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Interbank Transactions on the Intraday Frequency: "Different Market States and the Effects of the Financial Crisis"

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Abstract
The focus of this paper lies in the study of the intraday distribution of the number of transactions and transaction volume (absolute and mean per transaction) in the interbank credit market e-MID in different market states around the events of the financial crisis of 2007. The results show that the distributions of the number and of the volume of transactions can be characterized as U-shaped and the distribution of the mean per transaction as three-peaked. However, there are important differences when it comes to the comparison of the different market states and the differentiation between sell and buy transactions. Moreover, this study detects stylized facts about the market regarding the number of trades and the volume during the day. Sell transactions are higher in each market state. This highlights the fact that this market is used widely to deposit excessive liquidity in all intervals during the day. Furthermore, differences within these variables during different market states can be observed, which highlights the importance of this analysis. This study can strengthen our understanding of the interbank credit market as it is important for policy makers and the daily trading strategies of banks. Additionally, implications can be seen as the basis for further empirical and econometric research.

Keywords: Interbank credit market, e-MID, intraday frequency, financial crisis

1. Introduction

The beginning of the great financial crisis of 2007 and the events afterwards led us to rethink the architecture of the modern financial system and raised different questions from a practical and theoretical point of view. The major key element of this discussion is the financial interconnectedness that links financial institutions as well as through interbank credit markets (Affinito and Pozzolo, 2017). Due to the well-functioning of the interbank credit markets until that time period the interest on interbank lending was relatively low.

After the outbreak of the financial crisis and the resulting events, the interest in the global interbank credit markets rose again from a theoretical and practical point of view. These markets play a major role in the well-being of the financial system as a whole as banks can manage their liquidity needs. This in turn affects the credit supply of households and firms. Central banks also monitor the well-functioning of the interbank credit markets because it is of great importance to ensure a smooth transmission of the monetary policy rules to this market (Beaupain and Durré, 2013).

One major problem for the analysis of these markets is the data availability. This is the case also for the EONIA (European Overnight Index Average), which represents the only official data for

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overnight (ON) credits in the Eurozone. Due to the lack of data, it is not possible to audit the market in a more detailed way (Spelta et al., 2019). The data availability of the EONIA, which is only available on the daily frequency, restricts an analysis of intraday patterns on this market (Beaupain and Durré, 2011). Together with the well-functioning of these markets and thus the low research interest, this has been reasons why interbank credit markets and their modeling are still considered by many economists as "black boxes". Or in other words, as Allen et al. (2019) state, that our knowledge of how the interbank markets work in detail is still very limited. However, a rise in the research interest after the outbreak of the financial crisis in the year 2007 occurred and changed our understanding of it.

The only organized interbank credit market in the Eurozone and the US is the e-MID market (Mercato dei Depositi Interbancario) which is located in Milan, Italy. On this market, banks can allocate liquidity from an ON basis until credits with a maturity of one year. These transactions may be buy-initiated or sell-initiated. The market functions fully transparent and based on the limit order book principle. Beaupain and Durré (2011) show that the e-MID market is a representative market for the whole money market in the Euro area and Arciero et al. (2016) state that this was the fact also until the outbreak of the Italian debt crisis in 2011. Furthermore, this market is taken into account by different policy makers e.g. by the European Central Bank (ECB) (Beaupain and Durré, 2013).

As there is on other interbank credit markets, the ON segment on the e-MID market represents around 90% of the market in terms of the number of transactions and the volume of transactions. As stated in different studies e.g. by Arciero et al. (2016) the e-MID market can be regarded as a benchmark of the Euro area money market, especially on the ON maturity. Again, on the ON basis, the e-MID represented around 53% of the EONIA in terms of volume before the outbreak of the financial crisis in 2007. Especially during the year 2006, it is shown that the market volumes are even higher than the EONIA market (Brossard and Saroyan, 2016).

The e-MID market has undergone systematic changes especially during the financial crisis of 2007, as it was the case for other interbank credit markets (Hatzopoulos et al.,2015). That is the reason why in many different studies, the market conditions are compared, before, during, and after this financial crisis (see e.g. Gabbi et al., 2012, Jeleskovic and Demertzidis, 2018).

A major literature string focuses on the network formations of the e-MID market in the intraday frequency. The analyses from Fricke and Lux (2015), and more recently e.g. Kaltwasser and Spelta (2019) and Spelta et al. (2019), put focus on the network aspects of this e-MID market.

Since the ON segment is the major key element of the market in terms of number and volume of the transactions, different studies focus on the interday and intraday behavior of different interbank variables. On an interday basis, different studies look at interbank variables and their changes among the days. Hartmann et al. (2001) and Beaupain and Durré (2008) analyze the number of trades and the volume of transactions in the interday domain. Gabrieli (2012) analyzes the interday behavior of volumes in the time between 2006 and 2008 and indicates that the volume drops especially after August 2007. Brossard and Saroyan (2016) analyze the shape of the mean daily interest rate in the period between 2006 and 2009. To only name a few.

In contrast to the interday studies different studies put also an emphasis on the intraday behavior of the interest rate on the e-MID market in the recent years. The studies conducted by Angelini

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(2000) and Baglioni and Monticini (2008) focus on the estimation of an intraday interest rate before the outbreak of the crisis in 2007. The studies by Baglioni and Monticini (2010) and Baglioni and Monticini (2013) estimate the intraday interest rate by taking into account the outbreak of the financial crisis. Until that point, all models were based on linear regressions. Demertzidis and Jeleskovic (2016) and Jeleskovic and Demertzidis (2018) used nonlinear models for the estimation of the spot intraday yield curve (SIYC) and argued that one has to move away from the assumption of a linear intraday interest rate, which becomes even more feasible after the outbreak of the crisis (for further details see Appendix A).

Previous research studied the behavior of interest rates on the intraday frequency highlighting some interesting methodological and theoretical aspects. However, other important variables on the e-MID market, meaning the number of transactions and volume (absolute and mean per transaction), have not been thoroughly examined yet.

Yet, these two variables are important for the understanding of an interbank credit market in general, since our understanding of these markets is quite limited and more findings in this area of research could be helpful for the understanding of the behavior of banks on the ON segment of the interbank credit market. In addition, the results of an intraday analysis are important also for the optimization of the trading strategies of banks. If e.g. the volume is low during some time intervals in the day, this has also an effect on the volatility of the interest rate and thus also on risk (Engler and Jeleskovic, 2016). Furthermore, banks could optimize their activity in the market by looking more closely at the distributions of these variables during the day.

As pointed out also by Beaupain and Durré (2008) the analysis of variables in the intraday domain could reveal some interesting market dynamics. The interbank market is the first transmission channel of monetary policy. Thus, based on the analysis of these two variables, the ECB could analyze the impact of its conventional and unconventional policies on the interbank market and thereby optimize them in the future. This identification of intraday dynamics could help central banks to intervene on the interbank credit markets, which could reduce systemic risk in the financial system as a whole (Kobayashi et al., 2018).

Furthermore, these variables, also on the intraday frequency, play an important role in further empirical econometric analyses. For example, Demertzidis and Jeleskovic (2016) and Jeleskovic and Demertzidis (2018) show that estimating an intraday yield curve generates better results when the number of transactions and the volume of transactions within the day can be considered as high. Therefore, findings in this research could be used from a methodological point of view for further studies using e.g. agent based modelling. Additionally, the recognition of recurrences in these distributions would allow us to implement further empirical or econometrical models in order to explain these phenomena.

Last but not least, distortions in these markets also have an impact on the real economy. As already described, the interbank market is an important source of liquidity for banks, which pass on these loans to consumers and companies. If there are problems with lending, this also has real economic effects.

Some studies already analyzed the intraday behavior of these two important variables, e.g. Hartmann et al., (2001) who focus on the distribution of the volume in the period of 1999-2000 and Beaupain and Durré (2008) who focus on the volume and number of transactions in the

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period of 2000-2007. However, to the best of my knowledge, no study has taken into account the changes of the distributions of the number of transactions and volume by comparing credits which have been sell initiated and buy initiated on different markets states. These different market states are of high importance, since the market has gone through systematic changes after the outbreak of the financial crisis. Hence, these are the main objectives of this paper:

First, my aim is to examine and discuss the intraday distribution of number of trades and volume (absolute and mean per transaction) by differentiating sell and buy transactions. Second, to analyze and discuss these distributions in different market states around major events of the financial crisis in 2007. Third, to highlight possible recurrences in the time series of the number of transactions and the volume on an intraday domain. These findings could then be used in order to estimate further empirical and econometric models (Finger and Lux, 2017).

The structure of this paper is as follows: After the introduction, I present a brief survey of the previous findings in this area of research, on the intraday behavior in terms of the number of transactions and the volume, either absolute or the mean per transaction. In chapter 3, I present the e-MID market briefly and the data sample used in this study. Chapter 3 also features different interday statistics of the mentioned variables in order to justify the use of the different periods and market states. In chapter 4, I analyze the distribution of the number of transactions in the different market states. In chapter 5, I focus on the volume and its distribution during the day. Section 6 is the conclusion.

2. Previous findings

As stated, only a few studies put emphasis on the intraday behavior of different important variables on the e-MID market, especially the volume and the number of transactions. The interest in research has recently grown exponentially, like the general interest in the interbank credit markets, especially after the outbreak of the financial crisis of 2007.

Besides the analysis of the intraday behavior of the interest rate, Angelini (2000) also shows the distribution of the trading volume during the day for the period of 01.07.1993 until 31.12.1996. His data set includes the hourly means of the volume from the time band of 08:00- 09:00 until 16:00- 17:00. The time band of 17:00- 18:00 is excluded in his analysis. In terms of volume, he finds that in the morning the traded volumes in the first time band are low, are rising from 09:00 until 13:00 but drop in the next hour (due to the noon and lunchbreak effect) and rise again for the next two hours. At the end of the day, they are again almost zero at the last time band between 16:00-17:00 Therefore, this form of volume distribution can be described as U-shaped around the interval of 13:00-14:00 with almost no volume traded at the beginning and the end of each day in the sample period. Angelini (2000) argues that, this kind of trading activity is mainly driven by the specific arrangements of the Italian clearing system and the behavior of banks that increase their operations at the end of the day in order to adjust their liquidity positions due to revised forecasts of their balance sheets during the day.

Hartmann et al. (2001) focus on different aspects of the e-MID market on different maturities, including also the intraday frequency. For their analysis, they use a data sample in the period between 01.11.1999 and 31.03.2000. They exclude different days, like the end of the maintenance period and the week between Christmas and New Year. For their analysis, they use

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one-hour intervals of different interbank variables. By focusing on the distribution of the volume and the number of transactions during the day, they find out, that these distributions follow a U-shape. The authors show, that both of the variables are low in the morning, start to rise during the time of 09:00-10:00 and reach their maximum. After this time, they observe a decline with the lowest value being in the interval of 13:00- 14:00. After this interval, the variables rise again until the interval of 16:00-17:00 and fall again after this interval until the market closes at 18:00. Hartmann et al. (2001) argue that the main reason for high values of these variables in the morning are mainly driven by news which have been accumulated over the night. Furthermore, they argue that the reason for higher trading in the afternoon is due to the closing time of different payment systems and also due to liquidity needs of the banks in the e-MID market.

Palombini (2003) shows the intraday trading volume on the e-MID market using a sample that spans from 03.01.2000 to 30.09.2002. By using hourly means of the intraday volume, he finds that the volume exhibits a U-shape. He shows that the volume is low in the first time band, reaches its maximum in the time band between 09:00-10:00 and then declines until the time band of 13:00-14:00, which he calls the lunchbreak. After this break, the volume per interval rises again until the time band of 16:00-17:00 and drops again at the end of the day. Palombini (2003) states that these effects can be regarded on two major events during the day on the e-MID market: First, the time until 09:00 where the credit transaction of the previous business day are settled automatically and around 13:00 when cash balances from the Italian securities market are settled. Additionally, he states that these distributions do not change on volatile days, as e.g. at the end of the maintenance period.

Barucci et al. (2004) use a data sample that spans from 01.04.1999-31.08.2001. The authors here also exclude some days in their analysis. By using one- hour intervals, they show the distribution of the volume and the number of trades during the day. They discover, that the values of these variables are relatively low at the beginning of the day, rise afterwards in the interval of 09:00-10:00 and decline again until 14:00, where the minimum can also be found. Afterwards the distribution starts to rise again until 15:00 and drops again until the market closes. The distributions can therefore also be characterized here as U-shaped. The authors put furthermore focus on the difference between different days during the week, but the distributions remain qualitatively the same. The authors claim, based on these distributions the reasons provided by Angelini (2000), can therefore be verified.

Beaupain and Durré (2008) focus on different aspects of intraday und interday patterns of different variables. These also include the number and volume of transactions and the mean volume per transaction on the e-MID market. At the center of their attention is also, among other aspects, the identification of the changes of the operational framework of the Eurosystem after March 2004. Their data sample consist of ON transactions in the market between 04.09.2000-03.05.2007. In their study they use 30- minute intervals of the different intraday variables by also differentiating buy and sell transactions. For the purpose of their analysis, they construct two data samples, one before the 10th of March 2004 and one after this date. However, here also different transactions are removed from the data sample. The authors claim that in the intraday frequency there is clear evidence for intraday patterns. In their analysis, they showed that the distribution of the number of transactions and the volume of transactions is U-shaped with highs in the morning and in the afternoon with the lowest point of the distribution during lunchtime.

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For the first data sample, they found that the total volume is low at the beginning of the day, reaches its maximum at during the interval of 09:30 and starts to drop afterwards until 14:30. After that point, it starts to rise again with high values during 15:00 and 17:00. After that time, it decreases again until the market closes. During the second data sample, the distribution of volumes looks the same way with minor differences in the intervals of 15:00- 16:30. In both samples, the distributions of buy and sell transactions are quite similar. Beaupain and Durré (2008) state that the distribution of the number of transactions is almost the same as it is in the case of the volume in both cases. The distributions of the sell and buy transactions also have the same shape here. For the mean volume per transaction, the authors find a distribution with three peaks: The first at the opening of the market, the second at around 14:00 and the third high at around 17:30. In the first data sample, the order of the highs is 09:00, followed by 17:30 and the smallest high value at 14:00. In the second data sample authors find a small change, since the highest value is the one at the end of the day and not in the morning. Furthermore, here the distributions have the same distributions for buy and sell transactions in both samples. Small differences between the values of buy and sell are mainly seen in the morning when the market opens. Beaupain and Durré (2008) argue that these distributions are likely to reflect the uncertainty of the banks due to price movements in the financial markets and the availability of liquidity in the afternoon.

Iori et al. (2008) focus mainly on network aspects of the e-MID market. They also show the intraday distribution of the volume in the market during the period of January 1999 to December 2002. By doing so, they found that the distribution has a U-shape with two peaks, the first in the morning at around 10:00 and the second in the afternoon at 15:00. The authors argue that the peak in the morning can be explained by the fact that pending payments from the previous day must be repaid at around 09:00 and that in the afternoon banks settle mainly interbank and other financial payments.

Brunetti et al. (2010) use a data sample from 02.01.2006 until 01.04.2008 by taking into account in detail the ECB interventions after the outbreak of the financial crisis in August 2007. In their analysis, they put focus on a higher frequency than the previously mentioned studies, meaning five-minute intervals for different (self-constructed) intraday variables. Based on the volume per interval, which the authors call “intra-daily average trading volume” they found that the market activity is quite low at the beginning of the day and grows rapidly after 08:30. Before the outbreak of the financial crisis, the authors find a peak of the volume at around 09:30, and after the outbreak of the crisis, the peak moves to 09:45. After these time bands, the intraday volume declines until between 13:15 and 14:15 and starts to rise again until the time interval of 16:45. After this time interval, it falls again until the time when the market closes. Furthermore, they find that the values of these measures are higher for sell transactions. Their study gives interesting insights into the e-MID market, although they give no possible explanations for these distributions.

Cassola et al. (2010) focus also on different intraday variables on the e-MID market using a sample that spans from July 2007 to March 2008 in order to capture also the impact of the outbreak of the financial crisis of 2007. In their analysis, they use half-hour intervals. During the study, they focus also on the distribution of the intraday volumes and the intraday number of transactions. For the intraday volume, they argue that the distribution follows a U-shape. The

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market activity is high in the morning until 10:00, is relatively low in the mid-day and is higher again in the afternoon during the time of 16:00-17:00. The authors argue that this shape in the morning is mainly driven by the late liquidity shocks of the previous day. The closing of different payment systems and the liquidity needs of banks mainly affect the shape in the afternoon. During their study, they show some interesting insights into the market, meaning that these distributions have not changed significantly after the outbreak of the crisis. However, they remove different time intervals, meaning the first and the last interval of each day. Furthermore, in their analysis, they exclude different days like the first and last day of the reserve maintenance period proposed by the ECB or when the ECB conducted their main refinancing and also fine-tuning operations. Cassola et al. (2010) may focus to a small extent on the differentiation of buy and sell transactions, but do not show different distributions of intraday variables. They show only the difference between buy and sell transactions during their data sample.

Vento and La Ganga (2009), using a data sample which spans from 01.01.2005 until 30.06.2009, show also the distribution of the intraday volume on the e-MID market. By using hourly means of the intraday volumes, they also find that the distribution has a U-shape with low trading volumes after the market opens and a rise in the interval of 09:00-10:00. During this interval, the intraday volume reaches its first peak. The authors then show low trading activity at noon and then a second peak in the afternoon at around 16:00 to 17:00, even though the second peak is lower than the one in the morning. This distribution relies on the imbalances from transactions which have not been regulated during the night. This phenomenon explains the peak in the morning. The authors argue that the peak in the afternoon relies on the European banking federation deadline, at which banks post lending quotes at the rate of the EURIBOR (Vento and La Ganga, 2009).

Fricke (2012) uses a data sample from 01.01.1999 until 31.12.2015 and focuses mainly on network aspects of ON transactions on the market. Nonetheless, he also shows the fraction of trades occurring during the day, based on the fraction of trades occurring at a certain time during the day (based on hourly means). By doing so, he finds that the distribution of trades follows a two- hump U-shape. The number of credits are low in the time band between 08:00-09:00, rise until 10:00 and then fall until 14:00. After that time, the number of transactions again rise until 16:00 and fall until the market closes. In addition, Fricke (2012) gives some interesting insight into the distribution of the variable but does not distinguish between different periods in his large data sample nor gives explanations for these.

Raddant (2014) shows the distribution of the number of trades during the day based on a histogram of the number of trades during the day. Using a sample, which spans from 1999-2010, he shows that the distribution can be described as a U-shaped distribution, meaning that there are two high points in the distribution of the number of transaction in the e-MID market. The first one is in the morning at around 09:00 and the second one is at around 16:00, whereas the lowest number of trades can be found at around lunchtime at 14:00. Nor does Raddant (2014) give further explanations about this kind of distribution.

Engler and Jeleskovic (2016) focus on intraday credits based on higher frequency data, meaning 5-minute intervals, by using a data sample from 01.10.2005 until 31.03.2010. In their analysis, they found, among other aspects, that the intraday demand for liquidity on the e-MID market as

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measured by the seasonality of volume per trade follows a U-shape. Furthermore, they found evidence that the highest volatility of these measures can be found directly after the opening of the market and before the market closes at each day.

In order to conclude for the related literature, these studies can be divided into three major categories: First, these who do not put an emphasis on the outbreak of the financial crisis and focus more on the operational framework of the e-MID market, namely the studies by Angelini (2000), Hartmann et al. (2001), Palombini (2003), Barucci et al. (2004), Beaupain and Durré (2008) and Iori et al. (2008). Second, those who analyze the different distributions by taking into account the outbreak of the financial crisis, namely Cassola et al. (2010), Vento and La Ganga (2009) and Engler and Jeleskovic (2016). And third, the studies conducted by Fricke (2012) and Raddant (2014), who use quite large data samples which also include the outbreak of the financial crisis, but not taking into account the changes of market due to this aspect.

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The most important aspects of the studies are summarized in table 1.

Table 1: Summary of the related literature of distributions in the intraday domain

Study	Data sample	Frequency	Important findings	Arguments for the shape of distributions
Angelini (2000)	01.07.1993 - 31.12.1996	One Hour	Volume U-shaped with high values in the intervals of 09:00 and 15:00-16:00	Italian clearing system and adjustment of liquidity positions
Hartmann et al. (2001)	01.11.1999 - 31.03.2000	One hour	Volume U-shaped with high values in the intervals of 09:00- 10:00 and 15:00-16:00	News which have been accumulated over the night and closing time of different payment systems
Palombini (2003)	03.01.2000 - 30.09.2002	One hour	Volume U-shaped with high values in the intervals of 09:00- 10:00 and 15:00-16:00	Transactions of the previous business day and cash balances from the Italian securities market are settled
Barucci et al. (2004)	01.04.1999 - 31.08.2001	One hour	Volume and number of trades U-shaped with high values in the intervals of 09:00-10:00 and 14:00-15:00	Authors state they are in line with the study by Angelini (2000)
Beaupain and Durré (2008)	04.09.2000 - 03.05.2007	30-minutes	Distributions of volume and number of transactions for buy and sell follow a U-shape with peaks at 09:00- 09:30 and the intervals of 15:00-17:00. For mean volume per transaction: Distribution with three peaks at 09:00, 14:00 and 17:30	Uncertainty due to price movements in the financial markets and the availability of liquidity
Iori et al. (2008)	01.01.1999 - 31.12.2002	Not known	U-shaped volume distribution, with peaks at the intervals of 10:00 and 15:00	Pending payments from previous days and settlement of interbank and other financial payments
Brunetti et al. (2010)	02.01.2006 - 01.04.2008	5-minutes	U-shaped volume distribution with peaks at 09:30 and 16:30 before the outbreak of the crisis and at 09:45 and 16:45 after the outbreak of the crisis	No explanations due to focus on other aspects
Cassola et al. (2010)	01.07.2007 - 01.03.2008	30-minutes	Volume and number of transactions follow a U-shape with peaks in the interval of 10:00 and 17:00	Liquidity shocks of the previous day, closing systems and liquidity needs
Vento and La Ganga (2009)	01.07.2007 - 30.06.2009	One hour	U-shaped volume with peaks in the intervals of 10:00 and 17:00	Unbalances from transactions during the night and European banking federation deadline
Fricke (2012)	01.01.1999 - 31.12.2015	One hour	U-shaped volume with peaks in the intervals of 10:00 and 16:00	No explanations due to focus on other aspects
Raddant (2014)	01.01.1999 - 31.12.2010	Histogram	U-shaped volume with peaks in the interval of 10:00 and 16:00	No explanations due to focus on other aspects
Engler and Jeleskovic (2016)	01.10.2005 - 31.03.2010	5-minutes	U-shape seasonality in Volume per trade and trade intensity	Different explanations of intraday seasonality

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Based on section 2 of this paper, I can therefore state that the most studies use one-hour intervals in their analysis and cut off different intervals, due to methodological aspects. Furthermore, in these studies, some authors give some explanations for the distributions of the intraday variables and others show it only in a graphical way without giving theoretical explanations. Moreover, only the study conducted by Beaupain and Durré (2008), and to a less extent the studies by Brunetti et al. (2010) and Cassola et al. (2010), differ between buy and sell transactions.
With respect to the distribution of the number of transactions and the volume of transactions, I can state that all studies found the same shape of the distribution, namely a U-shaped distribution. For the volume and the number of transaction all have a U-shape with high values around 09:00-10:00 and mainly 16:00 before the outbreak of the crisis. After the outbreak of the crisis, the second peaks can be found in in the majority of studies during the interval of 17:00. Brunetti et al. (2010) conducted the only study which showed this movement of the distribution after the outbreak of the crisis. The only study which put focus on the distribution of the mean volume per transaction, is the one by Beaupain and Durré (2008), finding three peaks in the distribution, namely in the morning, around noon and before the market closes.

These U-shaped distributions of the number and volume of transactions can be found also on other segments on of the financial market. Regarding other overnight interbank credit markets, e.g. Bartolini et al. (2005), show these kinds of distributions, with minor differences, for the overnight federal funds rate in the US. The intraday analysis of the distribution of volume and number of transactions has also been carried out for different stock markets. Various studies focus on the stock market in the United States, e.g. Jain and Joh (1988) and Foster and Viswanathan (1993) show that the intraday volume on the New York Stock Exchange (NYSE) market also follows a U-shape. Ozturk et al. (2017) find clear evidence for a U-shape distribution of intraday volume and the number of intraday transactions by analyzing 50 companies listed in the S&P 500 stock market. Gurgul and Syrek (2017) find clear evidence of a U-shaped volume distribution for the majority of the companies listed in the DAX. The authors furthermore found out this trend is also observable for different companies in the Austrian and the Polish stock market. Moreover, on derivate markets, there are clear dynamics of intraday volume and number of transactions. Iwatsubo et al. (2018) e.g. show these distributions for gold and platinum futures at the stock exchange markets in Tokyo and New York. Additionally, on the market of cryptocurrencies Eross et al. (2019) found that there is an intraday distribution of volume during the day. They found that the distribution might be characterized as n shaped, meaning low values at the beginning of the day, high values in mid-day and lower values at the end of the day.

3. The e-MID

The object of this chapter is to present briefly the e-MID market and the general data set structure which is commercially available via the company e-MID S.p.A.

The e-MID market was founded in 1999 as an initiative of the Bank of Italy. On the e-MID market credits with a maturity from ON until one year can be traded and the market functions on the principle of the limit order book. The minimum volume of each credit transaction equals 50,000 euro. The market opens at each trading at 08:00 and closes at 18:00 in the afternoon.

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The data sample I use for the purpose of this paper includes all euro denominated credit transactions from 03.10.2005 until 30.03.2015 and includes 1,149 business days with a total number of credits of 426,392 credit transactions of different maturities. Out of these, 377,745 transactions are ON credits and 48,647 are the remaining credits with different maturities. Thus, in this sample period about 89% out of all credit were transactions on the ON level. Arciero et al. (2016) state that a shift from longer to shorter maturities meaning ON credits was observed especially after June of 2008. After that date, more than 90 % of all credit transactions were executed during that time frame.

As seen in section two of this paper, the majority of studies base their analysis of the intraday behavior of the key variables on hourly means. Here, I differentiate my analysis also from a methodological point: I follow Beaupain and Durré (2008) and Jeleskovic and Demertzidis (2018) and use 30-minute intervals of the different variables during the day. As the authors state, the findings using means on a higher, but not too high frequency, leads to the point where the results become more precise, and the practical relevance on a lower time scale becomes even higher. Additionally, I will focus on all credits, from the opening of the market at 08:00 until the market closes at 18:00, which are ten hours, without removing any time intervals or specific days. Hence, I base my analysis on 20 30-minute intervals. For visibility reasons, the time stamp of 08:30, which is the first interval, represents the interval of 08:00-08:30 and the time stamp of 18:00 represent the last interval of 17:30- 18:00 and so on.

The data structure which I have obtained is presented in table 2.

Table 2: Data structure of the e-MID market

Market	Duration	Date	Time	Rate	Amount	StartDate	EndDate	Quoter	Aggressor	Verb
TRAS_EUR	ON	03.10.2005	08:55:23	2,085	150	03.10.2005	04.10.2005	IT0271	IT0265	Sell
TRAS_EUR	ON	03.10.2005	09:05:29	2,08	115	03.10.2005	04.10.2005	IT0258	IT0271	Buy
TRAS_EUR	ON	03.10.2005	09:05:58	2,09	25	03.10.2005	04.10.2005	IT0259	IT0164	Buy

Market: Indicates the currency used for the credit transaction. On the e-MID market, transactions are mainly denominated in euros. As stated, all transactions observed for the purpose of this paper are denominated in euros.

Duration: Indicates the duration of each traded credit. Current maturities range from overnight credits with a maturity of one day, different weekly maturities, different monthly maturities and up to maturities with one year. Based on the duration, some credits have “broken dates” which means that the exact maturity of these credits is not known. These kind of credit transactions represent only a very small number of transactions.

Date: Indicates the date when the credit was executed between the two banks.

Time: Provides the exact time when the credit transaction was executed.

Rate: Represents the interest rate of the respective credit.

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Amount: Indicates the credit amount of the respective credit in millions of euros.

Start Date: Specifies the start date of the credit transaction.

End Date: Identifies the end date of the credit. On this date, the bank that acts as the borrower must repay the credit to the lending bank. In the case of ON credits, the repayment day is the next business day as has been already stated. However, the exact time of credit repayment also depends on whether the borrower or the lender is an Italian bank. In this case, the time of credit repayment is 09:00 on the end date of the credit. If the credit is conducted between two non-Italian banks, the time of repayment is 12:00. Based on these facts, the repayment time for ON credits is the next business day, at either 09:00 or 12:00.

Quoter: This is the bank that issues the contract of borrowing or lending in the order book.

Aggressor: Represents the active bank that chooses the credit request (lending or borrowing) from the order book.

Verb: Displays the type of transaction from the perspective of the aggressor. The verb "sell" means that in this case, the aggressor sells a credit to the quoter. Thus, this transaction can be called a sell transaction. The verb "buy" means that the aggressor borrows money from the quoter bank. Thus, this transaction can be called a buy transaction.

The representation of the general dataset of the e-MID shows that different information regarding the executed credit transactions for both market participants and non-market participants is available. However, information that is not freely available to non-market participants also exists. This includes, on the one hand, the exact names of the transaction partners. As already presented, both quoter and aggressor are displayed. This display includes a five-digit identification code consisting of two letters and three digits. The two letters reflect the country of origin of each bank and the three digits represent a specific bank code. The exact names of the banks are not identified. Additionally, the system does not display the exact time when a particular credit request (buy or sell) from the quoter bank was entered in the order book. Neither date nor time of the setting in is specified, so it is not known how long a credit request was listed in the order book before it was executed. Neither credit inquiries from quoter banks that were not selected by aggressor banks from the order book are freely available. Another important piece of information that is not freely available on the e-MID market is the exact repayment time of the credit. It is not possible to tell at what time a bank has repaid a specific credit. Hence, only the maximum maturity of repayment is known. Additionally, banks may refuse a specific credit transaction in the e-MID market (Iori et al.,2015). The number of these refused credit transactions is also unknown. By knowing this number, further analyses regarding the perceived risk profiles of each bank could be executed.

As stated, the interest of this paper does not only rely on the different descriptive statistics, but on their differences in different market states. Therefore, following different studies e.g. Gabbi et al. (2012) and Demertzidis and Jeleskovic (2016), I also divide my data sample into different subsamples which represent different market states.

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Many studies show that different reasons play a role in the declining of interbank transactions after the outbreak of the financial crisis of 2007 and the de facto interbank market freeze after the collapse of Lehman Brothers. Freixas and Jorge (2008) e.g. show that the main reason for this fact is the increase in counterparty risk. On the other hand, Ashcraft et al. (2011) argue that an important reason also lies in the reality of liquidity hoarding. Brunetti et al. (2019) focus more on the interconnectedness between banks in order to understand this phenomenon.

The first period is equal to 473 business days and ranges from 03.10.2005, the beginning of the data sample until 08.08.2007, one day before the outbreak of the financial crisis of 2007. This period can be called the "pre-crisis" period where the number of transactions and the volume of transactions is steadily increasing. Here, the market mechanism is functioning very well, meaning that the allocation of liquidity between banks is given.

The second period equals 281 business days and ranges from 09.08.2007, the day of the outbreak of the financial crisis of 2007 until the 14.09.2008, one day before the collapse of the investment bank Lehman Brothers. In this period, the number of transactions and volume of transactions (and the number of active banks participating in the market) are starting to decrease. This period is the "first-crisis period", although the market is still functioning.

The third period which is 166 business days long, ranges from 15.09.2008, the day of the Lehman Brothers collapse until the 12.05.2009 one day before the ECB reduces the key interest rate for the last time. During this period, the number and volume of transactions are decreasing even more, a fact that is also observable for the number of active banks in the market. This period is called the "second-crisis period" where the market does not function properly anymore, meaning that the liquidity provision between banks is disturbed. During this period, banks with liquidity surpluses search for other markets in order to find investment opportunities and banks with liquidity shortages rely more on the provision of liquidity from the ECB.

The last period is 229 business days long and ranges from 13.05.2009, the day of the last ECB key interest rate reduction until the end of the sample period at the 31.03.2010. In this period, the number and volume of transactions as the number of active banks is even lower compared to the other periods. Here again, the market does not function well anymore and the main source of liquidity is given by the ECB. This period can be called the "after- crisis period".

The different sub-periods are summarized in table 3.

Table 3: Presentation of the sub-periods

Period 1	03.10.2005-08.08.2007	Period before the crisis
Period 2	09.08.2007-14.09.2008	Outbreak of the crisis until the collapse of Lehman Brothers
Period 3	15.09.2008-12.05.2009	Lehman Brothers collapse until reduction of key interest rate
Period 4	13.05.2009- 31.03.2010	Key interest rate reduction until the end of the observation period

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The descriptive statistics regarding the interday frequency reveal following facts: During period 1, the pre-crisis period, the absolute number of transactions is 24,342 buy transactions and 75,928 sell transactions, whereas the mean number of transactions per day is equal to 99.06 buy transactions and for the sell transactions this value is equal to 302.95. In this period, the liquidity provision between banks with surpluses and banks with short-term cash needs is functioning well.

By taking into account period 2, I can state that the absolute number of transactions equals 24,342 buy transactions and 75,928 sell transactions. The mean number of buy transactions per day equals 86.62 and the mean number of sell transactions equals 270.2. Thus, the pre described drop in the number of trades per day is visible even though this trend is not so dramatic as it will be in the next periods. Still, as this is now in the first period of the crisis, the market is still functioning well.

The third period of the data sample, consists of 8,774 buy transactions and 34,081 sell transactions. During this period, the mean number of transactions drops even more and the market is no longer functioning properly anymore. The mean number of transactions per day equals to 52.85 for buy transactions and the mean number of transactions for sell transactions is equal to 205.31. What I can state furthermore here is that the difference in the number of transactions between buy and sell becomes smaller, therefore, there is a noticeable shift from sell to more buy transactions.

As already stated, the fourth period is regarded as the period outside the crisis, where the market is no longer functioning well. During this period, the number of buy transactions equals 9,625 and the number of sell transactions is 34,835. In the last period, the mean of the transactions per day drops even more to 42.03 for buy transactions and to 152.11 for sell transactions.

All these pre mentioned interday descriptive statistics regarding the number of transactions are summarized in Table 4.

Table 4: Mean number of transactions per day [1]

	Period 1	**Period 2**	**Period 3**	**Period 4**
Buy transactions	99.06 (46,860)	86.62 (24,342)	52.85 (8,774)	42.03 (9,625)
Sell transactions	302.95 (143,300)	270.2 (75,928)	205.31 (34,081)	152.11 (34,835)

The findings of the mean volume per day (in million euros) are summarized in table 5.

[1] In parentheses are the absolute number of transactions. These different numbers rely on the fact, that the sub-periods are differently long.

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Table 5: Mean volume per day in million euros

	Period 1	**Period 2**	**Period 3**	**Period 4**
Buy transactions	4,665.03	2,731.090	1,564.411	884.545
Sell transactions	17,099.96	11,398.338	5,833.06	3,198.772

By taking into account the findings in table 5, it is clear that the volume per day drops in period 2 and even more in period 3 and 4. These findings are consistent with the description of the different market states.

Furthermore, based on these means, it is apparent that the difference in terms of mean volume per day are becoming smaller from period 1 and 2 to period 3 and 4. This indicates that a shift from transactions of sell to transactions of buy in terms of volume can be observed.

The findings of the mean volume per transactions per day are summarized in table 6.

Table 5: Mean volume per transaction per day

	Period 1	**Period 2**	**Period 3**	**Period 4**
Buy transactions	47.86	32.19	28.68	21.95
Sell transactions	56.72	42.61	28.23	21.05

By taking into account the findings of table 6, it is clear that the mean volume per transactions drops during the different sample periods, especially after the Lehman Brothers collapse in period 2. This could therefore be an indicator that larger and more system relevant banks leave the market. What is also shown here is that the mean volume for buy transactions is smaller than the mean of sell transactions in period 1 and 2, but this changes in periods 3 and 4. Here the values are small for both credit types but the mean volume for buy transactions is higher than the ones of sell transactions. However, these differences are too small to be relevant from an economic point of view. One can only assume that buy and sell transactions in periods 3 and 4 become more balanced in comparison to periods 1 and 2.

Hence, these statistical facts regarding considered market variables highlight strong differences among those four market states as well as between the sell and buy credits. Now, a closer look into the intraday distributions is given.

4. Empirical results: Transactions

As already stated, in the center of interest of this paper are not only the distributions of the different variables but also to take into account the difference between the buy and sell initiated credit transaction in different market states.

In this section, I focus on the distribution of the number of transactions differentiated in buy-sell and in the different periods. Due to the fact that the previously mentioned periods are differently long and in order to capture this fact, the mean number of transactions per interval will be shown

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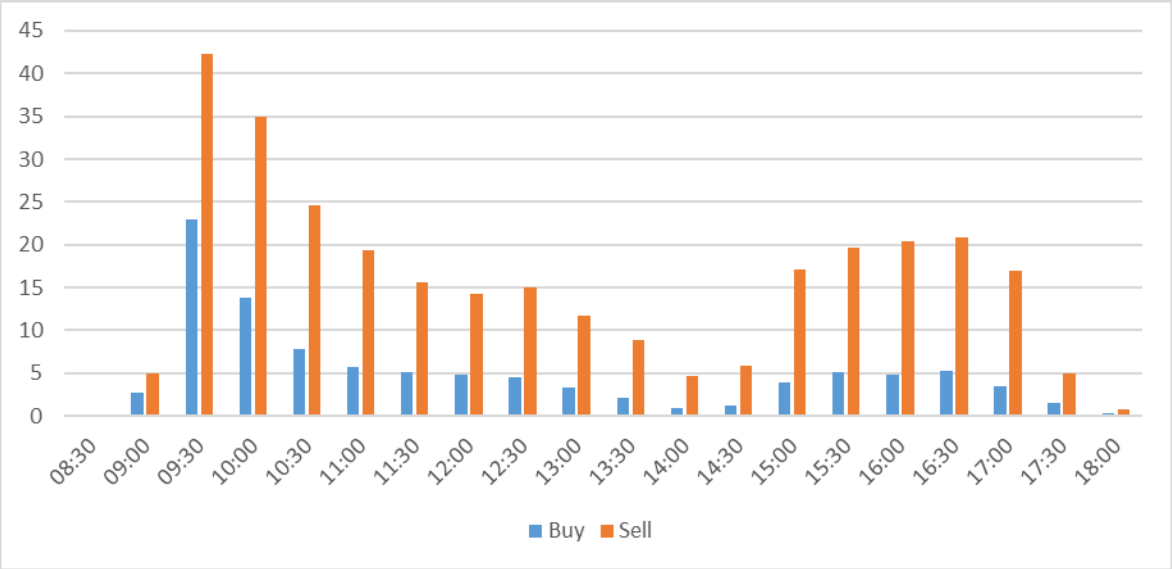
during this chapter. In order to visualize the effect of the intraday distribution of the variable of interest, I summarize all credit transactions of each specific time interval during the day and divide this number with the number of days of each period. In the end, I show these intraday distributions distinguishing over for the different periods which are defined above.

The results of the distribution of the number of transactions are shown in figures 1-4. In order to see exactly the difference between the buy and the sell initiated transactions, I show the distribution of both in one figure for each sub-sample period.

Figure 1: Mean number of transactions per interval in period 1



As can be seen in figure 1, in the first period the number of transactions in the first interval are low, reach their maximum in the interval of 09:30 and then drop until the interval of 14:00, with a small rise during the intervals of 12:00-12:30. From 14:00, the number of transactions rise again until the interval of 16:30 when they begin again to fall again until the market closes at 18:00. These trends are exactly the same for the buy and the sell transactions, with a small difference around noon. The distribution of the number of transactions can be described here as U-shaped, or a shape with two humps (m- shaped) when taking into account the low values at the beginning and the end of the day. The first hump is found at 09:30 and its second-high value in the interval of 16:00 and 16:30, with a low point during the interval of 14:00. What is also obvious is that the number of sell transactions is higher than the buy transactions in each interval in this period.

The distribution of the number of transactions for period 2 can be found in figure 2.

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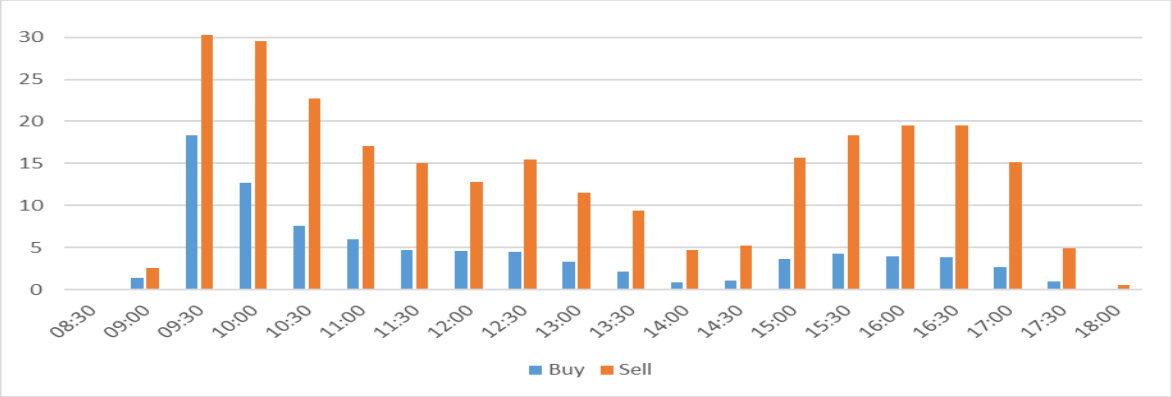
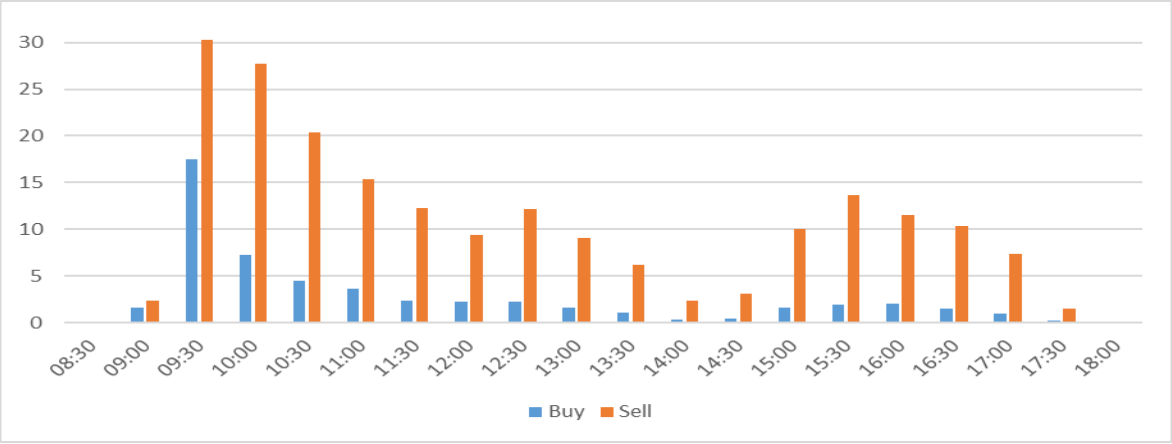
Figure 2: Mean number of transactions per interval in period 2



By taking a look at figure 2, we can see that the number of trades drops in comparison to period 2 in each interval for the sell and buy transactions. Furthermore, the distribution of the number of transactions in the first crisis period looks like the distribution of period 1. The number of transactions is low directly after the markets open and are high around the intervals of 09:30 and 10:00. From that time point, they fall again until the interval of 14:00, with a small rise during the interval of 12:30. From that time point again, the number of transactions rise again until 16:30 and drop afterwards until the market closes. Moreover, here the distribution of the buy and sell transactions have qualitatively the same shape. The difference here is, that the second hump for buy transactions can be found now at 15:30. Based on the findings in period 2, the number of transactions for sell transactions is again higher than the number of buy transactions in each interval. What is observable here, is that the gap between the values of sell and buy transactions becomes smaller in the most intervals during the day. This may highlight the fact that credit sellers begin to overthink acting on the interbank due to the general uncertainty after August 2007.

The distribution of the number transactions in period 3 can be found in figure 3.

Figure 3: Mean number of transactions per interval in period 3



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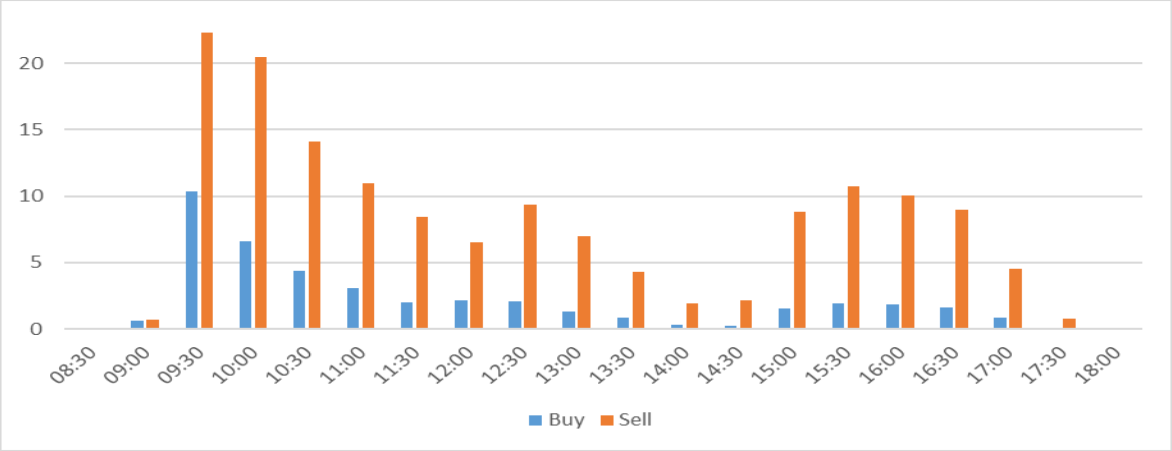
By taking a look at the distribution of the number of transactions in period three, it is visible that the number of transactions drop further more in each interval, for both sell and buy transactions. For this period, we can again state that the distribution of buy and sell initiated transactions have qualitatively the same shape, with some differences during the intervals of 15:30 and 16:00. During this period the gap between the sell and buy transactions becomes even smaller.

During this period the number of transactions is low at the start of the day and reach its maximum at the time interval of 09:30. From that point, they start to drop slowly until the interval of 10:00 and even more until the interval of 14:00, with a small rise during the intervals of 12:00-12:30. After the interval of 14:00, they start to rise again and reach their highest value during the afternoon until the interval of 15:30 for sell transactions and at 16:00 for buy transactions. After these intervals the values start to fall until the market closes at 18:00. In addition, during this period, the number of sell transactions is higher than the number of buy transactions in each interval and also a transfer from sell to more buy transactions in the most intervals can be observed.

The distribution of the number of transactions in period 4 can be found in figure 4. In this period only six transactions occur during the interval of 08:30 (five buy transactions and 1 sell transaction) and only 15 transactions (three buy transactions and 12 sell transactions) occur during the last of interval of 18:00 in the whole period. Hence, the first and the last interval in this period cannot be considered as representative.

Figure 4: Mean number of transactions per interval in period 4



Like all the aforementioned periods, the distribution of the transactions regarding buy and sell transactions have the same shape qualitatively. As in period 3, the number of transactions in this period are quite low in the beginning of the day rise in the interval of 09:30 and drop until the interval of 14:00, with one small rise at around noon. From the interval of 14:30 they rise again until the interval of 15:30 and drop again until the market closes. Thus, the distributions of the number of transactions have the same shapes qualitatively as they were in the period 3, where there the market was not functioning as well. For the buy transactions, the difference now between the intervals of 15:30 and 16:00 becomes smaller. During this period, the number of sell

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transactions is also higher than the number of buy transactions, whereas again a smaller gap between sell and buy transactions in the most intervals compared to the previous period is noticeable.

In order to sum up, the analysis of the number of transactions reveal some very interesting facts:

By taking into account the general distribution of the (mean) number of trades per interval, it is now clear, that in all mentioned periods and market states, the distributions can be described as U-shaped. As already described, the number of transactions are quite low during the first hour meaning that the market participants are quite inactive. One possible explanations for this fact is, that the banks monitor their liquidity needs during these intervals and optimize their daily trading strategies. The first hump can be found during the intervals of 09:00 and 09:30. The acting in the morning allows the banks to be liquid to a certain extent over the day. Possible explanations for this humps are manifold: On the one hand, the conditions of the Italian clearing system (Angelini, 2000) and the news which have been accumulated over the night (Hartmann et al., 2001), influence the behavior of banks to act early in the morning. On the other hand, the settlement of credit transactions of the previous business day (Palombini, 2003), and here especially those where no Italian bank was involved in a credit transaction, as in these cases the repayment time is 12:00 play a major role to act in these intervals. Furthermore, pending payments from previous days (Iori et al.,2008), as it the case for credit transactions with an involvement of Italian banks, influence the behavior of banks in order to act at these time intervals in the morning. Until the time interval of 09:00 the ON credits from the previous days must be repaid, so many banks become more liquid and can act after this interval more frequently, also on the e-MID market. Furthermore, imbalances from transactions during the night (Vento and La Ganga, 2009), liquidity shocks of the previous day (Cassola et al., 2010) and the uncertainty due to price movements in the financial markets and the availability of liquidity (Beaupain and Durré, 2008), are further reasons for the banks to act more frequently during the intervals of 09:00 until the interval 10:30.

The second hump can be found during the afternoon, two to two and half hours before the market closes. Possible explanations for this phenomenon are the adjustment of liquidity positions before the day closes (Angelini, 2000), the closing time of different payment systems (Hartmann et al., 2001, Cassola et al., 2010), the time point at which cash balances from the Italian securities market are settled (Palombini, 2003) and settlement of interbank and other financial payments during this time (Iori et al., 2008).

Between these two humps, there is also one interval at which the number of transactions is increasing. This is the interval of 12:30, or as stated the time between 12:00 and 12:30. This interval represents the time before lunch. Based on this kind of increase in the values, I can thereby state that the banks become active in the market before the lunchbreak, as they may know that the market is quite inactive during and after the lunchtime. This fact should also have been taken into account when analyzing the banks behavior on the e-MID market, as it stays intact during all periods and market states. This study is the first one to detect this effect immediately before the lunch-time.

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When now comparing the sell and buy distributions for this variable, it is apparent that the distributions have the same shapes as the market is functioning properly in the periods 1 and 2. This changes in the periods 3 and 4, when the market is not functioning properly anymore. Here, the hump in the afternoon for the buy transactions is earlier during the day, which can be regarded as an indicator of the greater liquidity needs of borrowing banks, as they might be concerned about their liquidity needs later in the day.

With regard to the comparison of the values between buy and sell transactions, it can be shown that the numbers of sell transactions are higher in each interval and in each period than those of the buy transactions. This aspect has also been pointed out by Beaupain and Durré (2008) for the interday frequency. This indicates that this higher activity in sell orders on the market may be caused by banks, to a large degree, in order to optimize their trading strategy when depositing larger liquidity.[2] Here in this study it is shown that this fact can be observed also in the intraday frequency in all intervals. This phenomenon stays stable over the time in the different periods and robust during the different values. It can therefore be called a stylized fact of the market (Cont, 2001, Winker and Jeleskovic, 2007). There is only a small amount of studies which focus on the findings and explanations of stylized facts on interbank credit markets. Their findings are basically found in the network formations of the market, as the studies of e.g. Craig and von Peter (2014) for the German interbank market or the studies e.g. by Fricke and Lux (2015) and Finger and Lux (2017) for the e-MID market indicate. This is, to the best of my knowledge, the first study which finds and shows a stylized fact of the distribution of the number of trades during the day on the e-MID market. Winker and Jeleskovic (2006) argue that, based on stylized facts on different segments of the financial markets, further analyses can be conducted in order to widen our theoretical understanding of the markets and in order to generate novel empirical or econometrical models. Furthermore, these stylized facts are important due to the fact that these phenomena on different segments of the financial markets are robust and must be explained. Additionally, these facts initiated different models, as it was in the case of the GARCH models for the explanation of the interest volatility (Bollerslev, 1986). Furthermore, these facts are of high interest in order to build up new estimation methods which can capture different asymmetries on the financial markets as in the case of agent based models (LeBaron, 2006) or microsimulation models (Castiglione and Stauffer, 2001 and Winker et al., 2007).

What is also noticeable in this context of the comparison of the values between the number of sell and buy transactions is, that the difference between them becomes even smaller in the most intervals from period 1 to period 4. This again means that banks are becoming more active in terms of borrowing credits. This may indicate the fact that the uncertainty of repayment when selling credits becomes larger, especially after the collapse of Lehman Brothers.

5. Empirical results: Volume

After the number of transactions, I will focus on the volume of transactions on the intraday basis. In this chapter, I divide my findings into two aspects: First, I show the distribution of the mean

[2] Banks put rather many smaller orders than one of huge volume to not influence negatively the price of the credit which is the interest rate in this section.

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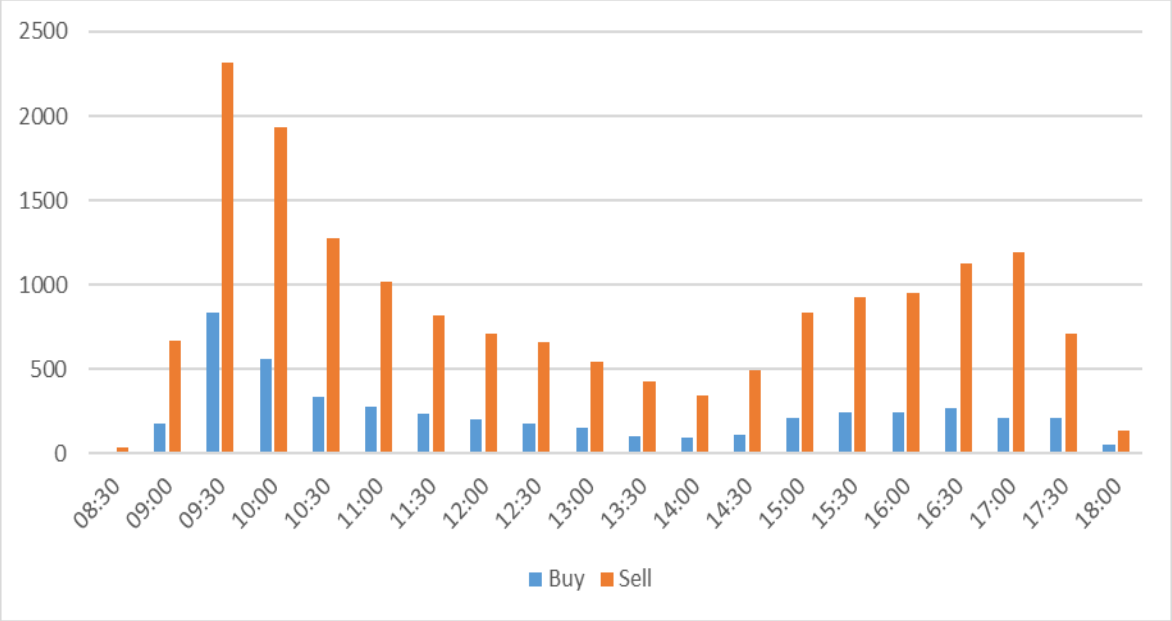
volume per interval during the day. In this case, the mean and not the absolute volume per interval is again taken into account in order to capture the different long periods. For this purpose, I sum up the volumes of the transactions of each specific time subinterval during the days and divide this number with the number of days in each period. Secondly, I will focus on the distribution of the mean volume per transaction.

As in the case of the distribution of the number of transactions, I also show the volume per interval and the mean volume per transaction in each interval differentiated in buy and sell transactions in one figure.

The distributions for the mean volume per interval in million euros can be found in the figures 5-8.

Figure 5 shows the distribution of the mean volume per day in the first period.

Figure 5: Mean volume per interval in period 1



By looking at the distribution of the intraday volume in period 1 it is noticeable that the values of the sell transactions are higher than those of the buy transactions in each interval. Furthermore, the distribution for buy and sell transactions have the same shape as it was also with the number of transactions. Here again, the distribution can be described as double-humped, or U-shaped. The volume per interval is low at the beginning of the day, rises from the interval of 09:00 until the interval of 09:30 and drops afterwards until the interval of 14:00. From that time interval, the volume rises again until the interval of 17:00 for the sell transactions and until 16:30 for the buy transactions. Afterwards it drops again until the market closes. In contrast to the number of transactions, an increase in the volume during the interval of 12:30 is not given.

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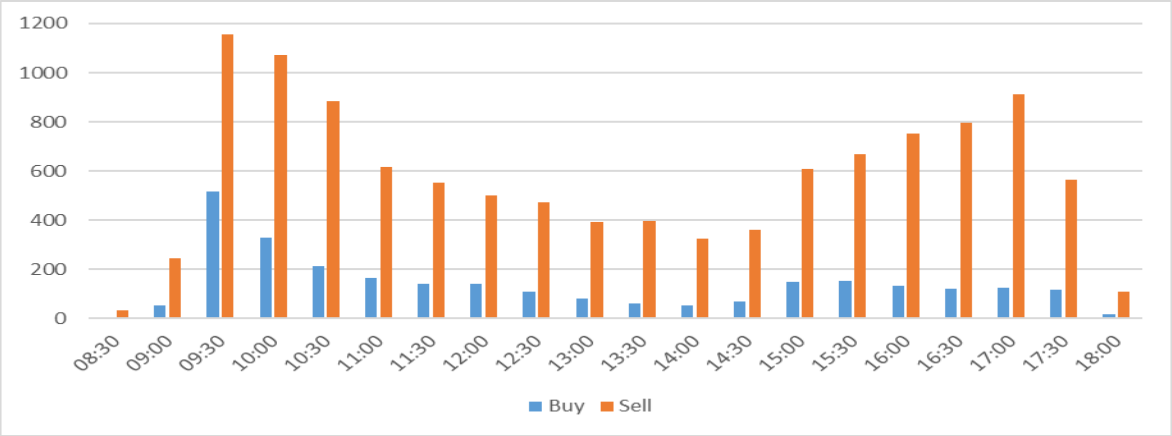
The volume per interval in period 2 can be found in figure 6.

Figure 6: Mean volume per interval in period 2

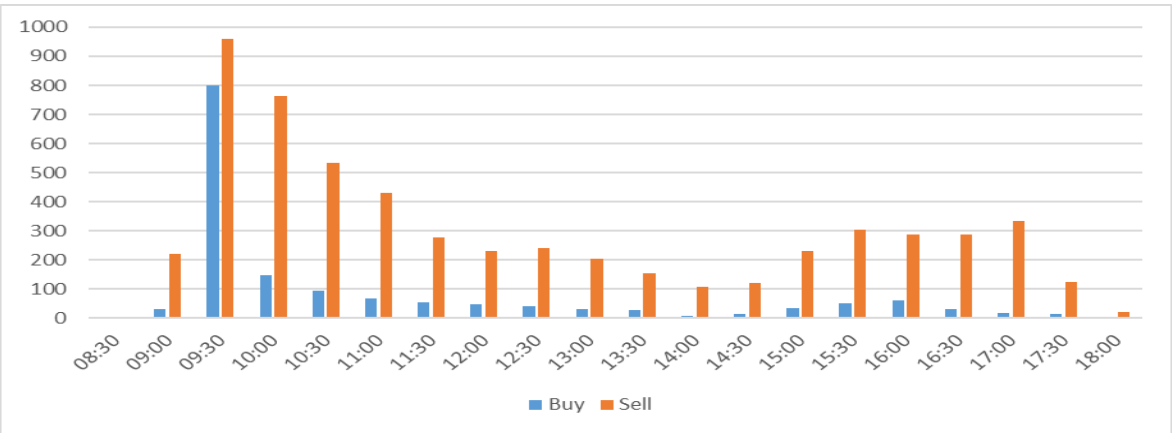


Regarding the intraday distribution of volumes in period 2, it is observed that the volumes per interval drop in each interval when compared to period 1. As in period 1, the values of the sell transactions are higher than the buy transactions in each interval. Furthermore, we can see, as it was the case for the number of transactions that the gap between sell and buy transactions is becoming smaller in this period.

Here also, the distribution of the buy and sell initiated transactions have the same shape, with some minor differences at the end of the day. The distribution can also be called in this period two-humped. Again, the distribution of volume is low at the beginning of the day, reaches its maximum at the interval of 09:30 and starts to drop until the interval of 14:30. After that time point, it rises again until the interval of 17:00 for the sell transactions and at 15:30 for the buy transactions. After these time intervals, the volume drops again until the end of the day.

The distribution of the intraday volume for period 3 can be found in figure 7.

Figure 7: Mean volume per interval in period 3



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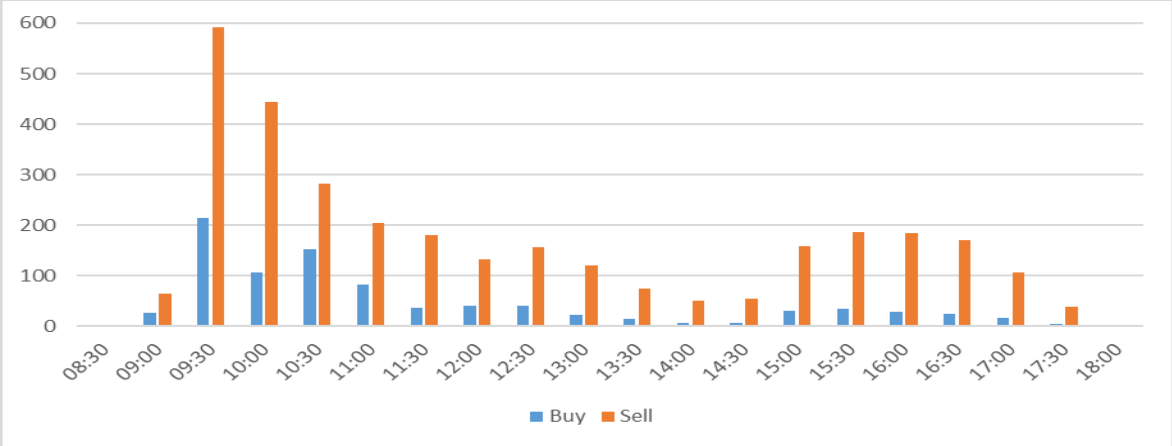
Regarding the results in period 3, we can see that the volume per interval drops even more dramatically in each interval. In this period, the values for sell transactions are also higher than the buy transactions in each interval, even though again the gap between the sell volumes and the buy volumes becomes smaller in almost each interval.

During period 3, the distributions of the volume between buy and sell transactions seem to differ now and the smoothness of the distributions differs in contrast to the previous periods. There are now not such clear distributions as it was the case for the number of transactions. However, the distributions for the sell and buy volumes may still be called two-humped. The first hump can be found for both distributions in the interval of 09:30 and the second hump in the intervals of 15:30- 17:00. What is further noticeable here is, that the second peak of the distributions differs again for the sell and buy distributions. The peak of the sell distributions can be found later in the day at 17:00 and for buy transactions at 16:00.

The distribution of the volume for period 4 can be found in figure 8. Due to the already stated extremely low number of transactions in the first and in the last interval of period 4 the values of the volume of transactions cannot be considered as representative as well.

Figure 8: Mean volume per interval in period 4



The distribution in period 4 shows that the values of the volume now are even lower than they were in the previous periods. Furthermore, the gap between the values is becoming even smaller. The distributions of the buy and sell transactions in this period do not look the same anymore and the smoothness of the distributions differs even more. In addition, during this period, the values for the sell transactions are higher in each interval than those of the buy transactions. The distributions may still be characterized in general as two humped-shaped, or U-shaped with high values in the morning in the intervals of 09:30 and 10:00 for the sell transactions and during the intervals of 09:30 to 10:30 for buy transactions. The second hump can be found during the intervals of 15:30 to 16:30.

In order to come to conclusion about the volume distribution, I can recognize some interesting facts: In general, the smoothness of the distributions differs and the recognition of patterns in the

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distributions becomes more difficult when compared to the number of transactions. However, in all mentioned periods, the distributions can be characterized two-humped or U-shaped, with high values in the intervals of 09:00-09:30 in the morning and high values in the afternoon. The reasons for such distributions have already been given in the previous chapter and hold for the volume of transactions as well. In contrast to the number of transactions, there is not an observable pre-lunchbreak effect.

Furthermore, there are again some similarities in the distributions in different market states. When the market is functioning properly in periods 1 and 2, the distributions of buy and sell transactions have the same shape. In these periods, however, the second peaks in the distributions also differ, meaning that the peaks of the sell and buy transactions differ. Also in these periods, the borrowing banks become more active earlier in the day than the credit lending banks. This fact highlights the aspect that the liquidity needs must be fulfilled earlier in the day, when acting as a borrower. The smoothness of the distributions changes in the periods 3 and 4 when the market is not functioning properly anymore. These changes in the smoothness of the distributions, especially when the market is not functioning properly anymore, highlights again the general uncertainty in the market. Likewise, the high values in the distributions also change. In the periods where the market is no longer functioning well, higher credit volumes can be observed earlier during the day. This also highlights the greater uncertainty in the market, as banks have to become active earlier during the day. Explanations for such distributions are the same as given in the previous sections for the number of transactions, which include pending payments from previous days (Iori et al.,2008) for the morning hump and the adjustment of liquidity positions before the day closes (Angelini, 2000), for the evening hump. This study is the first to show that higher credit volumes are executed earlier the day when the market is not functioning properly anymore.

When comparing now the sell and buy transactions, I can state that the shapes look similar in the periods 1 and 2, although the second-high values during the day differ already when the market functions properly. The distributions do not look the same qualitatively in the periods 3 and 4, which means, that, based on the volume during the day, the behavior of credit partners is different. Banks seem to behave differently when it comes to the disposition of excessive liquidity as it is the case for sell transactions and when liquidity needs are taken into account during the day, as it is the case for buy transactions.

Also interesting and noteworthy, is the fact that the volume of the sell transactions is higher than the volume of the buy transactions in each interval of the day and in each period. Thus, the previously mentioned stylized fact in the number of transactions can be observed also in the distribution of the volume. Based on these findings, I can state that banks use the market primarily in order to deposit liquidity in each interval of the day and in each period analyzed. To the best of my knowledge, this is the first study on the e-MID market which discovers this fact on the intraday distribution of the volumes.

Additionally, also based on the distribution of the volumes per day, it is clear that the gap between the sell and buy volumes becomes smaller from period 1 to period 4. This means that

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banks use the market even more frequently as a source of liquidity, rather than as an option of depositing liquidity amounts.

One other important variable regarding the volume distribution is the mean volume per transaction of each interval in order to detect when the credit transactions were executed with high volumes during the day. This variable is of high interest due to the fact that it can influence the behavior of the banks in the e-MID market as it can indicate at which time during the day to become active for the buy and sell of credits with a high volume. Additionally, based on this variable, banks can optimize their trading strategy. Furthermore, the mean volume per transaction is frequently used in econometric models for modeling order book dynamics (Hautsch and Jeleskovic, 2008). In order to capture this variable, I sum up all volumes in each interval and in each period and divide these volumes by the specific number of trades in each of these intervals. Also in this case the values of the buy and sell transactions are shown together for each period.

The distribution of the mean volume per transaction in million euros for the different sub-periods can be found in figures 9-12.

The distribution of the mean volume per interval in the period 1 can be seen in figure 9.

Figure 9: Mean volume per transaction per interval in period 1

As it can be seen in figure 9, the analysis of the distribution based on the mean volume per transaction does not provide such clear shape distributions as it was the case with the number of transactions and the volume of transactions. However, based on these findings some interesting facts can be noted. As in the other two variables, the distribution of the mean volume per transaction of the buy and sell credits have the same shape, with some minor differences during the dime interval of 14:00 until the interval of 14:30. The general distribution of the mean volume per transactions shows some evidences. First of all, it is clear that the credits with the highest volume for both credit transaction types are traded in the morning directly after the market opens in the interval of 08:30. The other intervals with high mean volume per transaction

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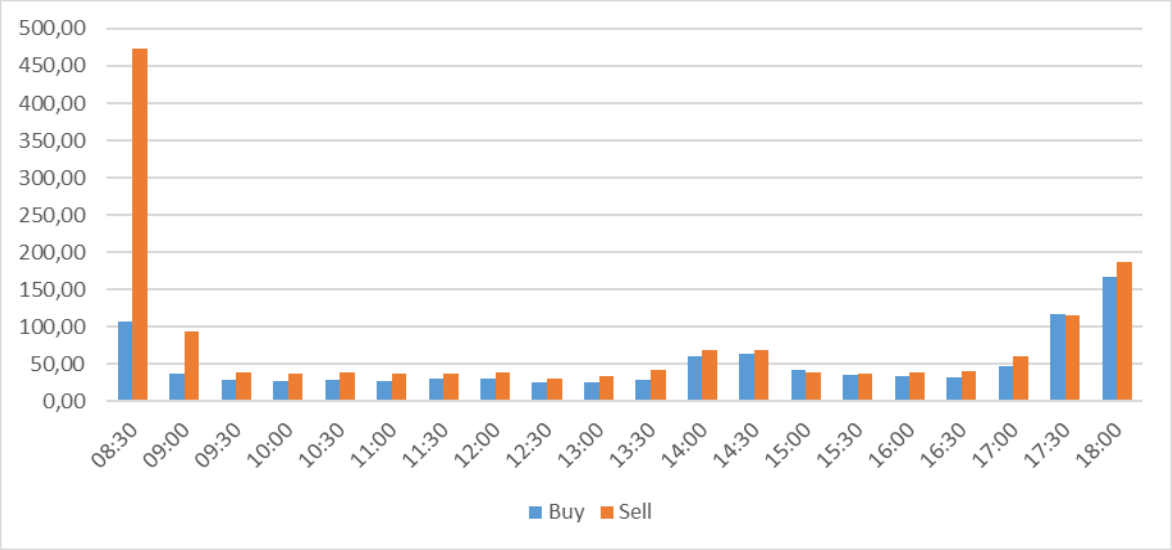
are the interval of 09:00, during the two intervals after the lunch time at 14:00 and 14:30 and during the last two intervals in the afternoon during the intervals of 17:30 and 18:00. As such, the distribution of the mean volume per transaction in period 1 can be characterized as a three-peak distribution. Besides these three peaks, the values remain relatively stable. In this period, the values for sell transactions are higher for almost all intervals, except the ones of 14:00 and 14:30.

The distribution of the mean volume per transaction in period 2 can be found in figure 10. It can be seen here that the mean volume per transaction drops in comparison to period 1. This can be regarded as a sign, that larger banks leave the market as has already been stated in different studies (e.g. Barucca and Lillo, 2018).

Figure 10: Mean volume per transaction per interval in period 2



Here, as in period 1, the mean volume per transaction distribution for buy and sell initiated looks almost the same during this period. After the start of the financial crisis in this period, the distribution of the mean volume holds its same shape as it was before the outbreak of the crisis. The credits with the highest mean volume per transaction can be found in the morning during the first two intervals and in the afternoon during the last two intervals. Here also, the mean volume per transaction remains quite stable during the day with an increase during the intervals of 14:00 and 14:30. In this period, the values for the sell transactions are also higher than the ones of the buy transactions, except for the intervals of 15:00 and 17:30.

The distribution of the mean volume in period 3 can be found in figure 11. Here it is apparent that mean volume per transaction takes smaller values indicating an even higher downgrade in the number of banks and the number banks trading credits with high values during this period.

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Figure 11: Mean volume per transaction per interval in period 3

By taking into account the distribution in period 3, it can be seen that the distribution for sell and buy initiated transactions does not follow the same trend anymore as it was in the periods 1 and 2 when the market was still functioning well. Furthermore, the smoothness of the distributions changes. For the sell initiated credit transactions, high values can be seen at the opening of the market in the intervals of 08:30 and 09:00. The mean volume per transactions takes again high values during the intervals of 14:00 and 14:30 and again in the afternoon during the intervals of 17:30 and the interval of 18:00. In this period, there are yet again therefore distributions with three peaks: One in the morning, one after the lunch- time and one before the market closes. The mean volume per transaction for buy-initiated transactions is low as the market opens and gets higher in the interval of 09:30. High values can be seen again during the intervals of 14:00 and 14:30 and right before the market closes during the intervals of 17:30 and 18:00. Here also, the distribution can therefore be described as one with three peaks, but the sell and buy values do not follow exactly the same trend anymore. In more intervals, the buy values are also higher than the ones for sell transactions.

The distribution of the mean volume per transaction in period 4 can be found in figure 12. Based on this figure it can be seen that the mean volume drops even more compared to the previous periods which is again a sign for the leaving of foreign banks and the general uncertainty in the market.

Figure 12: Mean volume per transaction per interval in period 4

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As figure 12 shows, the distribution of the mean volume per transaction does not look the same way for buy and sell transactions, although it still shows some interesting facts. The mean per transactions drops even more during this period, which again highlights the fact that the market becomes less system-relevant. The mean volume for sell transactions is high again in the morning during the intervals of 08:30 and 09:00 and is quite volatile during the day. Peaks again can be found after the lunch break around the intervals of 14:00 and 14:30 and in the last two intervals of the day. For the mean volume per transaction based on buy transactions I can state that it is not high when the market opens but in the second interval of 09:00. During this period, peaks for the distribution can be found before the lunchbreak in the intervals of 10:30 and 11:30 and also after the lunchbreak at the interval of 14:30. Thus, banks acting as credit borrowers in this period must search longer for credit partners for high value transactions credit lenders. The last peaks again can be also found in the last two intervals of the day at 17:30 and 18:00. During this period, I cannot state anymore that in the most intervals the values for sell transactions are higher than the ones of buy transactions.

As it can be seen, in all these mentioned distributions for the mean volume per transaction do not show such clear distributions as it was the case in the previously-mentioned variables. This analysis does, however, reveal some interesting highlights:

The general shape of the distribution can be described as a distribution with three peaks: One in the morning, one after lunch-time and one directly before the market closes. For the morning peak, I can therefore state that the adjustment of liquidity positions (Angelini, 2000), news which have been accumulated over the night (Hartmann et al., 2001) or the imbalances from transactions during the night Vento and La Ganga (2009) are directly transferred to the liquidity management of the banks, since in the morning high value credits per transaction are been sold and bought. The high values right when the market opens and before it closes become even more noteworthy after the outbreak of the financial crisis. This means that banks buy or sell credits with high values after the outbreak of the financial crisis right when the market opens due to risk constrains and news during the day and before the market closes as there is a higher degree of uncertainty for events during the night. Finally, the high values during the first two intervals would suggest that many of these high volume credits are accounted among Italian banks, which have to be paid back until 09:00. Credit-buying banks may thus act so early in the morning in order to fulfill their credit obligation until the payback time of the credits until this time band. This would also explain the fact that there are higher values of the mean volume per transaction until this interval.

What I can also again state is, that the market participants borrow or sell credits with high values directly after lunch. Thus, there might be a tendency of the bankers to sell and buy high valued credits after the lunchtime. The high values in the afternoon again highlight the fact, that banks become active right before the market closes, as they search for other trading opportunities during the night. What is also possible is that there is here a connection between the volume of each credit and the interest rate. There might be the possibility to take up higher value credits in the morning, after lunchtime and before the market closes, to smaller credit costs meaning smaller interest rates. Here also, further analysis must be undertaken in order to test this hypothesis.

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By moving away now from the general distribution and coming to the comparison of sell and buy transactions, I also find some interesting insights. For the sell transactions, the general shape of the distribution remains the same in all periods and market states. This means that based on the mean volume per transaction the banks providing credits as sellers do not change their behavior. The image is not so clear for the buy transactions: In the periods 1 and 2, the general shape remains the same, as it was for sell transactions. Afterwards in periods 3 and 4, banks take up larger credits later on the day, and not exactly after the market opens. This could again highlight the general uncertainty of the market regarding the possibility of repayment of the credit-buying banks, when the market is not functioning properly anymore. Further differences can also be found when comparing which values are higher during the day. In the first two periods, the values for sell transactions are mainly higher than the one for buy transactions. This changes when the market is no longer functioning properly. In some intervals during these periods, the sell values are higher and in some other, the buy values are higher. This again highlights the fact that when the market no longer functions properly, the transaction behavior of the banks changes. Based on these findings, I can thus state that the market becomes more volatile, highlighting on the one hand the uncertainty of liquidity for buy transactions and on the other hand, the need of banks to deposit excessive liquidity in the market for sell transactions.

When we now compare the different periods among them, I can state for periods 1 and 2 that the distributions in these periods for buy and sell transactions look almost the same and follow the same trend, with minor differences. Furthermore, we see in both periods, high values during the first two intervals in the morning and the last two intervals in the afternoon, whereas this variable stays relatively the same during the rest of the day with some increase during the intervals of 14:00 and 14:30. During these two periods, the values in the morning are higher than in the afternoon, meaning that the need for higher volume credits is higher in the morning than in the afternoon, when the market still functions properly. To sum up, for the periods 3 and 4 do not follow the same trend anymore. There are differences in the distribution of the mean volume per transactions for sell and buy initiated transactions and the smoothness of the distributions changes from period 3 to period 4, which is also a sign for the general uncertainty of the market. There are still, however, some similarities in the distributions.

6. Conclusion

This study presents the first analysis which takes explicitly into account the distribution of key variables on the Italian interbank credit market e-MID in the intraday frequency. That is to say, the mean number of transactions, the mean volume of transactions and the mean volume per transaction when additionally considering the differences between buy and sell credits in different market states. That means, I distinguish between buy and sell initiated credits and show the distribution of these variables during the day by analyzing the effect of the financial crisis of 2007 and onwards on these measurements.

The analyzed distributions highlight important findings: The distributions for the number of trades and the volume of trades in the different intervals can be characterized as double- humped, with high values in the morning and in the afternoon. Reasons for the hump in the morning are, e.g. liquidity shocks of the previous day and in the afternoon the closing systems and liquidity

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needs for the night (Cassola et al., 2010). For the distributions of the number of trades, another upward trend is found before the lunchbreak, highlighting the fact that banks become active during that time, knowing that the number of transactions is low afterwards. What is also important to take into account is that, when the market does not function properly anymore we can observe the phenomenon that more credit transactions take place earlier during the day highlighting the greater intraday uncertainty in the market. This general two-humped shape is consistent with the findings of previous studies as reported in section 2. This fact is interesting, due to the fact that all aforementioned studies beginning from Angelini (2000) who takes into account a data sample which spans from 01.07.1993 - 31.12.1996 until the findings of this analysis, find two-humped (or U-shaped) distributions which are still intact on the e-MID market. Thus, this is a general feature of the market.

By taking a closer look to the distributions of the number of trades, further interesting facts can be found: The distributions of the sell and buy trades have the same shape when the market is functioning properly in periods 1 and 2. This changes when the market is not functioning properly anymore in periods 3 and 4. Furthermore, the smoothness of the distributions changes, highlighting the general uncertainty of the market. This is more visible for the borrowing banks, as they are confronted with higher liquidity constraints during the day. This forces these banks to act earlier in the morning.

By taking into account the distributions of the volume of transactions, the smoothness of the distributions changes even more from period to period. This again highlights the general uncertainty of the market, even though the shape of the distributions is qualitatively the same in period 1 and 2 for buy and sell transaction but this changes again in period 3 and 4.

When comparing the values of the sell and buy transactions in both variables, number and volume of transactions during the day, it is evident that the values of the sell transactions are higher than those of the buy transactions in each interval and in each period. This is a stylized fact of the e-MID market which has been first detected in this analysis. Additionally, the gap between these two variables becomes smaller in each period. This highlights the fact that there is a shift from credit selling to even more credit buying in the e-MID market. This again also highlights the changing behavior of market participants and the general uncertainty of the market.

Based on the findings of the mean volume per transaction, I can state that in all periods the distribution shows some clear evidence for high values in the morning, as soon as the market opens and in the afternoon just before the market closes. The distributions of the sell transactions show that their shape is mainly still intact in all periods. This fact is not given for the buy transactions. During first two periods, the buy transaction distributions are qualitatively the same and in line mainly with those of the sell transactions. This changes in periods 3 and 4. Thus, based on this variable, I can state that credit selling banks did not change their behavior but buy banks did it to a great extent. The previously described stylized fact cannot be shown based on the results of the mean volume per transaction. The values of the buy transactions are higher at some intervals during the day than those for the sell transactions and in some intervals the situation is the other way around.

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As already stated, there are differences between the distributions of sell and buy transactions for all variables analyzed in this paper, especially when the market is no longer functioning properly. To a large extent, this difference in sell and buy transactions is not taken into account in different papers regarding the e-MID market. The majority of studies presented, e.g. Hartmann et al. (2001) or Brunetti et al. (2010) do not take into account these differences although it is quite clear that the empirical and theoretical findings may differ when taking into account these differences. By taking into account the fact that the sell transactions are higher regarding the number and the volume of the values of buy transactions and thus the argument that the market is primarily used in order to deposit excessive liquidity, one could conclude that there might be an oversupply of interbank credits on the market. On the other hand, this oversupply may generate a lower interest rate for these credits as it may follow the basic microeconomic principle of higher supply leading to better lending conditions in terms of lower interest rates. In order to verify this hypothesis, further research is needed which puts focus on the relationship between the number and volume of transactions, the type of the transactions (buy or sell) and the intraday interest rate. This could again have an impact on the behavior of banks on the market, regarding whether they act on the market as a credit lender or credit a seller.

Unexpected events during the day may force the bank to become active during the day in the interbank credit market and to overcome liquidity shocks. In this manner, the knowledge of when the most transactions (in terms of number of trades and volume of trades) and those transactions with the highest volume per transaction take place on the market are of high interest. Such analyses become even more important when the liquidity management is distorted after the outbreak of the financial crisis and the following events, as shown in the previous chapters.

Due to this kind of analysis, our understanding of the international interbank credit markets rises sharply. From a policy point of view, anomalies in the intraday dynamics indicate changes in the market states. The described differences in the buy and sell transactions should also be taken into account by further theoretical modelling as well as on different econometric time series approaches or in the analysis of the network effects of the e-MID market as well.

When comparing the findings with the other studies presented in section 2, I can state that the findings presented in this paper give much clearer results considering that the market functioning changes. This fact should be taken into account when analyzing the e-MID market in the intraday frequency. When comparing my findings based on the mean number of transactions and the mean volume per interval with the findings of previous studies, I can state that these are in line in the periods 1 and 2, when the market functions properly. This changes when the market is not functioning anymore in periods 3 and 4, as the smoothness of the distributions change. Hence, for the analysis of the interbank credit market, different market states and the differentiation of sell and buy transactions should be taken into account. By comparing my findings based on the mean volume per transaction with the previous studies, I can state that the results may be in line again when the market functions well, but do change when this is not given anymore. This analysis represents the first study to show these changing intraday distributions on the e-MID market. The findings based on the mean volume per transaction could play an important role for the liquidity management of banks, since they can now optimize their trading strategies when it comes to the selling and buying of credits with high values. Furthermore, these findings could be

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used for further econometrical or empirical analyzes, as e.g. for the implementation of further network formations on the e-MID market.

By taking into account the comparison with other segments of the financial markets, my results show that there are similarities in these distributions. The questions which arises is whether a previous / later trading in these segments of the financial markets may affect the behavior of the trading in the e-MID market. This could also be an explanation for the different distributions on the e-MID market.

What is furthermore interesting to analyze in the near future is the volume distribution by comparing different types of aggressors and quoters based on the country of origin. The mean volume per transaction for credits between Italian banks in my data sample equals 22.54 million euro. On the other hand, when a foreign bank is involved in the credit transaction, the mean volume per transaction is more than four times higher than between Italian banks, at 98.64 million euro. By looking at this measurement for credit transactions only between foreign banks, calculations show that the mean per transaction is 263.99 million euro, which is approximately ten times higher than the mean of the credit volume between Italian banks. Therefore, from my point of view, further research should be aimed at the different countries of origin and based on my findings in this paper by also taking into account the intraday distribution and the different market states.

Furthermore, I suggest analyzing the market based also not only on daily data, but also on a lower frequency, e.g. on a monthly or yearly basis. Based again on calculations it can be shown that there are differences between the monthly values of the number and the volume of transactions. Therefore, it would be useful, from a theoretical but also from a practical point of view, if further research would consider patterns of monthly effects in the market, which could influence the behavior of the banks in the market. In addition, different market states might be again distinguished. Results obtained by moving away from the intraday domain would be also interesting from a theoretical point of view, as these credits with higher maturities are not being traded due to short liquidity constraints but due to other reason, e.g. for longer term investments. It was one of the aims of this paper to establish an empirical starting point for these kinds of research.

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Conflict of interest:

I hereby disclose any actual or potential conflict of interest along with the paper, including financial, professional, personal or other relationships with other people or organizations.

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