Daytime is money

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Daytime is money

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Abstract

Based on real-time trade data from the Swiss franc overnight interbank repo market and SIX Interbank Clearing (SIC) – the Swiss real-time gross settlement (RTGS) system – we are able to gain valuable insights on the daytime value of money and its determinants: First, an implicit hourly interbank interest rate can be derived from the intraday term structure of the overnight rate. We thereby provide evidence that an implicit intraday money market exists. Second, we show that after the introduction of the foreign exchange settlement system CLS the value of intraday liquidity has increased during the hours of the CLS settlement cycle. Third, the turnover as well as the liquidity in SIC influence the intraday rate correspondingly. These facts provide evidence for the cost of immediacy. Features like RTGS, delivery-versus-payment and payment-versus-payment substitute credit risk with liquidity risk which in turn increases the value of intraday liquidity. The analysis is central bank policy relevant insofar as different designs of intraday liquidity facilities and different collateral policies result in different intraday term structures for the overnight money market.

JEL-Codes: E58, G21, G28
Keywords: interbank money market, intraday credit, term structure

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1 Introduction

The institutional framework through which central banks provide the financial system with intraday and overnight liquidity share a number of features. Martin/McAndrews (2008) provide a summary of the literature according to which one crucial difference between intraday and overnight liquidity remains puzzling: There is an interbank market for overnight (ON) reserves whereas there seems to be no interbank market for intraday reserves. We provide empirical evidence that the ON rate in the Swiss franc interbank money market shows a clear downward trend throughout the operating day of the SIX Interbank Clearing (SIC), the Swiss real-time gross settlement (RTGS) system. Based on real-time trade data from the Swiss franc repo platform we derive an implicit intraday interest rate from the intraday term structure of the ON market. Therefore, in Switzerland, like in some other countries as well, an implicit intraday interbank market for money exists.

We interpret this as evidence for the cost of immediacy of RTGS systems postulated by Kahn/Roberds (2001). Using a neoclassical monetary model they show that if intraday credit is available from the central bank on a collateralized basis, RTGS will impose an intraday liquidity cost. This interpretation is also consistent with the following evidence found that the implicit intraday interest rate depends on the turnover as well as on the liquidity in SIC. This also mirrors the theoretical findings in VanHoose (1991) and Angelini (1998) who apply a model of a bank's intraday liquidity management in an RTGS system.

Our results also highlight that a remarkable change has taken place after the introduction of the foreign exchange settlement system Continuous Linked Settlement (CLS) in 2002.[1] During the opening hours of CLS the level of the implicit intraday interest rate has increased. This is evidence for the presumption by Baglioni/Monticini (2008) that the introduction of CLS and the corresponding payment-versus-payment (PVP) mechanisms could trigger the development of an intraday money market. Indeed, after the introduction of CLS the value of intraday liquidity increased and, hence, the implicit price for intraday credits rose. Incorporating settlement features such as PVP or delivery-versus-payment (DVP) mechanisms into RTGS systems can increase the number and value of time critical payments that have to be settled until a certain time of the day. As a consequence, banks face higher intraday liquidity needs in order to fulfill their settlement obligations.

The Swiss National Bank (SNB) has provided free and collateralized intra-

[1] For more information on CLS and its settlement mechanism see Kahn/Roberds (2000).

day liquidity on the basis of repo transactions since 1999. Neither before nor after the introduction of this standing facility has an explicit interbank market for Swiss franc intraday liquidity developed. The use of the intraday liquidity facility is pegged by the opportunity costs of collateral and transaction costs. These costs are not equal among participants of the Swiss franc repo platform. Evidence for this is that some banks do make use of the SNB's intraday facility and some don't. The availability of intraday credits from SNB's intraday credit facility however also affects the bank's term in the ON market. Regression results based on bank specific information show a different willingness to pay for ON funds of banks that use the SNB's intraday facility and such that don't.

The paper is structured as follows. The next section provides a short overview of SIC and the SNB's intraday facility. Section 3 describes the data stemming from the Eurex repo trading platform and SIC. In the subsequent section the econometric methodology is presented. The last two sections discuss the results and provide concluding remarks.

2 SIC and the SNB's intraday liquidity facility

2.1 SIX Interbank Clearing

Having started operations in 1987, SIC is one of the oldest RTGS systems.[2] Initially, design and architecture of the system were rather simple. The three main building blocks consisted in the non-allowance of intraday liquidity (in contrast to overdrafts in Fedwire and collateralized intraday credits in Target2), a central queuing mechanism and the strict "first in - first out" (FIFO) rule for payments processing and settlement. The transfer of funds in SIC is subject to the strict condition that the bank issuing the transfer order holds adequate balances on its SIC account. In the event of insufficient coverage, the transfer order is automatically held pending until covering funds have accumulated in the account through incoming payments or any form of credits by the SNB. The system automatically retries to settle pending payments on a continuous basis. The settlement algorithm stayed the same until 1994 when priorities were introduced.[3] In December 2001 the settlement algorithm was enriched with circles processing.[4]

Ever since the early stages of planning, it has been envisaged to provide for the settlement of various interbank payment services in SIC. This process started in 1995 with the integration of the securities settlement system SECOM of SIX SIS AG (SIS), the Swiss International Central Security Depository (ICSD). This link allows a delivery-versus-payment (DVP) mechanism in securities settlement by settling both the cash and the security side on a trade-by-trade (gross settlement) basis. In 2002 the process of integration has been ended so far by the integration of CLS. This was done in a rather straightforward and simple way. All CLS members were given a special subaccount in SIC. This account serves the only purpose of settling CLS related cover payments. For all other payments the main accounts are used.[5] SIC operations start at 17.00 p.m. the day before the actual value date. End of day is scheduled for 16.15 p.m. Within the SIC settlement day, CLS settlement cycles take place on an hourly basis from 7 a.m. to 12 a.m. on the actual value date. CLS members have to meet a

[2] For a comprehensive description of the system see Heller, Nellen and Sturm (2000).

[3] From an individual participant's perspective, the settlement sequence of payments is determined by the chosen priority. Within a specific order of priority, the FIFO-rule applies.

[4] In case the system is not able to settle payments for a certain period of time, the algorithm is searching for bilateral off-setting payments. On average circles processing is activated once to twice daily.

[5] Other interbank payment services that are settled in SIC comprise cash flows resulting from retail payment clearinghouses and the exchanges (or their central counterparties) such as SIX Swiss Exchange (SIX x-clear), Scoach and Eurex (Eurex Clearing).

pay-in schedule set by CLS in due time. This requires large amounts of reserve balances to be transferred during specific time slots. However, SIC serves as a settlement system for both, large-value payments and retail payments. The overwhelming number of transactions is retail oriented whereas the overwhelming value of payments stems from large-value interbank payments. Risk and efficiency considerations were the deciding factors that convinced the Swiss financial market and the SNB to opt for such an integrative solution. SIC allows for final settlement in central bank money and concentration of settlement allows for pooling of liquidity. The size and time criticality of CLS payments, however, led to a solution with two separate accounts for CLS participants.

2.2 The SNB's Intraday Liquidity Facility

The main intention of the SNB's intraday liquidity facility is to facilitate the settlement of payments via SIC and foreign exchange transactions in the CLS subaccounts. All banks that have access to the Swiss franc repo market can obtain intraday funds from the SNB. The intraday liquidity has to be covered with 110% of collateral eligible for SNB repos. As intraday liquidity has to be repaid by the end of the value day, it is not considered for the fulfillment of the minimum reserve and liquidity requirements. SNB provides intraday credits on an interest rate free basis. Banks can repay the intraday liquidity drawn at any time during the day. This standing facility has been introduced in 1999 and has since then been used intensively by market participants. Starting with the introduction of intraday liquidity specifically designated for CLS ("Intraday CLS") the average monthly drawn volume increased by CHF 5 bn to approx. CHF 8 bn (see figure 1).[6]

[6]See Jordan (2007) for more information on the SNB's standing facilities.

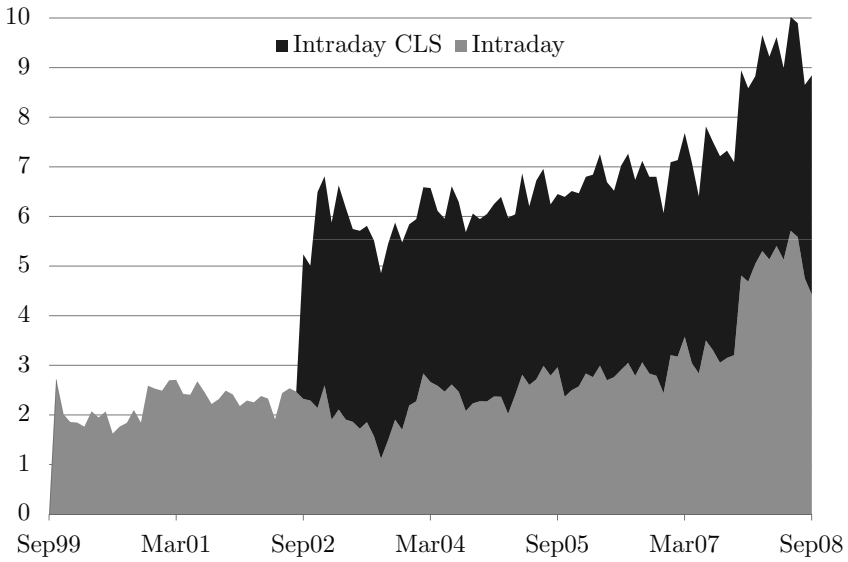

Figure 1: Average Monthly Drawn Intraday Volume (in bn CHF)

3 Data and stylized facts

In June 1999 the Swiss franc repo trading, clearing and settlement system was launched and has since then provided market participants with an integrated platform for repo transactions. Almost all interbank repo transactions in Swiss francs are traded on the Eurex repo trading platform and only a negligible amount is carried out over-the-counter (OTC).[7] The Eurex repo trading platform is thus the representative market for repo transactions in Swiss francs.

The data used in this study consists of interest rates that were charged for Swiss franc ON repo transactions between commercial banks on the Eurex repo trading platform. In particular, each data point provides information on the two banks involved, the interest rate charged, the collateral category chosen as well as the cash amount provided. The sample covers all transactions that were concluded from 18 June 1999 to 15 September 2008. Since the SNB's provision of reserves changed considerably after September 2008, we exclude this period. The ON repo market is the most liquid market segment of the Swiss franc repo market. During the considered period a total of 130 banks acted either as cash taker or provider. Since the introduction of the platform in 1999 the average number of active banks as well as the average daily volume increased significantly. In 2000 9 banks traded an average daily volume of CHF 320 million, while in 2008 approximately 50 banks traded CHF 6,5 billion per

[7]For a detailed overview on the characteristics and development of the Swiss franc repo market see Jordan (2007) and Kraenzlin (2007).

day. Overall the dataset consists of 100,200 ON transactions conducted on 2,319 business days.[8] Approximately 60% of the ON liquidity was transacted during the last two hours of the business day (between 2 and 4 p.m.).

We split participants on the Swiss franc repo market into two categories: Banks that actively use the SNB's intraday facility ("Intraday Users") and such that do not ("No Intraday Users"). The classification into these two bank categories is done as follows: Up to the date on which a bank has used the intraday facility for the first time, it is considered as "No Intraday User". All subsequent transactions are considered for the "Intraday Users" category. Figure 2 shows that the "Intraday Users" conclude on average two-thirds of the ON volume between 2 and 4 p.m. This behavioral pattern suggest that the "Intraday Users" prefer to draw from the SNB's intraday facility in the morning in order to settle payments in SIC or CLS and repay the intraday liquidity in the afternoon by concluding ON transactions. The "No Intraday Users", in contrast, transact approximately 60% of the volume until noon, whereof they are especially active from 9 to 10 a.m. In order to settle payments in SIC these banks therefore favor to obtain the necessary funds directly in the ON market. In this case the ON liquidity virtually exerts a dual function, namely as intraday liquidity to settle payments and ON liquidity as funding tool. Therefore, "No Intraday Users" act as cash takers relatively more often during the early morning hours. On average, "Intraday Users" accounted for approximately 85% (90%) of the ON volume before (after) the introduction of CLS.

Furthermore, we use data on the volume of unsettled payments in SIC. The hourly volume of unsettled payments in SIC is derived by subtracting the settled volume up to that hour from total daily turnover in SIC. The volume of unsettled payments in SIC (PU_t) is derived by subtracting the cumulative hourly turnover (U_t) from total daily turnover (U_T). Turnover generated by the SNB which results, among others, from monetary policy operations is excluded. In January 1999, on average only 28% of the volume of payments had been settled by 1 p.m.; by September 2008, this figure increased to 83%. The increase in volume of settled payments can mainly be subscribed to the positive impacts of intraday liquidity.

[8] These transactions are fully comparable with each other as they are against SNB eligible collateral and as the collateral is not subject to a haircut (or initial margin). No haircut applies as the net exposure a party holds vis-a-vis each participant is calculated twice daily. If the net exposure exceeds the unilaterally defined variation margin, a margin call is triggered. Credit and market risks are therefore offset to a great extent and as a result no haircut applies.

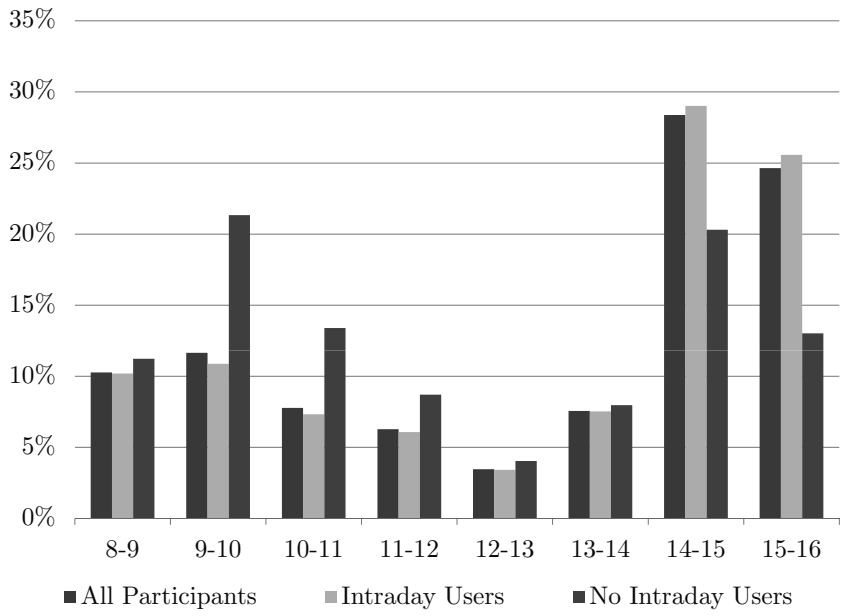

Figure 2: Hourly ON volume in % of total

4 Methodology

With the data at hand two types of regressions are run. The first regression estimates the implicit intraday term structure of the ON interest rates and the second regression relates the pattern found in the first regression to the conditions prevalent in SIC, namely the intraday liquidity usage and the turnover.

All regressions are run for the whole sample, namely from 18 June 1999 to 15 September 2008 as well as for two sub-sample periods.[9] The introduction date of CLS on 10 September 2002 is considered as a structural break. This is done in order to investigate whether the introduction of PVP for foreign exchange transactions, namely the introduction of CLS, increased the cost of immediacy. An increase in the implicit price for intraday credits would validate the hypothesis by Baglioni/Monticini (2008) that CLS has fostered the establishment of an implicit market for intraday credits.

All regressions are first run for the banking system as a whole. However, as seen in figure 2, the "No Intraday Users" conclude significantly more ON trades in the morning than the "Intraday Users". We expect that the use of the SNB's intraday facility lowers the banks' willingness to pay high ON rates in the morning. By drawing intraday liquidity, a bank can prefund its liquidity needs

[9]The last two days of the minimum reserve period as well as the last day of the month are excluded from the regression as ON rates tend to be particularly volatile on these days. See Benito et.al. (2006) for an empirical analysis on the volatility of the Euro ON interest rate (EONIA).

to settle the payments either in SIC or CLS early in the day. Later in that day, when ON rates are expected to be lower, the bank can repay the intraday credit by concluding an ON transaction on the interbank market. Hence, to evaluate if the banks' willingness to transact and pay in the ON market depends on the use of the SNB's intraday facility, the regressions are also run for these two bank categories.

4.1 Estimation of the intraday term structure

In order to measure the implicit intraday interest rate we closely follow the approach by Baglioni/Monticini (2008). Let $t = 1, ..., 8$ denote the time bands during the day, with $t = 1$ being the first time band from 8 a.m. to 9 a.m. and $t = 8$ the last time band from 3 p.m. to 4 p.m.[10] Transactions are settled immediately after the trade is concluded. Once a trade is concluded and matched, the securities are instantaneously blocked and a payment message with high priority is sent to SIC. Given the availability of securities and funds, settlement usually takes place within a few seconds. Repayment of all ON transactions concluded on the Swiss franc repo market is automatically triggered by SIS at 7:50 a.m. Hence, compared to an ON transaction concluded at 10 a.m., the time length of an ON transaction at 9 a.m. is one hour longer. The set of hourly interest rates $[r_1, r_2, ..., r_8]$ thus represents the "intraday term structure" of the ON rates and, therefore, the intraday price of money. In contrast to Baglioni/Monticini (2008), r_t represents the hourly volume weighted interest rate.

To account for day-to-day differences in the level of ON rates which may, for example, result from interest rate hikes or day specific tensions, we derive the hourly interest rate differential ($\bar{r}_t$). The hourly interest rate differential is calculated by taking the difference between the volume weighted interest rate (r_t) charged on overnight loans for each hourly band ($t = 1, ..., 7$ or 8) and the ON rate over the entire day (r_T). Finally, this differential is used to obtain the net intraday term structure.

To estimate the term structure of the ON interest rate we run a least square dummy variable regression. We thereby test whether the overnight rate significantly depends on hourly dummies ($d_i = 1$ if $t = i$ and $d_i = 0$ otherwise) for each opening hour of the Swiss franc repo market. The time band $t = 1$ (from 8 to 9 a.m.) is used as reference variable and is represented by the constant (α). ε_t are the regression residuals.

[10] Banks can conclude trades on the Swiss franc repo market starting at 7 a.m. However, as transactions are seldom concluded between 7 a.m. and 8 a.m., the first time band is defined to take place between 8 a.m. and 9 a.m.

$$\bar{r}_t = \alpha + \sum_{i=2}^{8} \beta_i d_i + \varepsilon_t \tag{1}$$

Based on these regression results we can derive a synthetic measure of the hourly interest rate charged in the Swiss franc repo market, by calculating the following equation:

$$\bar{r}_t = \bar{r}_1 - s \cdot t \tag{2}$$

where $\bar{r}_1$ represents the interest rate difference for the first time band, s the synthetic value and t the time elapsed during the day. The coefficient s basically shows the decline of ON rates during the day and is a measure for the decrease in willingness to pay for ON funds towards the end of the day. The average daily synthetic value as well as the synthetic value for the time bands s_{8-12} (during the CLS settlement cycle) and s_{12-16} (when the CLS settlement is finished) are calculated.[11]

4.2 Explaining the intraday term structure

As set out in Angelini (1998), the hourly ON interest rate theoretically depends on the volume of unsettled payments in the payment system. In order to explain the intraday term structure we account for the banks' liquidity needs by taking the volume of unsettled payments as an explanatory variable. However, the degree of liquidity stress that the volume to be settled exerts on a bank depends on the actual liquidity available in the system.[12] We account for this by using the hourly outstanding intraday liquidity drawn from the SNB's intraday facility as the second explanatory variable. We expect that a high volume of unsettled payments in SIC increases liquidity stress and hence banks' willingness to pay higher ON rates. High hourly outstanding intraday liquidity in turn leads to a lower willingness to pay and hence a flatter intraday term structure. Such results would validate the hypothesis that RTGS systems favor the development of an implicit market for intraday funds, or in theoretical parlor, RTGS systems impose a cost of immediacy.

As mentioned in subsection 2.2, banks can either draw intraday liquidity for SIC or for CLS specific subaccounts in SIC. Intraday liquidity designated

[11] The average hourly synthetic value is determined by dividing the difference between d_8 and the constant by the number of time bands.

[12] We only look at the two groups. Hence we account for the intraday liquidity on a group level rather than on an individual bank level. As a consequence, no direct effects of liquidity drawings by individual banks are considered.

for CLS is in general used in CLS subaccounts until 12 a.m. Usually, banks subsequently transfer remaining balances on their CLS subaccounts to their SIC main accounts. Consequently, banks normally use these funds only after 12 a.m. for settlement of payments in the main accounts of SIC. The liquidity variable, I_t, is thus the hourly outstanding intraday volume drawn for main accounts plus the hourly outstanding volume of intraday liquidity drawn for CLS subaccounts. The latter variable is set to zero for the time before 12 a.m.[13]

[13]Banks can repay intraday liquidity at any time during the day. If this has not been the case, repayment will automatically be activated by SIS at 3 p.m. As a consequence the hourly intraday volume need not be the amount of intraday liquidity drawn from the SNB's intraday facility. In the following, we account for the fact that repayment of intraday liquidity was done before 3 p.m.

5 Regression results

5.1 Estimation of the intraday term structure

The regression results are displayed in table 2 and plotted in figures 3 and 4. The first three regressions estimate the implicit intraday term structure for the entire sample (1), for the time period before (2) and after the introduction of CLS (3). All three regressions show a clear downward pattern of the ON interest rate throughout the opening hours of the Swiss franc repo market. In the morning (afternoon) participants paid approximately 1bp (3bp) above (below) the daily volume weighted ON rate. Furthermore, regressions (2) and (3) reveal that the introduction of CLS marks a structural break. After the introduction of CLS, ON rates stay as high as at the beginning of the day until the end of the CLS settlement cycle at noon. Only from then on the intraday term structure follows the beforehand seen clear downward pattern. In addition, the difference between opening and closing intraday rates has become smaller after the introduction of CLS. Overall, regression results provide evidence that the value of intraday money has increased during the hours of the CLS settlement cycle. This can be taken as evidence that the introduction of PVP for foreign exchange settlement has increased the cost of immediacy. Before PVP a bank could delay paying its leg of a transaction until it was convenient and less expensive. With the introduction of CLS and hence PVP, banks must make their payments at a specific time during the day – which is relatively early in Switzerland – at a time where there is competition from other payment needs.[14] We estimate the mark-up on hourly ON rates due to CLS to be approximately $0.50bp$ per hour, leading to a total of roughly $1.5bp$ for the CLS settlement cycle.[15]

The bank group specific regressions (4)-(7), where we differ between "Intraday Users" and "No Intraday Users", show that the ON rate gradually declines for both bank groups during the day. Figure 4 plots the intraday term structure. Before the introduction of CLS the two bank groups' willingness to pay differed significantly: "Intraday Users" paid approximately $2.8bp$ more for ON funds in the morning than in the evening, while "No Intraday Users" paid around $5bp$ more. This is intuitive as the latter group's overall willingness to pay a premium for ON funds in the morning is higher than for those banks that make

[14] In contrast to our findings Baglioni/Monticini (2008) find a declining implicit intraday term structure throughout the day in a sample that covers a period after the introduction of CLS. A possible explanation here fore may be the difference in relative importance of CLS banks in the respective markets. In markets where CLS banks are the dominant players, such as in Switzerland, the implicit cost of intraday funding during CLS hours is more likely to increase.

[15] To quantify the average hourly mark-up we sum up the differences between the $\bar{r}_{\text{after CLS}} - \bar{r}_{\text{before CLS}}$ at 8 a.m. and 12 a.m. respectively and divide this sum by the number of time bands.

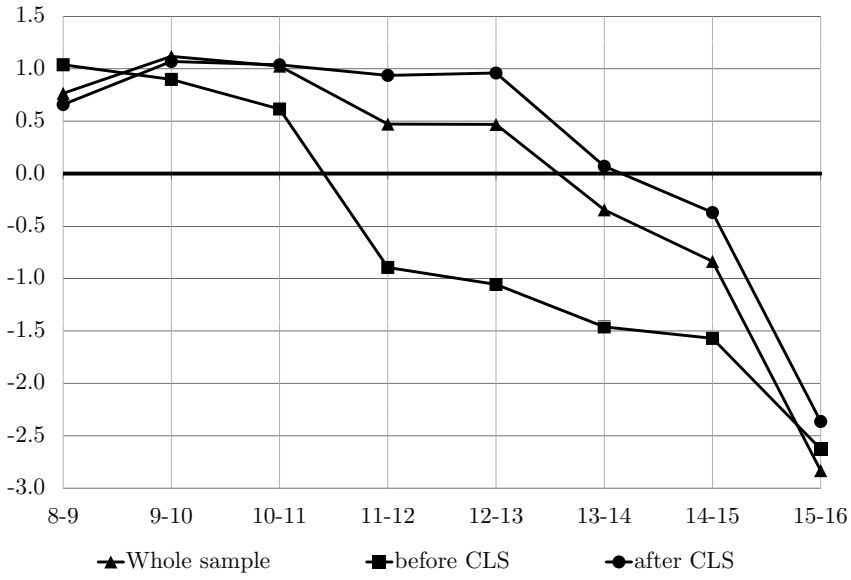

Figure 3: Intraday term structure (in bp)

use of the SNB's intraday facility. The "Intraday Users" can get liquidity at an interest of zero at the SNB and still have the opportunity to get less expensive ON funds in the evening. At the end of the day the difference in willingness to pay converges.

After the introduction of CLS the hourly interest rate differential during the CLS settlement cycle remains for both groups as high as at the beginning of the day. The introduction of CLS again marks a structural break. It is evident that the difference between the two bank groups' willingness to pay remains stable at the level of approximately $2bp$ and does not converge to zero as was the case before the introduction of CLS. We would expect the willingness to pay for ON funds as intraday liquidity at the end of the day to be the same for both groups since almost all payments are settled. A necessary condition for such a price difference is non-anonymous trading. This applies for the Eurex trading platform.[16] The lack of trade anonymity may have fostered price difference between participants.[17] However, non-anonymous trading is not a sufficient explanation for the non-convergence to occur and remains puzzling. Finally, it is evident that the difference between the beginning and end of day interest rate differential ($\bar{r}_8 - \bar{r}_1$) for "No Intraday Users" decreased from $5bp$ to $3.5bp$ whereas it stays at the level of $3pb$ for "Intraday Users". The decrease in difference for

[16] On the Swiss franc repo market an interbank relationship has to be enabled by both banks. In the period of observation roughly 25% of all potential interbank relationships were activated bilaterally.

[17] Such a price difference should not be evidenced in an anonymous interbank repo market where a central counterparty (CCP) is present.

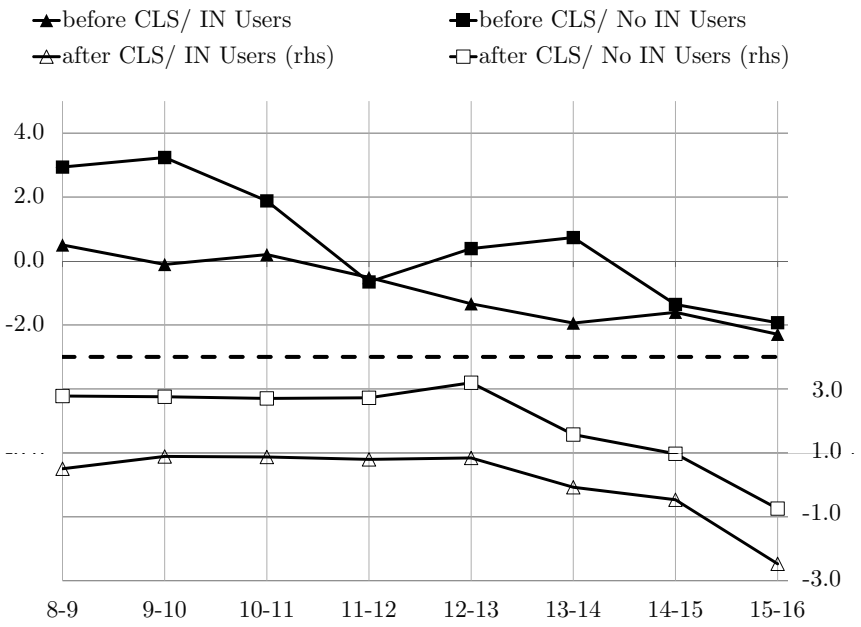

Figure 4: Term structure w/r to bank categories (in bp)

"No Intraday Users" stands for a lower volatility of ON rates throughout the day.

Table 1 provides information on the average hourly synthetic value. For the entire period of observation (1) the average hourly decline in price of money is estimated to be $0.51bp$. This demonstrates that ON funds are less valuable the more time has elapsed in the trading day as these funds exert less the dual function, namely as intraday liquidity to settle payments and ON liquidity as funding tool. This is in line with the result that Baglioni/Monticini (2008) obtain for the unsecured interbank money market in Euro. The decline in prices for the two subsamples, before (2) and after the introduction of CLS (3) mark a slight change from $0.52bp$ to $0.43bp$. The change gets more visible if we consider the synthetic values for different time bands, namely during (s_{8-12}) and after the CLS settlement cycle (s_{12-16}). The synthetic values after and before CLS are significantly different for both time bands. The synthetic value decreases constantly for the period before CLS. After the introduction of CLS the synthetic value stays constant or even slightly increases in the first time band and then decreases more sharply in the second time band. Participants in the Swiss franc repo market thus value ON funds in the afternoon less valuable than during the settlement hours of CLS. Differently said, the value of intraday money during the hours of the CLS settlement cycle has become higher after the introduction of CLS. The average daily synthetic value is also evidence that

the willingness to pay of "Intraday Users" decreased by less than that of "No Intraday Users". While "Intraday Users" pay almost the same intraday interest rate of around $0.40bp$ before and after the introduction of CLS, the one for "No Intraday Users" decreases from $0.70bp$ to $0.50bp$.

		r_1	s	s_{8-12}	s_{12-16}
(1)	overall sample	0.77	-0.51	-0.10	-1.10
(2)	before CLS	1.04	-0.52	-0.64	-0.52
(3)	after CLS	0.66	-0.43	0.09	-1.11
(4)	IN Users (before CLS)	0.50	-0.40	-0.34	-0.32
(5)	IN Users (after CLS)	0.50	-0.42	0.10	-1.10
(6)	No IN Users (before CLS)	2.94	-0.70	-1.20	-0.77
(7)	No IN Users (after CLS)	2.78	-0.50	-0.02	-1.31

Table 1: Average hourly synthetic value (in bp)

5.2 Explaining the intraday term structure

As shown in subsection 5.1 the intraday term structure of the ON interest rate defines a positive hourly rate in the money market. In this section we try to explain the intraday term structure. The volume of unsettled payments in SIC and the hourly outstanding intraday liquidity drawn from the SNB's intraday facility are taken as explanatory variables. Again we run the regression for the entire sample (1), for the period before (2) and after the introduction of CLS (3) as well as for the subgroups "Intraday Users" (4)-(5) and "No Intraday Users" (6)-(7). The regression results are given in table 3.

In all regressions the volume of unsettled payments in SIC has a highly significant and positive influence on the intraday term structure of the ON interest rate. We take this as evidence that higher liquidity stress, indicated by the volume of unsettled payments, results in a higher hourly ON rate. The influence of unsettled payments has decreased since the introduction of CLS. For the "No Intraday Users" the influence remains larger than for "Intraday Users".

In regressions (3) and (5) the outstanding intraday volume yields highly significant and negative coefficients. In all other regressions the coefficients are insignificant. The effect of intraday liquidity on ON rates is only evident for the period after the introduction of CLS and only for the "Intraday Users". This result can be attributed to the fact that intraday liquidity specific for CLS, which

amounts to more than half of total intraday volume drawn, is made available for the main accounts of CLS participants after noon. This additional liquidity further boosts their settlement performance in SIC and reduced their liquidity stress. The regression only accounts for the direct effect of intraday liquidity on the ON rates. Hence it is consistent that the hourly outstanding intraday volume only exerts a significant influence on "Intraday Users" willingness to pay.

The smaller influence of unsettled payments on ON rates after the introduction of CLS can mainly be attributed to the indirect benefits of the SNB's intraday facility for both, "Intraday Users" and "No Intraday Users". Taking into account that the intraday volume drawn has substantially increased since September 2002 (see figure 1), the use of the SNB's intraday facility has attenuated liquidity stress resulting from unsettled payments. Unsettled payments have been reduced heavily over settlement hours after the introduction of CLS. This says that the available intraday liquidity does not only yield a direct positive effect for "Intraday Users" but indirectly affects settlement for all members via a smoother settlement, i.e. privately drawn intraday liquidity yields a positive externality.[18] Indeed, the hourly unsettled payments coefficients are reduced for both groups in regression (4) and (5) for "Intraday Users" and (6) and (7) for "No Intraday Users". Nevertheless, "No Intraday Users" stay under a higher liquidity pressure than do "Intraday Users", which explains why "No Intraday Users" willingness to pay is $2bp$ higher than that of "Intraday Users" (see discussion in subsection 5.1).

[18] If a bank draws intraday liquidity to settle payments early in the morning, all participants of the payment system benefit from additional intraday liquidity since they can settle their own payments with incoming funds from other participants. This is true for both banking groups, whether or not the receiver uses the SNB's intraday facility.

6 Comparisons and conclusions

The theoretical literature represented by VanHoose (1991) and Angelini (1998) postulates the emergence of an intraday interest rate in the interbank market. Baglioni/Monticini (2008) perceive the empirical evidence regarding the price of intraday liquidity to be rare and inconclusive. Indeed, Angelini (2000) finds no relevant intraday pattern in the level of interest rates for the ON market in the Italian screen-based e-MID interbank market for the period from mid-1993 to end-1996. Looking at the same market, Barucci et.al. (2003) find a downward pattern for the period January 1999 to August 2001 and Baglioni/Monticini (2008) find a clear downward pattern for the period 2003 to 2004. For the unsecured US ON federal funds market Bartolini et.al. (2005) find a similar downward pattern for the deviation of an average half hourly rate from the target rate in the period from February 2002 to September 2004.

This paper provides further empirical evidence on the implicit price of intraday liquidity. Based on data from the secured ON market in Switzerland, we show that a downward sloping intraday term structure has existed at least since the introduction of the Swiss franc repo market in 1999. This is additional evidence for the theoretical results by VanHoose (1991) and Angelini (1998).

Baglioni/Monticini (2008) explain the switch from no to a clear downward pattern of the ON rate that took place between Angelini (2000) and their own analysis by the introduction of real-time settlement and the PVP mechanism for foreign exchange transactions (TARGET in 1999 and CLS in 2002). The move towards gross settlement and PVP is claimed to have made intraday liquidity more valuable and to have created incentives for banks to charge a price for it.

We find corresponding evidence for these claims. The downward pattern of the ON rate depends on the liquidity needs stemming from the RTGS system. The implicit intraday interest rate positively depends on the corresponding turnover and negatively on the outstanding volume of intraday liquidity. We interpret this as evidence for the "cost of immediacy" of RTGS systems as postulated by Kahn/Roberds (2001). We also find evidence for the positive externality of higher market liquidity that is claimed by Angelini (1998). Higher market liquidity drives down pending payments for both groups of participants, namely "Intraday Users" and "No Intraday Users". Correspondingly, both groups profit from lower liquidity stress that results in a lower implicit price of intraday liquidity.

Additionally, we provide empirical evidence that the introduction of CLS

has increased the price of intraday liquidity. This is due to the strict pay-in schedule of the CLS settlement cycle. CLS membership requires banks to dispose of large amounts of intraday liquidity to meet the time critical CLS pay-in schedule. As a consequence, the introduction of CLS has increased the price of intraday liquidity for all banks. Since the introduction of CLS the level of the ON rates stayed more or less constant from the beginning of the day until the end of the CLS settlement cycle at noon. In the afternoon the implicit price of intraday liquidity follows a clear downward pattern again.

The scarcity of intraday liquidity and the corresponding reaction of banks to price intraday liquidity such as claimed by Baglioni/Monticini (2008) can also be verified by evidence on the Swiss franc repo market. The introduction of CLS resulted in banks applying differentiated pricing for banks that do and those that do not make use of the SNB's intraday credit facility. The latter pay higher ON rates at the beginning of the day. After the introduction of CLS the beginning of day difference does not disappear towards the end of the day but keeps almost constant until the end of the day. We attribute this to the segmented market structure and the non-anonymity of the market.

It is also interesting to compare the hourly implicit intraday interest rate of the Euro with the one of the Swiss franc money market. The difference between the beginning and end of day ON interest rate is $3.5bp$ for the Euro and $3bp$ for the Swiss franc money market. In comparison to Baglioni/Monticini (2008), our hourly interest rate measure is based on one hour less. Taking this into account, the *hourly* implicit intraday interest rate is $0.5bp$ and $0.43bp$ for the Euro and Swiss Franc money market respectively (see results for regression (3) in table 2). Baglioni/Monticini (2008) point out, that the market intraday interest rate in the US is pegged by the overdraft fee applied by the Fed. The annualized hourly fee for overdraft is $1.5bp$.[19] Furfine (2001) derived the hourly implicit intraday interest rate for the unsecured US money market and obtained a rate of $0.9bp$. Compared to the empirical evidence for the US and Euro money market the hourly implicit intraday interest rate for the Swiss franc money market is thus the lowest.[20]

Baglioni/Monticini (2008) argue that their estimate of the intraday interest

[19] See Baglioni/Monticini (2008), p. 1539 for the derivation of the annualized hourly fee.

[20] There is one basic difference between the hourly implicit intraday interest rate for CHF and the ones for the Euro and the USD. The latter two results are based on the unsecured interbank money market, whereas the former is based on the secured money market. However, to obtain the hourly implicit intraday interest rate the difference is taken between the hourly ON rate and the overall daily ON rate. Hence the risk premium related to the bank specific data is filtered away by this differencing. Therefore, results are comparable.

rate provides an indirect evidence that the cost of collateralizing intraday loans from the Eurosystem is lower than the fee charged by the Fed. This might explain why the Fed investigates the introduction of an additional collateralized intraday overdraft facility for Fedwire.[21] Following this line of argument, the difference between the hourly interest rate for Euro and Swiss Franc could be traced back to structural differences between the respective intraday credit facilities. One potential source could be transaction costs for which evidence is hard to find. Another source could be the respective collateral policies applied by the two central banks. Whereas in the Eurosystem only Euro denominated collateral is eligible, the SNB allows for a much wider variety of currencies.[22] Since the SNB's collateral policy allows for a greater diversification in collateral holdings, opportunity costs may be lower and as a result lead to a lower hourly implicit intraday interest rate.

[21] See the Federal Reserve Board's request for public comment on its proposed changes to its daylight overdraft policy:
http://www.federalreserve.gov/newsevents/press/other/20080228b.htm

[22] See Bank for International Settlement (2006) for more information on the respective collateralization policies across G-10 central banks.

Appendix: Regression Results

	(1) overall sample	(2) before CLS	(3) after CLS	(4) before CLS IN Users	(5) after CLS IN Users	(6) before CLS No IN Users	(7) after CLS No IN Users
Constant	0.00765***	0.01038*	0.00658***	0.00502	0.00504**	0.02937**	0.02778***
	(-0.00193)	(-0.00507)	(-0.00189)	(-0.00557)	(-0.0019)	(-0.00941)	(-0.00403)
dummy 9	0.00353	-0.00140	0.00411	-0.00610	0.00384	0.00300	-0.00023
	(-0.00253)	(-0.00668)	(-0.00238)	(-0.00687)	(-0.0024)	(-0.01332)	(-0.00471)
dummy 10	0.00260	-0.00422	0.00379	-0.00301	0.00368	-0.01057	-0.00075
	(-0.00243)	(-0.00638)	(-0.00233)	(-0.0069)	(-0.00236)	(-0.01218)	(-0.00488)
dummy 11	-0.00293	-0.01933*	0.00278	-0.01018	0.00292	-0.03592	-0.00056
	(-0.00262)	(-0.00757)	(-0.00232)	(-0.00746)	(-0.00233)	(-0.01887)	(-0.00514)
dummy 12	-0.00296	-0.02095**	0.00301	-0.01839*	0.00337	-0.02548	0.00415
	(-0.00267)	(-0.00689)	(-0.00249)	(-0.00744)	(-0.0025)	(-0.01703)	(-0.00603)
dummy 13	-0.01110***	-0.02500***	-0.00588**	-0.02443***	-0.00580**	-0.02204*	-0.01206*
	(-0.00228)	(-0.00595)	(-0.00216)	(-0.00644)	(-0.00217)	(-0.01095)	(-0.00484)
dummy 14	-0.01602***	-0.02609***	-0.01029***	-0.02106**	-0.00970***	-0.04296***	-0.01807***
	(-0.00229)	(-0.00599)	(-0.0021)	(-0.00648)	(-0.00211)	(-0.01242)	(-0.00451)
dummy 15	-0.03597***	-0.03664***	-0.03022***	-0.02794***	-0.02974***	-0.04867***	-0.03521***
	(-0.00282)	(-0.00692)	(-0.00253)	(-0.00739)	(-0.00255)	(-0.01359)	(-0.00592)
No. Obs.	13,454	3,511	9,519	3,197	9,379	1,106	3,176
R-squared	0.03	0.02	0.05	0.01	0.05	0.03	0.04
Adj. R-squared	0.03	0.02	0.05	0.01	0.05	0.02	0.04

***: significance on the 1% level; **: 5% level; *: 10% level; robust standard errors are reported in parentheses

Table 2: Descriptive regression

	(1) overall sample	(2) before CLS	(3) after CLS	(4) before CLS IN Users	(5) after CLS IN Users	(6) before CLS No IN Users	(7) after CLS No IN Users
Intraday (in bn)	-0.00009	0.00060	-0.00183***	-0.00136	-0.00199***	0.01015	0.00129
	(-0.00039)	(-0.00301)	(-0.00032)	(-0.00302)	(-0.00032)	(-0.00594)	(-0.00081)
Unsettled Payments (in bn)	0.00031***	0.00047***	0.00017***	0.00035***	0.00016***	0.00074***	0.00043***
	(-0.00003)	(-0.00006)	(-0.00002)	(-0.00006)	(-0.00003)	(-0.00014)	(-0.00005)
Constant	-0.01639***	-0.03608***	0.00071	-0.02706***	0.00066	-0.05972***	-0.00902
	(-0.00248)	(-0.00812)	(-0.00211)	(-0.00821)	(-0.00213)	(-0.0175)	(-0.00504)
No. Obs.	13,361	3,418	9,519	3,162	9,379	1,040	3,176
R-squared	0.02	0.02	0.03	0.01	0.03	0.03	0.03
Adj. R-squared	0.02	0.02	0.03	0.01	0.02	0.03	0.03

***: significance on the 1% level; **: 5% level; *: 10% level; robust standard errors are reported in parentheses

Table 3: Explanatory regression

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