DOCUMENTOS DE TRABAJO

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A NEW LIQUIDITY RISK MEASURE FOR THE CHILEAN BANKING SECTOR^{*}

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Abstract

The objective of this work is to construct an appropriate measure of liquidity risk for Chilean banks. There are already several measures of liquidity risk in the literature. Most of these metrics are based on specific assumptions and expert opinion. In order to overcome the potential problems associated with discretionary assumptions, and to exploit the information available, similar to the work of Drehman and Nikolaou (2012), we propose a metric based on the behavior of banks in the procurement operations Chilean open market (OMO). Due to the particularities of the implementation of monetary policy of the Chilean economy, we introduce an adaptation of the original metric. We calculate the liquidity indicator at an aggregate level and for a sample of groups of banks in a period that includes the recent crisis in the sub-prime. After that, we compare this indicator with a variety of standard metrics proposed in the literature. We find that our metric reasonably captures episodes of liquidity crises and therefore can be used as a complementary tool in the assessment of systemic risks.

Resumen

El objetivo de este trabajo es construir una medida adecuada del riesgo de liquidez para la banca chilena. Existen ya varias medidas del riesgo de liquidez en la literatura. La mayoría de estas métricas se basan en supuestos específicos y la opinión de expertos. Con el fin de superar los problemas potenciales asociados a supuestos discrecionales, y de aprovechar la información disponible, de un modo similar al trabajo de Drehman y Nikolau (2012), se propone una métrica basada en el comportamiento de los bancos en las licitaciones de las operaciones de mercado abierto chileno (OMA). Debido a las particularidades de la implementación de política monetaria de la economía chilena, implementamos una adaptación de la métrica original. Calculamos el indicador de liquidez a nivel agregado y para una muestra de grupos de bancos en un periodo que incluye la reciente crisis de las sub-prime. Luego de ello, comparamos este indicador con una variedad de métricas estándar propuestas por la literatura. Encontramos que nuestra métrica captura razonablemente bien los episodios de crisis de liquidez y por ello puede ser utilizada como una herramienta complementaria en la evaluación de riesgos de carácter sistémico.

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1 Introduction

Liquidity risk is inherent to banking activity because of maturity transformation. Long-term assets co-exist with short-term liabilities.

During the last decade banks all over the world have been heavily reliant on short-term wholesale funding, more on the commercial papers market and less on retail. However, during 2007, in advanced economies, those markets froze when doubt over the quality of their asset/solvency emerged (Schmieder et al, 2012). This reliance on the deep and broad unsecured money market resulted in liquidity challenges for many banks. In spite of the lack of attention to liquidity risks in recent decades (Goodhart, 2008), it has attracted renewed attention since the last turmoil (2007-2008). Before the crisis, international regulatory standards were predominantly focused on credit risk (BIS, 2009).

Liquidity risk metrics are based on different sources of information. Some of them are based on *balance-sheet* data of banks. This information can be used to measure liquidity risk at bank -and systemic- level as in Federico (2012). For example, within the balance sheet based indicators we can find the liquidity coverage ratio (LCR), the net stable funding ratio (NSFR) -both introduced by Basel III- and the liquidity mismatch index (LMI), by Brunnermeier et al. (2009). Other measures are *market based*, such as the ones proposed by the ECB (2007) and the BoE (2007). These ones are built as a composition of liquidity measures such as bid-ask spreads, return-to-volume ratio and liquidity premia. Finally, in the main interest of our paper, some indicators depend on *banks' behavior in the context of monetary policy operations*, i.e. how commercial banks' bid schedules behave in open market operations conducted by central banks. In this line, our reference work will be that of Drehmann and Nikolaou (2012). These authors construct a funding liquidity risk indicator from banks' asked bid rates and volumes in the Main Refinancing Operations performed by the European Central Bank. Basically, the more liquidity constrained an institution is, the higher is the spread between a benchmark and their asked rate.

To contribute to a growing research on liquidity risk measures, in this paper we adapt a metric for funding liquidity risk -proposed by Drehman and Nikolau (2012)- and apply it to the Chilean banking industry. In order to address this task it would be necessary to underline our assessment on the concept of liquidity. As described in Drehmann and Nikolaou (2012), funding liquidity is defined as the ability to settle obligations with immediacy. It is interesting to distinguish it from market liquidity; Brunnermeier and Pedersen (2009) note that market liquidity refers to the ease to sell an asset (therefore asset-specific), and funding liquidity to the ease to access funding (therefore agent-specific). In the previous definition, funding liquidity risk is driven by the probability that over a specific horizon the bank will become unable to settle its obligation with immediacy so it is, therefore, forward looking.

We revise different liquidity risk measures -funding and market based- in order to check the ones that better fit the Chilean banking sector given the available information. Looking at their benefits and drawbacks we will build a selection of metrics of liquidity risk.

To replicate some of the measures of liquidity risk for Chile, it is necessary to understand the context and the objective of open market operations (OMOs) conducted by the Central Bank of Chile (BCCh).

The BCCh's liquidity policy is conducted differently from most of the international central bank

policies (in particular the Fed and the ECB). Unlike the European Central Bank (ECB), which injects liquidity every week, the BCCh mainly drains liquidity through the sales of short term notes (PDBC of different maturity) and of long term bonds (BCP and BCU). This is due to the fact that in emerging economies there is excess of inflows. Thus, we need to alter the Drehmann and Nikolaou's *Liquidity Risk Premium* (LRP) indicator. The idea behind this measure is that banks reveal their liquidity risks through their bidding behavior in the OMOs conducted by the monetary authority.

We construct a unique database using the OMO of the BCCh. From September 2002 to November 2012, our data contains all the OMO auctions for every bond and note offered by the BCCh, including the volumes and asked bid rates by every authorized bank operating in Chile. Using this information, we introduce an adapted LRP indicator for an emerging market liquidity policy, such as that of Chile: the CALRP, or Chilean averaged liquidity risk premium. We show that our metric manages to capture reasonably well the main episodes of liquidity stress in the last decade, especially during the recent financial crisis. Once computed this metric, we test some features about the OMO's bidding behavior of local banks and describe the modified LRP dynamics. Finally, we compare our version of LRP metric (CALRP) against other - local and international - liquidity risk indicators proposed by the literature, highlighting periods of local policy intervention or changes in regulation. As a robustness check, we also test the relationship between void processes on our CALRP indicator.

The paper is structured as follows. Section 2 provides a survey of existing measures of liquidity risk. Section 3 describes the OMO auctions and liquidity facilities performed by the BCCh. Section 4 presents the Liquidity Risk Premium indicator adapted to the Chilean context. Section 5 presents a data description. Section 6 presents the results. Section 7 presents a comparative analysis, and finally Section 8 concludes.

2 A brief survey of existing measures of liquidity risk

In this section we present different ways of modelling a liquidity risk measure. These alternatives use balance-sheet information (at bank -and banking system- level), market information, or bank behavior - revealed in the biding behavior in open market operation auctions conducted by central banks. Table (1) describes the liquidity metrics covered in this work.

Metric	Sources	Liquidity Dimension
Liquidity Coverage Ratio: LCR	Balance sheet constraints	Funding
LIBOR-OIS spread: LOIS	Global funding markets prices	Funding
Global Financial Liquidity: GFL	Equity and other market spreads	Market
Prime Swap spread: PS	Local wholesale funding market prices	Funding
Chilean Liquidity Financial Indicator: CLF	Equity and other market spreads	Market
Chilean Averaged Liquidity Risk Premium: CALRP	Monetary Policy Behavior	Funding

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As shown in the table, we concentrate this investigation on a set of liquidity metrics that have been recently issued or applied across advanced and developing economies' financial authorities. In the next section we describe the rationale, construction, strengths and weaknesses of these metrics. Most of them are replicated using Chilean banking system information. However, in the case of CLF and CALRP we make an effort in adapting these metrics to the Chilean financial system idiosyncrasies. Additionally, in the analysis section (Section 8), we relate and compare the computed liquidity metrics.

2.1 Balance sheet based indices

2.1.1 At bank level

After the recent financial crisis (2007-2009), the BIS introduced two liquidity requirements. Based on balance sheet data, these measures provide information at bank level, and then aggregate, for the whole banking sector or cluster. These measures are the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR). Both metrics intend to measure the fragility of each bank and of the system to a shock using a stress test based approach.¹

Another measure is the Liquidity Mismatch Index (LMI) proposed by Brunnermeier et al. (2011). It is based on a weight earmarked to the assets and liabilities depending on their liquidity characteristics, for different stress scenarios. The LMI can give individual and aggregated information, can identify SIFIs and, also, takes into account market and funding liquidity information (similar to the balance sheet indices above).

One of the benefits of this kind of measures is that these can be presented at the bank and aggregate level. Another advantage is that these metrics take into account both market and funding liquidity. Where the funding dimension is calculated as a function of the market liquidity of the assets on the balance sheet of each agent. On the other hand, the main drawback of these measures is that they depend on the stress scenario in place, and it is always difficult to assess the severity of shocks with only a few crises in the past.² Additionally, balance-sheet based measures are sensitive to the weight and categorization of assets and liabilities; besides the fact that banks' balance-sheet information is hard to read, it changes quickly, and is subject to changes in regulation, accounting standards and window dressing. In conclusion, these indices help to understand the fragility of a bank and the bank-ing industry as whole, but there are reasons to explore other alternatives based on mark-to-market information.

In this paper, and in order to compare different liquidity metrics, we develop a Chilean version of the LCR, which is computed using banking balance-sheet data that ³.

$$LCR_t = \frac{Stock \, of \, High \, Quality \, Liquid \, Assets}{Total \, Net \, Cash \, OutFlows \, Over \, Next \, 30 \, Days} \tag{1}$$

¹In general BCCh instruments constitute an important portion of banks' liquid assets (see Tables (18) and (17)). There are only a few banks where these represent less than 10% of the volume. For the NSFR and LCR definitions and constructions see BIS (2010) and (2013)

 $^{^{2}}$ Nevertheless, we acknowledge that in order to calibrate the parameters it is possible to use international data of similar economies.

 $^{^{3}}$ This is accessible through the C08 file. This archive contains information of local based banks balance sheets, available through the Chilean banking supervisor (SBIF).

2.1.2 At system level

To capture the banking systemic exposure to liquidity risk, Federico (2012), following a similar methodology to the one introduced by Basel III for the NSFR, constructs a set of indices that measure how vulnerable a banking system is to a sudden drying-up of liquidity in emerging markets. By assigning weights to assets and liabilities according to their liquidity characteristics, a "Cash Shortage" index for every bank in every country used in the sample is built. This is used to build two aggregate metrics, namely the "Coverage of New Lending" and "Impaired New Lending". The author claims that these are valid indicators since they are robust in explaining output contractions across Latin America's and other developing countries' markets after the Lehman event.

The metric elaborated by Federico (2012) has similar benefits and drawbacks as the previously described balance-sheet based indicator. Additionally, for its construction, as the author points out, depending on the source of information, the metrics need to be corrected for a breakdown of liabilities by currency.

Although this type of indicators are feasible using the Chilean banking system information, we do not generate them, since the supporting literature is still in a preliminary stage of development.

2.2 Market based indices

2.2.1 Market spreads

Numerous market based liquidity risk measures in the literature are mainly rate spreads. These metrics mainly measure the funding dimension of liquidity. The most commonly used are spreads between overnight interbank market, and central bank policy rates, such as the LIBOR-OIS spread (LOIS). These measures are easy to understand and compute, and since daily measures can be obtained, liquidity stress episodes can be quickly revealed. However they are not bank specific, and it is difficult to disentangle liquidity risk from other risks -like solvency risk- , and they are less easy to build when markets are shallow or in a development phase.

The local Chilean version of the LIBOR-OIS is the *Prime-Swap spread* (PS), proposed by Ahumada and Álvarez (2009), which is available for different maturities (90, 180 and 360 days). The information used to build this indicator comes from a survey and a marketed overnight SWAP rate, similar to the LIBOR-OIS.

2.2.2 Composite indices

Other type of market liquidity metrics use more aggregated data. The ECB (2007) and the BoE (2007) derive, build and propose Global Financial Liquidity (GFL) indicators based on bid-ask spreads, exchange rates, stock returns, return-to-volume ratios, liquidity premia of corporate bonds, interest rate swaps, among others. These indicators are constructed by normalizing the series and adding them up into a composite metric.

In this paper, we replicate the composite metrics GFL and CFL. Although the complete set of market data needed for constructing the indicator could be difficult to obtain for Chile due to the insufficient depth of the markets (compared to the developed economies), we are able to build a local version: the Chilean Financial Liquidity indicator (CLF). We make some assumptions and use all the information available, to the best of our knowledge.

$$CLF_t = \sum_{i=1}^n \frac{C_t^i}{\sigma_T^{C_i}} \tag{2}$$

It can be noticed in the formula that the main assumption is that the components of the index are independently identically and normally distributed, thus these are comparable and the resulting liquidity indicator should be also normally distributed. In this case, C_t^i defines the indicator's *i*th value at time t and T is the number of periods considered for the calculation of the standard deviation. The number of series considered for the CLF analysis (n) is equal to four, for the GLF is six, and the time period is set to 7 years⁴.

The LIBOR-OIS, PS and the CLF are compared to other proposed liquidity metrics in section (8).

2.3 Bank behavior based index - Monetary based

The Liquidity Risk Premium (LRP) indicator introduced by Drehmann and Nikolaou (2012) measures funding liquidity risk using banks' biding behavior in the weekly open market operations of the ECB. As it is difficult to estimate the liquidity risk of a bank, the authors assume that banks have an idea about it and reveal their balance sheet liquidity situation and preferences their transactional behavior during OMOs.

The intuition behind the LRP indicator is that there is a cost in obtaining liquidity from a central bank, and that this cost reflects banks' funding liquidity risk. Accordingly, banks with bigger liquidity problems will be more willing to incur a higher cost of getting liquidity. Along this line of thought, Nyborg and Strebulev (2004) show that illiquid banks bid more aggressively than liquid ones. In Chile this means that banks would ask for lower prices on the BCCh papers and notes⁵.

We also find that the mechanics behind the relationship between banks' liquidity and their bidding behavior at monetary auctions is rather intuitive. Furthermore as Drehman and Nikolau (2012) indicate - apart from mere instinct - that it has been shown theoretically that this relationship exists (see the works of Nyborg and Strebulaev (2004), and Valimaki (2006)).

Using data from 175 Main Refinancing Operations (MRO) conducted by the ECB from 2005 to 2008 with information on 1055 banks, Drehman and Nikolau (2012) measure the LRP, interpreted as the average insurance premium banks are willing to pay in the OMOs to insure themselves against funding liquidity risk.

⁴For details about the series included, please refer to Table (2).

 $^{{}^{5}}$ It should be noted that the main source of financing for commercial banks in Chile are deposits (over 50%). Thus, metrics the use of information from the deposits market - such as the PS spread - would be a direct approach. However, the focus of the present work is the analysis of a source of information that has not yet been explored in the literature for the Chilean case: the demand for papers Central Bank through the auctions data of the open market operations.

In order to build a Chilean version of the LRP index we need to use information from the OMOs performed by the BCCh. However, its definition must be adapted, since the ECB injects liquidity and the BCCh mainly drains it through an auction process managed by the respective central banks.

In figure (1), we can observe the differences between both auctions processes and the interpretation about liquidity risk in each of them. In Drehman and Nikolau (2012) we observe a direct mechanism. If a comercial bank needs liquidity, this bank will pay a higher return than others in order to get liquidity. On the other hand, in the Chilean case the liquidity risk also is represented by a high spread, but here it means that the liquidity constrained commercial banks are willing to participate in the auctions if and only if they obtain a sufficiently attractive return from BCCh and the offer to buy a lower volume.

Finally, for completeness, in the next section we describe the details about the BCCh liquidity management and how the described BCCh instruments' auction processes frame.

3 Open Market Operations and Liquidity Facilities of the BCCh

Open market operations (OMO) are a valuable tool in the implementation the monetary policy, due to their high degree of effectiveness and flexibility. Open market operations generally include, among others, purchase and sale of securities, repurchase (Repo), liquidity deposit (which replaced the anti repo) and currency swaps. These operations which act in conjunction with standing facilities, are intended to absorb or provide overnight liquidity at interest rates (which are dependent on the MPR), establishing a price channel where interbank market transactions are performed overnight.

OMO can be classified into "adjustment" and "structural" operations, depending on the extent and time they impact on the monetary base. The BCCh conducts adjustment operations in order to neutralize transitory liquidity fluctuations in the financial system, which might deviate the interbank rate (IBR) from the monetary policy rate (MPR). These operations are performed at the monetary policy rate, both to supply and absorb liquidity. As to terms, they are generally performed on an overnight basis.

The BCCh, through its Open Market Operations department (DOMA), keeps monitoring of the liquidity status of the financial system, considering its global conditions as well as the financial microstructure of the agents involved in the interbank market, for which purpose, it establishes permanent communication with those responsible for managing the liquidity of the banking corporations. The BCCh's instruments for doing these adjustments to the liquidity of the system are used by taking into account - among other variables - the circumstances the banking system is going through, the availability of collaterals of participating agents and the term of each operation. These operations are informed at market pre-opening times so as not to create information inconsistencies regarding trades taking place in the market that day. The regular communications channel is through direct telephone conferences and the website.

Structural operations are those conducted through changes in promissory note (PDBC) and bond (BCP, BCU and BCD) stocks. The first ones, with issuance terms ranging from 28 to 360 days, allow to manage and regulate the liquidity level of the financial system within a month or from one month to another. Bonds which have maturity periods equal to or longer than 1 year, are used to regulate

liquidity in more permanent time periods (from one year to another) and usually, their schedule is not altered as they respond to structural factors and are also intended for the development of the capital market. Planning of these promissory notes takes place every year and the monthly schedule of operations of the Bank is informed to the public in advance. This schedule contemplates liquidity demand expectations, maturity of previous period issuances, required reserve fulfillment strategies and seasonal effects affecting liquidity in the period. In turn, the scheduling of bonds is executed according to an annual schedule, usually announced to the market during the first days of the year. This schedule states instruments to be issued, with a description of terms, adjustments and total amounts to be bid.

The planning of these operations takes into account the main flows known for the year and demand and growth prospects of the monetary base consistent with the available economic scenario and the monetary policy course. Although the conduct of these operations has the primary goal of affecting the monetary base for extensive periods of time, the resulting rates of the bidding process have a direct bearing on the interest rates of the secondary market at different terms, reflecting and consolidating the economic expectations and the course of the monetary policy on the part of the agents at longer time horizons. That is why these operations are an important means of transmission and orientation of the monetary policy. Daily, and at the end of the day, the BCCh offers standing overnight liquidity facilities (SLF) and deposit facilities (SDF) to authorized financial institutions, which are used by banking corporations to handle the deficits or surpluses that are not directly managed through the interbank market. With this mechanism, the BCCh at all times sets a floating band with a ceiling and a floor of ± 0.25 of the MPR and permits a fluctuation of the IBR around the MPR without BCCh intervention. The Bank compensates the SDF at MPR -25 basis points and charge the SLF at MPR +25 basis points.

Additionally, and with a view to facilitating the liquidation of operations carried out through the Real Time Gross Settlement system (RTGS), the BCCh offers an intraday liquidity facility (ILF), which corresponds to a loan that must be repaid on the same day without cost of interest to the bank. All these facilities are always open to banking corporations. While the ILF is available for a large part of the day, liquidity and deposit facilities are only open at the end of the day. In case of operations injecting money into the system (bank loans), such as the SLF and the ILF, they must be implemented as securities repurchase operations 6 .

3.1 Term structure management

The BCCh monetary operations manage not only the MPR, but the whole term structure. In this section we analyze these actions and the effects to the yield curve, providing a classification in terms of maturity and availability of the instruments: permanent or transitory.

The SDF, SLF and REPO are permanent operations for the monetary policy management and implementation. On the other hand, the fine tuning of the term structure is performed by the BCCh instruments auctions in the primary market - that are less frequent - and some occasional and unconventional operations, such that of the FLAP. In this sense, the BCCh instruments auctions contribute in the margin to the shape of the term structure (slope and curvature) and reflect the banking sector immediate liquidity conditions. The amount associated to the permanent operations is considerably

 $^{^{6}}$ For more information about the BCCh's liquidity management see Central Bank of Chile's Liability Management (2011).

higher than those associated with the BCCh instruments (over a million times higher). However, the BCCh auctions are comparable in volume to the unconventional policies, such as the FLAP. To give a context, the FLAP was implemented between 2009 and 2010 and their total amount for each year accounted for 22.5% and 4.4% of all papers tendered by the BCCh, respectively.

Figure 8 describes the implementation of monetary policy in the BCCh. There are various instruments in its toolkit to drive market liquidity (affecting bank's funding liquidity). On the permanent type of operations we have the Standing Deposit Facility (SDF) and Standing Liquidity Facility (SLF), which operate overnight. These instruments allow commercial banks to manage liquidity shortages and surpluses that are not resolved in the interbank market during the day. Since the BCCh charges MPR+25pb by SLF and MPR-25pb by SDF it ensures that the interbank interest rate (IB) is aligned with the monetary policy rate (MPR). Other short maturity - frequently traded - instruments are those with a repurchase agreement (REPOs). With a lower frequency and longer maturity (more than 30 days), we have the BCCh assets auctions. These are scheduled in advance every year. Finally, the BCCh also has implemented unconventional policies facing temporary liquidity shortages - such as the FLAP - during the past financial crisis (2009-2010).

As shown in Figure 8 REPOs are considered as liquidity injections. They would push the yield curve down, making it flatter. This is because in the REPO, the BCCh buys financial assets in exchange for an amount in pesos and simultaneously agrees to sell them within a specified period (1-30 days). These operations generate incentives to hold BCCh instruments because these (and other safe assets) are required as collateral. The FLAP works similarly to the REPO, but with longer periods (60 days).

In case of longer maturities (2, 5 and 10 years), the BCCh instruments auctions are less frequent, and drain liquidity from the market. The BCCh sells fixed income assets of its own issue, in exchange for an amount in pesos. This would push the yield curve upwards making it steeper. The opposite occurs when the BCCh decides to stop the auctions program, perceived as a liquidity relief, pushing the yield curve down, making it flatter.

4 The CALRP indicator

We elaborate our local version of the LRP (the CLRP) by following the structure of the previously described local OMO mechanism. In contrast to the original LRP, the idea behind our measure is that given the Chilean financial sectors particularities -due to the OMO structure- banks are less willing to use their cash to *purchase* notes and bonds from the central bank in case of increased illiquidity. Intuitively, banks with tighter liquidity either submit higher bid rates - equivalently a lower price -for the notes, submit lower bid volumes, or do not participate at all in the auction ⁷.

⁷It has to be mentioned that a possible drawback of the LRP type of liquidity metrics is that we cannot extract from the data the exact reasons motivating the agents to participate. We can just infer (and test) that is due to illiquidity. However, for small banks (investment banks in the Chilean case)- since their balance sheets are more volatile - their liquidity decisions could greatly variate over time and would make the auction participation decisions less informative for liquidity management purposes.

The original Drehman and Nikolau LRP definition appears in (3). It is the aggregated difference between the bid and a *marginal* rate⁸ for each bank at each auction, weighted by the volume of each bank's allotment.

$$LRP_{t} = \frac{\sum_{i=1}^{N} \sum_{b=1}^{B} \left(max \left\{ 0, BidRate_{b,i,t} - E_{t}(MarginalRate) \right\} \cdot Volume_{b,i,t} \right)}{E_{t}(allotment)} \cdot 100$$
(3)

Where $BidRate_{b,i,t}$, and $Volume_{b,i,t}$ are the rate and volume of bank *i* (from 1 to *N*), which submits *b* bids (from 1 to *B*) at time (auction) *t*. $E_t(MarginalRate)$ is the expected marginal rate. These are instruments auctioned by the commercial banks that the central bank buys. It is calculated as the aggregated difference between the bid and the corresponding *marginal* rate. Where the marginal rate is the closest expected financial alternative or benchmark rate. The LRP indicator is calculated for each bank at each auction, weighted by the volume of each bank's allotment. In this case, the higher the spread, the lower the liquidity.

As previously mentioned, in the case of the BCCh's OMO mechanism, the buyer and the seller switch places. Thus, we need to alter the original definition of the LRP by adapting the weights and benchmark rates for every asset sold by the BCCh⁹.

In (4) we show the local version of the LRP (i.e. the CLRP). The transformed weights are calculated as the portion of the central bank total allotment of the specific asset acquired by the specific commercial bank. Thus, the weights take into consideration the differences in spread but regarding the volume that the agents are offering to buy in each auction. Notice also the absence of the expectations operator on the denominator. Given that all the BCCh auctions are programmed in advance, there is certainty about the total volume of assets to be allocated at every auction.

$$CLRP_t^{10} = \sum_{i=1}^{N_t} \sum_{b=1}^{B_t} \frac{(max \{0, BidRate_{b,i,t} - E_t (MarginalRate)\})}{(N_t \cdot B_t - 1)} \frac{(TotalBidVolume_t - BidVolume_{b,i,t})}{TotalBidVolume_t} \cdot 100$$
(4)

Where $BidRate_{b,i,t}$, and $BidVolume_{b,i,t}$ are the rate and volume of bank *i* (from 1 to *N*), which submits *b* bids (from 1 to *B*) at time (auction) *t*. $E_t(MarginalRate)$ is the expected marginal rate and $TotalBidVolume_t$ is the total volume of the auctioned BCCh instrument. These are instruments auctioned by the central bank that the commercial banks buy in the primary market: PDBC30, PDBC90,

 $^{^{8}\}mathrm{That}$ is, the closest expected financial alternative or benchmark rate, which is calculated using a combination of swaps.

⁹The CLRP metric is constructed for a variety of BCCh assets traded in the OMOs' primary market, covering maturities of 30 days to 20 years: PDBC30, PDBC90, PDBC180, PDBC360, BCP2, BCP5, BCP10, BCU2, BCU5, BCU10 and BCU20.

¹⁰Banks with few transactions of BCCh instruments have greater weight in the CALRP. The rationale behind this characterization is that if banks trade a low volume it means that they are less willing to give up their liquidity. We acknowledge that this definition makes that the CALRP may overweight some longer maturity BCCh instruments due to infrequent trading. However, we have checked that in most of the instruments we have sufficient trading information to overcome this issue.

PDBC180, PDBC360, BCP2, BCP5, BCP10, BCU2, BCU5, BCU10 and BCU20. The CLRP is computed as the aggregated difference between the bid and the corresponding *marginal* rate. Where the marginal rate is the closest expected financial alternative or benchmark rate, which in the Chilean case is calculated using a combination of swaps. As for the weights, these are calculated as the portion of the central bank total allotment of the specific asset acquired by the specific commercial bank. Thus, these weights take into consideration the volume that the agents are offering to buy in each auction. If the volume is high we assume that the particular commercial bank is less liquidity constrained.

In some cases, due to the infrequent participation of any specific bank, the CLRP indicator becomes too sensitive to volume acquisition of a specific auction. In order to overcome this issue, we compute another version of the weights. In (5), we depict the more robust version of the Chilean liquidity indicator, the CALRP¹¹, were we average the weights of a set of auctions (i.e. 10) in which the bank participates.¹² This modification allows the liquidity metric to become less dependent in the current operation and thus more structural.

$$CALRP_{t} = \sum_{i=1}^{N_{t}} \sum_{b=1}^{B_{t}} \sum_{j=k-9}^{k} \frac{(max \{0, BidRate_{b,i,t} - E_{t} (MarginalRate)\})}{(N_{t} \cdot B_{t} - 1)} \frac{(TotalBidVolume_{j} - BidVolume_{b,i,j})}{TotalBidVolume_{j}} \cdot 100$$
(5)

As shown in (4) and (5), the CLRP and CALRP formulas depend -apart from bid rates and volumes- on a reference rate (i.e. the *MarginalRate*), which is the expected future comparable rate for each instrument. Consequently, this rate relies upon the BCCh asset that is auctioned. In the case of PDBC30 instrument auctions, as the comparable swap instrument does not exists, we compute the benchmark as a composite of swap rates of different maturities (90d, 180d and 1y). In this case we have that SWAP30_t = $\frac{7 \cdot \text{SWAP90}_{t} - 5 \cdot \text{SWAP180}_{t} + \text{SWAP360}_{t}}{3}$. In all the other assets auctioned, the comparable maturity instrument is available.

In the same spirit of the original LRP, and in contrast to other liquidity metrics, the Chilean version (CALRP) has the advantage of being calculated at bank level. However, the CALRP results can be also aggregated at other levels. In this work, in order to protect the anonymity of the BCCh auction participants, we present the results at a cluster or system level ¹³.

5 Data

Our CALRP data set comes from the transactional information of all the instruments auctioned by the BCCh. Those instruments are the PDBC, BCP and BCU but only nominal instruments are considered

¹¹The CALRP stands for the Chilean Averaged Liquidity Risk Premium.

 $^{^{12}}$ In this case we need to add an aggregation term. That is a sum operator for 10 auctions. This operation goes between k - 9 and k, where k represents the auction that is occurring at time t.

 $^{^{13}}$ For the long-term instruments auctions, it should be noted that there are institutional investors with a greater participation. It is observed that these institutions absorb a high percentage of BCCh instruments. For the case of 5-year bonds, over the last 10 years they have a 38% average participation; whereas in the 10-year bonds they have a 44%. Of course this makes our indicator less accurate for these instruments, especially in the definition of weights, because the preferences of institutional investors could contaminate our results. However, the banking sector is still is an important player even in these long-term assets.

to make the analysis consistent with the monetary policy interest rate ¹⁴.

The auctions considered were conducted from September 2000 to November 2012. This data allows us to follow the bidding behavior of the 21 major banks in the Chilean financial system. The information includes the submitted bid schedule -bid rate and bid volume- of each bank, and the allotted volume earmarked by the authority. These data is not publicly available. However, information of benchmark marginal rates are obtainable through the BCCh web site. The rest of the data sources is described in Table 2.

Data series	Frequency	Source	Metric	Comments
Bids for BCCh PDBC notes	weekly	BCCh	CALRP	private
(30d, 90d, 180d, 1y; in CLP)				
Bids for BCCh BCP bonds	weekly	BCCh	CALRP	private
(2y, 5y, 10y, 20y; in UF)				
Swap Rates	weekly	BCCh	CALRP/PS/CLF	public
(30d, 90d, 180d, 1y, 2y, 5y, 10y, 20y)				
Banks Balance Sheet data	monthly	SBIF	LCR	private
(C08 file)				
Prime deposit rate	daily	LVA Indices	PS	private
(90d)				
Bid-Ask spread	daily	Santiago $SE/$	CLF	private
(Stock Mkt Index IPSA, SWAP CLP Rates 3y)		Blomberg		
Return to volume ratio	daily	Santiago $SE/$	CLF	private
(IPSA, Central bank bonds (secondary market))		BCCh		
Bid-Ask spread	daily	Bloomberg	GFL	public
(FTSE 100)				
Return to volume ratio	daily	Bloomberg	GFL	public
(FTSE 100, S&P500)				
Libor - Govt bond spread	daily	Bloomberg	GFL	public
(US, EUR, GBP)				
LIBOR - OIS spread	daily	Bloomberg	LOIS	public

Table 2: Data and sources

Now we turn to the descriptive statistics. As shown in Table 3 and 4, the peaks of void auctions are distributed along the financial crisis and at the end of 2009, 2010 and 2011. For the short maturity instruments, the percentage of void auctions increased during the financial crisis, but peaked in 2011 and 2012.

In the case of long term maturity, as presented in Table (5), instruments the evidence is somewhat mixed. On the one hand, the 2-year bonds in pesos (BCP2) void auctions peak in 2009, right after the crisis. On the other hand, longer maturity instruments' void auctions represent a greater percentage between 2007 and 2010.

We are interested in the auctions' effectiveness. The intuition tells us that there is a relation between void auctions and liquidity. The rationale is that when liquidity conditions are more stringent,

¹⁴The objective of this research is to relate the preference for BCCh instruments in the context of the implementation of monetary policy, leaving out the implications of fiscal policy related to BTP. Hence, these instruments are not included in the analysis.

PDBC30						PDBC9	00	
Year	Auctions	Amount	Banks	Void	Auctions	Amount	Banks	Void
2005	54	12524	99.8%	0%	54	7348	100%	0%
2006	100	15376	99.9%	3%	97	8036	100%	1%
2007	86	13708	100.0%	1%	84	4533	100%	0%
2008	95	12633	100.0%	3%	60	2585	99.3%	5%
2009	102	21691	100.0%	1%	96	7922	100%	9%
2010	115	47676	87.1%	1%	64	6054	97.5%	11%
2011	95	54224	94.4%	7%	91	7266	96%	21%
2012	74	53118	94.7%	4%	37	4597	95%	32%
Total	721	230951	94.9%	3%	583	48341	98.7%	9%

Table 3: Descriptive statistics: auctions and effectiveness - short term papers

Table 4: Descriptive statistics: auctions and effectiveness - short term papers

PDBC180					PDBC360			
Year	Auctions	Amount	Banks	Void	Auctions	Amount	Banks	Void
2005	-	-	-	-	-	-	-	-
2006	-	-	-	-	-	-	-	-
2007	2	77	100%	0%	2	77	100%	0%
2008	22	700	100%	27%	22	782	99%	23%
2009	54	985	100%	44%	15	432	100%	0%
2010	31	719	86%	23%	36	911	92%	22%
2011	15	331	97%	73%	-	-	-	-
2012	10	189	98%	60%	-	-	-	-
Total	134	3000	96%	40%	75	2202	97%	18%

commercial banks are more constrained to acquire BCCh papers. Thus, the auctions are more prone to be declared ineffective. In section 6.2, we will test this hypothesis.

BCP5 BCP2 BCP10 Year Auctions Amount Banks Void Auctions Amount Banks Void Auctions Amount Banks Void 2005 24702 82% 4%33 377 95% 3% 33 318 98%6% 20069 339 87%0%13336 76%0%515578%0%21%20071353092%23%1491%35%100%4201 1995%89% 2008 25773 20%23657 9%11160 68%18%20091824287%33%1219870%17%_ -2010 37 98%16%1119 72%28% 829 40_ _ _ 2011 1347699%15%30 1421 56%7%20972 56%5%2012 1751491%6%2476%17%1771940%12%7194405 92%15%189 5247 74%13%2344 60% 9%Total 15687

Table 5: Descriptive statistics: auctions and effectiveness - long term papers

Marginal rates are a key element in the construction of our CALRP indicator, since the results depend on the choice of this variable. That is how these interest rates are constructed using the relevant swap rates, in order to account for expectations. In Table (6) we present the relevant benchmark (or marginal) rates moments across different time windows. We can see that all marginal rates (i.e. the benchmark rate for equivalent alternative investments) peak in 2008, during the financial crisis period. In parentheses it is shown the standard deviation of the different marginal rates. These figures show that during the financial crisis there was an increase in the time-series volatility that remained high for two more years, after it stabilized to pre-crisis levels in 2011.

Year	PDBC30	PDBC90	PDBC180	PDBC360	BCP2	BCP5	BCP10
2005	3.83	4.19	4.04	4.32	5.05	5.95	6.63
	(0.45)	(0.43)	(0.74)	(0.67)	(0.74)	(0.56)	(0.38)
2006	4.93	5.09	5.25	5.43	5.99	6.47	6.85
	(0.26)	(0.16)	(0.11)	(0.12)	(0.23)	(0.33)	(0.39)
2007	5.33	5.41	5.47	5.48	5.77	6.10	6.35
	(0.34)	(0.39)	(0.44)	(0.46)	(0.49)	(0.42)	(0.36)
2008	7.10	7.18	7.20	7.05	7.07	6.96	6.95
	(0.86)	(0.83)	(0.83)	(0.77)	(0.73)	(0.64)	(0.56)
2009	1.96	1.69	1.57	1.86	2.91	4.64	5.35
	(2.22)	(1.89)	(1.56)	(1.19)	(0.76)	(0.56)	(0.58)
2010	1.53	1.76	2.09	2.72	3.72	5.11	5.86
	(1.01)	(1.11)	(1.17)	(1.03)	(0.63)	(0.19)	(0.22)
2011	4.76	4.78	4.82	4.88	5.19	5.56	5.83
	(0.77)	(0.60)	(0.50)	(0.50)	(0.61)	(0.57)	(0.54)
2012	5.00	4.93	4.87	4.80	4.96	5.21	5.45
	(0.07)	(0.07)	(0.13)	(0.23)	(0.31)	(0.28)	(0.23)

Table 6: Descriptive statistics: marginal rates

* Standard deviations in parentheses

Another element of the CALRP indicator we are constructing is the bidding behavior. Table 7 shows the bidding behavior of banking institutions when operating at the OMO of the Central Bank. It can be observed that -similar to the marginal rates- the peaks in all the instruments are reached during the crisis period in 2008. In the case of volatility, we see that the time-series variability (i.e. volatility of the average bids) and its cross-section counterpart (average of bids' volatility) increased in 2008 and remained high until 2010, but decreased to pre-crisis levels in the following years.

Now we have described the data; in the next section we present our results for the CALRP indicator.

Year	PDBC30	PDBC90	PDBC180	PDBC360	BCP2	BCP5	BCP10
2005	3.74	3.96			4.61	5.56	6.04
	(0.68)	(0.71)			(0.29)	(0.45)	(0.30)
	[0.65]	[0.68]			[0.28]	[0.44]	[0.30]
2006	4.71	4.84			5.90	6.08	6.25
	(0.37)	(0.34)			(0.26)	(0.24)	(0.59)
	[0.30]	[0.27]			[0.30]	[0.27]	[0.36]
2007	5.00	5.14	6.18	6.23	5.86	5.98	5.45
	(0.47)	(0.50)	(0.16)	(0.18)	(0.42)	(0.52)	(0.05)
	[0.39]	[0.44]	[0.12]	[0.19]	[0.45]	[0.42]	n.d
2008	7.58	6.98	7.32	7.19	7.31	7.12	7.75
	(1.22)	(0.85)	(0.69)	(0.61)	(0.70)	(0.78)	(0.44)
	[1.15]	[0.72]	[0.65]	[0.59]	[0.72]	[0.74]	[0.41]
2009	1.79	2.11	1.49	2.99	3.25	4.71	
	(2.15)	(2.17)	(1.58)	(1.74)	(0.92)	(0.45)	
	[2.10]	[2.00]	[1.37]	[1.73]	[0.86]	[0.42]	
2010	1.27	1.82	2.69	3.16	4.26	5.67	
	(1.05)	(1.12)	(0.94)	(1.08)	(0.70)	(0.20)	
	[1.05]	[1.14]	[0.94]	[1.03]	[0.66]	[0.15]	
2011	4.65	4.97	5.43	4.63	5.49	5.71	5.99
	(0.79)	(0.67)	(0.48)	(0.28)	(0.58)	(0.67)	(0.63)
	[0.76]	[0.66]	[0.49]	n.d	[0.56]	[0.65]	[0.64]
2012	4.93	4.99	5.02		5.24	5.39	5.56
	(0.19)	(0.20)	(0.27)		(0.26)	(0.26)	(0.24)
	[0.12]	[0.17]	[0.21]		[0.26]	[0.24]	[0.24]

Table 7: Descriptive statistics: bids average rates

(1) In parentheses standard deviations from banks by date.

(2) In square brackets deviations from system by date.

6 CALRP results ¹⁵

In this section we present the results of our major contribution: the CALRP. As we previously mentioned, this indicator can be built at bank level. However, we must avoid the presentation of individual data because of confidentiality concerns, that is why we aggregate the results. Figure (2) shows the Chilean banking systems aggregate results (by BCCh instrument). We can observe that for the shortest maturity assets (PDBC30), the CALRP indicates that this part of the yield had an approximate increase of 100bp of risk premium at the end of 2009, coinciding with shortages in international financial markets funding. On the other hand, we see that the longer maturity instruments show an

¹⁵The participation of pension funds and other institutional investors is highly relevant in the Chilean economy. Thus, their impact in the final adjudication rates should be a matter of further analysis. As a robustness check of our results, we have revised that their influence on final rates is only binary (see figure 10 and 11 in Appendix). When they participate, the adjudicated rates are lower and their interval of variation is shorter. However, in the auctions where institutional investors are not present, we observe higher levels and wider range of settled rates.

increase in the CALRP in 2010 and 2011.

At a more detailed level, in Figure (3), we present the results of CALRP aggregated at cluster level. These cluster's groupings are defined by size and are described in BCCh (2007). In cluster 1 appear the biggest banks of the Chilean banking system, the rest of the groups are medium sized banks (1 and 2) and small banks. The plot shows that large and medium banks present a similar liquidity behavior, as measured by the CALRP. However, investment and retail banks follow different patterns. This would be explained by the fact that the latter banks' businesses are of a different nature. Investment banks have excess liquidity with virtually no consumer deposit or external financing, that is used mainly for trading purposes. On the other hand, retail banks - as opposed to commercial banks - do not use external financing, and mainly provide low volume and high revenue consumer-type of credit. Thus, they have relatively lower liquidity needs ¹⁶.

Table 8 contains the CALRP yearly average, calculated by BCCh instrument. We can observe that all instruments evidence a liquidity spike in 2008, during the crisis. We can also see that the peaks - describing lower banks' funding liquidity - of short maturity instruments were achieved in the same year. However, for the higher maturity instruments, peaks were achieved in 2010 and 2011.

Year	PDBC30	PCBC90	PDBC180	PDBC360	BCP2	BCP5	BCP10
2005	-0.3	-2.5	-	-	-0.5	-5.0	-7.9
2006	-3.7	-4.0	-	-	-2.6	-6.6	-7.5
2007	-5.3	-4.3	4.2	4.3	0.2	-3.0	-5.4
2008	6.0	4.1	9.3	11.2	2.7	1.2	3.0
2009	-2.8	2.3	5.3	13.6	7.5	9.7	-
2010	-2.7	0.7	7.4	12.9	9.9	10.5	-
2011	-0.7	4.3	11.6	18.9	5.8	3.7	2.2
2012	-1.0	2.0	7.3	-	4.1	2.2	0.5
Total	-1.3	-0.1	7.2	12.2	4.2	1.9	-2.1

Table 8: CALRP Liquidity indicator by instrument and year

Additionally, Figure (4) depicts different time events that could coincide with or be related to developments in the banking system's liquidity. On the one hand, short term liquidity -as measured by the CALRP of PDBC30- is associated to regulations events affecting the short term market. Whereas CALRP calculated using longer maturity instruments is naturally more correlated to regulations affecting the long term market operations.

First, we present examples of short term financial market regulations and their influence on the short maturity instruments' -PDBC30- CALRP. In June 2005, the BCCh authorized the purchase of credit securities through REPOS with BCCh. This coincided with the increase of the liquidity premium of short maturity BCCh instruments, mainly because the REPOS constitute an alternative source of short term financing/investment. Another short term measure was introduced in May 2006, where an

¹⁶For details about the anual averages, please see Table 14, 15 and 16 in the appendix

electronic deposit facility was introduced at the BCCh, for monetary operations purposes. This new system introduced a liquidity friction that lasted for one quarter, until the institutions adapted their operations. We also observe an increase in the short maturity CALRP after the BCCh authorized to raise the pension fund (PF) limits on foreign investment. This imposed a constraint in local financing of commercial banks operating in Chile. Finally, the peak was achieved right after the Lehman event in 2008 and it decreased after the announcement of the BCCh flexible liquidity policy programme (FLAP)¹⁷.

Second, we present events that coincide with longer maturity CALRP -BCP5- fluctuations. In the case of the long term CALRP indicator, we see that there is some increase after the FLAP in 2008, because these instruments were competing against short term BCCh securities with relatively better pricing conditions. In June 2009 the BCP5 instruments were suspended, coinciding with a Chilean government bond issuance. The instruments were allowed back in 2010 showing an increased CALRP premium and volatility across banks, mainly due to rebalancing of the commercial banks' investment portfolios, after the measure.

6.1 CALRP term structure

As we have shown previously, the CALRP indicator reasonably captures episodes of commercial banks' liquidity contraction at different maturities or horizons. However, to get a better view of the CALRP term structure and put our metric in historical/maturity context, we analyze the liquidity risk premium yield over time (see Figure (5)).

On the one hand, we have that for the short maturity instruments, the 2008-2009 period was particularly problematic in terms of liquidity. On the other hand, in contrast to the short maturity instruments, in the case of the longer maturity, there are other peaks produced more recently.

The sources of different timing structure of CALRP are explained by large scale adjustments in commercial banks' balance sheets for the longer instruments' maturity case. However, in the case of short term maturity CALRP, we observe that liquidity is more sensitive to events of global or local financial fragility. Additionally, we observe reversions in the CALRP term structure curves, especially in 2008. This would be in favor of Borio and Zhu (2008) and others that describe this phenomenon as one indicator of financial vulnerability, due to unanticipation of monetary policy.

6.2 Void auctions analysis

There is an outcome at which every auction is exposed: a void process. This occurs in case the seller does not accept any of the bids. In this case, the BCCh determines that an auction is void by using expert criteria. These criteria are based on different pieces of market information: surveys, the banking system and the auction history data. The BCCh staff basically draws an implicit price threshold for every auction. When the bids are not attractive enough, the BCCh declares the auction void.

We are interested in understanding the reasons behind a void auction. This would serve as robustness check for our proposed liquidity indicator. Figure (5) shows certain correlation between the level of the CALRP indicator and the frequency of void auctions. To confirm this relationship, we

 $^{^{17}}$ For more details please refer to the appendix, section (11.2).

perform a statistical analysis. Specifically, we test the hypothesis indicating that when liquidity is scarce, commercial banks will be *excessively* unwilling to participate in a BCCh auction. Thus, we can check the correlation of our metric of liquidity (the CALRP) with the appearance of a void auction process. Equation (6) shows our model specification for each BCCh asset j and auction occurred at time t^* .

$$\mathbb{P}\left(\text{Void auction} = 1\right)_{j,t^*} = \Phi\left(\alpha + \beta \cdot CALRP_{j,t^*} + \epsilon_{j,t^*}\right)$$
(6)

Tables 9 and 10 show the results of our probit regressions of void auction dummy as independent variable, and the associated CALRP indicator as explanatory variable. These tables refer to long and short maturity BCCh papers, respectively.

	D 1.4	ME	D 1.4	ME	D 1.4	ME
	Probit	M. E	Probit	M. E	Probit	M. E
	0.040**	0 011**				
CALRP BCP2	(0.049^{**})	(0.011^{++})				
	(0.023)	(0.005)	a a a adululu			
CALRP BCP5			0.093^{***}	0.012^{***}		
			(0.020)	(0.003)		
CALRP BCP10					0.141	0.009^{**}
					(0.089)	(0.004)
Constant	-1.307^{***}		-1.787***		-1.592^{***}	
	(0.182)		(0.203)		(0.276)	
Observations	155		187		85	
Pseudo R-squared	0.0391		0.227		0.128	
Monthly data, 2005-2013.						

Table 9: Void auctions: BCP

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

M. E: marginal effect.

	Probit	M. E	Probit	M. E	Probit	M. E	Probit	M. E
CALRP PDBC30	0.023^{***}	0.001^{**}						
CALRP PDBC90	(0.000)	(0.000)	0.131^{***}	0.010^{***}				
CALRP PDBC180			(0.010)	(0.002)	0.083^{***}	0.031^{***}		
CALRP PDBC360					(0.021)	(0.000)	0.037	0.009
_							(0.025)	(0.005)
Constant	-2.192***		-1.860***		-1.027***		-1.485^{***}	
	(0.124)		(0.124)		(0.213)		(0.377)	
Observations	736		579		126		73	
Pseudo R-squared	0.0486		0.208		0.114		0.0384	
Monthly data, 2005-2013.								

Table 10: Void auctions: PDBC

Standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

As shown in Tables 9 and 10, it is clear that there is a positive and statistically significant relation between a void auction and our liquidity indicator. This means that the greater the spread between the proposed and the marginal rate - or lower liquidity - the higher the probability of observing a void action. The regularity is more pronounced in the cases where the regression has a high R-square. Those regressions coincide with a high number of observations -or instruments trading frequency. That is the case of BCP instruments at five years and PDBC instruments at 90 days.

Clearly the results in this section need to be read carefully. This is because the higher value of our indicator often coincides with the exact date where an auction is declared null. Thus, the results cannot be directly interpreted as a predictor of void auctions. Nevertheless, the CALRP metric allows to understand one important determinant of a BCCh null auction: banking system liquidity.

7 Liquidity and credit

As Cornett et al. (2011) suggest, one of the most regarded -and potentially dangerous- consequences of a considerable liquidity shortage is the possibility that this financial tension is translated into a credit contraction. The problem is worse in case two elements are present. The first element is creditworthiness. If credit quality does not considerably change through the liquidity crisis period, the banking deleveraging process causes a -potentially inefficient- financial contraction. There are no apparent reasons to consider that there is a relationship between credit quality and banks liquidity. The second element to be considered is financial dependence. Higher the financial dependence on banking credit, the worse the outcome for households and firms.

Table (11) indicates that there is a statistically significant correlation between liquidity shortages and credit supply. This evidence is consistent with of Alfaro et. al. (2003), where the authors find that monetary policy (i.e. aggregate funding liquidity) is transmitted to credit supply. We observe that shorter maturity liquidity is more correlated with consumer credit and is not correlated with longer maturity types of credit (i.e. mortgage and commercial loans). We also observe that the the relationship between banks' funding liquidity and credit supply is economically higher for consumer credit. This suggests that shorter maturity credits are more sensitive to liquidity fluctuations. Whereas longer maturity loans are more "irreversible", so banks cannot adjust these in times of financial turmoil.

Finally, we also tested the same regression but using PS spread as dependent variable. The results are similar but weaker than using CALRP 18 .

CALRP	Consumer	Commercial	Housing	Total
PDBC30	-0.44***	-0.00	-0.01	-0.02
	(0.16)	(0.10)	(0.08)	(0.10)
	[0.08]	[0.00]	[0.08]	[0.00]
PDBC90	-0.88***	-0.41***	-0.52***	-0.40***
	(0.16)	(0.10)	(0.07)	(0.11)
	[0.28]	[0.17]	[0.43]	[0.15]
BCP2	-0.87***	-0.48***	-0.49***	-0.50***
	(0.13)	(0.07)	(0.06)	(0.07)
	[0.38]	[0.39]	[0.46]	[0.41]
BCP5	-0.76***	-0.41***	-0.39***	-0.43***
	(0.08)	(0.04)	(0.04)	(0.04)
	[0.51]	[0.53]	[0.50]	[0.61]
BCP10	-0.77***	-0.15**	-0.54***	-0.20***
	(0.10)	(0.06)	(0.08)	(0.04)
	[0.62]	[0.14]	[0.55]	[0.42]

Table 11: Liquidity (CALRP) and credit growth

This table shows the coefficients, standard errors and R-square of individual univariate regression between the CALRP (grouped by instrument) and credit growth (by type of credit).

Monthly data, 2005-2013

Constants not reported

Standard errors in parentheses

In brackets, adjusted R-square.

*** p<0.01, ** p<0.05, * p<0.1

 $^{^{18}\}mathrm{This}$ results are presented in the appendix.

As a robustness check, we have calculated the correlation of non-performing loans and the CALRP in Table (12). We observe very low, or virtually no correlation, especially in the case of consumers' loans. Although this analysis does not imply any direction of causality, we can infer that the effect of liquidity in credit growth does not coincide with agents' creditworthiness. It would correspond more to a supply effect given by banks' financial opportunities.

CALRP	Consumer	Commercial	Housing	Total
PDBC30	0.00	-0.01*	-0.00	-0.00
	(0.00)	(0.00)	(0.01)	(0.00)
	[0.04]	[0.03]	[0.00]	[0.01]
PDBC90	0.01^{*}	-0.00	0.06^{***}	0.01^{***}
	(0.00)	(0.00)	(0.01)	(0.00)
	[0.00]	[0.01]	[0.28]	[0.11]
BCP2	0.00	0.01	0.07^{***}	0.02^{***}
	(0.00)	(0.00)	(0.01)	(0.00)
	[0.01]	[0.03]	[0.57]	[0.38]
BCP5	0.00	0.00	0.06^{***}	0.02^{***}
	(0.00)	(0.00)	(0.00)	(0.00)
	[0.03]	[0.03]	[0.66]	[0.46]
BCP10	0.00	-0.02***	0.05^{***}	0.00
	(0.00)	(0.00)	(0.01)	(0.00)
	[0.04]	[0.26]	[0.48]	[0.01]

Table 12: Liquidity (CALRP) and non-performing loans

This table shows the coefficients, standard errors and R-square of individual univariate regression between the CALRP (grouped by instrument) and non-performing loans (by type of credit).

Monthly data, 2005-2013

Constants not reported

Standard errors in parentheses

In brackets, adjusted R-square.

*** p<0.01, ** p<0.05, * p<0.1

8 Comparative liquidity analysis

In this section, we put all the metric calculation results into context. First, Figure (6) suggests that there is covariation among different metrics for liquidity. All the liquidity metrics included in this work experience considerable movements during the crisis period, especially during 2008. Second, Table(13) shows that there is a significant and positive correlation amongst all the indicators replicated and/or proposed in this work. Nevertheless, there are some differences to be analyzed.

The Chilean metric for liquidity of the local fixed income market -the PS- is very close with the LOIS and VIX. This suggests that the Chilean economy is highly dependent on global liquidity and/or external financial conditions. The mechanism operating this relationship appears in a recent paper. Bruno and Shin (2013) indicate that the mechanism through which international liquidity is transmitted into the domestic economies is through the leverage cycle.

In the case of market liquidity metrics, we can observe that the Chilean and international composite indices (CLF and GFL) are closely related. This suggests that the transmission channel of market liquidity is also relevant and significant.

In the case of our proposed CALRP, we observe that it captures well local market liquidity conditions, because of its high correlation with the PS indicator. However, we appreciate that it captures more the systemic variations and it does not vary too much in other episodes that are perhaps less relevant for aggregate liquidity risk.

We have shown that our local counterparts of liquidity metrics reasonably capture liquidity stress episodes. With our local version of liquidity metrics, there are certain differences to be highlighted, we find advantages and drawbacks for each measure. In the case of the CLF, although it captures the episodes in a great manner, it has also an excessive variation, this volatility makes the metric less useful as early warning indicator, since it 'jumps' too much. As for the PS, it is less volatile than the CLF, which is an advantage. It has also a good relation with historically tight liquidity periods. However, there are some issues. The PS depends partially on a survey, and it has only a system level interpretation. In the case of our CALRP indicator, it has certainly a low variation, except during the global crisis. Thus, it is a good measure for high magnitude events, but it does not capture well minor stress episodes.

	CALRP	GFL	CLF	VIX	LOIS	\mathbf{PS}
CALRP	1.00					
GFL	0.16^{*}	1.00				
CLF	0.07^{*}	0.47^{*}	1.00			
VIX	0.07^{*}	0.60^{*}	0.27^{*}	1.00		
LOIS	0.16^{*}	0.68^{*}	0.40^{*}	0.85^{*}	1.00	
\mathbf{PS}	0.24^{*}	0.53^{*}	0.13^{*}	0.30^{*}	0.43^{*}	1.00

Table 13: Correlation between liquidity indices

Represents correlation coefficients significance at the 5% level or better. Monthly data, 2005-2013

9 Conclusion

This paper presents a novel indicator of funding liquidity of the Chilean banking system inspired by the methodology proposed by Drehmann and Nikolaou (2012). It is based on banks' biding behavior, through their bidding schedule (bid rate and volume), on notes and bonds auctions conducted by the BCCh.

Compared to other liquidity indices, the CALRP indicator can be constructed at the same time as information about the auctions is available, which is easily accessible from within the BCCh; it captures well the liquidity crisis episode; is not expert dependent; and we argue that only measures liquidity risk.

We acknowledge that one of the main drawbacks of our liquidity indicator is that the decision of not to participate at all in the auctions is not captured, then, a more reliable measure of the LRP (or CALRP) indicator should account for this fact. However, as a mitigating factor, we find that there is significant correlation between a void auction process and our liquidity indicator. Additionally, it would be interesting to see how the notes and bond of the BCCh are traded in the interbank -secondary- market. Further research will address these concerns.

One limitation in building the CALRP indicator for instruments of higher maturity is that these instruments are auctioned, in general, less frequently than instruments of lower maturity (e.g. 30-day notes PDBC 30), and therefore it is harder to build a more reliable version of the CALRP for this kind of instruments.

As many - if not all - liquidity indicators, our CALRP suffers from the fact that it can be contaminated by other effects, such that of institutional investors participation (e.g. because of regulatory changes) or other market phenomena that could be happening simultaneously. However, our analysis suggests that, this indicator provides a good summary statistic of the bank's reactions when facing monetary policy operations. Moreover, since, as we have pointed out, we observe a high correlation with banking credit. Acknowledging all the statistical caveats, the evidence suggests that our metric reflects the tradeoffs between banking liquidity hoarding and credit supply decisions.

To sum up, we propose this indicator as a complementary metric that would help to explain risk and transmission of funding liquidity in the Chilean financial market, specifically in the commercial banking sector.

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11 Appendix

11.1 Figures



Figure 1: Comparison between auction processes



Figure 2: Agregated results by instrument







Large

Medium

Retail

•

Investment

PDBC30						PDBC90				
Year	Large	Medium	Retail	Invesment	Large	Medium	Retail	Invesment		
2005	-1.59	0.25	-0.02	5.19	-3.73	-0.74	-5.04	-0.65		
2006	-4.55	-3.27	-10.69	4.80	-4.23	-4.90	-7.48	-1.49		
2007	-5.85	-5.81	-13.73	2.33	-3.90	-6.15	-11.89	-0.26		
2008	7.49	8.31	-6.11	5.81	5.93	5.58	-18.03	5.13		
2009	-2.09	-3.78	-2.97	-3.40	2.23	2.13	4.47	2.20		
2010	-1.85	-3.26	-3.68	-3.07	0.79	2.89	-0.76	-1.53		
2011	-0.03	-1.53	1.33	-1.73	4.12	3.83	7.20	3.04		
2012	-0.30	-1.54	-0.69	-2.62	2.74	1.18	5.95	2.72		
Total	-1.10	-1.33	-4.57	0.91	0.49	0.48	-3.20	1.14		

Table 14: CALRP Annual average by cluster level - short term papers

Table 15: CALRP Annual average by cluster level - short term papers

PDBC180						PD	BC360	
Year	Large	Medium	Retail	Invesment	Large	Medium	Retail	Invesment
2005								
2006								
2007	3.43	2.42		12.98	3.70	4.02		7.07
2008	9.59	9.28	6.65	14.18	10.53	12.23		16.69
2009	4.05	4.46	11.51	6.58	13.39	13.80	8.85	14.71
2010	9.46	7.27	15.05	3.84	14.23	11.00	24.07	8.82
2011	11.14	8.23	18.92	6.81	11.20	34.36		
2012	4.54	11.11	3.69	3.22				
Total	7.03	7.13	11.16	7.93	10.61	15.08	16.46	11.82

Table 16: CALRP Annual average by cluster level - long term papers

		В	CP2			В	CP5			В	CP10	
Year	Large	Medium	Retail	Invesment	Large	Medium	Retail	Invesment	Large	Medium	Retail	Invesment
2005	-1.05	-0.81		1.25	-4.58	-5.42	-0.96	-5.70	-8.28	-8.52	-3.57	-8.78
2006	-2.22	-3.26	-1.74	-5.30	-5.95	-7.52		-7.56	-8.04	-8.51		-7.63
2007	-0.02	-0.23	-0.39	0.53	-2.66	-3.94	-1.08	-2.82	-4.83	-5.35		-7.29
2008	3.17	3.00	6.89	2.85	0.89	1.51	3.58	1.56	4.15	2.73	2.43	2.50
2009	8.21	6.50		9.92	10.93	8.97		8.54				
2010	10.31	10.90	5.58	8.32	12.58	12.61		9.83				
2011	6.99	5.68		5.46	3.97	4.06	5.83	3.89	2.29	2.08	2.30	1.51
2012	3.83	3.92	4.89	4.83	2.17	2.50	1.78	2.98	0.42	0.60	1.92	0.39
Total	3.65	3.21	3.05	3.48	2.17	1.60	1.83	1.34	-2.38	-2.83	0.77	-3.22



Figure 4: CALRP and economically significant events





Figure 6: CALRP and void auctions





















	2006	2007	2008	2009	2010	2011	2012	2013
Mean	14.3	13.8	14.4	18.1	18.6	18.0	17.3	15.6
$\mathbf{P50}$	13.8	13.0	13.1	16.2	16.2	15.8	15.2	14.1
P25	10.5	11.7	9.8	12.2	14.0	13.3	13.9	12.0
$\mathbf{P75}$	16.7	15.9	18.7	20.3	20.6	23.1	21.1	18.0
StdDev	7.4	5.9	6.7	8.1	7.8	6.5	5.9	5.6

Table 17: Liquid Assets participation in the Chilean Bank's Balance Sheet

Table 18: Central Bank Instruments participation in the Liquid Assets

	2006	2007	2008	2009	2010	2011	2012	2013
Mean	17.8	23.3	18.0	19.4	17.1	12.4	10.5	8.8
$\mathbf{P50}$	16.6	26.3	18.1	10.2	13.8	9.8	5.5	5.1
$\mathbf{P25}$	4.6	12.2	8.7	7.1	4.6	3.3	2.3	1.6
$\mathbf{P75}$	28.7	31.0	23.8	27.2	24.1	17.1	14.6	13.5
StdDev	14.4	14.3	11.3	20.8	16.1	11.5	12.2	9.7

11.2 Main financial measures taken by the Central Bank of Chile: 2005-2011.

June 30, 2005: (REPO) The Central Bank authorized the purchase of credit securities using buyback agreements (repos) between the Central Bank of Chile and financial institutions at variable interest rates, based on the average value of the MPR during the period the operation is in effect. This measure should deepen the market for these securities.

August 22, 2005: (BOND) The Central Bank announced a change to its policy of issuing its own securities, to offset the monetary effect of bond issues in indexed units of account (Unidades de fomento, UF) maturing in 10 and 20 years (BTU10 and BTU20) from the Treasury as of September.

November 3, 2005: (DER) The Bank empowered financial institutions to operate with local market derivatives based on Chilean Treasury bonds, making the corresponding changes to Chapter III.D.1 in the Compendium of Financial Regulations.

May 18, 2006: (LD) A new way for banks to deposit in the Central Bank was added, called the "Liquidity Deposit in Pesos for Banks and Finance Companies". This type of deposit, which serves the purpose of monetary regulation, operates through electronic communications between commercial banks and the Central Bank, through the open-market operations system, subject to supply and conditions that are set by the Central Bank on each occasion.

December 7, 2006: (EFSMPF) The Central Bank of Chile complemented the definition of the external formal secondary market in which pension funds can trade investment securities internationally, to include securities or other documents issued by foreign firms.

July 31, 2007: (PF1) The Central Bank raised the ceiling on pension fund investment in foreign securities to 35%. Moreover, it increased the ceilings on investment in foreign exchange with no foreign exchange coverage for each type of pension fund, 43% for type A, 28% for type B, 22% for type C and 17% for type D.

April 10, 2008: (INT1) The Central Bank has decided today to intervene in the foreign exchange reinforcing the international liquidity position of the Chilean economy adopting the following measure: increase international reserves by US 8 billion, by purchasing foreign currency, from Monday 14 April and until 12 December 2008. The first reserve purchase program, in force from 14 April to 9 May, will consist of daily purchases for about US 50 million, through competitive auctions.

The monetary effects of this measure will be set off so that the peso liquidity provision in the market is consistent with the monetary policy interest rate. During the period corresponding to the first aforementioned program, this will be implemented through short-term operations.

October 10, 2008: (FLAP) The Board of the Central Bank of Chile informs that new measures were adopted today, which are intended to flexibilize liquidity management in the domestic financial system, in response to a new deterioration of international financial markets. These measures, which will be implemented next week, include:

• To extend from one to six months the U.S. dollar swap purchase program. These swaps will

be offered at 60 and 90 days, alternately each week for US 500 million at each auction. This measure implies offering a maximum amount of up to US 5 billion.

- As a complement to the aforesaid program, to offer repo operations aimed at injecting liquidity in pesos at similar terms.
- To offer, every week and during the same six month term, renewable 7 day repo operations, which may have bank deposits as collateral. This measure allows expanding the universe of eligible collaterals for financing transactions.

June 15, 2009: (MD) The Central Bank modified its debt schedule by suspending the issue of five year peso bonds (BCP5), five year UF bonds (BCU5), and BCU10 in the primary market. At the same time, the Central Bank announced that it would buy back up to US 1.0 billion of its five and ten year Central Bank UF bonds. It further communicated that the measures described above are necessary to offset the impact on the fixed income market of the Finance Ministryś announcement, on the same day, of a new issue of Treasury bonds for approximately US 1.7 billion and a new program of foreign exchange sales totaling US 4.0 billion, in the form of competitive auctions of US 40 million a day.

January 3,2010: (MD2) BCP5 are reinstated.

November 4, 2010: (PF2) Chapter III.F.4, Pension fund investments of the Compendium of Financial Regulations was modified to raise the upper limit on total overseas investment by the pension funds from 60% to 80%. At the same time, the upper limit on overseas investment by type of fund was raised to 100% for type A funds, 90% for type B funds, 75% for type C funds, 45% for type D funds, and 35% for type E funds.

January 3, 2011: (INT2) The Central Bank of Chile has decided to initiate a foreign exchange purchase program to strengthen its international liquidity position. The foreign exchange purchase program will be sterilized through the issue of short-term instruments and the use of facilities for a total of US 2.0 billion dollars, together with bond issues in pesos and UFs (unidad de fomento, an inflation-indexed unit of account) for US 10.0 billion. The structure of this plan has been designed to soften the effects of the measure on prices in the debt market.

December 22, 2011: (FLAP2) The Central Bank of Chile will implement a temporary program to facilitate the financial systems liquidity management in pesos. The Bank will offer a floating rate repo program, for terms of up to 91 days.

Liquidity (PS) and credit growth. 11.3

CALRP	Consumer	Commercial	Housing	Total
DCao	0.05	0.04***	0.00	0.00***
PS30	0.05	0.06^{***}	0.02	0.06^{***}
	(0.03)	(0.02)	(0.01)	(0.02)
	[0.03]	[0.12]	[0.02]	[0.10]
DGoo	0.00	0.00	0.00***	0.01
PS90	-0.03	0.02	-0.03***	0.01
	(0.03)	(0.02)	(0.01)	(0.02)
	[0.02]	[0.01]	[0.07]	[0.01]
DC100	0.07***	0.00	0.05***	0.00
P5180	-0.07	0.00	-0.05	-0.00
	(0.02)	(0.01)	(0.01)	(0.01)
	[0.11]	[0.00]	[0.20]	Ž[0.00]
PS360	-0.07***	0.01	-0.04***	0.01
	(0.01)	(0.01)	(0.01)	(0.01)
	[0.19]	[0.02]	[0.21]	[0.01]

Table 19: Liquidity (PS spread) and credit growth

This table shows the coefficients, standard errors and R-square of individual univariate regression between the PS spread and credit growth (by type of credit).

Monthly data, 2005-2013

Constants not reported

Standard errors in parentheses

In brackets, adjusted R-square. *** p<0.01, ** p<0.05, * p<0.1

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