Box 1: The Impact of Arrears on the Large-Value Payment System (LVPS): An Initial Approximation through Simulations

1. Introduction

The large-value payment system (LVPS) is a network of participants who exchange payments during the day. Therefore, its proper functioning is based on the individual dynamics of each participant and not on the leadership of a particular institution or even on a general agreement among the participants. In other words, each institution organizes its payments individually, seeking to satisfy its own interests; however, such behavior does not necessarily create benefits for the rest of the participants in the system.

There are a variety of reasons why an institution may be unable to make payments on time. These can range from structural situations related to the institution's financial capacity to make its payments (i.e., bankruptcy) to momentary circumstances, such as a breakdown in its communications network or the impossibility of physically accessing the institution's facilities due to difficulties that affect law and order. In fact, problems with law and order can impact normal operation of the LVPS during the rest of the day.

Based on the foregoing, this section represents an attempt to quantify the possible impact on liquidity that may occur in the LVPS due to a temporary delay (i. e.: during the day) in the normal flow of an institution's operations, but in a situation where the affected institution would, in any case, comply with all its payments before the end of the day.

2. Necessary Minimum Liquidity (*Upper Bound*)

The Colombian LVPS, known as the Deposit Account System (CUD), provides a service for authorized participating institutions to transfer funds and record fund transactions between deposit accounts, in their own name or in the name of their clients, in order to settle obligations agreed on in financial markets, as well as clearing for other financial market infrastructures (FMIs).

Real time gross settlement (RTGS), which is the modus operandi of the CUD, allows money to be transferred and transactions to be settled one by one for their gross value and to be completed immediately (in real time), provided the originating institution has a sufficient balance in its deposit account. Thus, the CUD eliminates settlement risk by debiting the originator and crediting the payee immediately for each individual transaction.

The CUD has ways and means to expedite the settlement of transfer orders and to reduce the liquidity required for this purpose.[1] In addition, BanRep offers intraday repos to minimize obstacles to transactions and to help payments to be made on time.[2]

Although the system has mechanisms to optimize the settlement of transactions, it is the participants who, based on the liquidity sources available to them, manage the sequence in which they settle their payments during the day and, thus, their minimum liquidity needs.

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1 These mechanisms are described in Section 2 of Chapter III in the Payment Systems Manual, External Operating and Service Circular DSP-158 dated 17 January 2022.

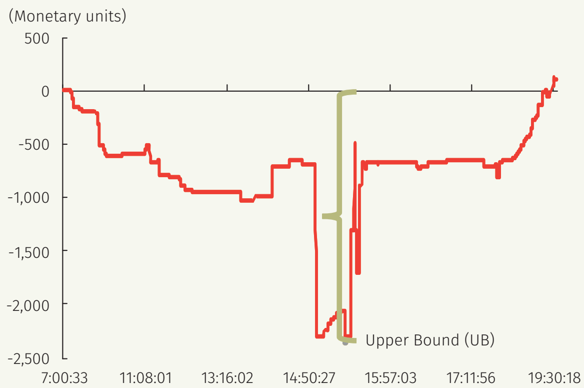
2 As per the provisions In External Regulatory Circular DFV-120, Issue 61 "Intraday Repo," in the Fiduciary and Securities Department Manual.

In RTGS systems, such as the CUD, a participant's minimum daily liquidity needs for a set of liquid transactions can be estimated, as suggested by Koponen and Soramäki (1998), via the upper bound (UB) concept, which represents the minimum balance the institution should have had at the start of the day to successfully settle all its payment obligations in the sequence in which they were recorded. This daily UB for an institution can be calculated as follows:

$$UB_t = \left| \, min\,[0; min \textstyle\sum_{j=0}^{t} (P_j^I - P_j^O); \forall t \in [0,T]] \right|$$

Where P_j^I y P_j^O are, respectively, the incoming and outgoing payments at time j, and T is the time when the system closes its operations for the day. Therefore, during an operating day between (0,T), if an institution had the following sequence of payments {(j=0,0),(j=1,+20(incoming payment)),(j=2,-40(outgoing payment)),(j=3,-60(outgoing payment)),(j=4,+10(incoming payment))}, then the value of its UB at different times during the day would be {(t=0,0),(t=1,0),(t=2,20),(t=3,80),(t=4,80)} and, for the entire day T=4, the minimum balance needed at the start of the day to meet the full sequence of payments (UB_T) would be 80.

Graph B1.1
Determining Mininum Liquidity Needs



Source: *Banco de la República* (DSIF).

It is important to note that the Basel Committee on Banking Supervision has now included this approach in its comprehensive supervisory framework, particularly with respect to the tools available to establish metrics to assess liquidity risk.[3]

As illustrated in Graph B1.1, the UB is the lowest point in an intraday balance path that starts with a balance of zero and is updated with each transaction that credits (debits) incoming (outgoing) resources at the time they are recorded (actual payments). Changes in the sequence or timing of an institution's payments, either to bring them forward or to delay them, may cause the liquidity needs or the UB to change. For example, if the value of payments received by an institution in one day is equal to or greater than the value of those it delivers, it could first wait to be paid and then make its payments with the liquidity it receives, strategically adopting a free-rider stance on intraday liquidity and, thus, reducing its UB to zero.

Accordingly, for an institution that postpones it payments and relies more on the resources it receives from its counterparties as a source of intraday liquidity to comply with its obligations, the balance at the start of the day becomes less important. On the other hand, the situation of the counterparties receiving payments from the postponing entity could be the opposite, since the delay in the resources they receive during the day reduces the importance of this source of liquidity to fund their payments and forces them to strengthen other alternative sources such as the start-of-day balance, to the extent determined by their UB.

When the path of an institution's intraday balance is located entirely above the horizontal axis (i.e., it is greater than zero), this means it has met all its payment obligations on time by funding itself with the liquidity it received from its counterparties.

In a LVPS such as the CUD (which does not grant overdrafts), an institution needs a balance at the start of the day that is at least

3 For more information, see "Liquidity Monitoring Metrics "(SRP050), a chapter that is part of Pillar II in the supervisory review process, available at: https://www.bis.org/basel_framework/standard/SRP.htm.

equal to the UB, if it is to settle all its transactions on time. Otherwise, part of its obligations might not be met in the observed sequence.

2. Delaying Payments and their Measurement

Delaying payments could favor the institution that does so, insofar as it allows it to fund a larger fraction of its payments with the liquidity it receives from its counterparties. However, an institution might not necessarily postpone payments during the day because of a strategic decision aimed at reducing its UB, but due to some operational failure, as mentioned in the introduction, such as the one associated with its computer infrastructure that prevents it from sending payments to its counterparties for a few minutes or hours.

To measure the impact of payment deferral on the minimum liquidity needs of CUD participants, a simulation exercise was done using the Bank of Finland's payment system simulator (Bof-PSS2). It is important to recognize, as an assumption in the exercise, that the institutions, except for the one that postpones its payments, assume a passive attitude, and send their payments in the "normal" sequence, despite the delay.

The exercise has multiple objectives. The first is to quantify the positive (negative) effects a temporary (i. e.: hours) postponement of payments would have on the postponing institution (the counterparties of the postponing institution). The second is to gauge if the counterparties of the postponing institution have enough additional liquidity (namely, the liquidity they can obtain through intraday repos with BanRep) to meet the increased liquidity needs (UB) resulting from the postponement; and the third is to quantify, at an aggregate level, the resulting net effect on liquidity needs (while the postponing institution may reduce its UB, its counterparties may increase theirs).

The ten days with the largest payments settled in the CUD were selected for this purpose (between 02 January 2020 and January 19, 2020), and the institutions' UBs were calculated for the payment sequences that were observed. The two-hour time slot when the largest payments in the day originated was identified for each of these days, and the financial institution that sent the largest payments was identified for each of these slots.

To gauge the impact payment deferral has on the individual liquidity needs (UB) of the deferrer and its counterparties, a scenario was developed in which the institution that most sends payments during the period with the largest payments on the selected days fails to do so and, only when that time period is over, does it recover the momentum in its payments by sending the payments that were not settled during that period, respecting the order in which they occurred originally.

Simulated payment sequences were constructed for this purpose for each of the selected days. This was done by changing the original schedule observed for the transactions sent by the most active institution within the two-hour period with the largest payment value for a schedule in which the institution maintains the actual order of its late payments but sends them consecutively with an interval of fifteen seconds between each deferred transaction, once the two-hour period is over.[4]

To evaluate how much the liquidity needs would vary at an individual and aggregate level because of an institution's payment deferral, the minimum liquidity needs (UB) were calculated for these new simulated payment sequences.

4 A two-hour deferral is the standard time considered in international best practices for the recovery and resumption of critical functions after an outage occurs. See "Federal Reserve System. Interagency Paper on Sound Practices to Strengthen the Resilience of the U.S. Financial System". April 2003 and the "European Central Bank – Issues Paper on Payment Systems Continuity. May 2005, at: https://www.newyorkfed.org/medialibrary/media/banking/circulars/11522.pdf and https://www.ecb.europa.eu/paym/pdf/cons/paysysbusinesscontinuity/paysysbusinesscontinuity.pdf

By way of illustration, Graph B1.2 shows the differential effects of two-day payment deferrals on the observed and simulated intraday balance paths and their respective UBs, for both the deferring institution and its main receiving counterparty.

As shown in Graph B1.2, for day five (5), the institution that stops sending payments in the 14:00:00-15:59:59 time frame would reduce its minimum liquidity needs (UB) by approximately COP 1.3 trillion (t), because the liquidity it receives during that time frame allows it to fund its delayed payments later, thereby reducing the need to fund its payments with its initial liquidity. On the other hand, its main counterparty receiving payments would experience a slight increase in its UB, on the order of COP 300 million (m), which corresponds to 0.2% of the observed scenario.

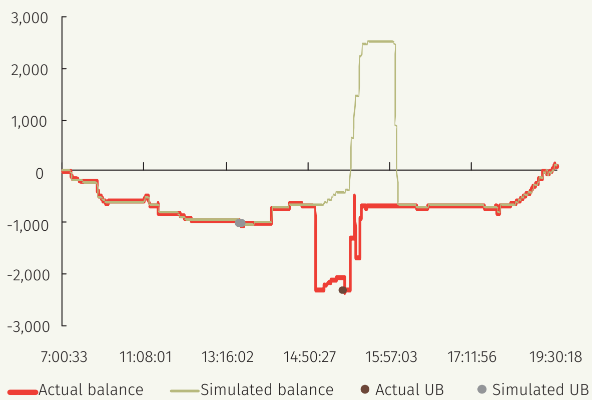
For day one (1), the institution that postpones payments in the same time slot would not obtain the benefit of reducing its UB but would cause its main counterparty to increase its UB by COP 49 billion, a figure that is equivalent to more than 1.8 times the minimum liquidity required in its observed sequence of payments (actual UB).

Graph B1.2
Effect of Payment Delay on the Intraday Balance and Minimum Liquidity Requirements

A. Institution delaying payment

i. Day 5 (10/01/2021)

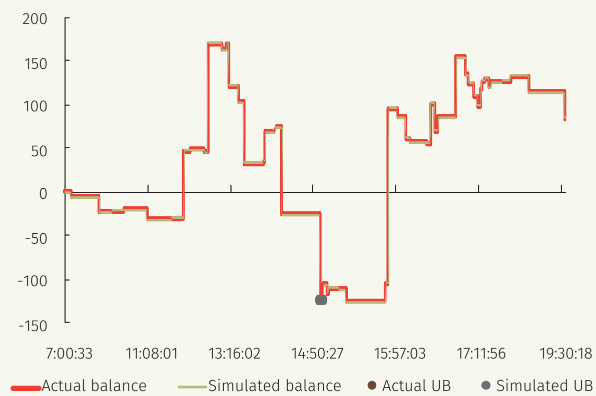
(Billions of pesos)



B. Main counterparty receiving payments

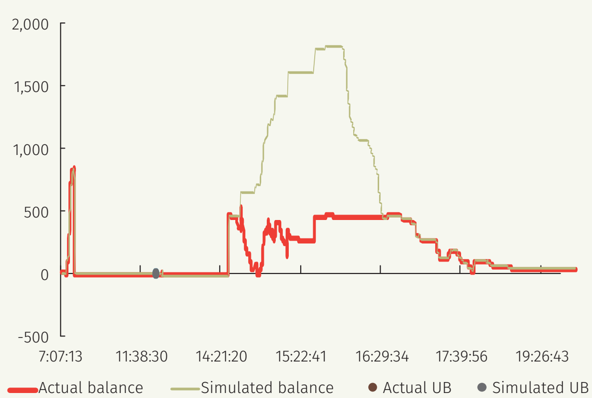
i. Day 5 (10/01/2021)

(Billions of pesos)



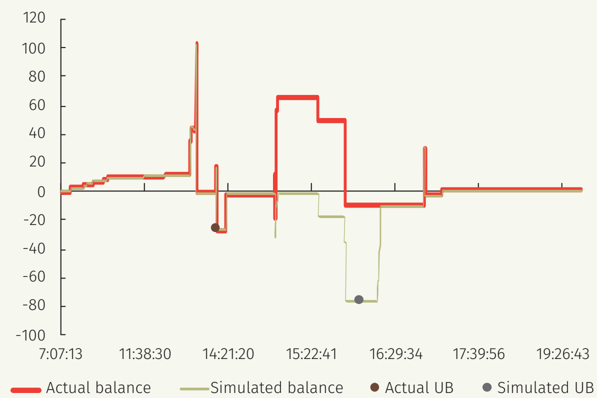
ii. Day 1 (03/12/2020)

(Billions of pesos)



ii. Day 1 (03/12/2020)

(Billions of pesos)



Source: *Banco de la República* (DSIF).

3. Initial Results

Summarized in Table B1.1 are the results of the simulation exercise for the ten days with the largest payment values settled in the CUD during the period under consideration. The two-hour window with the largest payment value, the value of settled payments and the minimum liquidity requirements (UB) for the observed and simulated payment sequences are shown for each of the days.

Table B1.1 is interpreted as follows. For day 2, the sum of all UBs of the institutions participating in the LVPS was COP 14,445.7 billion (b). As a result of the delay in payments by the institution with the largest payment value during the 14:00 to 15:59 time frame, the new value of the UB for the participants was COP 14,406.3 billion; in other words, it declined by COP 39.4 billion, net. This reduction is explained by three institutions that increased their UBs by a total of COP 28.6 billion and one institution (the one that delayed payments) that reduced its UB by COP 68 billion. Therefore, the following can be inferred from Table B1.1:

- The two-hour window in which the largest value of payments is settled is not always the same in the sample, but the most recurrent one is between 14:00:00:00 and 15:59:59:59.
- In the face of changes in payment sequences due to deferral, the minimum initial liquidity requirements (UB), in the aggregate, may increase or decline (i. e.: B – A).
- Increases in the UB in the system occur when:
  – The UB of the institution deferring payments remains the same, but that of its counterparties increases. This is observed on days 1 and 4, when the number of institutions that reduced their UB was zero, while 2 entities, for day 1, and 6 entities for day 4, increased theirs.
  – The reduction in UB experienced by the institution in arrears is more than offset by the increases in the UB of its counterparties. This occurs on day 6, when the decline in the UB of the institution in arrears was COP 55.1 (b), but the increase in UB experienced by 4 affected institutions was COP 143.8 (b).

Table B1.1
Minimum Liquidity Needs in a Scenario of Delayed Payments
(Billions of pesos)[a/]

Day	Date	Settled Value	Two-hour Time Slot with Highest Settled Value	Minimum required liquidity (UB)			Increases in UB		Reductions in UB	
				(A) Actual sequence	(B) Simulated sequence with two-hour payment delays	(B)-(A)	Number of institutions	Total value	Number of institutions	Total value
1	3/12/2020	56,644.3	14:00:00-15:59:59	8,597.8	8,647.7	49.9	2	49.9	0	0.0
2	3/16/2020	49,847.6	14:00:00-15:59:59	14,445.7	14,406.3	-39.4	3	28.6	1	-68.0
3	3/17/2020	47,863.0	17:00:00-18:59:59	14,398.8	14,352.6	-46.3	4	132.8	1	-179.1
4	9/14/2020	55,965.5	14:00:00-15:59:59	9,165.1	9,209.7	44.7	6	44.7	0	0.0
5	10/1/2021	50,374.0	14:00:00-15:59:59	13,817.5	12,500.2	-1,317.3	1	0.3	1	-1,317.6
6	11/2/2021	53,852.6	15:00:00-16:59:59	14,113.8	14,202.6	88.7	4	143.8	1	-55.1
7	11/22/2021	55,415.1	14:00:00-15:59:59	10,940.4	9,700.9	-1,239.5	4	22.0	1	-1,261.5
8	1/3/2022	39,604.6	13:00:00-14:59:59	14,591.8	13,641.1	-950.6	1	7.9	1	-958.6
9	1/14/2022	55,306.7	14:00:00-15:59:59	13,907.2	13,783.6	-123.7	4	91.7	1	-215.4
10	1/19/2022	52,678.9	13:00:00-14:59:59	14,255.9	14,221.0	-34.8	1	4.5	1	-39.4

a/ Payments settled in the CUD with the exception of those settled by BR, the DCV and retail-value FMIs.
Source: *Banco de la República* (DSIF).

- The reductions in the aggregate UB for the system are because the benefit in the reduction of the UB for the institution that postpones payments is stronger than the increases in UB experienced by its counterparts (days 5, 7, 8, 9, and 10).
- Payment deferrals on eight of the ten days would have benefited the deferring institution by reducing the requirement for larger opening balances to fund the value of its payments during the day.

4. The Capacity of Affected Participants to React

In view of these findings, it is helpful to determine if the counterparties, given the increased liquidity needs resulting from the delay by the main payment originator in the two most active hours, have sufficient resources to make their payments autonomously and without having to depend on outside sources of liquidity. Accordingly, an assessment is made as to whether the CUD balances of the counterparties observed at the beginning of the day would be sufficient to cover the increased liquidity needs resulting from the simulated scenario (UB estimated for the simulated sequence of payments). Moreover, recognizing that, besides their balance in the CUD, the institutions have a portfolio that can be used in intraday repo operations with BanRep, it will also be determined whether the addition of this liquidity would be sufficient to fund all their payments in the known sequence.

In general, Table B1.2 shows the increases in minimum liquidity requirements resulting from the simulated backlog scenario (simulated UB) could not be covered on most of the days in question by the actual CUD balances of the institutions that are counterparties on days 1 to 9 (except for day 5). However, when adding the possible liquidity to be obtained through repos with BanRep, these shortfalls are fully covered on days 1, 7 and 8, and partially covered on days 3, 4, 6, and 9.

5. Closing Comments

The simulation exercise outlined in this section is an initial approximation that makes it possible to quantify the liquidity effects a delay in payments by a relevant LVPS institution could have on the system. The methodology proposed by Koponen and Soramäki (1998), known as UB, was applied for this purpose. It involves estimating the maximum negative net positions the institutions can experience in one operating day. The sum of these positions is equivalent to the combined requirements of the system.

Table B1.2
Coverage of Minimum Liquidity Needs in a Scenario of Payment Arrears
(Billions of pesos)

Day	Date	Increases in UB Due to Payment Arrears		Insufficient CUD balance		Insufficient CUD Balance Plus liquidity backed by TES insufficient DCV	
		Number of institutions	Total increase	Number of institutions	Total balance lacking	Number of institutions	Total balance lacking
1	3/12/2020	2	49.9	1	42.7	0	0.0
2	3/16/2020	3	28.6	2	27.1	2	27.1
3	3/17/2020	4	132.8	4	129.5	3	102.1
4	9/14/2020	6	44.7	4	44.3	3	30.4
5	10/1/2021	1	0.3	0	0.0	0	-1,317.6
6	11/2/2021	4	143.8	4	143.7	2	4.0
7	11/22/2021	4	22.0	1	20.6	0	0.0
8	1/3/2022	1	7.9	1	7.6	0	0.0
9	1/14/2022	4	91.7	3	3.7	1	2.6
10	1/19/2022	1	4.5	0	0.0	0	0.0

Source: *Banco de la República* (DSIF)

The results were interesting in several respects. Initially, it was found that on only three of the ten busiest days of LVPS activity (days 1, 4 and 6 in Table B1.1) did the delay in payments by a relevant participant result in an increase in the aggregate needs of the system. This is because the increase in the liquidity needs of participants affected by the delay in payments was not fully offset by the decline in UB experienced by the participant delaying payments. Likewise, it was found that on days 1 and 4 the participant who delayed payments did not experience changes in its UB.

Another effect deals with determining whether those participants who experienced an increase in their UB had the capacity to absorb it; in other words, if the observed balances were greater than the new UB. In this case, on five of the ten days analyzed, the affected participants had sufficient liquidity (in cash and/or securities) to meet their increased liquidity needs autonomously and without having to depend on outside sources.

Although the sample analyzed is intended to illustrate the methodology used for the exercise, the latter turns out to be a starting point for knowing how sensitive the system's liquidity needs are to the impact a participant's delay of x hours. Initially, the expectation is that the more hours of delay, the greater the effect will be, although not in a liner sense. Gauging this will necessitate increasing the window of days analyzed, as well as the number of hours of delay in payments, which will be done with a computing tool that allows for processing the large amounts of data these types of simulation exercises require.

References

Koponen, R. and Soramäki, K. "Intraday Liquidity Needs in a Modern Interbank Payment System -A Simulation Approach," BANK OF FINLAND STUDIES E:14 • 1998.

Comité de Sistemas de Pago y Liquidación, y Comité Técnico de la Organización Internacional de Comisiones de Valores (2012). "Principios para las infraestructuras del mercado financiero," July; available at: https://www.bis.org/cpmi/publ/d94_es.pdf