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Reaction Functions of the Participants in Colombia's Large-value Payment System

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Reaction Functions of the Participants in Colombia's Large-value Payment System[1]

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Abstract

Large value payment flows can be disrupted by several types of failures such as operational incidents, problems experienced by the administrator of the payments settlement system, outages in the communications networks and the inability of a participant to submit payments due to insufficient liquidity. During any of these incidents, the participants of the system can either decide to stop, delay or continue sending payment orders, which fundamentally depends on the elements that originated the disruption, as well as on the alternative liquidity sources available to each entity. By means of Tobit models with random effects we evaluated the payments activity of Colombian financial institutions. Our results suggest that participants' reaction vary in accordance with the type of incident, along with the type of entity and its role in the market.

JEL: G21, E42, C24
Keywords: payment system, operational incidents, payment reaction function

I. Introduction

Large-value payment systems (LVPS) settle liquidity transfers (cash leg) from transactions between entities that participate in the financial markets. The settled payments in this system include all trading based in financial assets, monetary policy operations, central bank liquidity provision, direct funds transfers between financial entities, and operations between the Central bank and the Ministry of Finance. In Colombia, as in many other countries, LVPS is operated by the Central Bank.

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Since 1998 until the beginning of 2006, the Colombian large-value payment system LVPS (CUD) functioned as a pure real time gross settlement system (RTGS), and accordingly, the payments were liquidated in the same order that they were entered. As any pure settlement system, the orders of payments were processed as long as the funds in the sender's account were sufficient to allow its completion. Otherwise, these were rejected. With the aim of alleviating high liquidity requirements of this kind of settlement system, the Colombian Central Bank incorporated two liquidity optimisation mechanisms: the liquidity-saving and the retrial.

In January 10th 2006 a queuing structure along with liquidity-saving mechanisms (netting cycles) were adapted to the CUD. Under this queuing structure, a participant that is expecting incoming transfers could send orders of payments without having enough money in its account, as the payments that is about to receive will permit the achievement of the payments orders sent on that same day. Hence, the unsolved-transactions that came from Central Securities Depositary (DCV) or from the CUD could be processed through forwarding payments or netting settlements. Five netting cycles are daily executed, at specific hours. However, under special circumstances the Central bank could increase its number, especially when the system exhibits considerably high liquidity needs. The settlement of transactions could also be enhanced through the retrial mechanism that the DCV begins at 14:30 and restart every 30 minutes, after the end of the last execution. This mechanism consists of an automatic and periodic checking of participants' accounts balances, and allows the resolution of delayed payment orders.[4]

As stated by McAndrews and Potter (2002), the participants of large value payments systems (LVPS) may have access to several sources of liquidity, such as their own deposits at the central bank, money market loans, central bank liquidity provision, and the expected incoming transfers from other participants of the system. In accordance with these authors, the latter source of liquidity determines the *payments reaction function,* described as the interdependence or "strategic complementarities" that exist amongst the participants of the payment system in terms of liquidity. A payment reaction function can be measured as a linear relationship between the payments sent and received by an entity.

For the Colombian Central Bank this subject is of particular importance given that, as LVPS owner and system administrator, it might consider optimal to induce a more cooperative behaviour from

[4] The liquidity savings algorithm compares the unsettled incoming and outgoing payment orders of system participants that are in a queue, waiting for its solution. The solution mechanism computes the net value against the available balance of a participant's account considering both legs of transaction (securities and cash) (Bernal, Cepeda and Ortega, 2012). Detailed information on the way liquidity-saving algorithms and the retrial mechanism operate can be consulted in Banco de la República (2010).

the participants that delay the orders of payments (exhausting liquidity), especially when the system is suffering from failures. The literature on economics of payments had recognized the relevance of this subject, pointing out that the systemic impact of disruptions could be reduced if the participants are more willing to cooperate with the execution of payments that are expecting participants with high liquidity needs (Ledrut, 2007).

In this document we present several payments reaction functions of the entities that participate in the Colombian LVPS (CUD), estimated by means of Tobit models with random effects. In particular, we compared the estimated payments patterns of the days in which the payments system has suffered from a temporary liquidity disruption with a predetermined benchmark and with the three days that followed each disruption in the payments activity. For these estimations we included the entities with greatest participation in the execution of payments, amongst which there are three types: banks, brokerage firms and mutual funds.[5] Within each type, the included entities represent 80 per cent of the average monthly payments sent. The entity types are composed by eight banks, eight brokerage firms and ten mutual funds. To our knowledge, this is the first attempt to empirically estimate payments reaction functions of the entities that participate in the CUD.

The obtained results suggest that there are strategic complementarities (understood as the cases in which the entities increase their outgoing payments via LVPS as long as the coordination amongst them increases) in the payments send by financial market participants, but the coordination of payments' timing is rather low as can be inferred from the estimated parameters of the reaction functions. Under normal circumstances a higher coordination of payments is very likely, as long as it allows entities to reduce its demand for liquidity making payments less costly. However, after a failure the coordination of payments weakens, potentially deteriorating the liquidity position of some entities (e.g. brokerage firms) that may also encounter difficulties to access central bank's liquidity due, for example, to the lack of enough collateral.

The document is organised as follows. In Section II the literature on reactions functions for the large value payment system is summarized. Section III explains the methodology used to estimate the payment reaction functions in specific periods and the tested incidents. Section IV contains the main estimation results, and Section V concludes.

[5] Other entities having access to the CUD are pensions fund managers, commercial financial corporations (*leasing*), financial corporations, financial cooperatives, insurance companies, special official institutions (*Fogafin, Bancoldex*), among others. In December 2012, a total of 158 entities had direct access to the CUD.

II. Literature Review

In accordance with McAndrews and Potter (2002), an entity that participate on a large-value payment system (LVPS) can fund its payments using its own deposits at the central bank, loans from the central bank, money market loans, and incoming transfers from other participants of the system. Given that some of the entities could not have enough liquidity in its accounts at the central bank and that the loans are available at a cost, the payments that they send are mainly funded with the transfers that they receive from its counterparties.[6] The received payments as a source of liquidity are attractive to the system participants because it is cost-free. But the excessive dependence on this source may encourage the adoption of opportunistic strategies (free-rider problem) and affect the payments flow in the system. Thus, participants face the dilemma of incurring liquidity costs or delaying their payments (Bernal, Cepeda and Ortega, 2012).

The financial market participants' decisions about making early payments or delaying them critically depends on the relative costs of liquidity (opportunity cost of transferring securities as collateral, central-bank liquidity operations or money-market repo transactions) and the cost of delaying payments, as was shown by Bech and Garrat (2003). Hence, for a given structure of costs, participants could face the prisoner's dilemma by choosing to delay their payments, although they would had benefited even more from making early payments.

But beyond the decision of making early payments or delaying them what really matters is the coordination of the payments (synchronization) (McAndrews and Rajan, 2000), since this can become an essential source of liquidity, given by the direct relationship that exists in the frequent transactions between the same counterparties and the certainty of the incoming payments. As a result, there will be a higher degree of certainty in relation to the payments an entity is expecting from counterparties with which it usually deals, than those coming from unusual counterparties. Thus, the coordination of payments could be increased as long as the patterns of payments, given by the same entities and the same timing of payments, are repeated day-to-day. In this setting, an unanticipated disruption could magnify the uncertainty with respect to the payments that entities are expecting. The strategic complementarity (i.e. the coordinated harmonious interaction between decisions of all system participants) in the sending of payments can make incoming payments one of the main sources of liquidity, smoothing the payments flows, and hence, contributing to financial stability (Bernal et al. 2012).

[6] In accordance with Becher, Galbiati and Tudela (2008) incoming payments represented around 25 per cent of the total payments send through the CHAPS Sterling (U.K system) in October 2006.

In the economics of large value payments the concept of reaction function designates the relationship that exists between the payments sent and received by an entity, in an attempt to measure the strategic complementarities. For that reason, this subject is of relevant importance to central banks, especially during times of failures of the LVPS (McAndrews and Potter 2002, Ledrut 2007, Mills and Nesmith 2008, Perlin and Schanz 2010, and Merrouche and Schanz 2010).

The operational incidents of the payments system are usually related to failures that affect the system operator, failures in the communications networks and failures caused by the inability of one (or more) settlement participant to submit payment instructions to the system. Amongst these types of incidents, those that emerge from the system operator could be generated by failures in information technology, human errors of the staff operating the system or failures induced by external events such as natural disasters, power failures and terrorist attacks (Bedford, Millard and Yang, 2005).

An empirical estimation of payments reaction functions of the U.S-LVPS (Fedwire) participants after the terrorist attacks in September 11 of 2001 was developed by McAndrews and Potter (2002). As these authors suggested, these attacks generated operational disruptions in the communication networks, and hence, also caused a drop of the payments sent through the system. But this situation was rapidly contained by means of the actions taken by the Fed, especially designed to inject liquidity into the system and restore the payments coordination equilibrium. In this setting, payments coordination has been recognized as an essential tool to mitigate the impact of disruptions in the payments system (Bech and Garrat, 2012).

The temporary or permanent insufficiency of funds in the sender's account could also have systemic effects on the large-value payments system. In this matter, some studies such as that of Ledrut (2007), Mills and Nesmith (2008), Merrouche and Schanz (2010) and Perlin and Schanz (2010), examine how entities react in response to an operational failure experienced by one of their counterparties that also make use of the payments system. According to these authors, a simulated shock to the biggest entity of the system will make the remaining participants stop sending of payments to that entity, in an attempt to save liquidity. In line with these results Benos, Garratt and Zimmerman (2012) found that after the collapse of Lehman Brothers the banks of the U.K, participants of CHAPS, delayed payments to their counterparties due to their concerns about the bank-specific and system-wide risks.

III. Payment reaction functions

A reaction function relates the payments that a participant of the LVPS sends with the payments that this entity has received from its counterparties, as the following linear expression suggests (McAndrews and Potter, 2002):

$$P_t^A = \alpha + \beta R_t^A + \varepsilon_t \qquad (1)$$

Consistent with this function, participant A sends and receives payments that at time t are denoted by P_t^A and R_t^A, respectively. The parameter $'\alpha'$ represents the autonomous willingness of this participant to send payments, regardless of the payments received. The slope of the reaction function $'\beta'$, represents the marginal propensity of the participant A to send payments in response to the payments received from other participants of the system. In terms of liquidity, this parameter could be considered as a signal of how cooperative a participant of the payments system is. In such way, a positive and significant parameter $'\beta'$ corresponds to a participant that sends payments as soon as new payments enter into its account, at the same time that a positive estimation of this parameter is considered as a signal of the existence of payments coordination amongst entities. A negative parameter will belong to a participant that delays its payments disregarding if the balances in its account allow its completion, whereas a parameter equal to zero will indicate an entity that do not react to the payments received from its counterparties. As usual, ε_t represents the error term.

A. The estimation methodology

The chosen estimation methodology closely follows the structure of analysis proposed by McAndrews and Potter (2002), which consists of defining the dependent variable as the *total amount of payments sent* by an entity per minute. This variable is set as a function of an intercept term $'\alpha'$ and the total payments received from the other entities via CUD in the previous fifteen minutes ($'\beta'$).[7] To complete the set of regressors for each entity, the opening balance, the cumulative receipts minus its cumulative payments sent up sixteen minutes prior to the minute, are also considered.

[7] The time interval of fifteen minutes, proposed by McAndrews and Potter (2002), has been also accepted in other empirical studies as a standard unit to estimate payments reaction functions (Afonso and Shin, 2010). Hence, when the same time interval is considered, comparisons among different large-value payment systems can be easily established. Furthermore, in the local market it is quite common that an entity in trouble asks for fifteen minutes to the system's administrator to restore its normal payments flow.

In our data, the dependent variable exhibit a large number of observations at zero that reflects the cases in which an entity did not sent payments through the system. This type of variable has been termed in the literature as 'corner solution response', given that it relies on a continuous distribution over positive values, but there also exists a non-zero probability of that variable taking a value of zero (Yermack, 1995, and Wooldridge, 2010). Traditional panel data models such as the fixed effects were not considered to study these data, since these linear models could produce inconsistent parameters estimates as they ignore the fact that the dependent variable (measured by the total payments sent) can take either a positive value or a value equal to zero. In regard to non-linear panel data models, the Tobit with fixed effects was also discarded, given that empirical econometric literature has found for small and fixed samples that the slope estimators are not affected by the fixed effects, but the variance estimator is affected and that could weaken the inferences drawn from the estimated parameters (Greene, 2004). An alternative non-linear panel data model, the Tobit with random effects, adequately captures the statistical properties of the dependent variable (corner solution responses), and for that reason it was preferred to estimate the reaction functions.

In this context, the Tobit model is given by:

$$P_t^{A*} = \alpha + X_t^{A\prime}\beta + \varepsilon_t \qquad t = 1, 2, \dots, T \qquad (2)$$

$$\varepsilon_t / X_t^{A\prime} \sim Normal(0, \sigma^2) \qquad (3)$$

The value of the payments sent (P_t^{A*}) takes the form of a corner solution response:

$$P_t^A = \begin{cases} P_t^{A*} & if \quad P_t^{A*} > 0 \\ 0 & Otherwise \end{cases}$$

In equations (2) and (3) X_t^A contains the set of regressors mentioned above and two dummy variables. The first one reflects the facility that CUD provides to settle transactions coming from DCV or money transfers that were completed using netting cycles. Thus, this dummy takes the value of one when the CUD's liquidity saving mechanisms are activated and zero otherwise. The other dummy variable represents the automatic payments in the system. That is, the settlement of the net value resulting from clearing at the CEDEC (local cheques clearing) and ACH-CENIT (automatic clearing house), as these payments do not represent financial entity's willingness to send payments as the reaction function describes.[8]

[8] In regard to other 'automatic payments' it is worth to mention that those payments executed through the retrial mechanism were not included in the models because it is not possible to (isolated) identify this type of payments in the CUD. Likewise, the debits coming from DECEVAL (Central Securities Depository for corporate and government -non-sovereign- securities) were not included in the models, given that these payments cannot be regarded as 'automatic' as

Equation (3) assumes normality in the error term ε_t, and implies that the strict exogeneity of X_t^A does not hold, given that the exogenous variables (X_t^A) could be affected by the possible non-contemporaneous feedback that could emerge from lagged values of the dependent variable $\left(P_{t-S}^A\right)$.

B. Entities selected and the tested incidents

In order to select the entities for our estimations, we examine data registered during April 2011, given that this month is very close to the average yearly payments executed through the CUD. The payments sent by banks, brokerage firms and mutual funds on that month represented 84.6 per cent of the total payments that were settled in the system. For each type of entity, individual entities were selected to account for at least 80 per cent of the payment flows. This corresponded to eight banks (80.1 per cent), eight brokerage firms (80.6 per cent) and ten mutual funds (80.5 per cent). The payments sent by these 26 entities represented 67.9 per cent of the total payments sent through the CUD. In order to comprehend how the selected entities reacted to different types of disruptions, we estimated the reaction functions that emerged in response to incidents that would somehow have affected the normal pattern of the payments activity.

In the last decade the Colombian LVPS (CUD) has suffered four disruptions in the payments flow. Two of them can be classified as operational failures and the others as liquidity problems (produced by the inability of one participant to make payments). These incidents, which are of public knowledge, are briefly described next.

i. April 26th 2007 – The Blackout

In Colombia, the power outage that occurred in April 26th 2007 is the only case of operational disruption due to the LVPS system operator, so far. The disruption in the electricity flows generated by a power overcharge started in Bogota at 9:58 am. This outage, which lasted until 2:30 pm of that same day, also interrupted the supply of electricity to the entire country.

ii. February 26th 2010 – *Bancolombia's* operational failure

The technical failure of *Bancolombia*, the country's largest bank by asset size, generated several difficulties in its transactional channels, such as impeding its clients to withdraw or deposit money, and delivering wrong information about the balances of their deposits accounts. This incident was

long as each entity can manage the balances of the account associated to the CUD and hence, decide when a payment order will be executed.

originated by a failure of its technological platform, which started on Friday, February 26 of 2010, and lasted around three days. At the beginning of this failure, the highest delay by value in the *Bancolombia's* settled payments via CUD (10.8 per cent) was registered at 3:00 pm, while in the system this delay corresponded to 5.5 per cent.

iii. June 23th 2011 – The failure of *Proyectar Valores*

The first of two disruptions related to financial resources' management was generated by the brokerage firm *Proyectar Valores,* which in the end of May 2011 suspended its payment orders. In response to the inability of this firm to submit payments, the Financial Superintendency of Colombia (FSC) adopted in May 27th of that same year a preventive measure consisting of a special supervision measure (FSC Resolution number: 0826). Few days later, in June 22th 2011, the FSC decided to take over this brokerage firm (FSC Resolution number: 1000). Almost immediately to that intervention, the FSC announced the suspension of the activities of this firm in the market, and in October 4th ordered its compulsory administrative liquidation (FSC Resolution number: 1714).

iv. November 2nd 2012 – The failure of *Interbolsa*

The second case related to financial resources' management was that of Interbolsa, which at that moment was the largest brokerage firm operating in the Colombian money market and securities market. The failure to pay an intraday credit of 20 billion Colombian pesos (USD 11 million) with a local bank obligated its intervention through the FSC (FSC Resolution number: 1795), in November 2nd 2012. Two working days later, in November 7th 2012, the FSC ordered its compulsory liquidation (FSC Resolution number: 1812).

IV. Main estimation results

For the empirical estimation of the reaction functions we used minute by minute data of the payments registered from 7:00 in the morning until 20:00 in the evening, given that this is the period in which the CUD is operating.[9] The model we used was Tobit with random effects, estimated through the method of Maximum Likelihood. The main estimation results obtained from these panel data models are summarized in tables one, three, five and seven. These tables include the parameters estimated for every benchmark period along with the estimations for the day of the

[9] Before 7:00 a.m., CUD settles the fees charged for its services and the financial transactions' taxes. After 20:00 the transfers are related with the constitution or retrocession of Central bank's remunerated deposits, and interest payments and capital amortizations of sovereign bonds (TES).

incident and for the three following working days. The entities considered are banks, brokerage firms and mutual funds, and the group (All) that corresponds to these three types of entities.

With the aim of developing a proper analysis of the results obtained from static models, we used the robust standard errors (estimated by bootstrapping) to account for the possible problem of serial correlation in data.

- **The Benchmarks**

The estimated parameters for the time interval that is considered as the benchmark period could be affected as long as the patterns of payments change. Considering this feature and that the tested incidents are separated amongst them for more than a year, we examined them in a separate way, which was done through the definition of particular benchmark periods per incident. The analyses consisted of making comparisons of the estimated parameters in the day that an incident occurred with those obtained using data of the days that preceded each of them. Thus, each benchmark period includes information of the payments settled in the days previous to the occurrence of the incident that disrupted the payment flows, within the month in which the event took place (when possible).

- **Payments disruptions caused by operational failures**

In this sort of failures are found the power outage (the blackout) and the operational failure of *Bancolombia*. Tables 1 and 3 summarize the estimated parameters (average marginal effects) of the reaction functions related with these incidents. The remaining results as well as all some additional statistics (value of payments, opening balance, Central Bank liquidity and the number of send out payments) can be consulted in the tables presented in the annex.[10]

The benchmark period designated to evaluate 'the blackout' includes data of the payments registered from the 1st to the 25th of April 2007. As can be seen on Table 1, the estimated reaction function slope (marginal propensity to submit payments) of brokerage firms before, after and during the blackout were non-significant, suggesting that sending payments in response to the liquidity flows received from its counterparties, was null. The same occurred with the estimated intercept

[10] Even excluding the dummy of clearing at the CEDEC and ACH-CENIT, the estimated slopes remain practically without changes, due to its low participation in the total payments settled in the CUD. In 2012, for example, the net value resulting from this clearing barely represented 1.2 per cent of the average yearly payments settled in the system.

term in the day of the power outage, which indicates that their autonomous willingness to send out payments on that day was negligible. These results considered along with the dummy of liquidity-saving mechanisms (that almost always is positive and significant, as can be seen in the annex) evidence that brokerage firms usually have low levels of liquidity, which makes them more dependent on the activation of liquidity saving algorithms (netting cycles) to fulfil its payment obligations.

Table 1. The Blackout

	Benchmark (April 1st-25th)			
	All	*Banks*	*Brokerage firms*	*Mutual funds*
Reaction function slope	0.025	0.023	0.008	0.101
	(3.11)***	(3.85)***	(0.76)	(10.08)***
Autonomous willingness to send payments	1.9E+09	2.2E+09	1.5E+09	2.5E+09
	(8.90)***	(6.77)***	(4.85)***	(4.12)***
Number of observations	39,444	19,875	15,627	3,942
Number of participants	25	8	7	10

	The Blackout (April 26th)				April 27th				April 30th				May 2nd			
	All	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*
Reaction function slope	0.024	0.025	0.000	0.120	0.018	0.002	0.013	0.131	0.028	0.019	0.042	0.065	0.022	0.019	0.021	0.080
	(1.47)	(1.19)	(0.02)	(4.05)***	(0.69)	(0.11)	(0.44)	(2.38)***	(1.66)*	(0.84)	(0.99)	(0.40)	(4.09)***	(1.72)*	(1.45)	(0.70)
Autonomous willingness to send payments	1.9E+09	2.8E+09	1.7E+09	1.3E+09	1.8E+09	3.2E+09	1.8E+09	2.0E+09	2.0E+09	2.4E+09	2.8E+09	2.2E+09	1.9E+09	2.5E+09	2.8E+09	2.5E+09
	(4.31)***	(1.59)	(1.37)	(2.28)**	(5.59)***	(1.71)*	(2.54)***	(4.44)***	(6.25)***	(1.88)*	(2.62)***	(1.78)*	(8.43)***	(3.38)***	(0.76)	(3.43)***
Number of observations	2,486	1,275	950	261	2,582	1,370	958	254	2,484	1,384	801	299	2,779	1,429	1,066	284
Number of participants	25	8	7	10	24	8	7	9	25	8	7	10	25	8	7	10

Source: authors' calculations. (t-statistic values in parentheses).
Significant at 10%(*), 5%(**), 1%(***) levels.

The liquidity savings mechanism is composed by five netting cycles that are scheduled daily at 11:50, 14:20, 15:30, 16:15 and 17:45. The average liquidity saving reached through the liquidity savings mechanism –LSM- for compliance of transactions originated in the Central Securities Depositary (DCV), during April 2007, was greater than 85 per cent for the entire system. Table 2 exhibits the average liquidity saving per entity type, obtained as benefit of LSM during the month in which the power outage occurred.

Table 2. Average liquidity savings achieved through liquidity savings algorithms over DCV's transactions [a] (Millions of Colombian Pesos $)

	April 2007			
Average	Banks	Mutual Funds	Brokerage Firms	Total system
Gross value	1.274.787	64.126	884.504	2.554.520
Net value	132.212	22.706	129.997	366.661
Liquidity saving	89,6%	64,6%	85,3%	85,6%

[a] Statistics corresponding to the type of entities analysed in this document.
Source: authors' calculations with data from CUD.

The brokerage firms' liquidity savings were 85.3 per cent, slightly lower than the percentage registered for banks (89.6 per cent). For mutual funds and banks the results indicate that although the activation of the liquidity saving algorithms partially explains the payments that these entities made, their autonomous willingness to send payments, which depend on their deposits accounts balances at the central bank, is also an important determinant.

The size and scope of the reaction functions of both, mutual funds and banks, are very different from one another. For the group of banks this parameter turned out non-significant in the day of the disruption, while for mutual funds, these were significant in the day of the incident. Nevertheless, the ability of these latter entities to smooth the impact of the power outage on the payments system was low, given that the estimated marginal propensity to send payments for all of the participants (All) was usually similar to that exhibited by banks. A plausible explanation for this outcome is that banks are the type of entities that contribute the most to the payments in the system.

Once the electricity flows were restored in the afternoon of April 26th, the mutual funds was the only group that continued exhibiting significant payments reaction slopes. While in the case of banks, the results suggest that this group of entities decided to stop sending payments in the day of the incident, but went back to its earlier strategy of payments three days after the incident.

Table 3. *Bancolombia's* operational failure

	Benchmark (February 1st-25th)			
	All	*Banks*	*Brokerage firms*	*Mutual funds*
Reaction function slope	0.009	0.007	0.008	0.085
	(1.84)*	(1.44)	(1.02)	(5.63)***
Autonomous willingness to send payments	2.0E+09	3.1E+09	2.3E+09	2.3E+09
	(6.08)***	(7.88)***	(5.38)***	(7.07)***
Number of observations	60,563	27,229	25,615	7,719
Number of participants	26	8	8	10

	Bancolombia's operational failure (February 26th)				March 1st				March 2nd				March 3th			
	All	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*
Reaction function slope	0.008	0.002	-0.005	0.057	0.000	-0.007	0.011	0.070	0.035	0.028	0.023	0.020	0.002	-0.003	0.002	0.031
	(1.33)	(0.14)	(-0.26)	(8.18)***	(-0.02)	(-0.62)	(1.08)	(2.66)***	(2.17)**	(1.52)	(1.04)	(1.12)	(0.32)	(-0.33)	(0.09)	(1.34)
Autonomous willingness to send payments	2.9E+09	4.2E+09	4.0E+09	5.4E+09	2.6E+09	4.0E+09	2.2E+09	2.6E+09	1.8E+09	3.9E+09	2.0E+09	2.7E+09	2.3E+09	4.1E+09	2.9E+09	3.4E+09
	(6.57)***	(3.67)***	(4.40)***	(5.43)***	(7.87)***	(2.37)***	(2.62)***	(3.82)***	(3.71)***	(2.65)***	(1.15)	(4.36)***	(5.73)***	(2.89)***	(4.23)***	(4.46)***
Number of observations	2,821	1,397	1,084	340	3,334	1,551	1,342	441	2,895	1,327	1,162	406	3,041	1,348	1,307	386
Number of participants	26	8	8	10	26	8	8	10	26	8	8	10	26	8	8	10

Source: authors' calculations. (t-statistic values in parentheses).
Significant at 10%(*), 5%(**), 1%(***) levels.

Similar results were obtained from the examination of the 'operational failure of *Bancolombia'*, as can be seen in Table 3.[11] The group of mutual funds was again the one that presented statistically significant marginal propensity to send payments in the day of the incident. In response to the technical problems experienced by this bank, the mutual funds reacted decreasing the sending of payments, as is shown by the estimated reaction function slope that passed from 0.085 in the benchmark period (February 1st to 25th) to 0.057. Once again, the response that the entities exhibit as a whole (All) mostly follows that displayed by banks, which according to the estimated parameters were reluctant to send payments during the technical failure of this bank.

For the incident generated by the operational failure of *Bancolombia* (February 26, 2010) the average liquidity saving reached through the liquidity savings mechanism –LSM- for compliance of transactions originated in DCV is presented in Table 4. Two facts emerged from this information: banks and brokerage firms are the biggest participants in these transactions (with monthly average participation on total value of 59.4 per cent and 21.1 per cent respectively) and, at same time, these are the entities with the greatest liquidity savings under LSM. The liquidity savings of brokerage firms within the month that *Bancolombia* suffered from the operational failure were 90.7 per cent, while for banks this was 86.0 per cent. The benefits in terms of liquidity savings that these entities attained under LSM (to DCV's transactions) has become an incentive for which banks and brokerage firms usually delay the compliance of payments until the activation of the liquidity saving algorithms (netting cycles). In the case of brokerage firms, their low level of deposits in the accounts at central bank and the sizeable volume of transactions (conducted as part of their business), explain why these entities have been the market participants that benefit the most from the activation of this liquidity optimisation mechanism.

Table 4. Average liquidity savings achieved through liquidity savings algorithms over DCV's transactions [a] (Millions of Colombian Pesos $)

	February 2010			
Average	Banks	Mutual Funds	Brokerage Firms	Total system
Gross value	3.790.582	137.470	1.349.388	6.386.608
Net value	529.104	49.478	125.638	862.546
Liquidity saving	86,0%	64,0%	90,7%	86,5%

[a] Statistics corresponding to the type of entities analysed in this document.
Source: authors' calculations with data from CUD.

Although both of these events were short lived, it is not surprising that *Bancolombia's* technical failure caused an impact on the payments flow that lasted longer than those caused by the power

[11] The operational failure of this bank lasted three days, but this incident was evaluated using only information of the payments registered on February 26th of 2010, which was a Friday, given that during weekends the markets are closed.

outage. In fact, the restitution of the electricity flows took less than five hours, which allowed the settlement of delayed orders of payments in the same day of the incident. In contrast, the operational failure of *Bancolombia* lasted more than three days, which could possibly had weakened the confidence of other market participants in the ability of this bank to solve its technical problems. Besides the longer duration of this last event, the negative consequences on the stability of the payments pattern would have been exacerbated by market's perception of systemic importance regarding *Bancolombia*.

- **Payment disruptions caused by the inability of a participant to submit payments**

The consequences that the inability of a participant to submit payments to their counterparties could have on the payments system are examined with the failures of *Proyectar Valores* and *Interbolsa*. The duration of these incidents was slightly longer than the other two presented above given that, as a result of the FSC investigation, both brokerage firms were liquidated. Tables 5 and 7 present the results of the autonomous willingness to send payments (intercept term) and reaction functions slopes estimated for these failures.

For the case of *Proyectar Valores*, the selected benchmark period contains information of the payments registered from the 1st to the 22nd of June 2011. As seen on Table 5, the estimated slope of the reaction function for these days indicates that payments in the system were explained by the liquidity provided by all three types of entities (banks, brokerage firms and mutual funds). However, in the day that the Financial Superintendency of Colombia (FSC) intervened this firm (June 23rd), the banks decided to retain liquidity, whereas mutual funds and brokerage firms continued sending out payments.

Once the process of take-over of this firm by the FSC ended, the mutual funds continued sending payments (cooperating), in contrast to the lack of payments coming from banks in that day and the two days that followed this incident. The estimated parameters for the brokerage firms to the intervention of *Proyectar Valores* widely differ from that estimated for the other type of entities. This suggests that these firms increased the payments flow sent through the system in the day of the failure, unlike what was registered during the days that preceded and followed this incident. This, in other words, indicates that each entity (group of entities) could adjust its own strategies of payments (timing in the sending of payments) according to the level of its liquidity sources, information and expectations.

Table 5. The failure of *Proyectar Valores*

	Benchmark (June 1st-22th)			
	All	*Banks*	*Brokerage firms*	*Mutual funds*
Reaction function slope	0.029	0.031	0.003	0.094
	(3.90)***	(4.41)***	(0.45)	(4.72)***
Autonomous willingness to send payments	1.9E+09	2.2E+09	2.5E+09	3.3E+09
	(3.80)***	(5.25)***	(8.36)***	(4.11)***
Number of observations	43,466	20,081	18,268	5,117
Number of participants	26	8	8	10

	Proyectar Failure (June 23th)				June 24th				June 28th				June 29th			
	All	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*
Reaction function slope	0.027	0.022	0.019	0.092	0.012	0.011	0.007	0.058	0.010	0.006	0.034	0.118	0.028	0.028	0.016	0.113
	(1.58)	(0.89)	(1.77)*	(5.23)***	(1.30)	(0.78)	(0.42)	(2.50)***	(1.30)	(0.75)	(1.77)*	(5.20)***	(3.52)***	(4.52)***	(1.09)	(2.24)**
Autonomous willingness to send payments	2.5E+09	4.5E+09	1.1E+09	2.4E+09	2.0E+09	4.0E+09	1.7E+09	2.5E+09	1.6E+09	4.9E+08	6.6E+08	1.7E+09	2.2E+09	2.7E+09	2.2E+09	2.5E+09
	(3.88)***	(0.87)	(0.74)	(3.88)***	(4.58)***	(3.62)***	(1.77)*	(6.27)***	(3.26)***	(0.21)	(0.51)	(2.59)***	(5.30)***	(5.33)***	(2.08)**	(4.62)***
Number of observations	3,013	1,329	1,292	392	2,873	1,323	1,203	347	2,809	1,349	1,142	318	26,834	25,394	1,087	353
Number of participants	26	8	8	10	26	8	8	10	26	8	8	10	26	8	8	10

Source: authors' calculations. (t-statistic values in parentheses).
Significant at 10%(*), 5%(**), 1%(***) levels.

Banks and brokerage firms were, once more, the largest participants in these transactions and also were the entities that attained the greatest liquidity savings through netting cycles. In the month that this incident arose the liquidity savings for brokerage firms were 91.7 per cent while for banks it was of 84.3 per cent (Table 6).

Table 6. Average liquidity savings achieved through liquidity savings algorithms over DCV's transactions [a] (Millions of Colombian Pesos $)

	June 2011			
Average	Banks	Mutual Funds	Brokerage Firms	Total system
Gross value	4.282.697	163.997	1.329.718	6.450.184
Net value	671.494	48.889	110.821	966.724
Liquidity saving	84,3%	70,2%	91,7%	85,0%

[a] Statistics corresponding to the type of entities analysed in this document.
Source: authors' calculations with data from CUD.

For the failure of *Interbolsa* the selected benchmark period includes data of the payments registered between October 1st and November 1st 2012. As usual, the marginal propensity to send payments (reaction function slope) during that period turned out significant for banks and mutual funds. A more comprehensive view of these results indicates that the payments flow from these groups to other participants in the system was self-funded by means of a sound matching of the payments sent with the payments received (Table 7).

Table 7. The failure of *Interbolsa*

	Benchmark (October 1st-November 1st)			
	All	*Banks*	*Brokerage firms*	*Mutual funds*
Reaction function slope	0.038	0.044	0.004	0.089
	(2.25)**	(2.12)**	(0.71)	(7.33)***
Autonomous willingness to send payments	1.5E+09	1.8E+09	2.2E+09	2.8E+09
	(2.93)***	(2.12)**	(6.20)***	(7.39)***
Number of observations	66,245	31,248	26,835	8,162
Number of participants	26	8	8	10

	Interbolsa failure (November 2nd)				November 6th				November 7th				November 8th			
	All	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*
Reaction function slope	0.049	0.048	0.036	0.161	0.079	0.078	0.073	0.172	0.060	0.059	0.064	0.127	0.034	0.033	0.043	0.054
	(1.96)**	(1.36)	(1.35)	(7.94)***	(4.24)***	(1.82)*	(6.11)***	(4.04)***	(3.69)***	(1.51)	(4.15)***	(4.08)***	(6.21)***	(2.25)**	(9.60)***	(2.64)***
Autonomous willingness to send payments	2.7E+09	6.2E+09	2.7E+09	2.3E+09	2.7E+09	4.5E+09	2.6E+09	1.9E+09	2.6E+09	4.0E+09	1.8E+09	2.2E+09	3.1E+09	4.4E+09	3.8E+09	3.3E+09
	(5.61)***	(4.01)***	(4.72)***	(3.64)***	(5.43)***	(2.50)***	(4.86)***	(1.84)*	(5.04)***	(1.91)*	(2.13)**	(3.79)***	(5.42)***	(2.71)***	(8.80)***	(3.33)***
Number of observations	2,591	1,287	978	326	2,144	1,216	668	260	2,469	1,314	831	324	2,434	1,333	760	341
Number of participants	26	8	8	10	26	8	8	10	26	8	8	10	26	8	8	10

Source: authors' calculations. (t-statistic values in parentheses).
Significant at 10%(*), 5%(**), 1%(***) levels.

The parameters of the payments sent by mutual funds coincides with that estimated for all of the participants in the CUD (All), which were significant in the day of the failure (November 2nd) and in the three following days. According to these results, *Interbolsa* failure seemed to have stimulated the cooperation of the remaining brokerage firms in the market, as can be seen from the increase in their marginal propensity to send payments through the system.

In November 2nd of that year, the payments activity was rapidly resumed by the immediate intervention of the FSC, under whose authority these were totally settled. The central bank increased the access to liquidity facilities widening the range of collaterals to non-sovereign securities (e.g. corporate) and increasing the size of overnight repo auctions in 39.7 per cent with respect to the limit offered in the previous day. But the liquidity used by financial entities in percentage terms was considerably lower (71.7 per cent) than that used in November 1st (98.1 per cent).[12,13] Besides, on that same day the Colombian Central Bank scheduled six additional netting cycles. In total eleven netting cycles were activated (at 11:28, 11:50, 12:30, 13:00, 13:30, 14:00, 14:20, 15:30, 16:15, 16:55, and 17:45), but the total value of settled payments barely reached one fifth of the average daily value settled before this incident.

[12] In November 2th 2012 the daily cap was set at $8.1 billion of Colombian pesos of which $5.8 billion were used by financial entities.
[13] The External Resolution of the Colombian central bank of November 7th 2012 included credit securities rated by rating agencies securities, which broadened the eligible securities that central bank could (permanently or temporary) acquire in order to regulate the liquidity of the economy.

The increasing perception of risk that arose from the entities' knowledge of *Interbolsa*' situation reduced the trading in the securities market and money market, as suggests the registered payments settled through the CUD. The reduction in the number of settled payments coming from all financial entities on that day was of 25.9 per cent (2,495 transactions) with respect to the previous day (November 1st), and 36.2 per cent in contrast to the daily average of the prior month (3,911 transactions). In relation to the average daily value liquidated in October, the value settled in the debt government securities market decreased in November 2nd in more than 6.6 billion of Colombian pesos (82.3 per cent), while for the sell/buy backs that value was reduced in 1.3 billion (54.1 per cent). It seemed that banks and brokerage firms were cautious and preferred reduce their trading activity at that moment. That reduction in the volumes traded eased the fulfilment of the payments owed amongst entities without the necessity to exhaust the repo limit offered by the Central Bank.

The levels of liquidity savings reached in the month previous to the incident of *Interbolsa* were 95.2 per cent for brokerage firms and 87.6 per cent for banks (Table 8). However, the failure of this brokerage firm produced different effects in the Colombian large-value payment system (CUD) due to its relative size in the market.

Table 8. Average liquidity savings achieved through liquidity savings algorithms over DCV's transactions [a] (Millions of Colombian Pesos $)

	October 2012			
Average	Banks	Mutual Funds	Brokerage Firms	Total system
Gross value	4.113.491	171.363	1.834.386	7.629.709
Net value	508.883	53.369	88.841	832.554
Liquidity saving	87,6%	68,9%	95,2%	89,1%

[a] Statistics corresponding to the type of entities analysed in this document.
Source: authors' calculations with data from CUD.

For the days that followed the incidents of *Proyectar Valores* and *Interbolsa* the estimated reaction parameters slopes are positive, which suggests the existence of coordination (strategic complementarities) in the payments timing, especially that of banks and mutual funds. In accordance with McAndrews and Potter (2002), as long as the payments coordination amongst the participants of the LVPS increases, the payments sent by each entity to its counterparties will also increase. However for these specific cases, the degree of payments coordination is rather low, given that the parameters for banks do not exceed a value of 0.08, while for mutual funds albeit higher than banks (all of them lower than 0.18) are still located at low levels.

All in all, the obtained results suggest that there are strategic complementarities in the payments sent by the CUD participants. However, the coordination of payments timing is rather low as can be

inferred by the small size (low value) of the estimated slopes. Under normal circumstances an increase in the coordination of payments (reaction function parameter) will be desirable given that this will allow the entities to make less costly payments, at the same time that this will reduce its demand for liquidity. Payments coordination could be increased even more if system participants massively send payment orders during netting cycles. Nevertheless, and in accordance with Bernal et al. (2012), as long as the entities with less access to central bank liquidity and lower opening balances (such as brokerage firms) become more dependent on the payments received by its counterparties, the negative impact of temporary disruptions in the system could be exacerbated, given that these latter entities can suddenly stop the orders of payments due to their risk concerns.[14]

Even when some policy options such as the implementation of liquidity-saving mechanisms and the incentives for early submission of payments have been adopted by the CUD, other alternatives that could allow mitigating the risk of payments delays still remain pending. The most prominent of these strategies consists in the implementation and enforcement of binding throughput rules, successfully adopted in other LVPS such as CHAPS in U.K.[15] This strategy has represented risk-reduction benefits (Buckle and Campbell, 2003) and has facilitated the liquidity recycling in that system (Ball, Denbee, Manning and Wetherilt, 2011).

Analysing the failure of Interbolsa

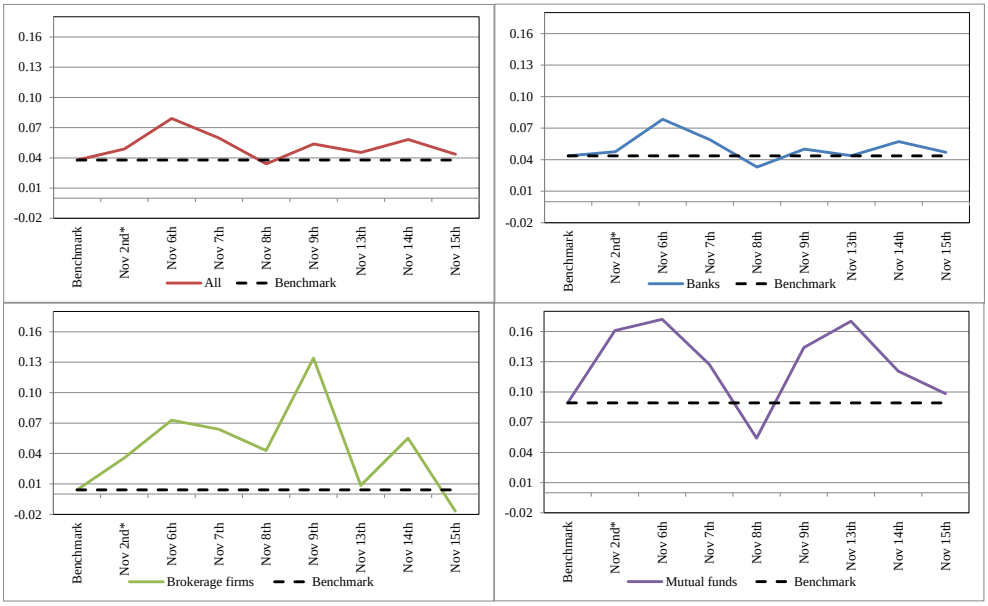
Amongst the incidents examined in the previous section the failure of Interbolsa is considered, once more, for being the most recent. The following section aims to provide a deeper understanding of the way in which the settled payments evolved over time, and to differentiate the reaction functions slopes exhibited by the financial entities' groups.

The easiest way to describe entities' payments activity day-to-day is using graphical analysis of the estimated reaction functions slopes over time, holding all other variables constant. In the following set of graphs we included the parameter estimates of the marginal propensity to send out payments for the selected benchmark period (October 1st – November 1st, 2012) described by the dotted line, and the results obtained for each day until November 15th (solid line) that is the day in which the reaction function slope returned to the estimated benchmark.

[14] Bernal et al. (2012) measured the contribution of liquidity sources in the Colombian LVPS in May of 2010 and found that brokerage firms and mutual funds (trust companies) heavily relied on recirculation of account-balance founds in 85 per cent and 75 per cent of their payments.

[15] Binding throughput rules consist of specific policies that force entities to send payments early, so as to complete a predetermined percentage of payments at a specific hour in a day.

Graph 1. Estimated slope of reaction function per type of entity



Source: authors' calculations.

As we mentioned before, the estimated slopes for the three group of entities included (All) closely follow the behaviour exhibited by banks. In both cases, the marginal propensity to send payments converges to the selected benchmark in November 15th. For mutual funds and brokerage firms the results widely differ from banks and the group "All". Mutual funds exhibit a greater marginal propensity to submit payments represented in an estimated parameter that remains positive since the beginning of this failure. While in the case of brokerage firms the estimated parameter overpass its corresponding benchmark parameter. Although the reaction function slope of brokerage firms turns negative in November 15th, this parameter is not statistically significant.

Financial entities' payments activity also depends on additional information different from incoming payments. Accordingly, it is worth considering other graphical methods that allow the inclusion of k-dimensional data. The methodology proposed by Chernoff (1973) facilitates the representation of multivariate data in a single drawing, producing individual faces (cartoons) that change with the considered parameters. For comparison purposes the algorithm behind these graphical representations transforms the variables into z-scores, in order to provide a constant scale amongst units, and hence, such representations are in relative terms. In accordance with this author, the facial representations allow the execution of cluster analyses, discriminant analyses, and also simplify the exposition of major conclusions. Likewise, this method enables the construction of a sensitivity graphical analysis per periods.

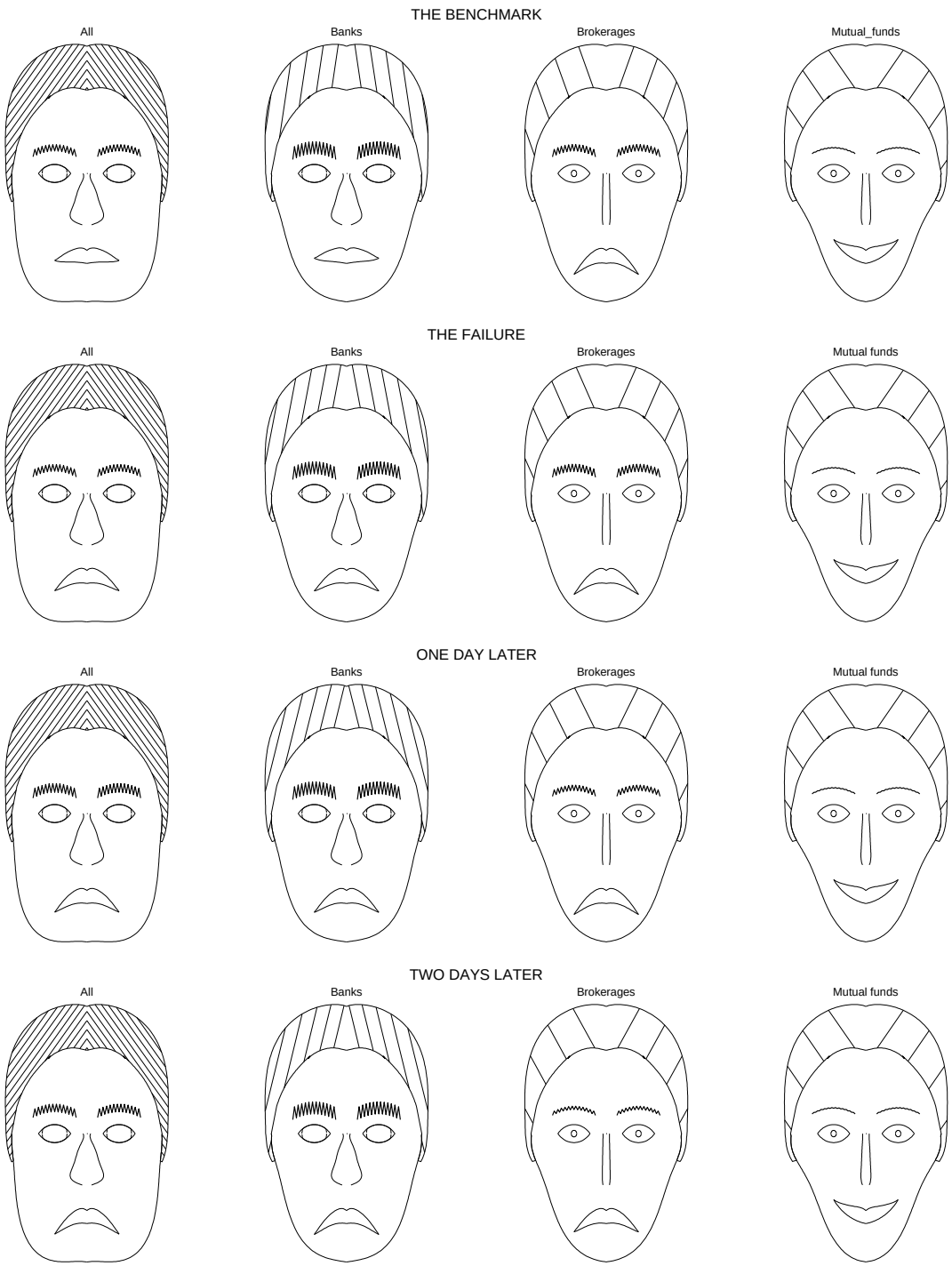
Given that these graphs rely on information per entity type, we used the estimated reaction slopes ′β′ that were obtained from the random effects Tobit models, as well as other variables related with the payments activity. In these graphics the estimated parameter of the marginal propensity to send payments is represented by the curvature of the mouth[16]. The remaining characteristics in the faces correspond to the value of payments (hair darkness and hair shading slant), the opening balance (pupil size), the liquidity provided by the central bank (nose), percentage participation in the number of sent out payments (face line) and the hub centrality (eyebrows density).[17] These graphical representations constitute a valuable tool of analysis, because it allows us to capture in a single image a set of variables that also explain the sending payments strategy chosen by each group of entities. Furthermore, the procedure could be used to analyse individual entities.

From the results for the selected benchmark period to analyse this incident is clear that the graphical representation for the group 'All' resembles that exhibited by banks, in terms of the reaction parameters as well as in terms of the central bank liquidity and hub centrality. The brokerage firms and the mutual funds display similar levels of central bank liquidity and value of payments, but they differ in the willingness to send payments parameters (mouth curvature). Concerning to this last parameter, the group that exhibits the highest propensity to submit payments to its counterparties (happiness) was that of the mutual funds, whereas brokerage firms exposed the less cooperative behaviour (sadness). The group of banks (with a serious face) is located in the middle of these two contrasting positions.

In the day of this failure the banks stopped their payments orders, affecting the liquidity provision of other entities, as can be seen from the mouth shape and size of the group 'All' in the set of graphs presented below. The situation worsened two days after this incident, as the cooperativeness degree of commercial banks dropped even more, with a face expression of sadness. Even when the mutual funds remained as the most cooperative group (expressing happiness) in terms of liquidity, its contribution to the entire group of participant entities in the CUD was nil.

[16] In regard to the shape of the mouth, an entity with a curvature that expresses happiness also exhibits a parameter of reaction that is bigger than those estimated for the other participants of the system. Hence, the curvature of the mouth (happiness, seriousness, calmness, anger or sadness) also expresses if an entity is more or less cooperative in the sending of payment orders. The happier, the more cooperative an entity is.

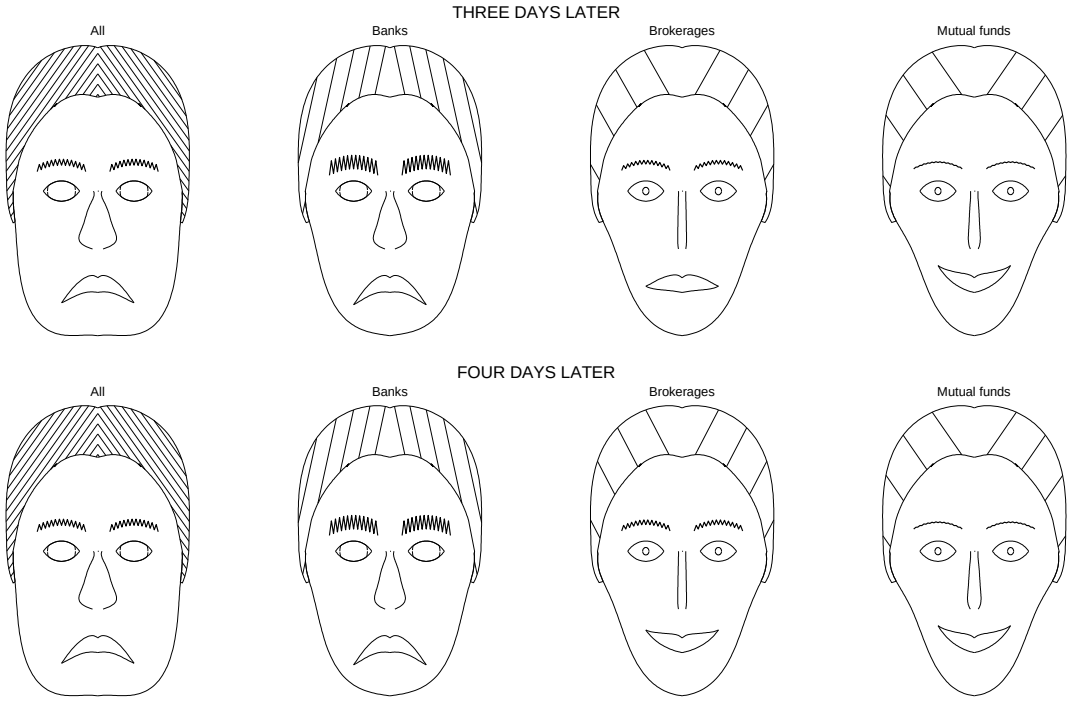
[17] Based on the HITS (Hyperlink Induced Topic Search) information retrieval algorithm (Kleinberg, 1998), hub centrality is a measure of the global importance of a participant as a distributor or sender within a network or system. Its main feature consists of determining the importance of a participant as a weighted average of the importance of the participants it distributes or sends to. As in Leon and Perez (2012), in this document hub centrality metric is related to payments.



Facial characteristics are related to the estimated payment reaction function (mouth curvature), value of payments (hair darkness and shading slant), opening balance (pupil size), central bank liquidity (nose), percentage in the number of payments sent (face line) and hub centrality (eyebrows density).
Source: authors' calculations.

Three days after the failure, in November 8th 2012, the brokerage firms changed their facial expression from sadness to seriousness, reaching, a day later, a high similarity with the payments patterns exhibited by the mutual funds (which remained happy). It seems that brokerage firms were

cooperating even more than what they did before the incident, as the change in the curvature of the mouth suggests. However, the change in their payments activities may be explained by other reasons different from a mere sense of cooperation within the group. Amongst these reasons we found: i) the temporary concentration of unsettled payments (from this and other brokerage firms) that occurred during the take-over by the FSC and the beginning of its liquidation process, time in which the stock market was slowed down; ii) and the early termination of obligations that brokerage firms are subject under the Securities Act Law.[18] Hence, as the payments activities were resumed, several pending payments coming from brokerage firms were sent through the system, increasing their marginal propensity to send out payments (reaction function slope, in November 9th) further than what this group of entities usually exhibit under normal circumstances (sadness face).



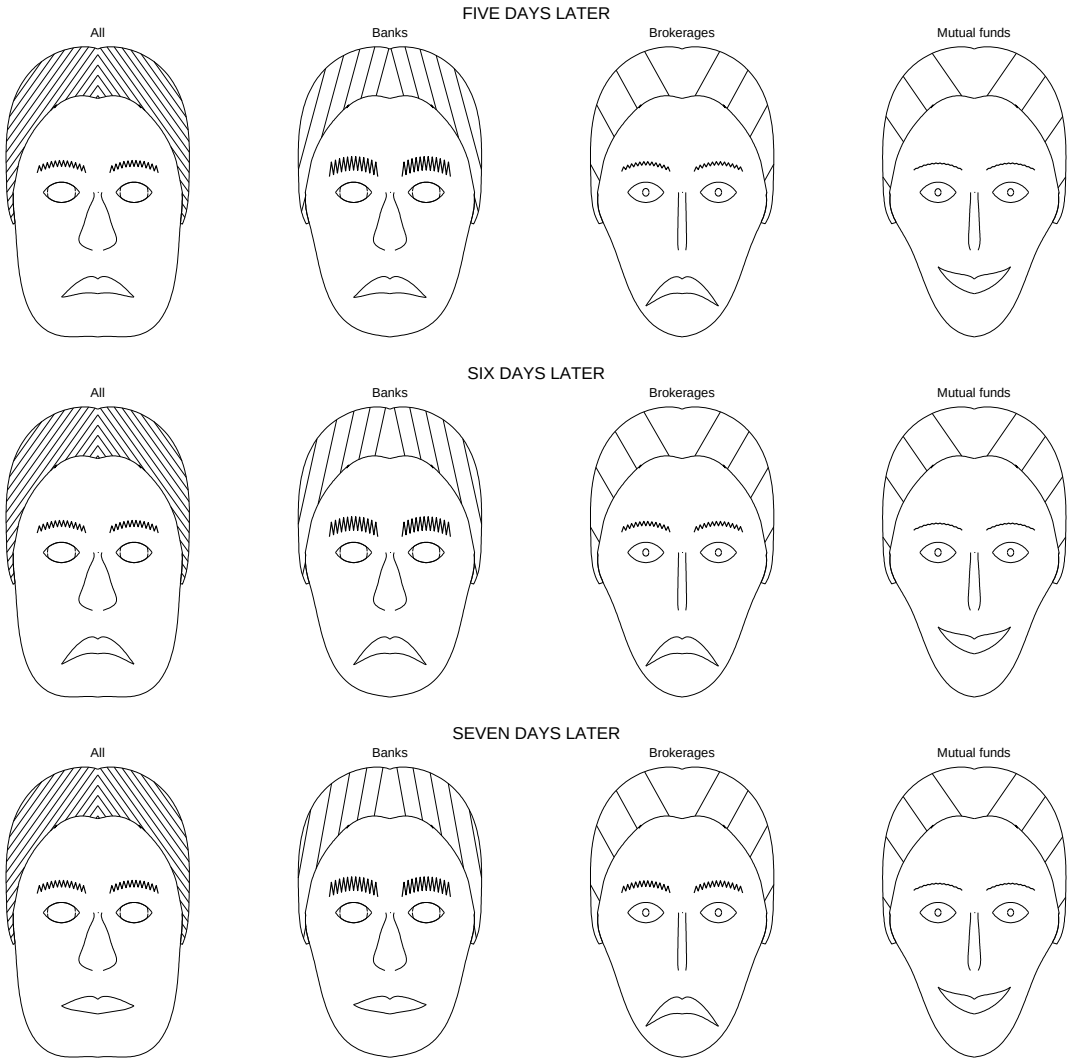
Facial characteristics are related to the estimated payment reaction function (mouth curvature), value of payments (hair darkness and shading slant), opening balance (pupil size), central bank liquidity (nose), percentage in the number of payments sent (face line) and hub centrality (eyebrows density).
Source: authors' calculations.

In regard to mutual funds, despite their cooperation in the sending of payments, the entire system remained under stress, also emulating the physical characteristics of commercial banks. The low cooperation of this latter type of entities is evident in their sadness face during these days.

Five days after failure of *Interbolsa*, the brokerage firms went back to its normal pattern of payments while the recovery of the whole system (resilience) took two more days (November 15th).

[18] Securities and Exchange Law 964 of 2005, Article 14.

As expected, this recovery emerged only until the parameters of the reaction function of commercial banks went back to normality.



Facial characteristics are related to the estimated payment reaction function (mouth curvature), value of payments (hair darkness and shading slant), opening balance (pupil size), central bank liquidity (nose), percentage in the number of payments sent (face line) and hub centrality (eyebrows density).
Source: authors' calculations.

To sum up, the presented results indicate that banks are the most important entities in terms of liquidity (hair darkness), but their marginal propensity to send out payments during this incident was moderate (mouth curvature). In contrast, the mutual funds are the entities with the highest marginal propensity to send payment orders, but their capacity to smooth the liquidity downwards cycles suffered by the entire system is nil. The payments patterns of the brokerage firms also differs from that exhibited by banks and mutual funds, given that their low marginal propensity to submit

payments along with their high liquidity needs could explain the reason for which the contribution of this type of entities to restore the payments flows after a disruption is negligible.

V. Conclusions

In the payments' literature the concept of reaction functions had been used to measure how the strategy of sending payments could be affected by disruptions. The estimation of this concept has been done by means of a linear function that relates the payments sent and received by an entity through the LVPS. According to the pioneer research of McAndrews and Potter (2001), a positive estimation of the reaction function is indicative of the existence of payments coordination amongst the entities, which is a desirable condition especially during periods of disruptions.

The Colombian LVPS (CUD) has suffered from a few failures amongst which, we evaluated those most recently occurred. These are the failure in the communication network (the blackout), a failure in an entity's operational platform (*Bancolombia*) and two other cases caused by the inability of a participant to submit payments (*Proyectar Valores* and *Interbolsa*).

In response to the disruption of the payments activity of Interbolsa, for example, the remaining brokerage firms stopped sending payments as the market slowed down. But as the Financial Superintendency of Colombia intervened and the central bank offered some liquidity facilities, these entities re-established the payments flows even further than what was previously registered. The estimated reaction parameters obtained from the random effects Tobit models allowed us to recognize that the response of the remaining financial market participants to this same incident was represented by a null change in the pattern of payments sent by mutual funds, which remained exhibiting the highest degree of cooperation, and a sudden stop in banks' payments. The analysis based on Chernoff faces allowed us to deepen in the differences that banks, brokerage firms and mutual funds exhibited during this incident. As these graphical representations indicated, the re-establishment in the sending payments (resilience) took around seven working days.

Some possible extensions on this topic could include the development of a methodology that allow characterise specific system participants' behaviour in regard to availability of their liquidity sources, and their payment strategies such as the free-rider.

The methodology used in this document could be helpful to oversee the functioning of the payment reactions amongst entities.

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ANNEX

The Blackout

	Benchmark (April 1st-25th)				The Blackout (April 26th)				April 27th				April 30th				May 2nd			
	All	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*
Receipts in the previous fifteen minutes	0.025	0.023	0.008	0.101	0.024	0.025	0.000	0.120	0.018	0.002	0.013	0.131	0.028	0.019	0.042	0.065	0.022	0.019	0.021	0.080
	(3.11)***	(3.85)***	(0.76)	(10.08)***	(1.47)	(1.19)	(0.02)	(4.05)***	(0.69)	(0.11)	(0.44)	(2.38)***	(1.66)*	(0.84)	(0.99)	(0.40)	(4.09)***	(1.72)*	(1.45)	(0.70)
Opening balance	0.003	0.003	0.010	0.014	0.002	0.000	-0.007	0.147	0.002	0.001	-0.056	-2.133	0.003	0.003	-0.339	0.139	0.002	0.001	-0.416	-2.618
	(4.39)***	(4.41)***	(1.71)*	(2.06)**	(1.26)	(0.04)	(-0.02)	(2.02)**	(0.71)	(0.09)	(-0.28)	(-0.44)	(0.57)	(0.41)	(-1.29)	(0.50)	(1.57)	(0.41)	(-0.30)	(-0.13)
Cumulative receipts minus its cumulative payments sent up sixteen minutes before	-0.013	-0.012	-0.014	-0.008	-0.029	-0.029	-0.022	0.000	-0.011	-0.009	-0.028	0.202	-0.026	-0.021	-0.096	-0.044	-0.022	-0.020	-0.006	-0.037
	(-1.89)*	(-1.47)	(-1.41)	(-0.46)	(-3.56)***	(-2.10)**	(-0.82)	(0.00)	(-1.00)	(-0.96)	(-0.78)	(2.55)***	(-2.20)**	(-1.78)*	(-1.44)	(-0.72)	(-3.60)***	(-4.60)***	(-0.54)	(-1.01)
Dummy of liquidity-saving mechanisms	1.20E+10	1.80E+10	1.11E+10	6.21E+08	8.36E+09	1.48E+10	5.76E+09	-6.26E+08	1.19E+10	2.25E+10	7.25E+09	7.03E+08	8.59E+09	1.55E+10	7.04E+09	-6.87E+08	1.60E+10	2.26E+10	1.69E+10	2.87E+08
	(3.81)***	(3.64)***	(1.93)*	(2.24)**	(3.45)***	(3.00)***	(2.02)**	(-0.79)	(3.35)***	(2.86)***	(1.41)	(0.85)	(2.84)***	(3.69)***	(1.36)	(-0.66)	(3.09)***	(3.15)***	(1.97)**	(0.39)
Dummy of clearing (CEDEC and ACH-CENIT)	2.05E+09	3.04E+09	-6.27E+08	7.37E+08	8.98E+08	1.54E+09	-1.70E+09	1.04E+09	2.07E+09	2.27E+09	-7.88E+08	-1.55E+09	2.46E+09	3.76E+09	-1.73E+09	-2.19E+09	4.87E+09	6.89E+09	3.77E+08	-2.58E+09
	(2.12)**	(3.01)***	(-3.18)***	(0.72)	(0.67)	(0.67)	(-3.57)***	(0.45)	(1.08)	(0.95)	(-1.30)	(-3.81)***	(1.25)	(1.59)	(-2.61)***	(-2.55)***	(1.72)*	(2.06)**	(0.50)	(-4.68)***
Constant	1.92E+09	2.18E+09	1.45E+09	2.51E+09	1.93E+09	2.84E+09	1.74E+09	1.30E+09	1.83E+09	3.19E+09	1.82E+09	1.97E+09	2.04E+09	2.44E+09	2.78E+09	2.23E+09	1.86E+09	2.53E+09	2.81E+09	2.53E+09
	(8.90)***	(6.77)***	(4.85)***	(4.12)***	(4.31)***	(1.59)	(1.37)	(2.28)**	(5.59)***	(1.71)*	(2.54)***	(4.44)***	(6.25)***	(1.88)*	(2.62)***	(1.78)*	(8.43)***	(3.38)***	(0.76)	(3.43)***
Log likelihood	-971625.8	-495104.4	-372322.7	-94847.2	-60973.1	-31621.4	-22434.7	-6265.2	-63196.0	-33852.6	-22737.5	-6044.7	-61576.1	-34645.6	-19127.1	-7214.3	-67650.9	-34997.0	-25665.2	-6832.4
Number of observations	39,444	19,875	15,627	3,942	2,486	1,275	950	261	2,582	1,370	958	254	2,484	1,384	801	299	2,779	1,429	1,066	284
Number of participants	25	8	7	10	25	8	7	10	24	8	7	9	25	8	7	10	25	8	7	10
Value of payments (millions COP), a	8,219,375	5,437,500	2,012,500	769,375	7,779,000	5,120,000	1,880,000	779,000	8,279,000	5,730,000	1,846,000	703,000	8,545,000	5,860,000	1,745,000	940,000	9,055,000	5,610,000	2,538,000	907,000
Opening balance	2,090,678	2,037,162	41,550	11,966	2,858,165	2,748,206	37,756	72,204	2,882,040	2,834,073	47,247	720	2,477,146	2,432,950	26,597	17,599	2,609,441	2,587,013	21,972	455
Central Bank liquidity (intraday and overnight repo, millions COP)	622,596	404,102	75,806	142,688	263,135	0	94,735	168,400	421,659	190,000	34,285	197,374	566,768	254,990	127,278	184,500	764,845	500,000	129,145	135,700
Number of sent out payments	2,420	1,433	831	157	2,561	1,574	831	157	2,719	1,732	831	157	2,852	1,865	831	157	3,269	1,929	1,115	225

a, for the benchmark these values correspond to the daily average mean (in the 16 working days of that period)

Bancolombia's operational failure

	Benchmark (February 1st-25th)				Bancolombia operational failure (February 26th)				March 1st				March 2nd				March 3th			
	All	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*
Receipts in the previous fifteen minutes	0.009	0.007	0.008	0.085	0.008	0.002	-0.005	0.057	0.000	-0.007	0.011	0.070	0.035	0.028	0.023	0.020	0.002	-0.003	0.002	0.031
	(1.84)*	(1.44)	(1.02)	(5.63)***	(1.33)	(0.14)	(-0.26)	(8.18)***	(-0.02)	(-0.62)	(1.08)	(2.66)***	(2.17)**	(1.52)	(1.04)	(1.12)	(0.32)	(-0.33)	(0.09)	(1.34)
Opening balance	0.003	0.002	-0.038	-0.005	0.002	0.001	-0.235	-44.435	0.004	0.003	-0.002	-0.207	0.004	0.000	0.012	0.370	0.004	0.001	-0.141	0.504
	(4.61)***	(4.32)***	(-1.59)	(-0.05)	(2.85)***	(0.82)	(-2.50)***	(-0.68)	(2.28)**	(0.92)	(-0.02)	(-0.01)	(1.90)*	(0.15)	(0.08)	(0.01)	(2.66)***	(0.59)	(-1.34)	(0.03)
Cumulative receipts minus its cumulative payments sent up sixteen minutes before	-0.012	-0.015	0.011	0.032	-0.017	-0.019	0.058	0.136	0.003	0.001	0.004	0.052	0.006	0.004	0.013	0.140	0.006	0.001	0.008	0.041
	(-3.13)***	(-4.89)***	(0.73)	(1.43)	(-2.21)**	(-2.69)***	(0.67)	(3.60)***	(0.64)	(0.17)	(0.22)	(2.43)***	(0.27)	(0.16)	(0.53)	(7.21)***	(0.74)	(0.15)	(0.90)	(0.55)
Dummy of liquidity-saving mechanisms	4.20E+10	7.80E+10	3.11E+10	1.66E+09	2.94E+10	4.80E+10	2.65E+10	-3.61E+09	3.06E+10	5.86E+10	2.46E+10	2.63E+08	4.84E+10	9.71E+10	2.43E+10	1.70E+09	3.77E+10	6.76E+10	3.07E+10	1.75E+09
	(4.10)***	(4.44)***	(2.40)***	(2.98)***	(3.43)***	(3.21)***	(2.26)**	(-4.00)***	(4.25)***	(3.43)***	(2.08)**	(0.21)	(3.37)***	(3.88)***	(2.59)***	(1.35)	(4.98)***	(3.91)***	(2.07)**	(0.60)
Dummy of clearing (CEDEC and ACH-CENIT)	2.50E+09	4.61E+09	-1.29E+08	-1.53E+09	2.06E+09	2.27E+09	7.64E+07	-5.16E+09	8.52E+08	2.17E+09	-1.39E+09	1.66E+09	6.04E+09	9.82E+09	-1.75E+09	3.85E+09	1.48E+09	3.42E+09	-1.21E+09	-3.87E+09
	(2.59)***	(3.18)***	(-0.26)	(-4.86)***	(0.78)	(0.99)	(0.04)	(-6.57)***	(0.60)	(1.22)	(-2.34)***	(1.57)	(1.69)*	(1.81)*	(-1.95)*	(0.74)	(0.89)	(1.20)	(-2.61)***	(-2.56)***
Constant	2.02E+09	3.11E+09	2.34E+09	2.34E+09	2.93E+09	4.18E+09	4.01E+09	5.44E+09	2.55E+09	4.01E+09	2.21E+09	2.62E+09	1.80E+09	3.91E+09	1.95E+09	2.66E+09	2.27E+09	4.12E+09	2.93E+09	3.36E+09
	(6.08)***	(7.88)***	(5.38)***	(7.07)***	(6.57)***	(3.67)***	(4.40)***	(5.43)***	(7.87)***	(2.37)***	(2.62)***	(3.82)***	(3.71)***	(2.65)***	(1.15)	(4.36)***	(5.73)***	(2.89)***	(4.23)***	(4.46)***
Log likelihood	-1528536.4	-695057.9	-631122.9	-187454.0	-70878.1	-35343.9	-26920.5	-8382.6	-83768.1	-39430.8	-32737.9	-10692.2	-73311.2	-33987.9	-28527.1	-9826.6	-76207.0	-34091.6	-32193.4	-9500.4
Number of observations	60,563	27,229	25,615	7,719	2,821	1,397	1,084	340	3,334	1,551	1,342	441	2,895	1,327	1,162	406	3,041	1,348	1,307	386
Number of participants	26	8	8	10	26	8	8	10	26	8	8	10	26	8	8	10	26	8	8	10
Value of payments (millions COP), a	16,085,789	10,157,895	4,500,000	1,427,895	14,051,000	8,610,000	3,850,000	1,591,000	17,439,000	11,560,000	4,410,000	1,469,000	15,543,000	10,060,000	4,050,000	1,433,000	14,379,000	8,620,000	4,050,000	1,709,000
Opening balance	4,605,852	4,546,065	57,476	2,311	5,707,230	5,651,950	55,062	217	5,687,867	5,632,148	53,341	2,378	5,482,531	5,408,783	71,040	2,708	5,047,144	4,989,848	54,408	2,887
Central Bank liquidity (intraday and overnight repo, millions COP)	933,134	507,595	86,627	338,912	58,943	30,038	4,390	24,515	1,111,313	730,000	48,893	332,420	571,200	120,000	59,200	392,000	709,495	100,000	89,625	519,870
Number of sent out payments	3,763	1,763	1,664	336	3,330	1,330	1,664	336	3,863	2,056	1,497	310	3,540	1,733	1,497	310	3,459	1,652	1,497	310

a, for the benchmark these values correspond to the daily average mean (in the 19 working days of that period)

Source: authors' calculations. (t-statistic values in parentheses)

Significant at 10%(*), 5%(**), 1%(***) levels

The failure of Proyectar

	Benchmark (June 1st-22th)				Proyectar Failure (June 23th)				June 24th				June 28th				June 29th			
	All	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*
Receipts in the previous fifteen minutes	0.029	0.031	0.003	0.094	0.027	0.022	0.019	0.092	0.012	0.011	0.007	0.058	0.010	0.006	0.034	0.118	0.028	0.028	0.016	0.113
	(3.90)***	(4.41)***	(0.45)	(4.72)***	(1.58)	(0.89)	(1.77)*	(5.23)***	(1.30)	(0.78)	(0.42)	(2.50)***	(1.30)	(0.75)	(1.77)*	(5.20)***	(3.52)***	(4.52)***	(1.09)	(2.24)**
Opening balance	0.004	0.003	-0.019	0.035	0.005	0.003	0.120	0.040	0.006	0.003	0.047	0.058	0.010	0.010	0.131	1.527	0.003	0.003	0.016	-0.214
	(6.76)***	(5.18)***	(-3.11)***	(0.97)	(2.05)**	(0.43)	(0.96)	(0.06)	(5.61)***	(1.97)**	(0.46)	(0.06)	(5.50)***	(2.44)***	(1.19)	(0.30)	(4.40)***	(6.20)***	(0.11)	(-0.0002)
Cumulative receipts minus its cumulative payments sent up sixteen minutes before	-0.020	-0.022	0.027	0.021	-0.015	-0.016	0.014	0.141	0.000	-0.004	0.047	0.108	0.003	0.002	0.067	0.141	-0.019	-0.019	0.027	0.094
	(-1.76)*	(-1.92)*	(2.59)***	(0.96)	(-2.00)**	(-1.67)*	(0.38)	(2.02)**	(-0.04)	(-0.48)	(1.42)	(2.90)***	(0.14)	(0.13)	(1.67)*	(0.88)	(-1.56)	(-1.97)**	(0.96)	(1.82)*
Dummy of liquidity-saving mechanisms	3.97E+10	7.24E+10	2.62E+10	1.11E+09	4.44E+10	7.91E+10	2.90E+10	1.74E+09	4.19E+10	8.08E+10	2.78E+10	-7.84E+08	4.35E+10	7.81E+10	1.88E+10	2.76E+09	7.10E+10	7.39E+10	3.26E+10	1.08E+09
	(5.24)***	(5.84)***	(2.53)***	(1.09)	(3.32)***	(3.78)***	(2.19)**	(1.87)*	(3.79)***	(3.67)***	(2.10)**	(-0.56)	(3.31)***	(4.20)***	(1.69)*	(0.97)	(5.49)***	(6.07)***	(2.02)**	(0.27)
Dummy of clearing (CEDEC and ACH-CENIT)	3.17E+09	5.73E+09	2.51E+06	-2.56E+09	-2.07E+09	-2.37E+09	3.61E+07	-3.30E+09	5.93E+09	7.55E+09	-1.76E+09	3.10E+10	7.99E+09	1.17E+10	6.81E+07	-2.20E+09	5.32E+09	5.52E+09	-2.33E+09	-6.42E+09
	(3.33)***	(5.53)***	(0.01)	(-2.41)**	(-0.90)	(-0.94)	(0.02)	(-3.50)***	(2.61)***	(2.19)**	(-3.15)***	(17.51)***	(1.63)	(1.88)*	(0.09)	(-1.41)	(5.07)***	(5.54)***	(-3.41)***	(-1.30)
Constant	1.85E+09	2.16E+09	2.49E+09	3.30E+09	2.49E+09	4.53E+09	1.08E+09	2.35E+09	2.01E+09	4.04E+09	1.65E+09	2.53E+09	1.56E+09	4.88E+08	6.58E+08	1.66E+09	2.18E+09	2.65E+09	2.17E+09	2.51E+09
	(3.80)***	(5.25)***	(8.36)***	(4.11)***	(3.88)***	(0.87)	(0.74)	(3.88)***	(4.58)***	(3.62)***	(1.77)*	(6.27)***	(3.26)***	(0.21)	(0.51)	(2.59)***	(5.30)***	(5.33)***	(2.08)**	(4.62)***
Log likelihood	-1111891.5	-520078.3	-452452.5	-125070.1	-77467.6	-34645.1	-31906.2	-9651.2	-73453.6	-34233.7	-29820.4	-8392.3	-71682.1	-34850.7	-27851.8	-7706.8	-694329.8	-657668.0	-26883.1	-8638.4
Number of observations	43,466	20,081	18,268	5,117	3,013	1,329	1,292	392	2,873	1,323	1,203	347	2,809	1,349	1,142	318	26,834	25,394	1,087	353
Number of participants	26	8	8	10	26	8	8	10	26	8	8	10	26	8	8	10	26	8	8	10
Value of payments (millions COP), a	18,176,000	12,386,667	4,380,000	1,409,333	20,896,000	14,200,000	4,850,000	1,846,000	19,010,000	13,440,000	4,280,000	1,290,000	17,919,000	13,100,000	3,740,000	1,079,000	17,544,000	11,750,000	4,130,000	1,664,000
Opening balance	6,544,630	6,446,742	81,242	16,646	6,388,056	6,299,911	77,897	10,248	5,839,926	5,733,526	73,430	32,970	4,334,369	4,251,900	80,615	1,855	4,334,369	4,251,900	80,615	1,855
Central Bank liquidity (intraday and overnight repo, millions COP)	3,957,545	3,533,495	93,698	330,353	3,039,710	2,500,000	98,310	441,400	2,914,714	2,524,994	37,170	352,550	3,105,786	2,745,986	41,950	317,850	4,956,788	4,479,998	60,690	416,100
Number of sent out payments	3,554	1,796	1,496	262	3,425	1,667	1,496	262	3,578	1,820	1,496	262	3,572	1,814	1,496	262	3,602	1,844	1,496	262

a, for the benchmark these values correspond to the daily average mean (in the 15 working days of that period)

Source: authors' calculations. (t-statistic values in parentheses)

Significant at 10%(*), 5%(**), 1%(***) levels

The failure of Interbolsa

	Benchmark (October 1st-November 1st)				Interbolsa failure (November 2nd)				November 6th				November 7th				November 8th			
	All	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*
Receipts in the previous fifteen minutes	0.038	0.044	0.004	0.089	0.049	0.048	0.036	0.161	0.079	0.078	0.073	0.172	0.060	0.059	0.064	0.127	0.034	0.033	0.043	0.054
	(2.25)**	(2.12)**	(0.71)	(7.33)***	(1.96)**	(1.36)	(1.35)	(7.94)***	(4.24)***	(1.82)*	(6.11)***	(4.04)***	(3.69)***	(1.51)	(4.15)***	(4.08)***	(6.21)***	(2.25)**	(9.60)***	(2.64)***
Opening balance	0.003	0.003	0.016	0.047	0.001	-0.002	-0.134	0.050	0.001	-0.001	-0.212	3.502	0.001	0.000	0.009	0.911	0.003	0.001	-0.221	4.584
	(6.87)***	(5.12)***	(0.59)	(8.74)***	(1.33)	(-1.22)	(-0.85)	(0.01)	(1.71)*	(-0.32)	(-1.06)	(0.05)	(1.25)	(0.00)	(0.11)	(0.05)	(1.61)	(0.61)	(-4.21)***	(0.33)
Cumulative receipts minus its cumulative payments sent up sixteen minutes before	0.003	-0.001	0.011	0.081	-0.004	-0.003	0.027	-0.056	-0.022	-0.026	0.019	0.377	0.019	0.020	-0.003	0.018	0.019	0.019	-0.007	0.012
	(0.47)	(-0.18)	(0.59)	(7.27)***	(-0.62)	(-0.47)	(1.17)	(-0.61)	(-1.14)	(-1.79)*	(0.52)	(1.53)	(1.19)	(1.36)	(-0.17)	(0.16)	(0.65)	(0.60)	(-0.49)	(0.20)
Dummy of liquidity-saving mechanisms	4.23E+10	6.71E+10	3.90E+10	3.09E+09	5.24E+09	4.00E+09	7.53E+09	2.88E+09	9.34E+09	1.35E+10	1.22E+10	-1.13E+09	1.58E+10	2.82E+10	6.62E+09	1.51E+09	1.45E+10	2.70E+10	1.15E+10	-2.39E+09
	(4.56)***	(5.28)***	(2.18)**	(5.07)***	(2.20)**	(1.49)	(2.08)**	(0.88)	(3.14)***	(3.59)***	(1.26)	(-0.75)	(2.42)***	(2.68)***	(2.72)***	(1.02)	(2.80)***	(4.07)***	(1.54)	(-1.19)
Dummy of clearing (CEDEC and ACH-CENIT)	3.18E+09	5.86E+09	-1.53E+09	-2.01E+08	1.16E+09	2.83E+09	-2.29E+09	-3.54E+09	1.36E+09	1.14E+09	8.20E+07		8.40E+07	-1.10E+09	4.42E+09	-1.35E+09	7.04E+08	1.73E+07	8.39E+09	-2.27E+09
	(2.15)**	(3.11)***	(-1.09)	(-0.23)	(0.59)	(1.01)	(-3.04)***	(-2.15)**	(0.51)	(0.33)	(0.04)	0.00	(0.05)	(-0.48)	(1.13)	(-0.60)	(0.59)	(0.01)	(34.05)***	(-1.81)*
Constant	1.50E+09	1.77E+09	2.17E+09	2.79E+09	2.69E+09	6.21E+09	2.69E+09	2.29E+09	2.68E+09	4.51E+09	2.62E+09	1.87E+09	2.57E+09	4.04E+09	1.75E+09	2.21E+09	3.09E+09	4.40E+09	3.84E+09	3.28E+09
	(2.93)***	(2.12)**	(6.20)***	(7.39)***	(5.61)***	(4.01)***	(4.72)***	(3.64)***	(5.43)***	(2.50)***	(4.86)***	(1.84)*	(5.04)***	(1.91)*	(2.13)**	(3.79)***	(5.42)***	(2.71)***	(8.80)***	(3.33)***
Log likelihood	-1693149.3	-806004.6	-676481.4	-200560.9	-65290.6	-32815.4	-23825.5	-7938.0	-54276.1	-31059.6	-16304.3	-6418.0	-62522.8	-33646.3	-19991.6	-7952.5	-62089.9	-34349.9	-18504.7	0.0
Number of observations	66,245	31,248	26,835	8,162	2,591	1,287	978	326	2,144	1,216	668	260	2,469	1,314	831	324	2,434	1,333	760	341
Number of participants	26	8	8	10	26	8	8	10	26	8	8	10	26	8	8	10	26	8	8	10
Value of payments (millions COP), a	19,300,000	12,565,217	5,195,652	1,539,130	13,603,000	9,330,000	3,050,000	1,223,000	13,968,200	10,150,000	2,640,000	1,178,200	14,604,900	10,620,000	2,520,000	1,464,900	15,034,700	10,730,000	2,623,700	1,681,000
Opening balance	6,377,335	6,331,930	28,689	16,717	7,255,663	7,192,173	32,979	30,511	7,552,640	7,519,980	32,133	527	7,066,817	7,009,243	51,070	6,503	7,469,253	7,398,690	68,873	1,690
Central Bank liquidity (intraday and overnight repo, millions COP)	4,389,857	3,876,545	121,012	392,301	4,677,155	3,975,000	263,355	438,800	4,607,161	4,110,000	119,161	378,000	4,347,271	3,800,000	184,171	363,100	3,602,800	3,050,000	164,000	388,800
Number of sent out payments	3,911	1,911	1,701	298	2,495	1,330	922	244	2,539	1,374	922	244	2,594	1,429	922	244	2,746	1,581	922	244

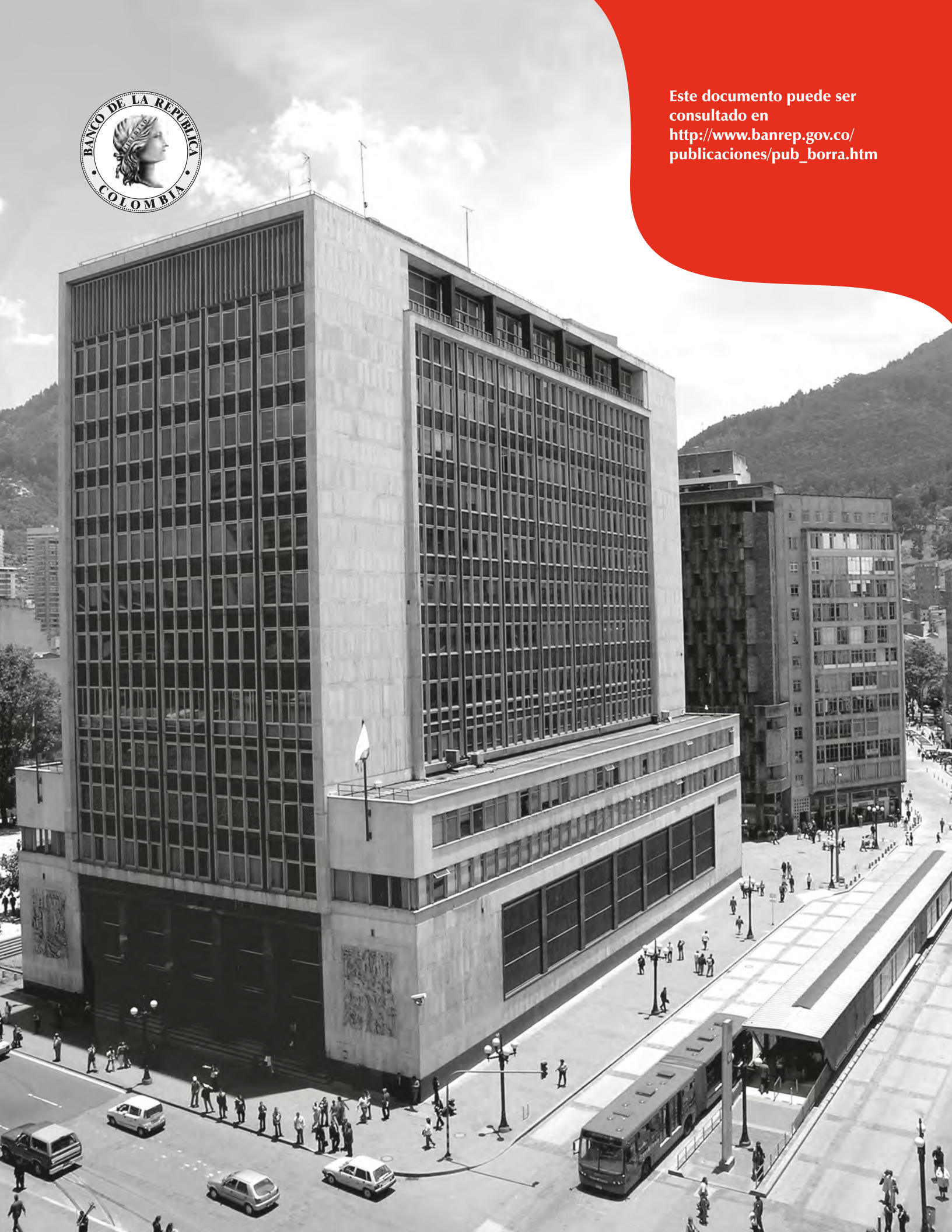
a, for the benchmark these values correspond to the daily average mean (in the 23 working days of that period)

	November 9th				November 13th				November 14th				November 15th			
	All	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*	*All*	*Banks*	*Brokerage firms*	*Mutual funds*
Receipts in the previous fifteen minutes	0.054	0.050	0.134	0.144	0.045	0.044	0.009	0.170	0.058	0.057	0.055	0.121	0.044	0.047	-0.017	0.098
	(2.14)**	(3.69)***	(2.59)***	(1.70)*	(4.67)***	(2.89)***	(0.55)	(2.85)***	(4.91)***	(1.85)*	(3.75)***	(2.74)***	(2.10)**	(1.84)*	(-0.98)	(2.95)***
Opening balance	0.003	0.004	-0.124	0.534	0.002	0.000	-0.032	0.136	0.002	0.001	-0.137	0.063	0.002	0.000	-0.035	0.948
	(1.60)	(1.49)	(-2.41)***	(0.59)	(1.59)	(-0.13)	(-0.30)	(0.01)	(1.60)	(0.58)	(-1.95)*	(5.88)***	(1.40)	(0.20)	(-0.25)	(2.63)***
Cumulative receipts minus its cumulative payments sent up sixteen minutes before	-0.003	-0.002	-0.082	0.026	-0.023	-0.023	0.171	-0.010	0.005	0.004	0.037	0.092	-0.028	-0.033	0.042	0.042
	(-0.08)	(-0.06)	(-2.92)***	(0.53)	(-1.86)*	(-3.06)***	(1.52)	(-0.15)	(0.62)	(0.39)	(1.47)	(2.93)***	(-1.61)	(-1.77)*	(1.02)	(0.48)
Dummy of liquidity-saving mechanisms	2.12E+10	2.85E+10	1.86E+10	2.02E+09	2.17E+10	2.74E+10	2.54E+10	1.46E+09	4.42E+09	5.91E+09	1.65E+09	2.25E+09	2.52E+10	2.83E+10	3.92E+10	-9.09E+08
	(3.45)***	(4.55)***	(1.34)	(0.73)	(2.13)**	(1.70)*	(1.33)	(0.35)	(1.33)	(1.32)	(0.68)	(0.82)	(2.37)***	(3.24)***	(1.21)	(-1.04)
Dummy of clearing (CEDEC and ACH-CENIT)	-1.17E+08	-5.45E+07	1.38E+09	0.00E+00	-3.34E+09	-4.32E+09	-4.35E+09	-3.66E+08	-1.73E+09	-3.04E+09	2.02E+08	1.83E+10	-2.64E+08	-8.23E+08	-1.32E+09	4.45E+09
	(-0.04)	(-0.02)	(0.52)	0.00	(-1.34)	(-1.39)	(-1.94)*	(-0.12)	(-0.77)	(-0.98)	(0.22)	(15.34)***	(-0.15)	(-0.34)	(-2.54)***	(0.43)
Constant	2.15E+09	1.01E+09	1.93E+09	2.02E+09	3.08E+09	5.48E+09	2.32E+09	2.67E+09	3.06E+09	3.54E+09	3.36E+09	2.80E+09	2.87E+09	4.47E+09	2.32E+09	3.09E+09
	(4.12)***	(0.49)	(5.03)***	(2.96)***	(4.38)***	(3.18)***	(2.75)***	(3.30)***	(7.46)***	(1.70)*	(5.03)***	(3.26)***	(4.54)***	(2.62)***	(1.88)*	(5.04)***
Log likelihood	-61249.2	-33694.9	-18613.3	-8330.0	-56623.0	-33219.2	-16129.6	-6944.7	-54816.3	-31257.1	-15519.5	-7462.5	-59972.8	-32817.1	-19456.8	-7589.6
Number of observations	66,245	31,248	26,835	8,162	2,591	1,287	978	326	2,144	1,216	668	260	2,469	1,314	831	324
Number of participants	26	8	8	10	26	8	8	10	26	8	8	10	26	8	8	10
Value of payments (millions COP), a	14,245,378	10,091,219	2,703,740	1,450,419	13,609,567	10,125,964	2,229,820	1,253,782	12,579,424	8,991,060	2,139,970	1,448,394	14,214,055	9,811,049	2,686,201	1,716,805
Opening balance	7,289,020	7,201,097	77,309	10,614	6,929,887	6,821,367	106,540	1,980	6,908,730	6,672,820	78,522	157,387	6,231,114	6,123,825	95,093	12,196
Central Bank liquidity (intraday and overnight repo, millions COP)	2,093,929	1,600,000	155,029	338,900	2,248,972	1,890,000	150,052	208,920	3,595,872	3,000,000	197,022	398,850	4,244,191	3,570,000	114,791	559,400
Number of sent out payments	2,623	1,532	761	330	2,328	1,445	646	237	2,051	1,235	565	251	2,653	1,540	860	253

a, for the benchmark these values correspond to the daily average mean (in the 23 working days of that period)

Source: authors' calculations. (t-statistic values in parentheses)

Significant at 10%(*), 5%(**), 1%(***) levels



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