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The intraday interest rate under a liquidity crisis: the case of August 2007

Angelo Baglioni (*) - Andrea Monticini (**)

Abstract. By analyzing high frequency data for the European interbank market, we show that the intraday interest rate (implicitly defined by the term structure of the ON rate) jumped by more than ten times at the outset of the financial turmoil in August 2007, resulting in an inefficiency of the money market. This took place despite the provision of unlimited free daylight overdrafts by the ECB, on a collateralized basis. We suggest that such result may be attributed to an increase of the liquidity premium and of the cost of collateral.

Keywords: intraday interest rate, liquidity crisis, money market, central banking

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(*) Università Cattolica - Milano (angelo.baglioni@unicatt.it)

(**) Università Cattolica - Milano (andrea.monticini@unicatt.it)

1 Introduction and summary

There is a broad consensus that the intraday interest rate should be set to zero on efficiency grounds. In this work we document that, while in normal times money market rates are roughly in line with this efficiency criterion, they may deviate by a large extent in a situation of liquidity tension, like the one taking place at the outset of the sub-prime financial turmoil. We provide an analysis of the European electronic interbank market (e-MID) with high frequency data, showing that the hourly interest rate − implicitly defined by the intraday pattern of the overnight rate − jumped by more than ten times (from 0.2 bp to 2.2 bp) in the reserve maintenance period starting on August 8th 2007. This finding has no straightforward explanation, since the Eurosystem supplies intraday liquidity at no cost and without limit, except for the collateral requirement. We suggest that this evidence may be attributed to an increase of the liquidity premium and of the cost of collateral.

Several recent contributions in monetary theory, focussing on the role of money as a medium of exchange, point to the optimality of a zero intraday rate (see Zhou 2000, Martin 2004, Bhattacharya *et al.* 2007). Other works, more focussed on the mechanics of the payment systems, stress that a positive cost of intraday liquidity may induce individual banks to delay payments, putting a negative externality onto the banking system (see Angelini 1998, Bech and Garratt 2003, Mills and Nesmith 2008, Martin and McAndrews 2008, FED 2006-2007). Our work contributes to this literature by showing that during a liquidity crisis the ability of the central bank to curb the (implicit) market price of intraday liquidity is limited, despite the provision of free (collateralized) daylight overdrafts.[1]

While the theory of the intraday interest rate is well developed, the empirical evidence

[1] Our evidence is also relevant to the debate over the alternative central bank policies for liquidity provision. See Mills (2006), Furfine and Stehm (1998), Lacker (1997).

is scarce, due to the absence of an explicit market for intraday credit. The implicit intraday rate has been estimated by Furfine (2001) for the federal funds market in the US and by Baglioni and Monticini (2008) for the e-MID market in Europe: both point to a very low level of the hourly rate (0.9 bp and 0.4 bp respectively) − although statistically significant. While the cost of intraday liquidity may be negligible under normal conditions, we show in this work that it may gain economic significance in times of liquidity tension.

2 The empirical evidence

2.1 The implicit intraday interest rate: definition

Following Baglioni and Monticini (2008), we consider an overnight (ON) interbank market where all loans must be repaid at the same time next day. Thus the starting hour of a contract (denoted by t) unambiguously determines the length of a loan (assuming real time settlement). Then we may define the implicit hourly rate i_t simply by:

$$i_t = r_t - r_{t+1} \tag{1}$$

where r_t is the ON interest rate observed in the market at time t. By estimating the term structure of the ON rate ($r_0, r_1, ..., r_T$, where 0 and T are the market opening and closing times respectively) we are able to provide an estimate of the hourly interest rate.

2.2 The data set

With 15 billion euros traded daily (on average) and 250 members from all over Europe and the US, the Milan-based e-MID market is the major electronic marketplace for interbank loans in the euro area. Trades start at 8 a.m. and ends up at 6 p.m., and they are settled in real time through TARGET payments. All ON trades matures at the same time next day[2].

The evidence presented here is based on all ON trades in the two reserve maintenance periods: 7.11.2007 - 8.7.2007 and 8.8.2007 - 9.11.2007.[3] As it is well known, the sub-prime crisis hit the financial markets on August 9th 2007, right at the beginning of the second maintenance period here considered. We drop the last day in each period: we consider this day as not informative, since the averaging facility[4] is not available by definition, and this makes this day different from all the others. The overall number of observations is 4,548 (of which 2,550 in the second period[5]).

2.3 The jump of the intraday rate

We begin our analysis by dividing the business day into 9 hourly time bands: from 9 a.m. to 6 p.m.[6], denoted by $t = 0, ...8$. For each business day, the average ON rate in each time band has been computed, from which the average rate of the whole day has been subtracted: we use interest rate differentials from the daily average (denoted by $\overline{r}_t$) in order to disentangle intraday patterns − which are our focus − from day-to-day patterns of the ON rate.

We estimate the following equation (2) in the two reserve maintenance periods here considered:

[2] Trades involving only Italian banks are repaid at 9 a.m. next day, and trades involving international banks mature by noon next day.

[3] Our results are robust to an extension of the time span considered, for example by considering the four maintenance periods before and after the outset of the crisis (see our working paper, available at: http://ideas.repec.org/p/ctc/serie3/ief0083.html).

[4] The reserve requirement is applied to the average end-of-day balance held in reserve accounts over the whole maintenance period, enabling banks to substitute the reserve of one day with that of some following day (within each period). Of course, this stabilizing mechanism is not available in the last day of a maintenance period.

[5] In this period August 15th has been dropped: this is a half-bank holiday, so very few trades are made.

[6] The first operating hour (8 a.m. - 9 a.m.) has not been included in our analysis, since very few trades take place at this time.

$$\overline{r}_t = c + \sum_{i=1}^{8} \beta_i \cdot x_i + \varepsilon_t \qquad (2)$$

where x_i are dummy variables – i stands for the hourly time bands following the first one – taking value 1 when $t = i$ and zero otherwise; $\varepsilon_t \sim i.i.d.\,(0, \sigma_t^2)$ with possibly $\sigma_t^2 \neq \sigma_s^2$ for $t \neq s$. The intercept c provides an estimate of the interest rate differential from the daily average during the first hourly band considered (9-10 a.m.). The values of the dummy coefficients β_i provides an estimate of the difference between the ON rate in each time band and the ON rate in the first time band. Thus an estimate of the implicit hourly interest rate i_t (defined in eq.(1)) is provided by the consecutive changes $(\beta_i - \beta_{i+1})$ $(-\beta_1$ for the first time band). The number of observations used in the regressions equals the number of business days in each period times the number of hourly time bands: $19 \cdot 9 = 171$ and $23 \cdot 9 = 207$ for the first and second period respectively.

The regression analysis provides quite strong results – shown in Table 1.[7] The interpretation of these results is easier by focussing on the bold columns, showing the estimated hourly rate for each time band: it is evident that during the second period such rate is larger than in the previous one in all the time bands. Let us clarify our results by means of an example. In the first row of the table, the value 0.34 means that – in the first period considered – borrowing ON between 9 and 10 a.m. costs on average 0.34 bp more than borrowing between 10 and 11 a.m. This difference, measuring the implicit hourly rate in the first time band, jumps to 3.2 bp in the second period.

The implicit hourly rates differ across the time bands. Therefore, in order to get a synthetic indicator of the hourly interest rate, we compute the mean hourly rates, shown

[7] All the coefficients are highly significant (with the exception of β_1 in the second period, due to high volatility in this hourly band). The standard errors have been obtained by heteroskedasticity and autocorrelation consistent (HAC) covariance matrix estimators (see Andrews and Monahan 1992).

at the bottom of the bold columns: each of them is the average of the values shown in the same column. It can be seen that – in the first period considered – the implicit price of a one hour interbank loan is 0.2 bp, on average across the whole day. The last column shows that the mean hourly rate jumps to 2.2 bp at the outset of the financial crisis, i.e. ten times more than in the previous maintenance period.

Table 1 - The estimated intraday rate before and during the crisis

		July 11th - August 6th		August 8th - September 10th	
Time band	Coefficient	Value in bp	$\beta_i - \beta_{i+1}$	Value in bp	$\beta_i - \beta_{i+1}$
9-10 a.m.	c	0.71^{***} (0.11)	**0.34**	9.50^{***} (2.7)	**3.20**
10-11 a.m.	β_1	-0.34^{**} (0.17)	**0.07**	-3.20 (2.97)	**3.77**
11-12 a.m.	β_2	-0.41^{***} (0.15)	**−0.21**	-6.97^{**} (2.96)	**0.39**
12-1 p.m.	β_3	-0.20^{**} (0.09)	**0.31**	-7.36^{***} (2.87)	**0.99**
1-2 p.m.	β_4	-0.51^{***} (0.16)	**0.17**	-8.35^{***} (2.83)	**1.54**
2-3 p.m.	β_5	-0.68^{***} (0.15)	**0.41**	-9.89^{***} (2.94)	**0.44**
3-4 p.m.	β_6	-1.09^{***} (0.11)	**0.43**	-10.33^{***} (3.02)	**3.94**
4-5 p.m.	β_7	-1.52^{***} (0.22)	**0.17**	-14.27^{***} (3.41)	**3.29**
5-6 p.m.	β_8	-1.69^{***} (0.34)		-17.56^{***} (4.41)	
	$Adj.R^2 = 0.34$		**Mean = 0.21**	$Adj.R^2 = 0.21$	**Mean = 2.19**
	$D.W. = 1.87$			$D.W. = 1.66$	

Note: (*), (**), and (***) denote 10%, 5%, 1% significance level respectively, based on HAC standard errors (shown in parenthesis).

In Figure 1 the fitted values of equation (2) are plotted – based on the estimated para-

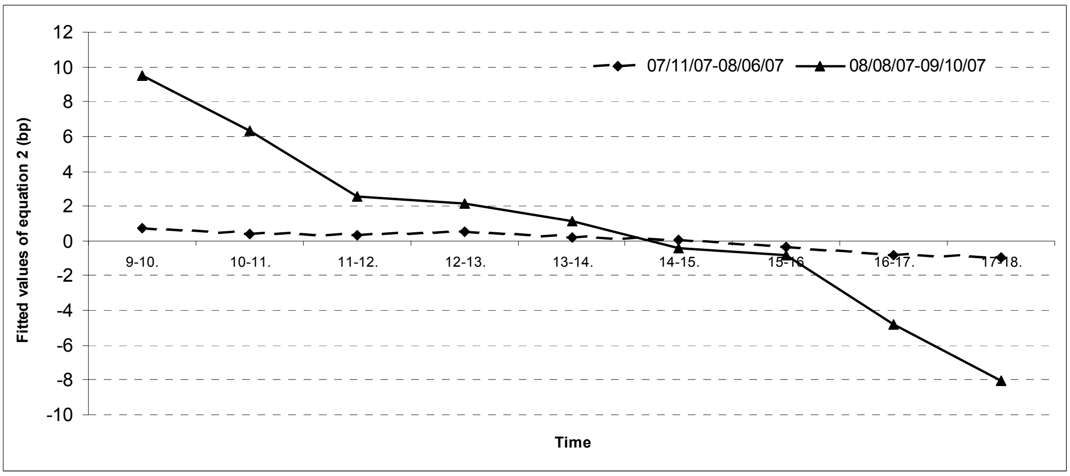

Figure 1: The switch of the ON intraday term structure

meters shown in Table 1 – for the first period considered (dotted line) and for the second one (solid line): each line provides a view of the intraday term structure of the ON interest rate – expressed as a differential from the daily average – in each period. The difference between the two periods is striking. Before the crisis the term structure is quite flat: the ON rate remains within a range of ± 1 bp from the daily average. During the crisis the term structure is much steeper: the ON rate is almost 10 bp above the daily average in the first hour; then it steadily declines until reaching at the end of day a level 8 bp lower than the daily average. This implies – for example – that borrowing overnight at 9.30 a.m. costs about 18 bp more than borrowing at 5.30 p.m.

3 Interpreting our results

As it is well known, the intraday interest rate is crucially affected by the cost of daylight credit provided by the central bank. Intuitively, a bank short of liquidity say at 9 a.m. has two alternatives: (i) borrow immediately in the interbank ON market, (ii) obtain intraday credit from the central bank and borrow later (say at 4 p.m.) in the ON market. If these two alternatives were perfect substitutes, such bank would not be willing to pay an implicit intraday interest charge (resulting from the difference between the ON rates at 9 a.m. and at 4 p.m.) larger than the cost of a seven hour loan from the central bank. This is the reason why the cost of daylight liquidity provided by the central bank may be seen as an upper bound for the implicit intraday interest rate, at least under normal conditions. Theories of bank intraday liquidity management are provided by VanHoose (1991) and Angelini (1998), showing that the intraday interbank interest rate – implicitly defined as the difference between the ON rate in the "morning session" and in the "afternoon session" – is positive in equilibrium, and its level depends on the price of central bank daylight overdrafts.

Consequently we have two candidate (not alternative) explanations for the observed jump of the intraday interest rate. First, the two above alternatives are *not* perfect substitutes, particularly in times of liquidity tension: this drives the market price of intraday liquidity above the cost of an intraday loan from the central bank. Second, the cost of intraday credit from the central bank has increased during the financial crisis. Let us examine them in turn.

Since the start of the financial turmoil, the uncertainty on the availability of funds in the interbank market grew substantially. In such circumstances a risk averse bank might have a strict preference for borrowing early in the ON market rather than borrow later (relying in the meantime on the intraday liquidity from the central bank), in order to make sure that she has enough funds to achieve her end-of-day targeted liquidity position. That's why a borrowing bank might be ready to pay an implicit intraday interest rate higher than the cost of central bank daylight credit. In other words, she is willing to pay a liquidity premium on an ON loan delivered early in the day.

Angelini (2000) provides a model where risk averse banks shift their interbank trades from the afternoon to the morning, to hedge from an increased volatility of the ON rate. His model can be applied in our context, since the volatility of the ON rate did grow significantly at the outset of the crisis.[8] This can explain the preference of banks, short of liquidity, for borrowing early: they may be willing to pay a premium for an ON loan delivered early, in order to fix the price of the transaction.

Coming to the second explanation, we have to remember that the ECB does not charge any fee on intraday credit. The only cost comes from the collateral requirement: if a bank has to borrow eligible securities, she incurs in an explicit cost; to the contrary, if a bank holds eligible securities in her portfolio, she bears only an opportunity cost, as she is not free to trade such securities. Whilst the opportunity cost is hardly observable, a way to measure the explicit cost of collateral is provided by the Euribor-Eurepo spread:[9] this is the cost of borrowing eligible securities through a buy and sell back transaction, earning the Eurepo rate, and funding the deal by borrowing in the interbank market at the Euribor rate. The evidence points to a remarkable increase of the Euribor-Eurepo spread across the two reserve maintenance periods here considered. The average three-month spread goes from 7.6 bp before the liquidity crisis to 51.6 bp during the crisis[10]; the difference is statistically significant[11]. The main reason behind this jump has presumably to be found in the higher credit risk perceived by market participants. Whatever its origin, the widening of the spread

[8] The average intraday standard deviation of the ON rate was 0.074 in the second maintenance period considered in our work, compared with a 0.008 in the previous one. This goes together with a remarkable increase of day-to-day volatility: the standard deviation of daily average rates goes from 0.01 in the first period to 0.18 in the second one.

[9] Euribor and Eurepo are indexes of the interbank interest rates in the euro area, unsecured and secured respectively. They are provided by the European Banking Federation and are based on the information provided by a panel of prime banks. See http://www.eurepo.org/ for detailed information and for daily data.

[10] Standard deviations are 1.2 and 15.6 respectively. The two means are statistically significant (based on two tails t-test).

[11] The null hypothesis of equal means is rejected both by the parametric Welch two sample t-test and by the non-parametric Wilcoxon rank sum test at the 1% level.

implies a higher cost of collateral.

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