A Simple Model of Interest Rates in the Croatian Money Market

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Introduction

Money market is the heart of any national financial system. In a wider sense, its main purpose is even distribution of liquidity among economic agents, thus providing for smooth functioning of the financial leg of total economic activity. In a narrower sense, it is the market where financial institutions (most prominently - commercial banks) exchange liquidity surpluses among themselves to meet their clients' demand for liquidity. In this view, money market also plays a key role in the transmission mechanism of monetary policy as the central bank is almost the sole net provider of liquidity to the commercial banks. It also serves to preserve the stability of the financial sector of the economy, as illiquidity is often a first step to insolvency for a financial institution.

To serve its purpose to the fullest, a money market has to satisfy certain general conditions. According to Van 't Dack (1999), most central banks favour a smooth trend in key short-term interest rates and are willing to act towards reducing volatility. This is because volatile interest rates are often seen as obscuring policy signals, while more orderly market conditions are often seen as promoting a more rapid and more predictable transmission of monetary policy. Also, less volatile interest rate conditions are seen as helpful for financial institutions in better management of their exposure to market risks. Gray, Hoggarth and Place (2000) argue that most central banks consider volatility in short-run interest rates to be potentially harmful to the economy, so they choose to smooth the change in the price of money whenever possible.

With this in mind, in this paper we examine the path of price level and price volatility as measures of liquidity and risk in the most liquid segment of the Croatian money market - the inter-bank overnight loan market. Also, this market segment provides us with enough data to answer some additional questions important for an objective assessment of the state of the national money market. To this end, we employ the microstructural approach to financial market analysis, i.e. in our empirical investigation we consider the institutional arrangements for the exchange of money-market instruments in Croatia and focus on the interaction between the institutional environment and the resulting interest rate. This interaction is usually ignored by traditional economic analysis, which is concentrated on the existence of market equilibrium, without analysing how such equilibrium is actually achieved in the market.

Nevertheless, our empirical investigation is somewhat limited by lack of actual transaction data typically employed in the analysis of financial market microstructure, since our data are temporally aggregated to daily frequency. The long standing focus of Croatia's monetary policy on the exchange rate rather than on interest rates presents another challenge, as it means that there is no clear choice of the benchmark (policy) short-term interest rate in Croatia that forms the basis for the construction of the domestic yield curve. However, the introduction by the Croatian National Bank (CNB) of new monetary policy instruments and an adjustment of old ones in late 2005 (to be described later) seemed like a first step towards directing attention to the interest rates and away from the exchange rate in Croatia. Thus, this

paper comes at the right time as it makes a significant contribution to better understanding of the functioning of the Croatian money market before and after the aforementioned changes.

The paper is organized as follows. After this introduction, we provide a literature overview of the theoretical and empirical findings in the area of the (overnight) money market microstructure. Then we describe the historical development of the Croatian money market, paying special attention to description of its institutions and market players as well as to the interaction between the money market players and the monetary authority. In the fourth section we describe the general characteristics of our daily dataset, while in the fifth section we develop our hypothesis and present methods for testing them on our data. In the sixth section we present the results of our empirical investigation, and the seventh section concludes.

Literature overview

For a successful conduct of monetary policy, it is very important to understand the functioning of the money market and to be aware of the key elements that determine the money market interest rates, as well as the behaviour of the money market participants. In their study of the interbank markets for overnight loans of the major industrial countries, Bartolini et al. (2002) find that central banks' operating procedures and intervention styles have a significant impact on the short-term interest rates' day-to-day behaviour.

The available literature on money market microstructure that investigates the overnight money market segment is usually focused on few main issues. The first one is the linkage between changes in monetary policy and institutional environment and movements in the overnight interest rates [see Hartmann et al. (2001), Gaspar et al. (2004), Durre and Nardelli (2006)]. Other often discussed questions are the overnight interest rate volatility and factors that influence it [see Palombini (2002), Durre and Nardelli (2006)]; or how the overnight interest rate is affected by the liquidity management of the central bank [(see Ewerhart et al. 2003.)]. One also commonly investigated question is the existence of predictable patterns in the movements of the overnight interest rates [(see Benito et al. (2006)].

Most of the research on the Eurozone money market focuses on the connection between monetary policy instruments and procedures of their implementation and overnight interest rate. There are also many papers analysing how institutional details of the money market influence the behaviour of the overnight interest rate. The first empirical analysis of the microstructure of the euro money market was conducted by Hartmann, Manna and Manzanares (2001). They focused on the institutional environment and its implications on intraday volatility, quoting activity, trading volume and bid-ask spreads for the overnight deposits. The results of the examination show that the volatility and spreads are correlated with ECB monetary policy decisions and tend to be higher at the end of the reserve maintenance period for Eurosystem minimum reserve requirements, or on Thursdays, when ECB's interest rates decisions are released.

Gaspar et al. (2004) used the EONIA panel database which includes daily information on the lending rates applied by contributing commercial banks to show an increase in the time series volatility of the interest rates towards the end of the reserve maintenance period. They also find that the volume of trade and the use of the standing facilities are larger at the end of the maintenance period. According to Benito et al., **"end of maintenance period effect"** is a consequence of the averaging provisions to comply with reserve requirements and the **"calendar effects"** (end of month, quarter, half-year and year) could be connected with the cosmetic interventions by banks on their balances when they have to be reported to the supervisors or to the public. These two effects **will also be analysed in this paper**.

Durre and Nardelli (2006) developed a model in which they analysed the impact of changes to the Eurosystem's operational framework on the volatility of the interbank interest rate. Namely, overnight interest rates movements in the euro-area are closely connected with regular refinancing operations conducted by the European Central Bank, while the Eurosystem's key instrument for providing liquidity for the banking sector are the main refinancing operations (MROs) - (loans to the banking sector). In March 2003, ECB made some changes in the reserve maintenance period dates. Until then, reserve maintenance period used to start on the 24th calendar day of one month and ended on the 24th calendar day of the following month and it was independent of the dates of the Governing Council meetings in

which important decisions for the money market, such as interest rate decisions, are made. In order to avoid the possibility that the bid behaviour at the auctions is affected by expectations of the changes in the key interest rate in the subsequent reserve maintenance period, the timing of the reserve maintenance period was set to start on the settlement day of the MRO following the Governing Council meeting and the maturity of the MROs was shortened from two weeks to one week.

Durre and Nardelli (2006) show that the average volatility level is significantly lower under the ECB's new operational framework. Blanco and Alonso (2006) and Durre and Nardelli (2006) also showed that the volatility of very short-term interest rates in EU is not transmitted to longer-term interest rates. Cassola and Morana (2006) also showed that changes to the ECB's monetary operations framework affected only the very short end of the yield curve. The CNB introduced similar type of **changes to** its **monetary policy** operational framework during 2005. and their **influence on the money market interest rates** is one of the questions investigated in this paper.

According to Neyer and Wiemers (2003), there is a positive spread between the interbank market rate and the central bank rate as a consequence of the intermediation. The result of their theoretical analysis shows that an increase in the central bank rate leads to a likewise increase in the interbank market rate and that there is a positive relationship between the total liquidity needs of the banking sector and the interbank market rate. This relationship cannot be tested in the Croatian example, since there is no "central bank rate" in Croatia, and the recently introduced reverse repo rate that mimmicks **the official rate has no variability** needed for the econometric analysis (it is set at a constant level of 3,5%).

Ewerhart et al. (2006) write about manipulation in the money markets, considering it as a big challenge for the operational implementation of monetary policy, because it can result in increase in volatility of the overnight interest rates and could make the liquidity management more complicated, both for banks and for the central bank. They also point out that manipulation can negatively affect the market's confidence in monetary policy implementation and therefore influence longer-term refinancing conditions. That is another indication that understanding of the money market is essential for efficient monetary policy.

There is no published research that we are aware of that analyzes the microstructure of the Croatian money market in a narrow sense, or more precisely, that deals with any aspect of liquidity and efficiency of the inter-bank money market in Croatia. One brief reference to these issues is provided by Galac and Dukić (2005), who surveyed domestic commercial bankers in late 2004. Their survey showed that the **bankers** (as the most active money market participants) **found** the Croatian **money market to be very inefficient**. At that time, they had some expectations of the CNB's announced measures to reduce the volatility of money market (short-term) interest rates in 2005. However, they found the lack of longer term benchmark rates for the domestic currency, caused by the lack of government bond issues in domestic currency with longer maturities, to be even more disturbing. In such circumstances bankers relied on Treasury bill rates at issuance for short-term pricing basis, and on the imported EURIBOR rates (connected with the price of their foreign funding) for longer term pricing basis.

Money market in Croatia

The participants who can trade in the Croatian money market include banks and other financial institutions (building societies, insurance companies, investment and pension fund management companies, funds and others), the CNB and the central government through the Ministry of Finance (MF). It is possible to trade with domestic currency - Kuna (HRK) or foreign currencies, but Kuna trading absolutely dominates the market. Securities that can be traded in the money market comprise short-date securities issued in a series with a maturity of under one year, such as Treasury bills, the CNB bills, commercial papers, certificates of deposit, banker's acceptances, and long-dated debt securities with the maximum remaining maturity of one year. However, in Croatia it is common that short-term securities are traded in the stock exchange rather than in the money market.

The money market participants in Croatia can trade in two ways - via organized money market - The Zagreb Money and Short Term Securities Market d.d. (ZMM), where trading is public and relatively transparent; or directly with each other in the interbank money market without intermediaries and outside the organized market, that is over-the-counter. Most of the money market participants trade both ways.

Since its establishment in 1990, the ZMM has functioned as an organized and regulated market for public trading by the money market participants. It is regulated by the Money Market Act, while the CNB is responsible for the supervision of its activities. Its main activity is the organized matching of demand and supply of money market instruments, but in order to improve transparency and safety of the trading, it also monitors daily liquidity indicators and business results of its participants. Trading safety is enhanced by trading limits that every participant defines for its counterparties.

In February 2004, the ZMM launched SETT - an electronic trading system that enables simultaneous electronic real time trading by all participants in various money market instruments and provides all necessary information to the participants on current market situation, supply, demand and transactions. Unfortunately, the SETT system still does not function in practice, because the money market participants still prefer to make transactions by phone. One consequence is the lack of the intraday data, such as time of transaction, interest rate bids and asks, initiator of transaction, etc. that would enable more detailed analysis of the Croatian money market microstructure.

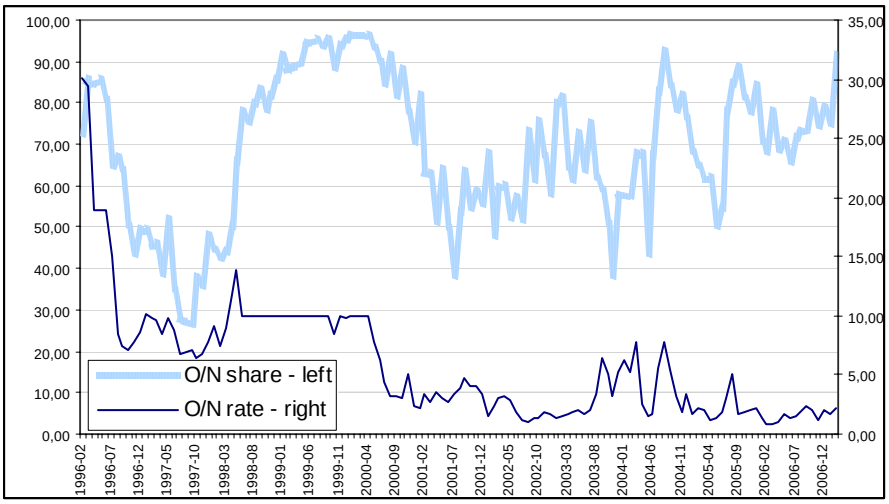
Among the money market participants, the CNB with its measures and activities, such as open market operations, changes to the reserve requirement and payment system upgrades has had the most influence on the development of the Croatian money market. Another very important money market participant is the central government. Through its Ministry of Finance it is continuously issuing Treasury bills to fund short term financing needs of the central government. At a same time, these bills represent the only acceptable collateral at reverse repo auctions held regularly by the CNB to manage the aggregate liquidity of the banking system.

There are also some other institutions that make trading in the money market possible and safe, such as the Central Depositary Agency and the Croatian Financial Services Supervisory Agency. Also important is the market initiative of the Croatian Banking Association aimed at creating benchmark interest rates on the Croatian interbank market. Beginning in 2002. ZIBOR (Zagreb Interbank Offered Rate) is published to represent a unique benchmark offered

interest rate for Kuna (HRK) on the Croatian interbank market. ZIBOR reflects the average rates of the largest Croatian banks for deposits in Kuna based on internationally recognized maturities, ranging from overnight to 6-months. The official figures are published daily on Reuters system at 11.00 local time as an ordinary arithmetic average of daily quotes for ten maturities provided by eight largest Croatian banks. However, as Galac and Dukić (2005) reveal, major money market players in Croatia do not view ZIBOR as a benchmark shortest term interest rate, as they believe that there is not enough liquidity in the domestic money market to force the realized interest rates close enough to this rate.

Historically, the development of the Croatian money market began in 1994, when the official domestic currency Kuna was introduced. But although the 90s were the period of introduction of many new and sophisticated instruments in the markets around the world, the trading in Croatian money market remained very simple (mostly concentrated in overnight loans), usually accompanied by very high interest rates. This was partly due to the fact that Croatia was in the middle of transition process with huge liquidity problems in the whole of the economy (Faulend and Šošić, 2001). The market-based efficient functioning of the Croatian money market then began much later in late 2000, while the period between 1994 and 2000 could be divided into four stages, as explained next.

Figure 1. Montly trading volumes and average interest rates in Money Market Zagreb



Source: CNB

During the first stage, the overnight interest rate was set administratively at 8,5% from August 1994 till May 1995. Then, in the second stage interest rates were deregulated and financial intermediaries were encouraged to seek higher yields. At first, newer liquid banks used this opportunity to lend money to older illiquid banks at very high interest rates, so the average annual overnight interest rates reached almost 30% till March 1996. Although the yields were extremely high, the lenders were not exposed to risk, because it was reasonable to assume that the government would not allow the failure of those systemically important banks. After the financial recovery of "old banks", this second stage of the money market development was also over.

In the third stage, between September 1996 and March 1998, money market was stable and overnight interest rates fluctuated between 7,5% and 10,5%. These tranquil times were interrupted abruptly by the emergence of huge problems in the banking system (Jankov, 2000) that caused a liquidity crunch in the money market beginning in the second quarter of 1998.

Monetary authorities reacted by setting interest rates administratively again, and at a same time guaranteeing the safety for lenders. As a result of these measures, the overnight interest rate was implicitly fixed at 10% in this fourth stage of the money market development that lasted over one year.

Thus, the true functioning of the Croatian money market then began after abandoning of the administratively set overnight interest rate in May 2000. In the last quarter of 2000, the annual overnight interest rate stabilized between 3% and 3,5%[1]. The year 2000 marked a breakpoint also in the sense that it was a period when many domestic banks were sold to foreign owners and many new instruments were introduced to the market, resulting with a significant increase in market liquidity and efficiency. This was also connected with inflows of foreign capital into the domestic banking sector and a strong deposit growth as a consequence of the introduction of Euro in the EMU.

After the year 2000, the role of the CNB in the money market kept growing continuously[2]. In the last quarter of 2002 the central bank started publishing volumes and interest rates realized in money market trading on a daily basis. Only at that time had the CNB begun collecting data from the unbrokered money market segment, despite the fact that it was relatively well known that this market segment wass much bigger in size, measured by the total trading volume. This initiative greatly increased the transparency of the domestic money market, and also enabled the central bank for the first time to analyze the effects of its policy changes on the whole of the market.

Finally, in April 2005 regular reverse repurchase agreement operations were introduced to the market, aiming to increase the effectiveness of monetary policy through decreasing the undesired volatility of interest rates in this market. The reverse repo auctions were set up as a regular and short term facility, so that liquidity injected one week is automatically withdrawn the next week. This instrument also enables banks to better manage their liquidity, since auctions are held regularly and banks are able to bid for the amount of eligible collateral. However, since money market interest rates remained almost equally volatile in the moths following the introduction of reverse repo auctions (even though the repo rate at these auctions has stabilized at a constant level of 3,5% shortly after their introduction), the central bank made further adjustments of monetary policy instruments in November 2005. The key changes involved: 1) inclusion of all calendar days in a calculation period for reserve requirement, 2) rescheduling the calculation and allocation day from the eighth day in a month to the second Wednesday in a month, and 3) increasing the symmetry of the implicit interest rate corridor by setting the interest rate in the CNB's deposit facility to 0,5% and the interest rate in the lending facility to 7,5%. This operational policy framework of the monetary policy is still in effect in mid-2007.

[1] For year-by-year details of money market conditions see Appendix 1.
[2] For details on how the monetary policy influences money market conditions, see Appendix 2.

Data description

For the construction of relevant dependent variables for our analysis, we use daily data on realized interest rates and volumes in overnight trading in the Zagreb Money Market (MMZ) from January 2001 to February 2007 and the same type of data for trading in the unbrokered inter-bank market (IB) from September 2002 to February 2007. For the independent variables in this period we distinguish among indicators of monetary policy parameters, calendar effects, liquidity conditions and interest rates expectations[3]. This section briefly describes this dataset.

The dataset is irregularly dated as it consists of the trading days only (holidays and weekends excluded). Moreover, in order to have a continuous sample, the workdays during which no trading activity took place are excluded from the dataset before performing statistical analysis (17 out of 1539 observations are excluded for the MMZ segment, and 6 out of 1119 for the IB segment). Excluded observations are marked by the variables *d_next* (*d_last*) that counted the number of trading days until (since) the next (previous) trading day (ranging from 0 to 4). Additionally, the dummy variable *mmz_not* equals 1 on the day immediately following the excluded working day with no trading activity in the MMZ market segment, and the dummy variable *ib_not* is defined analogously.

From the internal CNB data we established a calendar of important monetary policy decisions and actions, including also dates of the reserve requirement maintenance periods, of central banks' reverse repo auctions, and of T-bills and bond auctions held by the Ministry of Finance. The most important among these dates is June 6, 2005 when the first truly successful reverse repo auction was held by the central bank. The period beginning on this day is marked by a value of 1 on the dummy variable *repo* in our dataset. The next most important date is December 14, 2005, since when the banks have to satisfy their minimum reserve maintenance requirement on all days, including weekends and holidays. The period beginning with this date is labeled by a value of 1 on the dummy variable *rr_change*.

For each day in the dataset, the variable is created counting the ordinal number of any day within its reserve requirement period (*d_rrp*), the number of remaining trading days (not including the current day) until the end of the current maintenance period (*d_rrp_next*), and the elapsed number of trading days (not including the current day) since the beginning of the current maintenance period (*d_rrp_last*)[4]. In a similar manner, the number of remaining trading days until the successful reverse repo auction day (*repo_next*), until the next successful T-bill auction day (*tbill_next*) and until the next government bond issue day (*knbond_next*), are assigned to their respective count variables, starting with a date at an average number of days prior to the first occurrence of such events in the dataset.

Some other possible "calendar effects" often studied in the literature are captured by the dummy variables marking ends of calendar months, quarters, and years (*ld_m*, *ld_q*, and *ld_y*). Also, for each day, the ordinal number reflecting its position within the current week (1 to 5) and the current month (1 to 31) is assigned to the appropriate variable (*d_w* and *d_m*). An additional calendar feature is captured by the variable *repo_last*, equal to one on days following the last reverse repo operation until the last day of the current reserve requirement maintenance period. Finally, the dummy *pensions* equal 1 on just one day during each month

[3] For the table with independent variables and the calendar of monetary policy actions see Appendix 3.
[4] Note that by construction d_rrp_next=0 marks the last day of the reserve requirement period, while d_rrp_last=0 and d_rrp=1 both mark the first day of the reserve requirement period.

(beginning in September 2003) during which the government borrows very heavily directly in the money market to meet its monthly social pensions payout obligation.

Relevant interest rate variables include carefully selected leads and lags of various benchmark rates. Among policy rates we record the CNB's deposit facility rate (*cnb_dep*), lending facility rate (*cnb_lend*) and the target policy rate (*cnb_repo*), in the short period since their introduction in mid-2005. Also, apart from the possible liquidity premium over the shortest rate that they generate, interest rates on the risk-free T-bills should also influence interest rate expectations to the extent that they are predictable themselves. In the absence of daily trading data, we use volume-weighted interest rates realized in regular T-bills auctions, with maturities of 91, 182 and 364 days (*tb91ir*, *tb182ir* and *tb364ir*). In order to control for possible money market integration effect, data on the benchmark EMU interbank rate (*eonia*) are also included in the dataset.

To assess the (banks') liquidity condition on any given trading day we compute several indicators based on the amount of money carried in banks vaults and central bank accounts relative to the minimum average balance of these funds required at the end of the last day of the relevant reserve maintenance period. The main indicator watched by the central bank daily and published monthly, the so called "free money", is labeled *bfr* (banks' free reserves) in our dataset. We calculate it from the total Kuna reserve requirement (*krr*), its portion allocated to the special account at the central bank (*akrr*) and the portion that is maintained jointly in banks' vaults and transaction accounts (*mkrr*) in the following manner:

$$BFR_t = \sum_{i=t-D\_RRP+1}^{i=t} (MKRR_i + AKRR_i - KRR_i)$$

Regarding dependent variables, overnight interest rate in each market segment (*mmz_onir* and *ib_onir*) for each day is calculated as the volume-weighted average of the interest rates realized on trades closed during that day. Aggregated trading volumes of trades realized during a day (*mmz_ont* and *ib_ont*) are expressed in millions of the domestic currency (Kuna). Additionally, we use the daily data on the reported aggregate demand (*mmz_d*) and supply (*mmz_s*) of liquidity surpluses in the MMZ (also expressed in millions of Kuna). As usual in the literature, daily interest rate volatility is calculated from the above variables in two ways: as the square change and as the absolute change of the interest rate relative to the previous workday with recorded trading activity. For ZMM, volatility measures are labeled *mmz_onir_abs_ch* and *mmz_onir_sqr_ch*. Analogous labels for the unbrokered interbank market are *ib_onir_abs_ch* and *ib_onir_sqr_ch*.

Basic descriptive statistics for the dependent variables are presented in Table 1. It follows that the IB market segmet is much larger in volume terms, and that the overnight interest rate is slightly higher and slightly less volatile in this market segment. This could easily be a microstructural consequence of the fact that small banks trade equally in both market segments, while large banks trade almost exclusively in the IB segment[5]. So, a larger trading volume in the IB market creates more liquidity and less interest rate volatility, while a slightly higher interest rate could probably be interpreted as compensation for a higher positional risk of lenders in this market. Also, there is a reason to believe that the trading volume and the interest rate in the MMZ segment are largely predetermined by the developments in the IB segment. So, in the remainder of this paper we focus on analyzing the interest rate movements

[5] This fact was verified for 2002-2007 period using CNB's bank-by-bank money market data not reported here.

in the IB market segment[6], which also means that we use the slightly shorter sample covering data from Sep. 2, 2002 to Feb. 13, 2007.

Table 1. Dependent variables – descriptive statistics

	mmz_onir	*mmz_ont*	*mmz_onir_abs_ch*	*ib_onir*	*ib_ont*	*ib_onir_abs_ch*
Mean	2.745007	80.69021	0.779343	2.982407	351.0725	0.767552
Median	2.105000	68.60000	0.380000	2.169789	310.0000	0.290902
Maximum	10.00000	344.0000	7.500000	10.39989	1425.000	8.359808
Minimum	0.000000	0.000000	0.000000	0.200000	0.000000	0.000146
Std. Dev.	2.005386	57.93448	1.016822	2.443665	239.5345	1.143743
Skewness	1.387909	0.989927	2.407844	1.383473	0.905262	2.611092
Kurtosis	4.337852	4.030443	10.32528	3.981907	3.873894	11.01395
Jarque-Bera	602.1423	319.4471	4825.577	399.7586	188.4437	4212.567
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	4177.900	124182.2	1174.470	3319.418	392850.1	848.1446
Sum Sq. Dev.	6116.812	5162149.	1557.095	6640.308	64147235	1444.196
Observations	1522	1539	1507	1113	1119	1105

Source: CNB

In this period, the interest rate variable *ib_onir* fails to pass the ADF unit root test without an intercept and a trend included in the test regression at the 1% significance level. So, to be on the safe side, in the remainder of this analysis we look at the daily change in the interest rate $ib\_onir\_d=ib\_onir_t-ib\_onir_{t-1}$ between two consecutive trading days with recorded overnight activity in the IB market. The correlogram of the *ib_onir_d* series clearly shows mean-stationarity. It also appears to show a strong relatively high order moving average pattern in conjunction with a pronounced non-linear weekly pattern (highly negative autocorrelation on lags 1 and several multiples of 6, together with a high positive partial autocorrelation on lags 1 to 5, and several multiples of 5). Therefore, some complex univariate time series effects on the mean of *ib_onir* are not eliminated by differencing.

The transformed interest rate variable *ib_onir_d* has a very peaked and right fat-tailed reasonably symmetrical empirical distribution around zero as found in most financial time series. Its time series shows alternating periods of high and low variability around the zero level, pointing towards the conditional heteroscedasticity. Moreover, the correlogram of the squared *ib_onir_d* displays very strong positive partial autocorrelations on most lags up to lag 5, but also significant positive autocorrelations at relatively high lags. All this indicates that higher order GARCH effects may be present in the autocovariance structure of the *ib_onir_d* variable. Also, positive (*_poz*) and negative (*_neg*) changes of *ib_onir_d* do not seem to come from the same distribution, as positive changes greater than 6 points are significantly more common, than negative changes, whereas in the neighborhood of 4 points negative changes are significantly more common, indicating a possible asymmetric GARCH structure. Basic statistics related to the overnight interest rate in the IB market are presented in Table 2.

[6] The Eviews output of the IB market analysis that follows is presented in the Appendix 4.

Table 2. Overnight IB market segment interest rate – descriptive statistics

	ib_onir	*ib_onir_d*	*ib_onir_d_neg*	*ib_onir_d_poz*	*ib_onir_sq_ch*	*ib_onir_abs_ch*
Mean	2.982407	0.001461	0.385238	0.386699	1.920497	0.771937
Median	2.169789	-0.054273	0.054273	0.000000	0.085865	0.293026
Maximum	10.39989	8.359808	6.839910	8.359808	69.88639	8.359808
Minimum	0.200000	-6.839910	0.000000	0.000000	2.12E-08	0.000146
Std. Dev.	2.443665	1.386443	0.849649	0.949795	5.721847	1.151435
Skewness	1.383473	0.452773	3.668569	3.795770	5.672898	2.598633
Kurtosis	3.981907	9.866693	18.65878	20.57036	45.65801	10.87137
Jarque-Bera	399.7586	2222.679	13855.11	16974.17	90277.39	4122.278
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	3319.418	1.625049	428.3847	430.0097	2135.593	858.3944
Sum Sq. Dev.	6640.308	2135.590	802.0340	1002.244	36373.62	1472.966
Observations	1113	1112	1112	1112	1112	1112

Source: CNB

Just examined times series properties of *ib_onir_d*, together with some calendar effects exposed next, will be used in the next section of this paper to model the behavior of the overnight interest rate in the IB segment of the money market, to the extent that this behavior cannot be modeled by structural variables (examined next) representing economic effects expected to actually directly affect the movements of this interest rate. The analyzed univariate calendar effects[7], can be summarized as follows:

1) the median interest rate would markedly rise on mondays and fall on fridays until the final revision of the monetary policy operational framework of Dec. 2005 (i.e. *d_w* = 1 and *d_w* = 5 mean effects are observed under *rr_change* = 0);
2) the median interest rate would rise on both days prior to the reverse repo auction and fall on the day of the auction until the final revision of the monetary policy operational framework of Dec. 2005 (i.e. separate *repo_next* = 0 , 1, 2 mean effects are observed under *rr_change* = 0);
3) the median interest rate rises mildly on the day of the heavy government borrowing (i.e. *pensions*=1 mean effect is observed);
4) the median interest rate rises sharply one day before the T-bill auction (i.e. *tbill_next*=1 mean effect is observed);
5) the median interest rate markedly rises on the first day of the required reserve maintenance period (i.e. *d_rrp* = 1 mean effect is observed);
6) the median square change of the interest rate only fell after the final revision of the monetary policy operational framework of Dec. 2005, while the sole introduction of reverse repo auctions actually increased it (*rr_change*=1 and *repo*=1 volatility effect is observed);
7) the median square change of the interest rate and its dispersion were higher on mondays and on fridays until the final revision of the monetary policy operational framework of Dec. 2005 (i.e. *d_w* = 1 and *d_w* = 5 volatility effects are observed under *rr_change* = 0);

[7] Graphical analysis of all calendar effects is presented in Appendix 5.

8) the median square change of the interest rate and its dispersion were significantly higher 2-3 days prior to the reverse repo auction until the final revision of the monetary policy operational framework of Dec. 2005 (i.e. separate *repo_next* = 2 and 3 volatility effects are observed under *rr_change* = 0);
9) the dispersion of the median square change of the interest rate is higher 1-2 days prior to the T-bill auction (i.e. *tbill_next* = 1 or 2 volatility effects are observed);
10) all other calendar events don't appear to have influence on the interest rate change and its volatility, including end-of month, quarter and year effects, and the distance to the day on which the government issues a Kuna denominated bond;
11) many of the analyzed effects are byproducts of other effects and are not reported above (e.g. the unreported *d_last* = 2 with *rr_change* = 0 is almost entirely due to the *d_w* = 1 with *rr_change* = 0 effect, as occasions with two consecutive non-trading days that are due to holidays and not due to a weekend are extremely rare);
12) even some of the reported effects may prove redundant in a multivariate environment (e.g. the reported *tbill_next*=1 mean effect may be entirely due to the *d_w*=1 mean effect, as T-bill auctions are regularly held on Tuesdays).

In the last part of the data section of this paper we turn to the presumed structural variables, measuring or approximating market liquidity and interest rate conditions and expectations. It is well established in the economic literature that tomorrow's price of an asset should be mostly unpredictable based on today's information available to those who could profit from it. Thus, only contemporaneous and future information should influence the price, which means that only "ex-post" prediction of prices should be possible in practice. In our data set, such information is contained in *ib_onir_d* series itself as well as in time series of banks' free reserves (*bfr*), total Kuna reserve requirements (*krr*), IB market overnight trading volumes (*ib_ont*), MMZ market overnight trading volumes (*mmz_ont*), MMZ market bid (demand) volumes for all maturities (*mmz_d*), MMZ market ask (supply) volumes for all maturities (*mmz_s*), lending volumes in the reverse repo auctions (*repo_bil*), volumes of T-bill auctions (*tb91*, *tb182* and *tb364*), interest rates of T-bill auctions (*tb91ir*, *tb182ir* and *tb364ir*), and EMU overnight interest rate benchmark (EONIA).

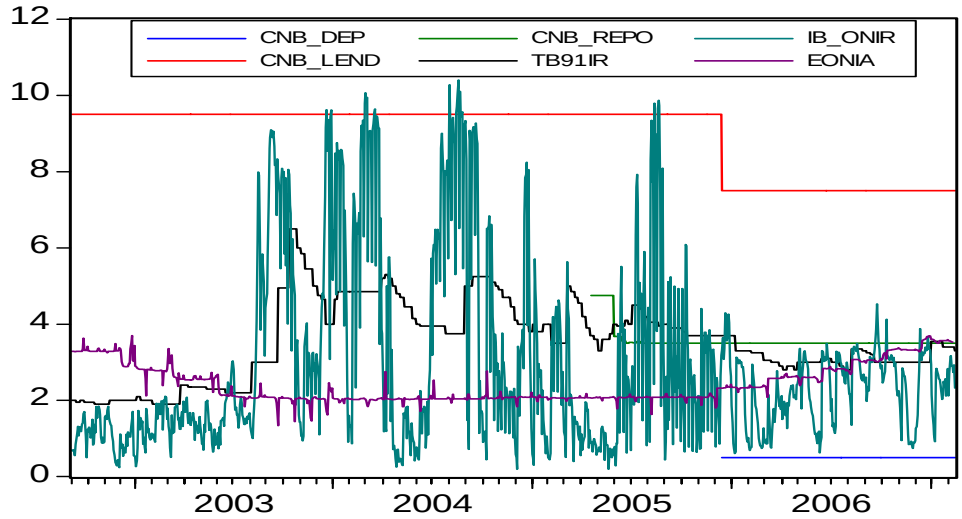
Structural relationship between interest rates in the analyzed period is immediately obvious from Figure 2 and the discussion in the previous section of this paper. The lending facility rate (*cnb_lend*) presents a ceiling on the IB market overnight interest rate (*ib_onir*) until some time between Summer of 2005 and the final revision of the monetary policy operational framework in December of 2005, when this role is overtaken by the reverse repo rate (*cnb_repo*). There are two inseparable causes of the delayed reaction of banks to the repo rate's ceiling role: 1) it took time for the CNB to build the credibility of its reverse repo facility in a sense that banks are assured that the liquidity shortages will be met by the reserve supply at a fixed interest of 3,5%, while at a same time speculative recourse to the deposit facility (overbidding) will be penalized by rejection of some portion (or all) of bids at reverse repo auctions, and 2) it was only after the final revision of the monetary policy operational framework that the first day of the required reserve maintenance period coincides with a reverse repo auction, eliminating the banks' uncertainty about the ability to meet the reserve allocation requirement at the beginning of the next maintenance period.

The ceiling role of the two interest rates should not be taken literally, because there is a limit on the number of days during a month for the use of the CNB lending facility, and there is a possible accumulation of liquidity shocks between two reverse repo auctions. Also, it should be noted that before the introduction of the CNB deposit facility, the interest rate floor was

zero, while in the latter period this role is performed by the CNB deposit facility rate (*cnb_dep*). Thus, an error correction mechanism should be at work, the one that quickly returns overnight interest rates within their natural bounds *cnb_repo* and *cnb_dep*. It is clear that after the introduction of reverse repo auctions, this correction period should be shorter than a week, but this should also hold for the earlier period, because the T-bills that matured every week provided the necessary cushion during that time.

As far as the other two interest rates considered are concerned, it appears that there are no money market EU integration effects in the observed period, nor is the overnight rate influenced by the developments in the government finances. Namely, there appears to be no correlation between the overnight rate in the IB money market and the EMU overnight reference rate (*eonia*), while the price that the government is paying for its shortest term financing (*tb91ir*) appears correlated with lagged values of the interest rate prevailing in the overnight IB market. Finally, considering the lack of interest rate derivatives market and the previously described rudimentary interest rate channel of monetary policy in Croatia, it is difficult to construct any reasonable interest rate expectation variables. It can only be conjectured that the net increase in banks' 91-day T-bill holdings on the day of a T-bill auction indicates an expected fall in the money market interest rates (prior to this net increase!) bellow this T-bill's rate, and vice versa - but these daily data are not available to us. Similarly, the net increase in the outstanding banks' borrowings at the reverse repo window on the day of a reverse repo auction may indicate an expected rise in the money market interest rates over 3,5% (prior to this net increase!).

Figure 2. Daily IB and CNB rates with last reverse repo and T-bill auctions rates



Source: CNB

Regarding the dependence of the overnight money rate on the liquidity conditions (of banks), it is necessary to separate current and expected liquidity condition variables, as well as observable and unobservable variables, from the perspective of those trading in the overnight market, primarily the banks. In this view, banks free reserves (*bfr*) are a daily measure of banks' liquidity unobservable to banks and observable to the central bank (with one day's lag), which is necessary for the credibility of reverse repo auctions as explained in the previous paragraph. Banks can only discern current aggregate liquidity situation from the lagged values of overnight money rates (*ib_onir*, *mmz_onir*), corresponding trading volumes (*ib_ont*, *mmz_ont*), the registered demand and supply (total, not just overnight) in the smaller MMZ

market segment (*mmz_d* and *mmz_s*) and from the total volume of bids accepted at regular reverse repo auction (*repo_bil*), that are all published with a one day lag.[8]

On the other hand, it is reasonable to assume that the future demand for liquidity on the first day of the next reserve maintenance period is relatively predictable. In particular, banks monitor their reserve requirement calculation base daily, and the CNB always announces changes to the reserve requirement calculation parameters well in advance (calculation base coverage, general required reserve rate, Kuna portion of the foreign currency based required reserve rate, maximum maintenance to allocation ratio, remuneration interest rate). Thus, the future value of the total Kuna denominated required reserve (*krr*) as well as its allocation (*akrr*) and maintenance (*mkrr*) portions are known in advance.

Banks can combine their knowledge of future required reserves with the discerned current liquidity conditions of the previous paragraph to minimize their costs of borrowing (lending) the deficit (surplus) funds in targeting the zero (desired) level of free reserves on the first day of the next maintenance period, conditional on the quality of their "model" for assessing aggregate current liquidity conditions. Given that changes in banks' strategies regarding the path of their individual *bfr*s during the course of the maintenance period are immediately reflected in *ib_onir* via demand or supply of their free reserves in the overnight market, we do not analyze leads of the *krr* time series (nor the associated announcements of the reserve requirement operational changes) any further.

Returning to the dependence of the overnight interest rate on aggregate free reserves as the most important structural variable, it appears from Table 3 that this relationship is rather complex and nonlinear[9]. This follows from the fact that the correlation between *ib_onir_d* and several lagged series of public information is higher than the correlation between *ib_onir_d* and lagged *bfr*. But, more importantly, the sign of the correlation between *ib_onir_d* and most of the lagged variables in Table 3 is "wrong", including the sign on the correlation of *ib_onir_d* and some sensible non-linear transformations of lagged *bfr* that do exhibit high correlations with *ib_onir_d* (first two rows of Table 3). It is possible that these correlations are just a byproduct of the high negative autocorrelation of *ib_onir_d* series (last row of Table 3) that is typical for daily and higher frequency economic data. Thus in the next section of this paper we turn to modeling the overnight interest rate in the IB market in a more realistic multivariate setting.

Table 3. Correlations between *ib_onir_d* and selected structural variables

Positively correlated variables::	*ib_onir_d*	Negatively correlated variables:	*ib_onir_d*
bfr(-1)**d_rrp*(-1)/(*d_rrp_next*(-1)+1)	0,22	*log*(*repo_bil*_LAST(-1))	-0,05
bfr(-1)/(*d_rrp_next*(-1)+1)	0,21	*dlog*(*mmz_d*(-1))	-0,07
dlog(*mmz_s*(-1))	0,07	*log*(*ib_ont*(-1))	-0,10
bfr(-1)**d_rrp*(-1)	0,05	*dlog*(*mmz_ont*(-1))	-0,13
log(*mmz_s*(-1))	0,05	*log*(*mmz_d*(-1))	-0,13
dlog(*repo_bil*_LAST(-1))	0,01	*log*(*mmz_ont*(-1))	-0,18
dlog(*ib_ont*(-1))	-0,02	*d*(*mmz_onir*(-1))	-0,31
bfr(-1)	-0,03	*ib_onir_d*(-1)	-0,33

Source: CNB

[8] In reality, banks can also view trading volumes and interest rates realized in money market trading with longer maturity loans in both market segments, but we viewed these data as superfluous in the existing data set. Also, banks' dealers receive a stream of private information from flows of orders during the day, that may be much more important for the formation of the interest rates, but this information is unobservable to all others.

[9] In Table 3, a series of changes in a [log of] series named s lagged by t periods is denoted as d[log](s(-t)).

The modelling exercise[10]

Our modelling strategy is general to specific, beginning with the univariate time series model (Model 1) that adequately describes most of the standard time series properties of the daily change in the IB market overnight interest rate described in the previous section: its complex ARMA structure and a higher order asymmetric GARCH process in its conditional volatility. Such a model is then sequentially appended by appropriate variables representing the observed calendar effects, both in the level and in the conditional volatility of the interest rate changes. Based on the observed changes to t-statistics of the entered variables at each step, a more parsimonious model containing both time series elements and calendar effects is chosen in a stepwise manner (Model 2). Finally, this model is sequentially completed by a battery of carefully constructed structural variables, representing floors and ceilings on the interest rate, as well as current and past liquidity conditions, and reserves supplied and absorbed by the central bank and the government. The parsimonious representation of this model is again chosen based on the sequence of changes to individual t-statistics of the entered variables at each step, with a hope but without a bias towards replacing some of the non-structural (time-series and calendar) variables by their structural counterparts (Model 3).

As expected, Model 1 is a rather complex ARMA-EGARCH(1,2) model with residuals of the (log-)variance equation following the Student's t distribution with 2,38 degrees of freedom. The included AR(5), AR(10) and AR(20) terms model high autocorrelations at the respective lags, while MA(1) term makes the model more parsimonious. Despite its complexity, the model accounts for only 23% of the total variation of the *ib_onir_d*. What is even more disturbing is that the constant is significantly negative, and not all autocorrelation has been accounted for. Any attempt with a simpler model gives a much poorer performance that far outweighs the gain in parsimony, while a richer ARMA structure does not deliver a significantly improved fit. The only characteristic that is modelled fully adequately by this model is conditional heteroscedasticity of the series. Based on the above observations, it appears that this model is as far as one can go by univariate modelling of the interest rate changes in the IB market. The model specification is as follows:

$$ib\_onir\_d_t = -0.06 + 0.20\ ib\_onir\_d_{t-5} + 0.14\ ib\_onir\_d_{t-10} + 0.05\ ib\_onir\_d_{t-20} - 0.12\ u_{t-1} + u_t$$

$$u_t = \sigma_t^2 e_t \text{ with } e_t \sim t(2,38)$$

$$\ln(\sigma_t^2) = -0.39 + 0.85\ |u_{t-1}/\sigma_{t-1}| - 0.34\ u_{t-1}/\sigma_{t-1} + 0.19\ u_{t-2}/\sigma_{t-2} + 0.45\ \ln(\sigma_{t-1}^2) + 0.49\ \ln(\sigma_{t-2}^2)$$

Gradually adding the calendar effects to Model 1 specification does reduce its initial ARMA structure while the GARCH structure remains intact, and the distribution of residuals becomes even more leptokurtic. Among the calendar effects listed in the data description section, only one observed mean calendar effect (tbill_next=1) is not significant in the mean equation, and two observed variance calendar effects (d_w=1 and repo_next=3, both under rr_change=0) are not significant in the (log-)variance equation. The constructed Model 2 shows a significantly better in-sample fit from Model 1, as 37% of the total variation of the *ib_onir_d* is accounted for. This reduction is achieved primarily by a better fit to distant lags of the model's residuals. However, the model constant remains significantly different from zero, and

[10] All models are estimated using standard Eviews package. Estimation outputs are given in Appendix 7.

still not all of low order autocorrelation has been fully eliminated from the residuals. The model specification is as follows:

$$ib\_onir\_d_t = -0.06 + 0.07\ ib\_onir\_d_{t-5} - 0.45\ (d\_w=5)(rr\_change=0) + 0.47\ (d\_w=1)(rr\_change=0) + d\_rrp=1 - - 0.61\ (repo\_next=0)(rr\_change=0) + 0.46\ (repo\_next=1)(rr\_change=0) + 1.05\ (repo\_next=2)(rr\_change=0) + + 0.22\ (pensions=1) - 0.14\ u_{t-1} + u_t$$

$$u_t = \sigma_t^2 e_t \text{ with } e_t \sim t(2,91)$$

$$\ln(\sigma_t^2) = -0.94 + 0.79\ |u_{t-1}/\sigma_{t-1}| - 0.25\ u_{t-1}/\sigma_{t-1} + 0.24\ u_{t-2}/\sigma_{t-2} + 0.71\ \ln(\sigma_{t-1}^2) + 0.18\ \ln(\sigma_{t-2}^2) + + 0.3\ (repo=1)(rr\_change=1) + 2.01\ (d\_w=5)(rr\_change=0) + 0.72\ (repo\_next=2)(rr\_change=0)$$

Finally, adding some structural variables to Model 2 improves a bit further the model's overall fit to 40% of explained total variance of *ib_onir_d*, while at a same time the model becomes significantly simpler. First, the *pensions* dummy and the moving average term fall out of the mean equation, while the model's constant is finally indistinguishable from zero. Second, the variance equation loses both the second order leverage effect (asymmetry) and the second lag of the conditional variance, so that a much simpler autocovariance structure emerges. The just described model specification of our Model 3 is given by:

$$ib\_onir\_d_t = -0.02 + 0.13\ ib\_onir\_d_{t-5} - 0.5\ (d\_w=5)(rr\_change=0) + 0.5\ (d\_w=1)(rr\_change=0) + + 1.77\ (d\_rrp=1) - 0.41\ (repo\_next=0)(rr\_change=0) + 0.3\ (repo\_next=1)(rr\_change=0) + + 1.29\ (repo\_next=2)(rr\_change=0) + 0.06\ (tb91ir_{t-1} - ib\_onir\_d_{t-1}) - 0.01\ d\_rrp_{t-1} bfr_{t-1}/1000 + u_t$$

$$u_t = \sigma_t^2 e_t \text{ with } e_t \sim t(2,83)$$

$$\ln(\sigma_t^2) = -0.68 + 0.4\ |u_{t-1}/\sigma_{t-1}| + 0.22\ u_{t-1}/\sigma_{t-1} + 0.93\ \ln(\sigma_{t-1}^2) + 0.34\ (repo=1)(rr\_change=1) + + 2.07\ (d\_w=5)(rr\_change=0) + 0.55\ (repo\_next=2)(rr\_change=0)$$

Model 3 confirms in a multivariate setting some of the conclusions of the data analysis from the previous section of this paper. Most importantly, in the period after Dec. 13, 2005, the size of the expected overnight interest rate changes in the IB market is mostly influenced in an anticipated manner by structural variables such as a reasonable nonlinear transformation of the free reserve variable and the spread of the 91-day T-bill rate over the overnight interest rate (all lagged one day). This also means that the central bank is at advantage in forecasting tomorrow's overnight rate, since it has knowledge of aggregate banks' free reserves lagged one day, while banks know only their own free reserves. One billion Kuna of free reserves scaled up by the length of the elapsed time since the beginning of the reserve maintenance period reduces the next day's expected interest rate change by 1 basis point in Model 3. Similarly, one percentage point deviation from 91-day T-bill rate adds 6 basis points to this expected change in the opposite direction of the deviation.

One very famous feature of the market confirmed by Model 3 is that before the final revision of the monetary policy operational framework of Dec. 2005, the expected interest rate change would be about half percentage point higher on Mondays, and about half percentage point lower on Fridays, than on other three days of the week, other things being equal. Also during that period, but after the stabilization of reverse repo auctions in June 2005, expected interest rate change is another 1.29 percentage points higher on Monday before the auction (on top of the half percentage point Monday-effect for the whole period before Dec. 2005). This effect is

only partially reversed on the day of the auction when a 41 basis points smaller change is expected. The only other effect that measures up in size to the Monday effect is the effect of the reserve maintenance period start date. On that day, and on that basis alone, the expected change in the interest rate is as much as 1.77 percentage points higher than on any other day in the whole dataset. Finally, the only surprise in Model 3 is to be found in its conditional variance equation that indicates a rise in the conditional variance in the last part of the dataset after the final revision of the monetary policy operational framework of Dec. 2005. We believe it possible that the entire contribution of the previous period to the conditional volatility series is already accounted for by the "monday before repo auction" and the "friday before the operational framework revision" effects, that are both included in the conditional variance equuation.

To summarize, we are able to build a relatively parsimonious model that accounts for over 40% of variability in daily changes of the overnight interest rate in the IB segment of the Croatian money market. The mean equation of the model contains two structural variables and six calendar effects, some of which could also be considered as structural, while it contains only one time series component that is apparently associated with the regular weekly pattern of the changes. The modelling exercise strongly confirms perverse day-of the week effects on the expected interest rate change in the period prior to the final revision of the monetary policy operational framework of Dec. 2005. The model also says that in that same period the calendar effects are reinforced by the effects of the reverse repo auction timing, so that expected interest rate change is even greater shortly before the reverse repo auction (i.e. on a Monday after the introduction of the reverse repo auctions), and smaller on the day of the auction (Wednesday). The finally selected model gives an upper hand in the shortest term prediction of the interest rate movement to the central bank due to its private information on one of the only two permanent structural effects - banks' free reserves. It also stipulates that absent other stronger influences, this interest rate will slowly move towards the 91-day T-bill rate, as might have been expected.

Conclusion

As set out at the beginning, in this paper we analyzed the interest rate formation process in the Croatian money market, to assess its efficiency and to provide a solid basis for inevitable further research in this area. We have shown that even though, historically, the development of the Croatian money market began in 1994, it was only after abandoning of the administratively set overnight interest rate in May 2000 that it became truly market-based. Moreover, it was not until the last quarter of 2002, when the central bank started publishing market information on a daily basis, that the market became fully transparent. Thus, there is nothing to say about the money market efficiency in Croatia prior to late 2002.

Exploiting the market transparency, we compiled a dataset that enabled us to analyze more formally the efficiency of the Croatian money market in the period from late 2002 to early 2007. We have shown that the larger of the two money market segments, the unbrokered interbank market, was not very efficient in a narrow sense, until the final revision of the monetary policy operational framework of Dec. 2005. This inefficiency was most prominently displayed by a rather high degree of predictability of the overnight interest rate changes in this market in that period. We have analyzed this predictability in some detail, and shown how after the indicated time period it has vanished.

Factors that will influence further development of the Croatian money market in the following period are closely connected with the changes in regulations due to the harmonisation with acquis communautaire of the EU, and especially with the new Markets in Financial Instruments Directive (MIFID), which defines new regulations for business with financial instruments. Strong capital inflows from abroad, mostly in a form of foreign direct investments, will also have a very important role in the money market, as well as the introduction of new, sophisticated instruments widely used in the markets around the world, encouraged by new technologies and improved legislation. It should all result in higher velocity of the money in payment system channels. In such an environment, the liquidity management should be more complex and the role of the central bank in the money market should increase further.

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Appendix 1: Monetary policy and money market in Croatia, year by year

Stable or predictable money market conditions are nowadays considered an important ingredient of an efficient monetary policy transmission mechanism. That is why most central banks have begun to pay much more attention to stable day-to-day, and sometimes even intraday, market conditions. The money market is affected by actual monetary measures introduced by the central bank, but it is also influenced by the expectations of money market participants about future central bank actions in this respect. Over the past few years, there have been several very significant changes in the monetary policy operational framework in Croatia, some of which were aimed at achieving stable money market conditions, and some of which unintentionally disturbed them.

The functioning of the Croatian money market de facto began only after abandoning of the administratively set overnight interest rate in May 2000. After that time the non-administrative role of the CNB in the money market started increasing. By 2001, economic environment was marked by the intensification of the credit growth helped by the considerable increase in all monetary aggregates and the credit activities of banks. Liquidity of the banking system was high during the whole year and interest rates were on a downward trend, but still very volatile. The trend changed when banks decided to reduce their CNB bills and Treasury bills holdings and increase their foreign exchange investments abroad, that resulted with an interest rates increase. In that period Kuna CNB bills auctions, used by the central bank to affect the level of liquidity in the system, were the most flexible and most efficient monetary policy instrument.

Entire 2002 was marked by high Kuna liquidity and considerable increase in already high primary liquidity of the banking system. This was a consequence of a strong growth of foreign exchange supply in the domestic market due to the Euro changeover effect, which forced central bank to intervene and create needed Kuna liquidity. The year 2002 was also the year when the payment system reform[11] in Croatia was successfully completed. This stimulated a high liquidity of the banking system during that year, as banks held on to precautionary reserves in the form of vault cash because of the uncertainty related to the effects of this reform on their daily cash management. The result was low and stable money market rates during entire 2002. Like in 2001, the most important instrument for sterilising the liquidity created through foreign currency purchases were Kuna CNB bills.

At the beginning of 2003, the CNB for the first time introduced an administrative ceiling on banks' credit growth and an administrative floor on the foreign currency liquidity reserves. These new measures led to a reduction in the primary liquidity of banks in the second half of the year and consequently to higher interest rates in the money market in that period. As Kuna liquidity creation through foreign exchange transactions decreased, banks ensured the needed liquidity through redemption of the matured CNB bills denominated in Kuna, accumulated during the previous period of high liquidity.

In the second half of 2003, monetary policy tightening continued and demand for Kuna liquidity strengthened further as a consequence of the increased Kuna portion of the reserve requirement allocation in September, and then again in November, resulting with a reduction in the banking system Kuna liquidity followed by a sharp increase in money market interest rates. Due to the introduction of the central bank's measures to reduce the banks credit

[11] http://www.hnb.hr/platni-promet/e-nacionalni_klirinski_sustav.htm?tsfsg=584c6b6ac3380715e34f739d2132d2e7

activity, during the first three quarters in 2003 there was a significant drop in surplus Kuna liquidity of banks from above HRK 10 bn to below HRK 1,5 bn and the corresponding increase in the annual average overnight ZMM brokered loan rate from less than 1,5% in 2002 to more than 6% in 2003.

Beginning with 2003, the deficit of free Kuna liquidity reserves in the market would normally push the overnight interest rates over 9%, while the surplus of Kuna liquidity in the market would usually result with overnight rates falling below 2%. That period is also special for it was the first time that a transmission of high volatility in the money market rates to the interest rates on the short-term bank deposits was observed. That presented a very strong case, otherwise well known by active market participants, that the domestic financial market lacks a benchmark (policy) short-term interest rate.

In 2004 monetary policy tightening continued, and market instruments began giving way to more administrative measures, as the CNB became less able to combat the trend of virtually unlimited inflow of liquidity surpluses from the EU to less developed financial markets in a search for a higher yield. The required reserve averaging was made stricter, and the connected lending was effectively barred (it dictated a 100% required reserve) while the use of Lombard loans was limited to only five days per month. Central bank also stopped issuing foreign currency denominated CNB bills and effectively stopped issuing Kuna denominated CNB bills by refusing to increase their interest rate in order to discourage further capital inflows. In July 2004 the CNB imposed a marginal reserve requirement on banks' foreign borrowing.

Continuing the trend from second half of 2003, interest rates fluctuated strongly in 2004. Apart from monetary measures, the strongest influence on the interest rates and banking system liquidity in 2004 came from foreign exchange interventions. The overnight interest rates kept at relatively high levels early in the year and they gradually declined in the middle of the year. Owing to the tourist season they increased again and remained higher till September, when banking system liquidity recovered. Money market rates then remained relatively low until the year-end. The absence of possibility for banks to ensure the needed Kuna liquidity or to place their surplus Kuna liquidity through regular channels resulted in very volatile interest rates that would significantly increase with every beginning of the reserve requirement maintenance period.

Foreign exchange interventions and reverse repo operations were the main channels for reserve money formation and the source of the needed Kuna liquidity in 2005. Economic environment was characterised by faster economic growth and a large inflow of foreign capital, while monetary policy was marked by a systematic implementation of measures for slowing down external debt growth. In that period, CNB introduced several new measures and a significant refinement of monetary policy instruments. The rate of marginal reserve requirement was raised in February and in May 2005, and the coverage base was broadened. In order to increase the central bank's ability to manage banking system liquidity, the CNB has redesigned and improved its set of monetary policy instruments in April 2005. That is the time when regular reverse repurchase agreement operations were introduced to the market, aiming to increase the effectiveness of monetary policy and to decrease undesired volatility.

The reverse repo auctions were set up as a regular and short term facility, so that liquidity injected one week is automatically withdrawn the next week, allowing the central bank better control over the level of liquidity in the banking system by choosing what proportion of the bids received to accept and by determining the interest rate at the auction. This instrument

also enables banks to better manage their liquidity, since they are held regularly and banks are able to bid for the amount of eligible collateral. One of the goals that the introduction of reverse repo auctions was hoped to achieve is the formation of a benchmark short term interest rate.

At the beginning of the year, Kuna liquidity was very high, while a precondition for a meaningful introduction of reverse repo operations was to create a liquidity deficit to boost banks' demand for additional funds. This was hoped to be helped by an increase in the Kuna portion of the reserve requirement, and by the summer season of higher demand for cash. Despite these developments, the Kuna liquidity remained high, and banks only made use of the interest-free intra-day loans within the limits in their settlement accounts (in addition to reverse repo auctions, the CNB introduced a deposit facility and an intra-day credit facility, at the same time). So, the reserve requirement was still the main instrument for automatic surplus Kuna liquidity sterilisation in 2005.

However, since money market interest rates remained almost equally volatile in the moths following the introduction of reverse repo auctions, the central bank made further adjustments of monetary policy instruments in November 2005, aiming to strengthen the function of the interest rate in reverse repo operations and decrease interest rate volatility. The key changes involved inclusion of all calendar days in a calculation period for reserve requirement, rescheduling the calculation day from the eighth day in a month to the second Wednesday in a month and also increasing the symmetry of the implicit interest rate corridor by setting the interest rate on bank's deposits with the CNB to 0,5% and the interest rate on the Lombard loan to 7,5%. The aim of these adjustments was to eliminate the procedural features of the reserve requirement allocation and maintenance process that had affected money market interest rates. Before these adjustments, the money market interest rates would rise on the first working day following a weekend or a holiday and on the reserve requirement allocation day, and they would fall on the last working day before a holiday. Fine tuning of the system's Kuna liquidity management and the November 2005 adjustment of monetary policy instruments made it easier for banks to manage their own liquidity, and also for the CNB to plan and conduct reverse repo operations, that altogether led to an overnight interest rates stabilisation, particularly towards the end of 2005 and in 2006.

The period of unusually high liquidity that lasted from the 2005-end continued in the whole of 2006. It was encouraged by lowering of the reserve requirement rate in January, although the monetary policy tightening continued. The CNB raised marginal reserve requirement for the third time and widened its calculation base again, and it also introduced a special reserve requirement on debt securities issued by banks in March 2006. The CNB also introduced a range of prudential measures and expanded the base for the foreign currency liquidity floor to liabilities payable in domestic currency but indexed to foreign currency. Although the repo rate at which CNB accepts the banks' bids at the auctions still cannot be considered as the benchmark (policy) rate, the interest rate movements in 2006 show that the CNB's activities to ameliorate interest rate fluctuations generated by sudden changes in the banking system liquidity were successful. Open market operations, particularly reverse repo operations, became the main instrument for Kuna liquidity management in the second half of 2005 and in 2006. But although central bank monetary system liquidity management changed after the introduction of open market operations, the central bank nevertheless continued to make its presence felt on the foreign exchange market through foreign currency purchase and sale transactions.

Appendix 2: Monetary policy framework in Croatia

At this moment, there are three types of open market operations in Croatia: regular, fine tuning and structural operations. Regular operations - reverse repo auctions - were introduced in April 2005 and are used to increase or decrease the banking system's liquidity. Their main purpose was to stabilize the overnight interest rates and to insure easier and more efficient liquidity management for the banks. They are conducted every Wednesday as standard offer auctions with maturity up to one week and acceptable collaterals in form of the Ministry of Finance Treasury bills denominated in Kuna. They had a significant influence on the money market and its development, especially after the adjustment of monetary policy measures in November 2005. Fine tuning operations include direct purchase or sale of securities and are also used to increase or decrease the system's liquidity but since they are not used very often in practice, they have no important role for the money market interest rates. The same holds true for structural operations that include both purchase and sale of securities and repo and reverse repo operations.

Standing facilities include deposit facility, which allows banks to deposit surplus funds with the CNB at the end of the day with the interest rate of 0,5%; Lombard loan which is granted on the basis of a bank's application at the end of a working day with the interest rate of 7,5% and interest free intraday loan granted by setting a limit in a bank's settlement account during the day. These facilities define an "interest corridor" between the low rate of the deposit facility (0,5%) to the reverse repo facility (3,5%) and to the Lombard facility (7,5%). According to Ewerhart et al. (2006), the corridor systems, where the central bank is ready to ensure overnight liquidity, generally against collateral at rate a bit higher then market rate, and is prepared to absorb sufficient liquidity overnight at rate a little below the market rate, have been adopted in several currency areas, such as Australia, Canada, Euro area, New Zealand and Great Britain. The aim of such corridor is to decrease overnight interest rate volatility and Quiros and Mendizabal (2003) show that the introduction of a deposit facility could lead to a stabilisation of market rates. According to their analysis, the combination of a corridor system with a required reserve averaging mechanism provides a powerful framework to stabilize the overnight interest rate.

The most important monetary policy instrument in Croatia is the use of foreign currency auctions based on a discretionary decision of the CNB. They are used to protect stability of the domestic currency and maintain liquidity of payments in the country and abroad. Prior to the introduction of reverse repo auctions, they were also the main instrument for creating or destroying liquidity. In theory, they should have a significant impact on the money market interest rates and on the liquidity of banking system, but they do not allow the possibility of liquidity fine tuning and are less flexible compared to reverse repo operations. We will not test this relationship in our analysis here, as we focus our attention on the money market variables and ignore the cross-correlation between prices in the foreign currency market and prices in the domestic money market.

Fractional reserve requirement system also has a big impact on the Croatian money market and its interest rates. Domestic banks and branches of foreign banks in Croatia are obliged to hold the compulsory deposits on accounts with CNB during a certain defined period. The present reserve requirement rate is 17% and the calculation period lasts from the first to the last day of a calendar month. The calculation base consists of a Kuna component and a foreign exchange component, which are calculated separately, representing the average daily balance of Kuna and foreign exchange sources of funds in a single calculation period and

50% of the calculated foreign exchange reserve requirement is included in the calculated Kuna reserve requirement and allocated in Kuna. Percentage for allocating the Kuna component of reserve requirements amounts to 70%. The percentage for allocating the foreign exchange component of reserve requirements calculated on the basis of foreign exchange funds of non-residents and foreign exchange funds received from legal persons in a special relationship with a bank amounts to 100%, while the percentage for allocating the remaining portion of the foreign exchange component of reserve requirements amounts to 60%. Remaining portion of the reserve requirement may be maintained by the average daily balances in the accounts of liquid claims. Currencies of the foreign exchange component of reserve requirements are EUR and USD.

Until December 2005, the timing of the reserve maintenance period started on the 8th calendar day of every month and ended on the 7th day of the subsequent month (if it was a non-working day or holiday, the end of the maintenance period would be moved to the first working day after the 8th day in a month). Since December 2005, maintenance period lasts from the second Wednesday of a month to the day preceding the second Wednesday of the following month.

Another measure that affects the liquidity of banks is the minimum required amount of foreign currency claims that obligates them to invest a minimum of 32% of their foreign currency liabilities into liquid foreign currency claims. Reporting period is a calendar month but the limit has to be observed on a daily basis. Reporting deadline is 10 working days following the expiry of the reporting month, for each working day of the reporting month.

In order to limit capital inflows, in July of 2004 the CNB imposed a marginal reserve requirement. Its calculation base is the positive difference between the average daily balance of specific sources of funds and specific off-balance sheet liability items (contingent liabilities) in a particular calculation period and the average daily balance of these sources of funds and contingent liabilities in the initial calculation period. Marginal reserve requirement rate is at present set to 55% and the calculation period lasts from the first to the last day of a calendar month. The day of marginal reserve requirement calculation is the second Wednesday of a month. The entire marginal reserve requirement amount is held in foreign currency at the CNB.

Another measure focused on slowing down foreign borrowing of banks is a special reserve requirement. Its calculation base consists of a Kuna component, which represents the positive difference between the average daily balance of issued Kuna denominated securities in a particular calculation period and the average daily balance of issued Kuna denominated securities in the initial calculation period; and of a foreign exchange component, which represents the positive difference between the average daily balance of issued foreign currency denominated securities in a particular calculation period and the average daily balance of issued foreign currency denominated securities in the initial calculation period. Special reserve requirement rate is 55% and the calculation period lasts from the first to the last day of a calendar month and the initial calculation period is the period from 1 to 31 January 2006. The day of special reserve requirement calculation is the second Wednesday of a month. The entire special reserve requirement amount is held at the CNB.

It is also important to mention the short-term liquidity loan, which is granted to banks with liquidity problems provided that they are solvent and may be used for a period of up to six months. Interest rate equals the interest rate charged for the use of the Lombard loan facility

increased by 0.5 percentage points for the use of the facility up to three months and interest rate charged for the use of the Lombard loan facility increased by 1 percentage point for the use of the facility over three months. Banks may, exceptionally, use the loan for more than six months, but for no longer than twelve months, on the basis of other instruments of collateral, provided that the loan has been requested and guaranteed by the Republic of Croatia.

Appendix 3: Calendar and the list of variables

Table 1. Important monetary policy decisions from January 2002 – February 2007

Decision	Description	In effect since:
Decision on the Obligation to Report Trading on the Money Market	Regulates the obligation to report trading on the money market to the Croatian National Bank and the manner and the time limits set for such reporting.	September 2, 2002
Decision on the Purchase of Compulsory CNB Bills	The compulsory CNB bills shall be purchased by those banks whose placement growth at the end of the calculation period relative to 31 December of the previous year exceeds the permissible growth rate of 16%.	From January 15, 2003 to January 15, 2004
Decision on Reserve Requirement	Percentage of the calculated foreign exchange component allocated in kuna and added to the calculated kuna reserve requirements was increased form 25% to 35%.	September 8, 2003
Decision on Reserve Requirement	Percentage of the calculated foreign exchange component allocated in kuna and added to the calculated kuna reserve requirements was increased form 35% to 42%.	November 10, 2003
Decision on the Minimum Required Amount of Foreign Currency Claims	Obligated banks to maintain a minimum of 35% of their foreign currency liabilities by foreign currency claims on a daily basis	February 1, 2003
Decision on the Terms of Granting Short-Term Loans on the Basis of Pledged Securities (lombard loan)	From a maximum of 15 working days in a month, the number of days in which the Lombard loan could be used has been reduced to a maximum of 5 days in a month.	January 2004
Decision on Reserve Requirement	The percentage for allocating the foreign exchange component of reserve requirements calculated on the basis of foreign exchange funds of non-residents and foreign exchange funds received from legal persons in a special relationship with a bank was increased to 100%, while the minimum percentage of calculated reserve requirements that is allocated in accounts with the CNB was increased from 40% to 60%.	February 9, 2004
Decision on the Marginal Reserve Requirement	The base was a positive difference between the average daily balance of sources of funds from non-residents and legal persons in a special relationship with a bank in a particular calculation period and the initial calculation period. The initial calculation period was from 1 to 30 June 2004. The banks applied the MRR rate of 24% on the increase in their foreign liabilities and allocated the entire	August 9, 2004

	calculated MRR amount in foreign exchange to a special account with the CNB.	
Decision on Reserve Requirement	The reserve requirement rate was cut from 19% to 18%.	November 8, 2004
Decision on the Marginal Reserve Requirement	The rate of marginal reserve requirements was raised from 24% to 30%	March 8, 2005
Decision on the Minimum Required Amount of Foreign Currency Claims	The percentage of minimum required foreign currency claims that banks have to maintain relative to their foreign currency liabilities was reduced from 35% to 32%.	February 24, 2005
Decision on the Deposit Facility with the Croatian National Bank	The banks are enabled to use an overnight deposit facility for their kuna surplus liquidity in the form of monetary deposits remunerated at 0.5%, an interest rate which is also the floor of the interest rate corridor on the money market.	April 1, 2005
Decision on the Terms of Granting Short-Term Loans on the Basis of Pledged Securities (lombard loan)	Interest rate on the Lombard loan (7.5%) provides a ceiling to the interest rate corridor. Central bank raised the possibility of its use to 90% of the nominal value of T-bills pledged by banks, instead of the previous 50%, and repealed the maximum 5 day-use restriction within a month.	April 1, 2005
Decision on Reserve Requirement	The component of kuna reserve requirements allocated to the special accounts with the CNB was set at 70% of the calculated reserve requirements, while the percentage of foreign currency reserve requirements allocation was set at 60% of the calculated reserve requirement. The remaining share of the reserve requirement has to be maintained as an average in the accounts of liquid claims, over a one-month maintenance period.	April 8, 2005
Regular open market operations	Conducted by means of reverse repo transactions every Wednesday at auctions with a one week maturity. Participants at auctions are domestic banks which supply T-bills of the Ministry of Finance as collateral.	April 20, 2005
Decision on Reserve Requirement	Increase from 42% to 50% in the component of foreign currency reserve requirements that is allocated and maintained in kuna.	June 8, 2005
Decision on the Marginal Reserve Requirement	The rate of marginal reserve requirements from 30% to 40%.	June 8, 2005
Decision on the Terms of Granting Short-Term Loans on the Basis of	Lombard loan rate was cut from 9,5% to 7,5%.	December 14, 2005

Pledged Securities (lombard loan)		
Decision on Reserve Requirement	The period for the calculation of the base and the period for the reserve requirement maintenance also included non-business days.	December 14, 2005
Decision on Reserve Requirement	The reserve requirement rate was cut from 18% to 17%.	January 11, 2006
Decision on the Marginal Reserve Requirement	The base for the calculation of marginal reserve requirements was thus widened to include guarantees and warranties for the account of foreign persons used as a basis for foreign borrowing of domestic persons and funds received from leasing companies not in a special relation with a bank. Therefore, the banks were now obligated to calculate marginal reserve requirements at the rate of 55% on any increase in their average daily balance of funds received from leasing companies not in a special relation with a bank and contingent liabilities arising from guarantees and warranties on behalf of third persons in kuna and in foreign currency, used as a basis for foreign borrowing of domestic persons. The additional initial calculation period against which the increase in the average daily balance of such sources funds and contingent liabilities was measured was 1 to 30 November 2005. At the same time, in addition to their regular marginal reserve requirements calculation obligation of 40%, the banks also had to calculate additional marginal reserve requirements at the rate of 15% on any increase in their average daily balance of the sources of funds from non-residents and legal persons in a special relation with a bank compared with their average balance in the initial period from 1 to 30 November 2005.	January 11, 2006
Decision on the Special Reserve Requirement	Special reserve requirement on liabilities arising from issued securities.	March 8, 2006
Decision on the Minimum Required Amount of Foreign Currency Claims	Obligated banks to maintain a minimum of 32% of their foreign currency liabilities and kuna liabilities indexed to foreign currency by foreign currency claims on a daily basis	October 2, 2006
Decision on the Purchase of Compulsory CNB Bills	The compulsory CNB bills shall be purchased by those banks whose placement growth at the end of the calculation period relative to 31 December of the previous year exceeds the permissible growth rate of 12%.	February 28, 2007

Table 2. The initial set of variables considered for modeling money market interest rates

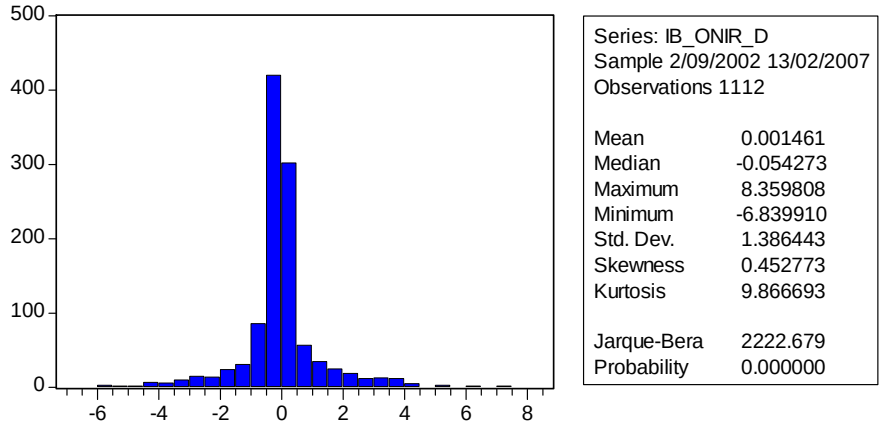
Variable	Variable description
t	end-of-day time index
T(t)	end-of-day time index of the last day of the maintenance period that contains the end-of-day index t
Dependent Variables	
mmz_onir	Dep. var.; vol.-weighted avg. daily int. rate in O/N trading in the MMZ
ib_onir	Dep. var.; vol.-weighted avg. daily int. rate in O/N trading in the IB
Reserve Supply Variables	
mmz_ont	MMZ overnight trading volume
ib_ont	IB overnight trading volume
mmz_d	MMZ registered demand for loans
mmz_s	MMZ registered supply of loans
repo_bil	Bids accepted at the CNB reverse repo auctions (total emission)
Monetary Policy Parameters	
repo	Equal to 1 since the first successful regular CNB reverse repo auction (June 6, 2005)
rr_change	Equal to 1 since the revision of the CNB req. res. operations (Dec. 14, 2005)
cnb_lend	Int. rate in the CNB lending facility
cnb_dep	Int. rate in the CNB deposit facility
cnb_repo	Int. rate in the CNB rev. repo operations
InterestRates	
eonia	Euro Overnight Index Average
tb91ir	Last auction int. rate on 91-day T-bills
tb182ir	Last auction int. rate on 182-day T-bills
tb364ir	Last auction int. rate on 364-day T-bills
Liquidity Conditions	
bfr	Banks' free Kuna reserves
krr	Kuna reserve requirement
a*krr*	Allocated Kuna reserve requirement
m*krr*	Maintained Kuna reserve requirement
tb91	Last 91-day T-bill subscription volume in the auction
tb182	Last 182-day T-bill subscription volume in the auction
tb364	Last 364-day T-bill subscription volume in the auction
Calendar Effects	
repo_next	Counts the days until th nexte CNB reverse repo auction
tbill_next	Counts the days until the next T- bills auction
knbond_next	Counts the days until the next government Kuna bond issuance day
pensions	Equal to 1 on the days when the government is borrowing on the money market
repo_last	Equal to 1 on days after the last repo operation in the req. res. maint. period
mmz_not	Equal to 1 on the days following workdays with no overnight trading activity
ib_not	Equal to 1 on the days following workdays with no overnight trading activity
d_last	Counts the days since the last trading day
d_next	Counts the days until the next trading day
ld_m	Last day of the month
ld_q	Last day of the quarter
ld_y	Last day of the year
d_w	Day of the week
d_m	Day of the month
d_rrp	Day of the current req. res. maint. period
d_rrp_last	Trading days since the last res. req. maint. period
d_rrp_next	Trading days until the next res. req. maint. period

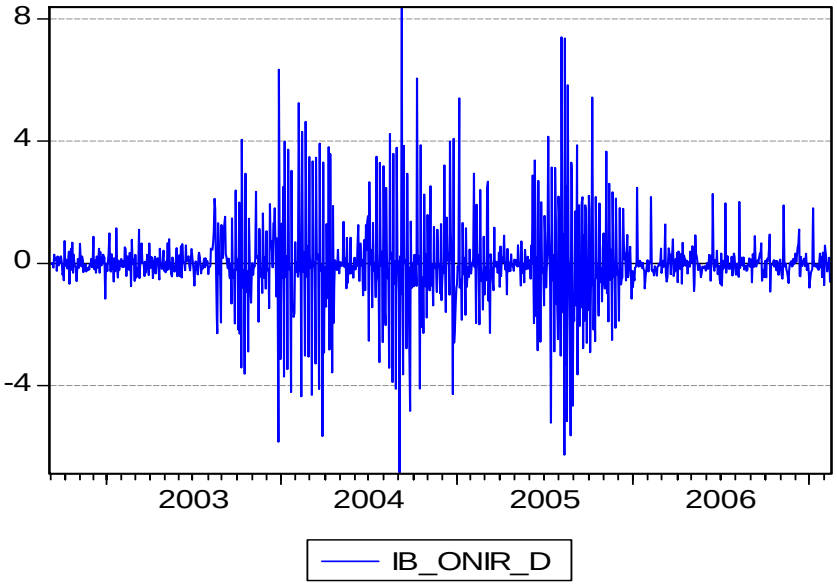
Appendix 4: Statistical properties of the dependent variable

Null Hypothesis: *ib_onir* has a unit root
Exogenous: None
Lag Length: 29 (Automatic based on AIC, MAXLAG=60)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.164148	0.0294
Test critical values:	1% level	-2.567099	
	5% level	-1.941116	
	10% level	-1.616503	

*MacKinnon (1996) one-sided p-values.





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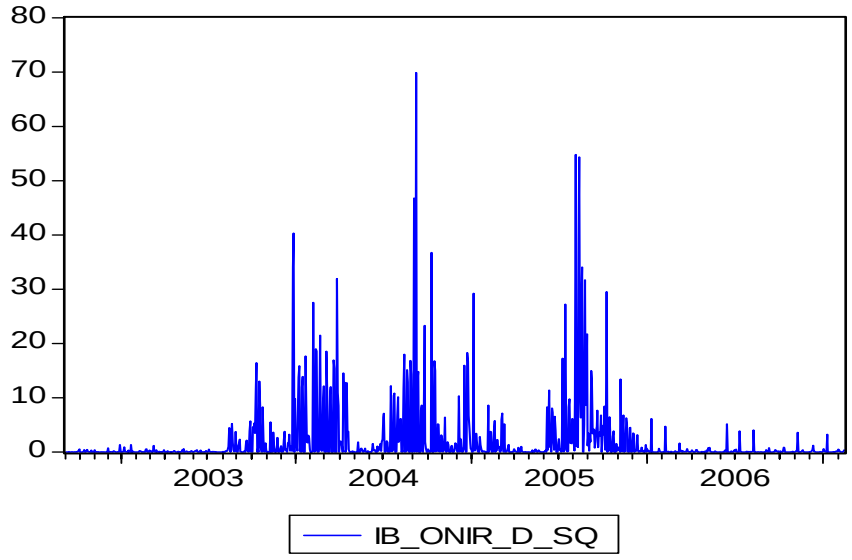
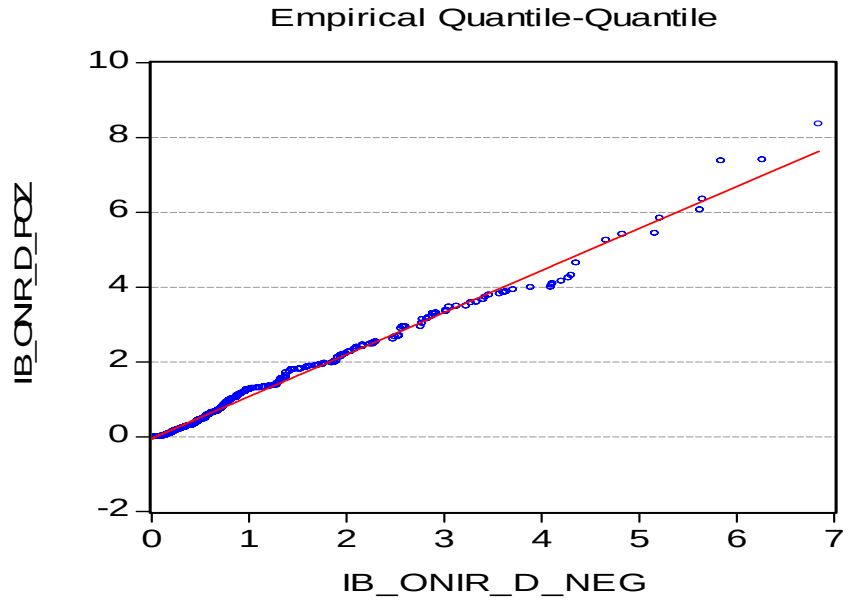
Sample: *ib_onir_d* 09/2002 13/02/2007
Included observations: 1112

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
***| |	***| |	1	-0.331	-0.331	121.89	0.000
.| |	*| |	2	-0.001	-0.124	121.89	0.000
*| |	*| |	3	-0.089	-0.148	130.68	0.000
*| |	**| |	4	-0.162	-0.286	159.98	0.000
.|*** |	.|*** |	5	0.446	0.332	382.95	0.000
**| |	.| |	6	-0.232	-0.016	443.08	0.000
*| |	**| |	7	-0.076	-0.194	449.53	0.000
.| |	*| |	8	-0.053	-0.102	452.71	0.000
*| |	*| |	9	-0.079	-0.084	459.76	0.000
.|*** |	.|* |	10	0.331	0.089	582.66	0.000
**| |	*| |	11	-0.219	-0.081	636.51	0.000
*| |	*| |	12	-0.059	-0.114	640.40	0.000
.| |	*| |	13	-0.035	-0.078	641.78	0.000
.| |	.| |	14	0.013	-0.009	641.96	0.000
.|** |	.| |	15	0.249	0.044	711.75	0.000
**| |	.| |	16	-0.193	-0.050	753.80	0.000



Date: 20/04/07 Time: 09:35
Sample: *ib_onir_d*_SQ 2/09/2002 13/02/2007
Included observations: 1112

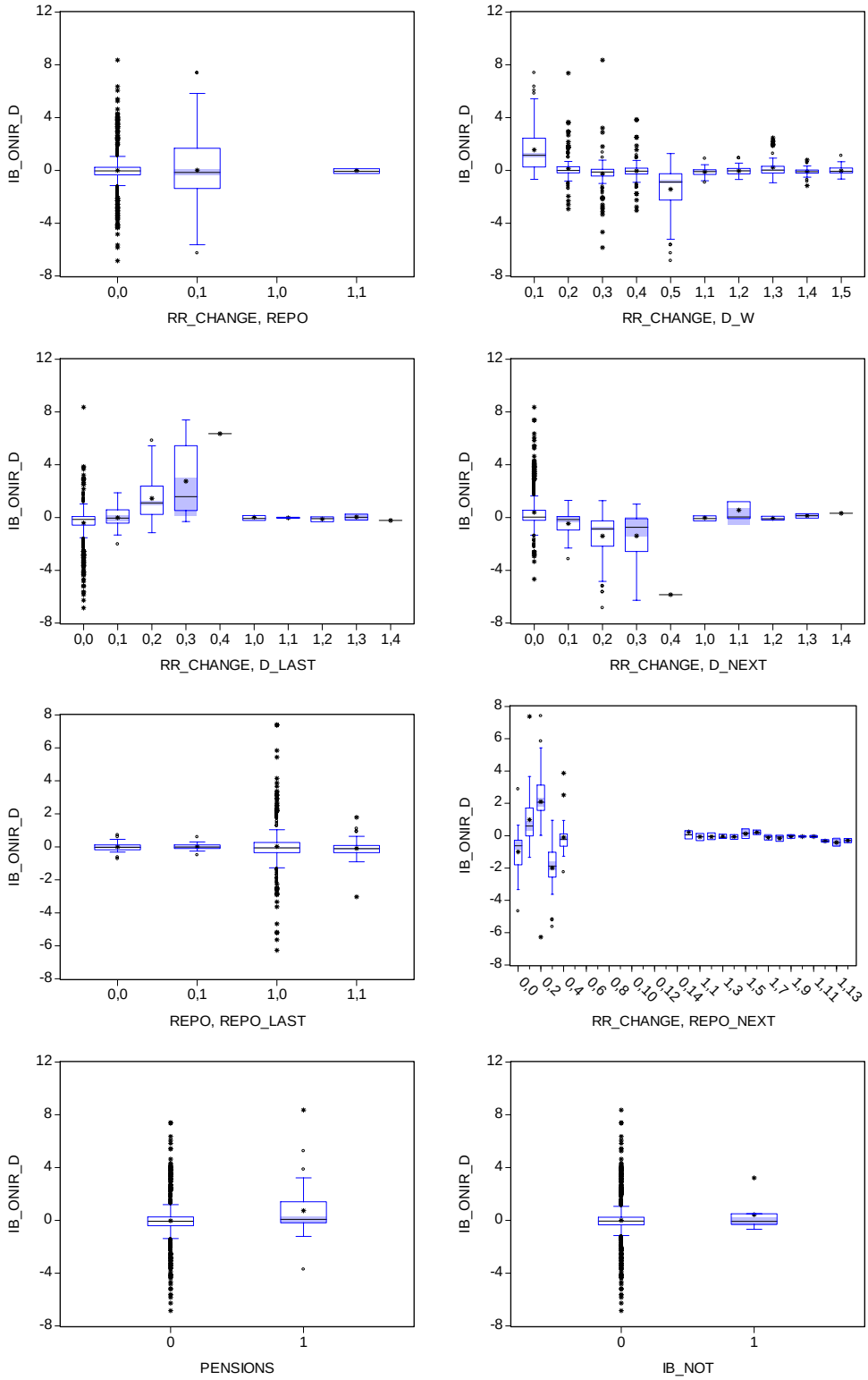
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
.|** |	.|** |	1	0.269	0.269	80.976	0.000
.| |	.| |	2	0.055	-0.019	84.352	0.000
.|* |	.|* |	3	0.178	0.181	119.56	0.000
.|** |	.|** |	4	0.319	0.250	233.17	0.000
.|*** |	.|** |	5	0.391	0.300	403.98	0.000
.|* |	.| |	6	0.125	-0.030	421.50	0.000
.|* |	.| |	7	0.099	0.036	432.51	0.000
.|* |	.| |	8	0.195	0.030	474.97	0.000
.|** |	.|* |	9	0.286	0.107	567.06	0.000
.|** |	.|* |	10	0.253	0.082	638.97	0.000
.|* |	.| |	11	0.115	0.020	653.87	0.000
.|* |	.| |	12	0.085	-0.040	661.98	0.000
.|* |	.| |	13	0.144	-0.032	685.22	0.000
.|** |	.| |	14	0.227	0.043	743.56	0.000
.|** |	.|* |	15	0.256	0.134	817.49	0.000
.|* |	.| |	16	0.072	-0.043	823.42	0.000
.| |	.| |	17	0.056	-0.017	826.97	0.000
.|* |	.| |	18	0.116	-0.056	842.15	0.000
.|** |	.| |	19	0.216	0.050	895.04	0.000

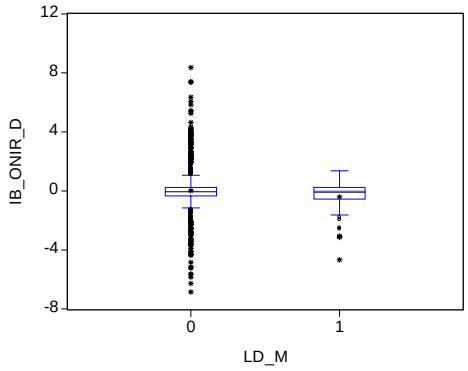


Date: 20/04/07 Time: 00:01
Sample: 2/09/2002 13/02/2007
Included observations: 1112
Correlations are asymptotically consistent approximations

*ib_onir_d*_NEG,*ib_onir_d*_ POZ(-i)	*ib_onir_d*_NEG,*ib_onir_d*_ POZ(+i)	i	lag	lead
**|. |	**|. |	0	-0.1848	-0.1848
.|* |	.|****** |	1	0.0934	0.6189
.|* |	.|. |	2	0.1045	-0.0015
.|* |	.|* |	3	0.1365	0.1093
.|***** |	.|. |	4	0.5360	-0.0194

Appendix 5: Calendar effects

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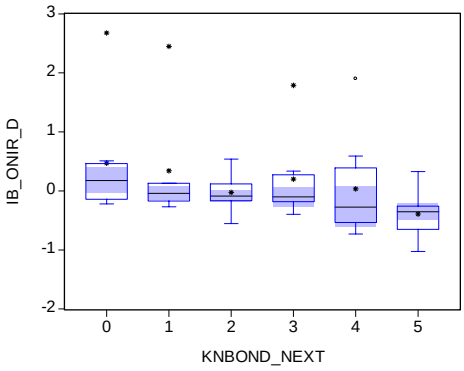
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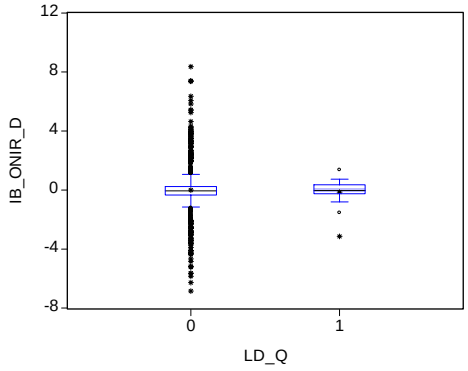
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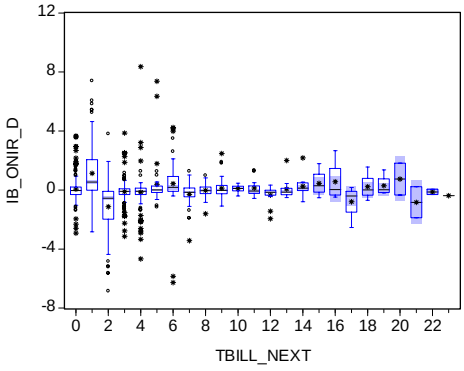
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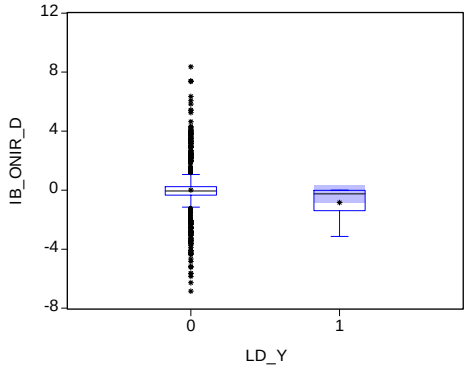
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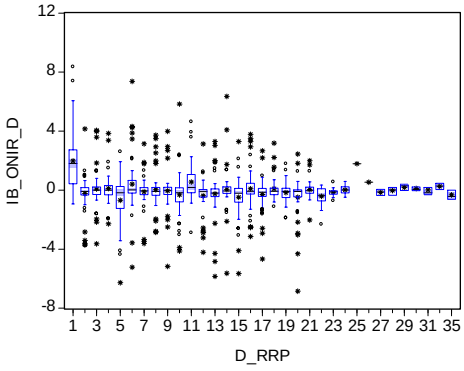
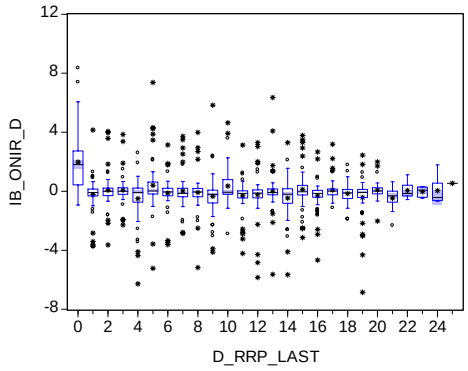
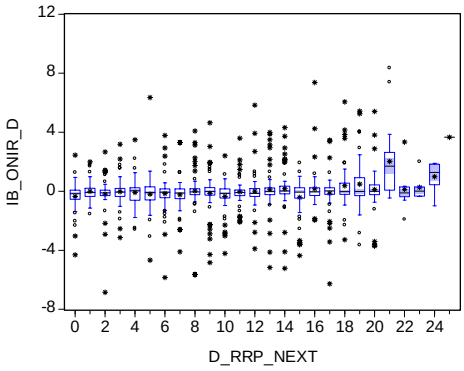
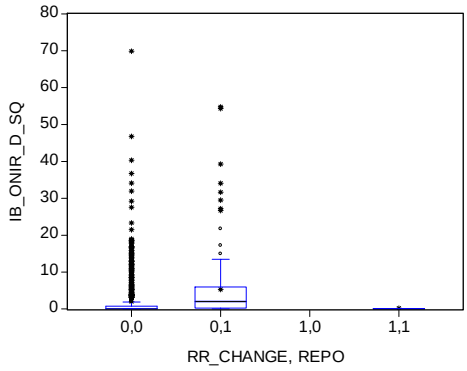

IB_ONIR_D
D_RRP


IB_ONIR_D
D_RRP_LAST


IB_ONIR_D
D_RRP_NEXT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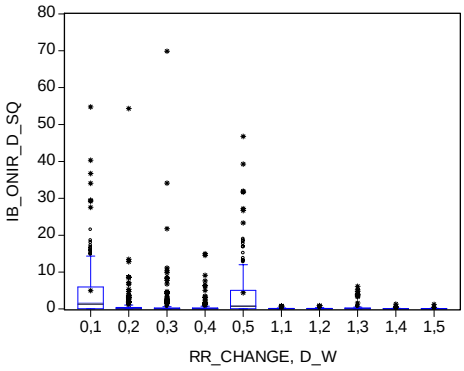
RR_CHANGE, REPO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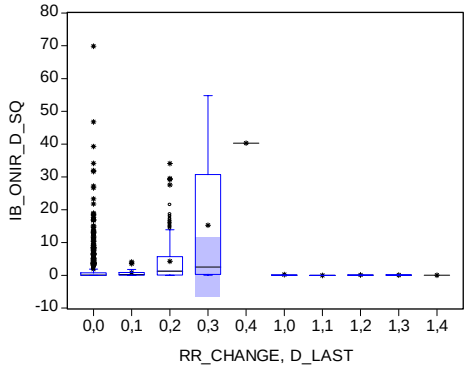
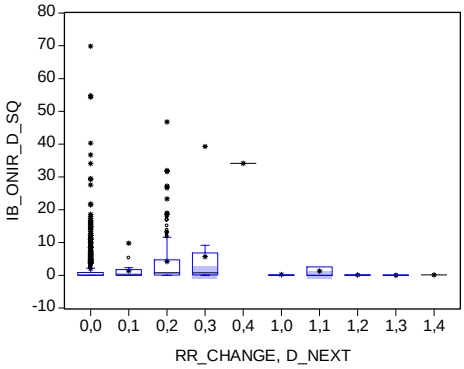
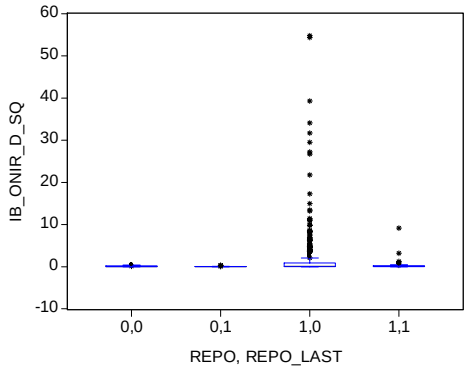
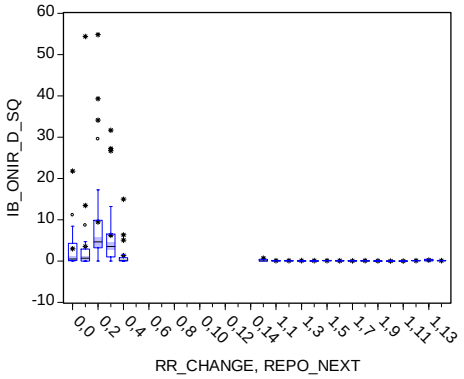
RR_CHANGE, D_W


IB_ONIR_D_SQ
RR_CHANGE, D_LAST


IB_ONIR_D_SQ
RR_CHANGE, D_NEXT


IB_ONIR_D_SQ
REPO, REPO_LAST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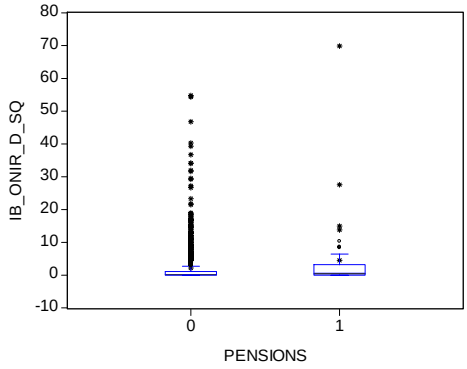
RR_CHANGE, REPO_NEXT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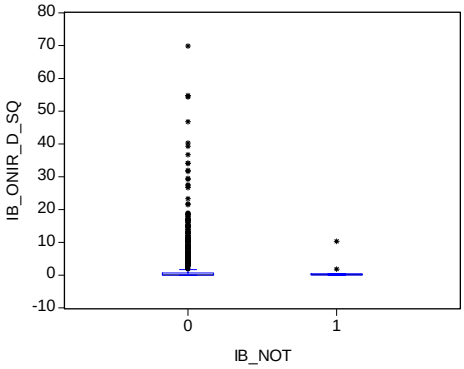
PENSIONS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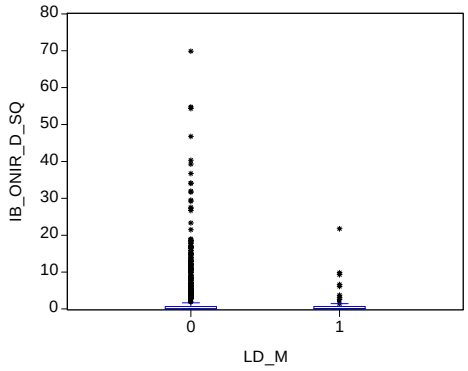
IB_NOT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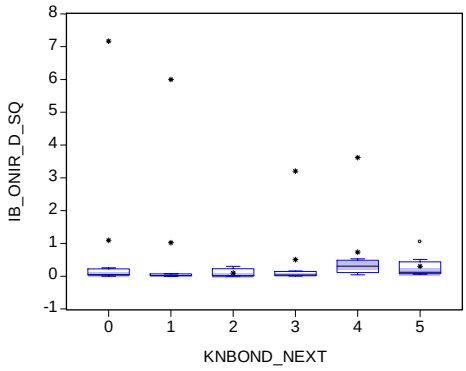
LD_M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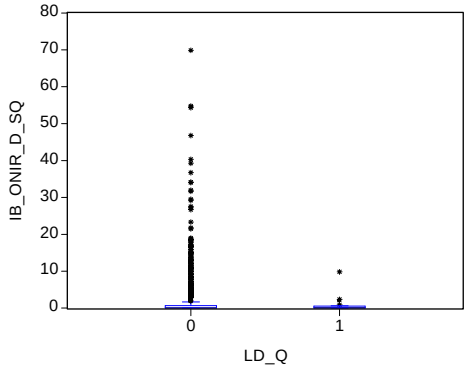
KNBOND_NEXT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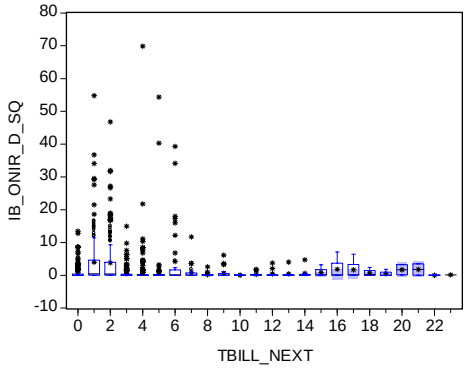
LD_Q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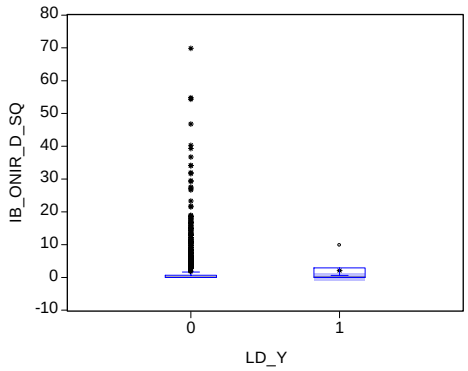
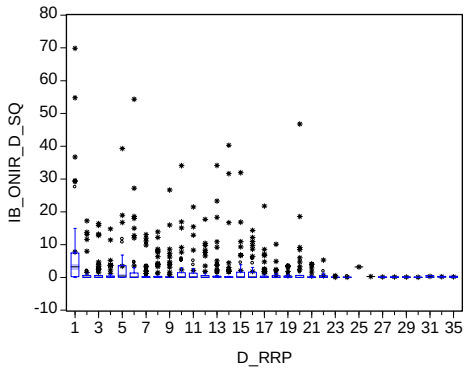
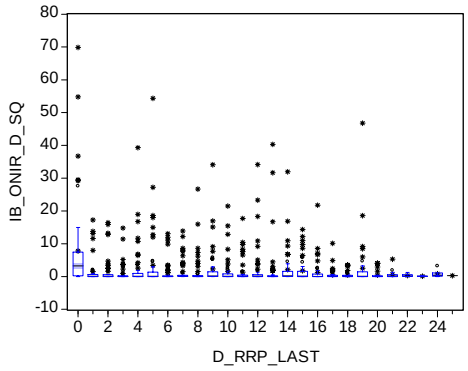
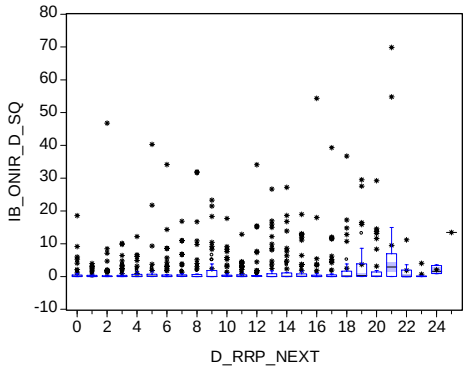
TBILL_NEXT


IB_ONIR_D_SQ
LD_Y


IB_ONIR_D_SQ
D_RRP


IB_ONIR_D_SQ
D_RRP_LAST


IB_ONIR_D_SQ
D_RRP_NEXT

Appendix 6: Parsimonious time-series models

Dependent Variable: IB_ONIR_D
Method: ML - ARCH (Marquardt) - Student's t distribution
Date: 23/04/07 Time: 05:08
Sample (adjusted): 1/10/2002 13/02/2007
Included observations: 1092 after adjustments
Convergence achieved after 26 iterations
MA backcast: 30/08/2002, Variance backcast: ON
LOG(GARCH) = C(6) + C(7)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(8)*RESID(-1)/@SQRT(GARCH(-1)) + C(9)*RESID(-2) /@SQRT(GARCH(-2)) + C(10)*LOG(GARCH(-1)) + C(11) *LOG(GARCH(-2))

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.059587	0.018459	-3.228126	0.0012
AR(5)	0.196933	0.022471	8.763731	0.0000
AR(10)	0.141322	0.020423	6.919832	0.0000
AR(20)	0.053103	0.017619	3.013946	0.0026
MA(1)	-0.121229	0.026581	-4.560721	0.0000
Variance Equation				
C(6)	-0.385189	0.048669	-7.914454	0.0000
C(7)	0.846934	0.226442	3.740189	0.0002
C(8)	-0.336678	0.121773	-2.764790	0.0057
C(9)	0.188916	0.089966	2.099852	0.0357
C(10)	0.453341	0.093708	4.837815	0.0000
C(11)	0.493264	0.092875	5.311062	0.0000
T-DIST. DOF	2.382380	0.224414	10.61599	0.0000

R-squared	0.238445	Mean dependent var	0.000990
Adjusted R-squared	0.230688	S.D. dependent var	1.398607
S.E. of regression	1.226724	Akaike info criterion	2.208398
Sum squared resid	1625.241	Schwarz criterion	2.263297
Log likelihood	-1193.785	F-statistic	30.74099
Durbin-Watson stat	2.385459	Prob(F-statistic)	0.000000

Inverted AR Roots	.91	.80+.25i	.80-.25i	.71+.51i
	.71-.51i	.48+.68i	.48-.68i	.28-.87i
	.28+.87i	.01+.84i	.01-.84i	-.27+.83i
	-.27-.83i	-.50+.67i	-.50-.67i	-.74+.54i
	-.74-.54i	-.79+.27i	-.79-.27i	-.87
Inverted MA Roots	.12			

Dependent Variable: IB_ONIR_D
Method: ML - ARCH (BHHH) - Student's t distribution
Date: 23/04/07 Time: 04:47
Sample (adjusted): 10/09/2002 13/02/2007
Included observations: 1107 after adjustments
Convergence achieved after 475 iterations
MA backcast: 30/08/2002, Variance backcast: ON
LOG(GARCH) = C(11) + C(12)*ABS(RESID(-1)/@SQRT(GARCH(-1)))
+ C(13)*RESID(-1)/@SQRT(GARCH(-1)) + C(14)*RESID(-2)
/@SQRT(GARCH(-2)) + C(15)*LOG(GARCH(-1)) + C(16)
LOG(GARCH(-2)) + C(17)(RR_CHANGE=1)*(REPO=1) + C(18)
(D_W=5)(RR_CHANGE=0) + C(19)*(REPO_NEXT_NA=2)
*(RR_CHANGE=0)

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.058610	0.011828	-4.955283	0.0000
(D_W=5)*(RR_CHANGE=0)	-0.445906	0.063155	-7.060514	0.0000
(D_W=1)*(RR_CHANGE=0)	0.470315	0.039914	11.78324	0.0000
D_RRP=1	0.996363	0.058940	16.90475	0.0000
(REPO_NEXT_NA=0)*(RR_CHANGE=0)	-0.614448	0.154271	-3.982911	0.0001
(REPO_NEXT_NA=1)*(RR_CHANGE=0)	0.457414	0.146156	3.129639	0.0018
(REPO_NEXT_NA=2)*(RR_CHANGE=0)	1.047986	0.200673	5.222346	0.0000
PENSIONS_NA=1	0.218847	0.052831	4.142395	0.0000
AR(5)	0.073622	0.025475	2.890023	0.0039
MA(1)	-0.136686	0.028493	-4.797221	0.0000
Variance Equation				
C(11)	-0.937611	0.071546	-13.10501	0.0000
C(12)	0.785475	0.114901	6.836110	0.0000
C(13)	-0.247857	0.072008	-3.442054	0.0006
C(14)	0.244498	0.072356	3.379083	0.0007
C(15)	0.705881	0.081023	8.712111	0.0000
C(16)	0.176036	0.075229	2.340019	0.0193
C(17)	0.299163	0.072333	4.135919	0.0000
C(18)	2.005839	0.224288	8.943131	0.0000
C(19)	0.723822	0.289632	2.499111	0.0125
T-DIST. DOF	2.912055	0.325619	8.943141	0.0000

R-squared	0.385036	Mean dependent var	0.001327
Adjusted R-squared	0.374287	S.D. dependent var	1.389537
S.E. of regression	1.099152	Akaike info criterion	1.934311
Sum squared resid	1313.243	Schwarz criterion	2.024815
Log likelihood	-1050.641	F-statistic	35.82015
Durbin-Watson stat	2.408086	Prob(F-statistic)	0.000000

Inverted AR Roots	.59	.18+.56i	.18-.56i	-.48-.35i
	-.48+.35i			
Inverted MA Roots	.14			

Dependent Variable: IB_ONIR_D
Method: ML - ARCH (Marquardt) - Student's t distribution
Date: 23/04/07 Time: 09:41
Sample (adjusted): 10/09/2002 13/02/2007
Included observations: 1107 after adjustments
Convergence achieved after 78 iterations
Variance backcast: ON
LOG(GARCH) = C(11) + C(12)*ABS(RESID(-1)/@SQRT(GARCH(-1)))
+ C(13)*RESID(-1)/@SQRT(GARCH(-1)) + C(14)*LOG(GARCH(
-1)) + C(15)*(RR_CHANGE=1)*(REPO=1) + C(16)*(D_W=5)
(RR_CHANGE=0) + C(17)(REPO_NEXT_NA=2)
*(RR_CHANGE=0)

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.021280	0.021537	-0.988056	0.3231
(D_W=5)*(RR_CHANGE=0)	-0.497894	0.066530	-7.483709	0.0000
(D_W=1)*(RR_CHANGE=0)	0.498818	0.050281	9.920581	0.0000
D_RRP=1	1.779983	0.050615	35.16697	0.0000
(REPO_NEXT_NA=0)*(RR_CHANGE=0)	-0.410572	0.147803	-2.777835	0.0055
(REPO_NEXT_NA=1)*(RR_CHANGE=0)	0.301602	0.144865	2.081949	0.0373
(REPO_NEXT_NA=2)*(RR_CHANGE=0)	1.292510	0.228093	5.666585	0.0000
TB91IR(-1)-IB_ONIR(-1)	0.062876	0.010522	5.975682	0.0000
BFR_T(-1)	-9.88E-06	1.71E-06	-5.776757	0.0000
AR(5)	0.130530	0.025009	5.219395	0.0000
	Variance Equation			
C(11)	-0.680050	0.057291	-11.87002	0.0000
C(12)	0.396240	0.065794	6.022442	0.0000
C(13)	0.216591	0.048964	4.423494	0.0000
C(14)	0.934304	0.013619	68.60360	0.0000
C(15)	0.337751	0.056146	6.015591	0.0000
C(16)	2.074497	0.231040	8.978964	0.0000
C(17)	0.551782	0.176532	3.125683	0.0018
T-DIST. DOF	2.831320	0.317605	8.914600	0.0000

R-squared	0.415530	Mean dependent var	0.001327
Adjusted R-squared	0.406406	S.D. dependent var	1.389537
S.E. of regression	1.070569	Akaike info criterion	1.936711
Sum squared resid	1248.123	Schwarz criterion	2.018164
Log likelihood	-1053.969	F-statistic	45.54281
Durbin-Watson stat	2.574954	Prob(F-statistic)	0.000000

Inverted AR Roots	.67	.21+.63i	.21-.63i	-.54-.39i
	-.54+.39i			