bank (henceforth \(B\)) is \(\lambda\), the share of other banks is \((1 - \lambda)\). Suppose that there is a large number of clients, and they are evenly distributed among the banks. (That is, there are no special banks that keep accounts with e.g., public servants, car dealers, etc. So if the size of the public servants' accounts is \(x\), then \(\lambda * x\) of these accounts are at \(B\). The balance sheet of a bank looks like this:

<table>
<thead>
<tr>
<th>R (liquidity reserves)</th>
<th>D (deposits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L (loans)</td>
<td>E (equity)</td>
</tr>
</tbody>
</table>
Capital (equity / net worth) is an important part of a bank’s balance sheet, but it does not play a role in our model because we deal with liquidity. There are two components of the liquidity reserve:

\[ R = R_C + R_D \]

where

- \( R_C \) - cash reserves
- \( R_D \) - account at the central bank

We assume that the bank can exchange cash and central bank account money reserves without transaction costs. Customers can pay to each other with cash and with deposit accounts. With deposit payment, \( D \) and \( R_D \) decrease, with cash payment, \( D \) and \( R_C \) decrease. In the first case, the liquidity outflow of the buyer’s bank equals the liquidity inflow of the seller’s bank. This is not always the case when making a cash payment: the customer may just withdraw the cash and keep it; or make a purchase with it, but the seller does not deposit the full amount in his/her bank.

We assume that customers have some cash holdings, so there are two types of systemic shocks: net withdrawal and net cash depositing.

First, let us assume that \( p \) percentage of customers purchase in a given period; and suppose that if a cash purchase is made, the seller will immediately deposit the proceeds in her/his bank. As a result of the latter assumption, we do not need to distinguish between the two types of liquidity reserves.

In this case, the liquidity flow of bank B is as follows:

- **liquidity outflow:** \( p^* \lambda (1 - \lambda) \)
  - \( (p^* \lambda) \) is spent by depositors of B, but due to the assumed even distribution of costumers \( (p^* \lambda) \) is liquidity is returned.

- **liquidity inflow:** \( (p^*(1 - \lambda))^* \lambda \)
  - \( (p^*(1 - \lambda)) \) is spent by the depositors of other banks, \( \lambda \) times this amount flows into B

Thus, the expected change in the size of the bank's liquidity is just zero.

Of course, this does not mean that the change is zero at all times. It is up to the bank’s Treasury to analyze the further properties of this flow, that is, to evaluate its higher order statistical moments over time. For example, there may be a net liquidity outflow on the first 5 days of the week because customers withdraw cash that is spent at various stores. Sooner or later, these stores deposit the money in the bank. More cautious stores deposit at the end of the day. Other stores will wait until Friday. And there may be forgetful or careless stores that do not deposit even at the end of the week. In any case, it can be assumed that the more cash a store has, the more likely it deposits it. For the bank, this means that the greater the liquidity shortage, the more likely the deficit decreases.

Customers usually spend their money evenly in time (so one-fifth of customers does the shopping on Monday, one-fifth on Tuesday, and so on). But shopping can be hampered by anything, so there may be days when liquidity at the bank is increasing: cautious stores deposit their cash revenue (from impatient costumers of other banks) at end of the day, patient or lazy costumers of the bank postpone their shopping. But the longer clients postpone, the more likely they withdraw money, and the bank’s liquidity surplus is reduced.

So an average 5-day week, when everyone is behaving normally, looks like this:

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>T</th>
<th>W</th>
<th>Th</th>
<th>F</th>
<th>sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>liquidity out</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>liquidity in</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>liquidity flow</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 1: A possible liquidity flow of the bank

But if the store is careless, or if customers are impatient (spending more than the average), it can turn negative; on the other hand, if stores are cautious, customers are patient (or customers of other banks are impatient), it can turn in a positive direction.

Independently of the process described, the bank may suffer a negative liquidity shock. We assume that customers are well informed and aware of the bank’s current liquidity situation. And the worse the liquidity situation is, the more likely they are to decide to withdraw their deposits. It is important to understand that there is no reason to panic because liquidity sooner than later returns to the normal level, i.e., negative deviations are only temporary. However, customers are unfamiliar with the liquidity process, and they can only monitor the size of liquidity.

**THE MODEL**

The liquidity position of banks is modeled on a discrete probability field. Let \( \mathbf{v} = (v_{-(n+1)}, v_{-n}, \ldots, v_0, \ldots, v_n) \) denote the probability distribution of the bank’s liquidity situation at a certain period, where the indices of the elements of the vector represent the liquidity status of the bank:

- **in states** \( -n \leq j \leq n \) the size of the bank’s liquidity is \( n + j \):
  - the normal state is \( j = 0 \):
  - in states \( j < 0 \) the bank is in liquidity deficit
  - in states \( j > 0 \) the bank is in liquidity surplus.

- **the state** \( j = -(n + 1) \) is the liquidity crisis when the bank is unable to meet its short-term payment obligations.

The bank randomly walks between these states for several periods. For the sake of simplicity, a period should be a day. During the first half of the day, the bank’s customers change the bank’s liquidity status. Ignoring the possibility of shocks, the bank jumps from state \( j \) to states \( (j - 1), (j + 1) \) with the probabilities \( p_{dj}, p_{mj}, p_{uj} \) respectively.

In line with the model assumptions, the bank knows the following about transition probabilities:

\[ p_{uj} \geq p_{uj} \quad \text{if} \quad i < j \]
\[ p_{dj} \geq p_{dj} \quad \text{if} \quad i > j \]
\[ p_{u0} = 0 \]
\[ p_{d0} = 0 \]
The bank is aware of this part of the model and, therefore, cannot get into a crisis. However, it is unaware that customers may withdraw liquidity from the bank as a precaution, not for financing their purchases, but for prudential reasons. More precisely, the bank is aware of the possibility of shocks, but it has no means to calculate the probabilities. If it had, it could adjust its liquidity strategy accordingly.

The probability of liquidity withdrawal, that is, entering the \((-n + 1)\) state in the \(i\)th state is \(p_s j\), where

\[
\begin{align*}
p_s j &= 0 & \text{if} & & j \geq 0 \\
p_s j &> 0 & \text{if} & & j < 0 \\
p_j &> p_s j & \text{if} & & i < j < 0
\end{align*}
\]

The interbank market opens in the second half of the day, where banks can lend or borrow money from each other or the central bank. The consequence of interbank activity is that the next day the shock probability changes, but the transition probabilities remain unchanged. The shock probability changes because customers decide to withdraw their deposits (the next day) depending on the observed size of the bank’s liquidity at the beginning of the day. However, they do not know where this liquidity comes from. Clients decide on “normal” withdrawals and depositings based on their own situation, which is not influenced by the interbank market.

If a bank falls in a liquidity crisis during the day, it will not be able to apply for a loan on the interbank market, so it will stay in state \(-n + 1\). The next day, the central bank can rescue banks in crisis by restoring their liquidity status to normal (state 0). The probability of rescue is \(pr\).

We first examine the random walk process, assuming no interbank lending. In this case, the transition probabilities are described by the following formula:

\[
M \in R^{(2n+2) \times (2n+2)},
\]

where the rows and columns of \(M\) are numbered (similar to \(v\)) from \(-n + 1\) to \(n\). The element \(m_{ij}\) denotes the transition probability from state \(i\) to state \(j\). Thus:

\[
\begin{align*}
m_{i,j-1} &= (1-p_s j) \times p d_j \\
m_{i,j} &= (1-p_s j) \times p m_j \\
m_{i,j+1} &= (1-p_s j) \times p u_j
\end{align*}
\]

if \(-n \leq j \leq n\):

\[
m_{-(n+1), -(n+1)} = 1 - pr
\]

\[
m_{-(n+1), 0} = pr
\]

Other elements of the matrix are zeros.

The dynamics of the model are described by the following equation:

\[
y_{t+1} = y_t M
\]

The steady state equilibrium of the model is the state vector \(v^*\) for which:

\[
\hat{v}^* = v^* M
\]

Since \(M\) is not positive, the equilibrium solution cannot be determined by eigenvalue search, but it can be found numerically.

We model the interbank market with the following constraint: banks that take liquidity loans are given exactly enough liquidity to have \(n\) units (to get into the state \(j=0\)), so the next day the bank is faced with \(p_s 0 = 0\) shock-probability.

The function \(f: R^{2n+2} \rightarrow R^{2 \times (2n+2)}\) represents the interbank market, i.e.,

\[
f(v) = (v_1, v_2)^T
\]

where:

\[
\begin{align*}
v_1 &+ v_2 = v \\
\text{and} & \quad v_1 \quad \text{represents banks who took out a liquidity loan, while} \quad v_2 \quad \text{represents those who did not.}
\end{align*}
\]

Since banks in the first group have zero probability of shock, so they face the \(M\) transition matrix in the first half of the following period:

\[
M \in R^{(2n+2) \times (2n+2)}
\]

\[
\bar{v}^{t+1} = v_1^t M + v_2^t
\]

The equilibrium of the model is the probability vector \(v^*\) for which:

\[
\begin{align*}
\bar{v}^* &= v_1^* M + v_2^* \\
\text{and} & \quad v_1^* \quad \text{represents banks who took out a liquidity loan, while} \quad v_2^* \quad \text{represents those who did not.}
\end{align*}
\]

**CENTRAL BANK STRATEGIES**

Prior to the opening of the interbank market, the aggregate liquidity deficit and surplus are:

\[
LD = \sum_{-n \leq j < 0} (-j)^* v_j
\]

\[
LS = \sum_{j > 0} j^* v_j
\]

In the interbank market, it is assumed that the central bank acts as a central counterparty, i.e., the banks do not contract with each other directly. The central bank distributes liquidity according to a predefined procedure, which has two components:

- actual liquidity supply:

\[
L_S = \min[LS, (1-c)*LD]
\]

where \(0 \leq c < 1\) denotes the cut constraining the available liquidity. The size of the cut expresses central bank discipline and flexibility.
• the principle of liquidity allocation implemented by
  the central bank according to the $f_3$ strategy functions.

As in the basic model:

$$f_3(v) = (v_1, v_2)^T,$$

and

$$v_3 + v_2 = 1.$$

At a given level of central bank discipline / flexibility (c), we examine four strategies (S).

$S = 0$ - in this case, the central bank does not lend at all, i.e.: $v_1 = 0$. This gives us the basic model without the interbank market.

$S = 1$ - in this case, the central bank randomly selects a $v_1$ vector that satisfies:

$$\sum_{-n \leq j < 0} (-j * v_{1,j}) = L3$$

$S = 2$ (LTH - Low To High) in this case, banks with low liquidity shortages will receive loans first, i.e.:

$$v_{1, -1} = min\{\frac{-1}{n} (L3 - \sum_{j < -1} (-i * v_{1,j})), v_j\}$$

and for $-n \leq j < -1$

$S = 3$ (HTL - High To Low) in this case, banks with high liquidity shortages will receive loans first, i.e.:

$$v_{1, -n} = min\{\frac{1}{n} (L3, v_{-n}), v_j\}$$

and for $-n < j \leq -1$

$$v_{1, j} = min\{\frac{-1}{n} (L3 - \sum_{j < -1} (-i * v_{1,j})), v_j\}$$

**NUMERICAL SOLUTIONS**

To evaluate the basic model and the central bank strategies, let n = 5, and the probabilities be as follows.

<table>
<thead>
<tr>
<th>$p_r$</th>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.8</th>
<th>0.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p_d$</td>
<td>0.05</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>$p_m$</td>
<td>0.05</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>$p_a$</td>
<td>0.05</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Table 2: Transition probabilities of the model

The probability of rescuing banks in crisis is $p_r = 0.1$

The results shown by Figure 1 can be interpreted in two ways:

- the individual bank will find itself in the various liquidity situations over the long-term with the probabilities shown in the figure. The expected liquidity of a bank based on probabilities belonging to fields -5, -4, ..., 5 is 4.52, which is lower than the ideal 5 - this is caused by negative shocks.
- the participants of the banking system are distributed among the liquidity conditions in the long run according to the probabilities shown in the figure.

Banks in a liquidity crisis are rescued (set to 0) by a third party in the base model with a 10% probability. In practice, this is usually the central bank and/or the government. The capacity of the central bank in the event of a liquidity crisis is unlimited, i.e., it can decide to rescue all banks in crisis immediately ($p_r = 1$), but it may also have the attitude of never saving anyone ($p_r = 0$) like the pre-Bagehot Bank of England. Depending on the probability of rescue, the proportion of banks in crisis (or more precisely, the equilibrium probability of the crisis) is shown in Figure 2. From this, it seems that the central bank does not have to be "overly" committed. On the one hand, even if it tries to save everyone right away, there will always be banks in crisis because they have just got there. (In the model, rescues occur in t, for banks that got in trouble in (t-1) or earlier. But in t, newer banks get into this state.) On the other hand, the flattening of the curve shows that the central bank is devoting ever greater resources to monitoring the market as a whole in vain, because after a while it can barely reduce the proportion of banks in crisis. Third, the more the central bank is willing to bail out the banks, the less they will pay attention to their liquidity situation, thus moral hazard is increasing. (The latter two factors, i.e., central bank cost and moral hazard are not included in the model).
market. In the second case (Figure 4), there is an interbank market, where, as described in the model, banks with liquidity shortage receive overnight credit. It is clear that in the latter case, the volatility of the size of (individual) liquidity is much lower.

A complete evaluation of central bank strategies would involve an examination of the statistical moments of liquidity flows. However, this goes beyond the scope of the study. Besides, our goal is not to choose the best strategy, but to demonstrate that the model presented may be suitable for this. Therefore, in the following, we focus only on the edge of the equilibrium distribution.

Figure 3: Random Walk without Interbank Market

Figure 4: Random Walk with Interbank Market.

Figure 5 shows the equilibrium crisis probability at a given level of the central bank rigor. The figure has several lessons:

- If the central bank does not apply a cut \((c = 0)\), then regardless of its strategy, there will be no bank in crisis in the long run. The explanation for this is as follows. Whichever field the bank is on (even \(j=-6\)), the probability of getting to \(j=0\) (in a reasonably long time) is 1. For a group of banks that reach state zero, the expected liquidity demand is the same as the expected liquidity supply since transition probabilities are symmetric around this state. Thus (since \(c = 0\)), the shock probability is zero for the members of this group. And since all banks are expected to touch the zero field in the long run, the equilibrium crisis-probability is zero.

- By operating a liquidity market, a lower equilibrium crisis-probability can be achieved than by increasing the chances of a rescue by the central bank \((pr)\). We have seen earlier that even in the case of immediate rescues, the share of banks in crisis cannot be reduced below 3%. That is, banks are better off with nets (access to liquidity, central bank guarantees, IMF credit line, etc.) than with fish (rescues in times of crisis).

Out of the three possible liquidity-providing strategies, with the central bank's increasing tightening \((c)\), the HTL strategy seems to be the best. However, with a low cut, the LTH strategy performs better. It also appears that the first strategy, when the central bank randomly distributes liquidity, sometimes dominates the other two. The result of the first strategy is actually partly the result of a simulation, since the central bank (the program that runs the simulation) randomly chooses the vectors that follow the rules of the strategy. Therefore, the realisation of this may be different from what is shown in the figure: if the central bank distributes liquidity randomly, depending on what is pulled out of the hat, the equilibrium distribution (including the likelihood of an equilibrium crisis) will be different.

Given the shock probabilities, it would be possible to calculate, in a given market situation (distribution), which liquidity allocation would lead to the best result, i.e., to the least equilibrium crisis-probability. However, the practical implementation of such a sophisticated strategy would be too demanding for the central bank since it would need to know exactly the probabilities of shock. If the central bank does not have this information and only knows (which is plausible) that banks with lower liquidity have a higher probability of shock, it should choose Strategy 3 (HTL).
CONCLUDING REMARKS

The previous section demonstrated, through a rather limited example, that the model may be suitable for analysing liquidity problems. The study can be extended to other areas. Small open economies that use foreign currency for their international transactions are facing the similar problem as banks do. The external balance of the economy - at best - fluctuates around zero, but in times when the external deficit is reducing the country's international reserves, panic among investors and sudden capital outflows can cause payment difficulties. It may be helpful if someone (such as the IMF) is ready to provide liquidity loans. The same can be said for companies where some subsidiaries are experiencing temporary payment difficulties from time to time. In this case, it may be handy if other affiliates or the parent company help, even by creating a cash pool.

The model can be refined to tell more about reality. There are three possible directions. With the introduction of players of different sizes, much more can be explored about the CCP's strategy choices. In this case, the question is not only what is the appropriate strategy based on the size of the individual liquidity shortage, but also whether e.g., can someone be big enough to be saved anyway. As we have pointed out, choosing the right strategy can be based on accurate calculations, provided that the probabilities of shock are known. Similarly, proper monitoring of the market can reduce the number of actors in the crisis to a sufficiently low level. But in practice, all this comes at a cost. It may be worth comparing these costs with the benefits of a well-chosen liquidity allocation. That is, rather than through some property of the equilibrium distribution optimisation could be done by introducing some sort of social utility function into the model. Last but not least, the model is currently not capable of demonstrating infections. This would require that the elements of the transition matrix are influenced by the current liquidity position of the participants.

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