INSTITUT NATIONAL DE LA STATISTIQUE ET DES ETUDES ECONOMIQUES
Série des Documents de Travail du CREST
(Centre de Recherche en Economie et Statistique)

n° 2010-16

Liquidity Problems in the FX Liquid Market : *Ask for the "BIL"* *

V. BORGY[1]
J. IDIER[2]
G. LE FOL[3]

---

* We thank Christophe Perignon and participants at the Banque de France seminar for useful comments and suggestions. This paper reflects the opinions of the authors and does not necessarily express the views of the institutions they are affiliate with.

1 Banque de France. vladimir.borgy@banque-france.fr

2 Banque de France. julien.idier@banque-france.fr

3 Université Paris Dauphine. gaelle.le-fol@ensae.fr

Abstract: Even though the FX market is one of the most liquid financial markets, it would be an error to consider it immune to liquidity problems. This paper analyzes on a long sample (2000-2009), all sets of quotes and transactions in three main currency pairs (EURJPY, EURUSD, USDJPY) on the EBS platform. To characterize FX market liquidity, we consider the spread, the traded volume, the number of transactions and the Amihud (2002) statistic for illiquidity. We also propose the computation of a new liquidity indicator, BIL, that solely relies on price series availability. The main benefit of such a measure is that it can be easily calculated on almost any financial market as well as allowing for a clear interpretation in terms of liquidity costs. Using all these advanced liquidity analyses, we finally test the accuracy of these measures to detect liquidity problems in the FX market. Our analysis, based on a signaling approach, shows that liquidity problems have arisen during specific episodes in the early 2000s and more generally during the recent financial turmoil.

Key Words: FX market, Liquidity, financial crisis.

Résumé : Même si le marché des changes est l'un des marchés financiers les plus liquides, ce serait une erreur de le considérer exempt de tout problème de liquidité. Ce papier analyse, en long échantillon (2000-2009), l'ensemble des cotations et transactions sur trois couples de devises (EURJPY, EURUSD, USDJPY) passées sur la plateforme d'échange EBS. Afin de caractériser la liquidité du marché des changes, nous considérons les fourchettes de cotations, le volume échangé, le nombre de transactions et la statistique d'Amihud (2002) d'illiquidité. Nous proposons également le calcul d'un nouvel indicateur de liquidité, BIL, qui ne repose que sur la disponibilité des prix de transactions. Les principaux avantages de cette mesure sont d'être facilement calculable quel que soit le marché et d'avoir une interprétation claire en termes de coûts de la liquidité. En utilisant l'ensemble de ces analyses avancées de la liquidité, nous testons finalement la capacité de ces mesures à détecter les problèmes de liquidité sur le marché des changes. Notre analyse, basée sur une approche du signal, montre que les problèmes de liquidité sur le marché des changes se sont produits de façon spécifique au début des années 2000, et plus généralement lors de la récente crise financière.

Mots-clés : Marché des changes, liquidité, crises financières

J.E.L. classification: G01, G15, F31.

1. INTRODUCTION

Based on trading volume activity, the FX market is, by far, the largest market in the world. According to the BIS (2007) survey, the daily spot and forward FX turnover is about USD 1.400 billion[5]. Activity on this market has increased sharply over the past decade: global FX market turnover almost doubled between 1998 and 2007. Furthermore, the infrastructures have been transformed, in relation notably with the development of electronic platforms. These evolutions have resulted in the involvement of a much broader range of market participants treating exchange rates as a separate tradable asset class. However, such transformations in the way in which currencies are exchanged are not without consequences for a key indicator, namely market liquidity.

This factor is characterized by three main features. First, liquidity has tended to increase due to overall market developments. Second, liquidity dynamics are characterized by strong seasonal effects. Third, liquidity plays a key role during financial crisis, leading in some cases to market collapses or strong arbitrage dynamics.

Liquidity has not been intensively studied on the FX market. Several reasons may account for this lack of interest. First, the FX market is known to be extremely liquid, and thus its study may be perceived as useless. Second, its high degree of decentralization generates fragmentation and low transparency of transactions which complicates the way to define market liquidity as a whole. Third, this market trades virtually around the clock from the Asian market opening on Sunday night until the US market closing on Friday afternoon. Finally, besides these specific features of the FX market, the usual problems encountered in analyzing market liquidity remain.

Indeed, the analysis of market liquidity may be tricky for several reasons. First of all, there is no perfect measure to monitor market liquidity and the concept itself is quite elusive. Some proxies are commonly used but, as mentioned by Goyenko, Holden and Trzcinka (2009), there is little consensus on which measures are best and whether they actually measure market liquidity. Aitken and Comerton-Forde (2003) show that order-based measures should be favoured and Idier, Jardet and Le Fol (2009) say that the several aspects of liquidity (i.e. immediacy, depth, tightness and resiliency) are very important to get a picture of liquidity as a whole. However, depending on the market organization, and its level of transparency, it is not always possible to implement the most appropriate liquidity measures. We are left with the difficult problem of choosing an accurate liquidity measure.

[5]The inclusion of foreign exchange swap contracts leads to a much larger figure of 3.200 billion USD.

The FX market shows the disadvantage of having to an extent all these difficulties and again this is the reason why only few studies deal with liquidity issues.

Our first contribution is to analyze FX market liquidity based on widely used liquidity indicators. Our dataset comprises all centralized transactions in the FX market occurring between January 1, 2000 and December 31, 2009 on the Electronic Broking Services (EBS) platform. Therefore, it is possible to analyze standard liquidity indicators almost since the creation of the euro area.

The second contribution is to propose a new liquidity indicator (called BIL hereafter) that only relies on transaction price series availability. This aims at further studying liquidity in the case where only price data are available. The main benefit of such a measure is that it can easily be calculated on almost any financial market and it also provides a clear interpretation of liquidity costs. Moreover, the use of high frequency data makes it possible to identify specific events such as liquidity accidents that would not be detected at a lower frequency.

Studies concerning the microstructure of exchange rate markets have focused on several issues. A first strand of the literature is devoted to the key role played by order flows on the exchange rates dynamics. Several important contributions, both theoretical and empirical, have been proposed noticeably by Evans and Lyons (2002). Indeed, one assumption of microstructure studies is the dispersion of information between agents and the role of market frictions in price discovery processes (see Amihud (2002), for example, for stocks). For instance, market organization does matter and interacts with macro factors influencing the path of exchange rate dynamics. Another strand of the literature is devoted to the analysis of volatility transmission between different regions of the world. These analyses of volatility spillovers have greatly benefited from the use of high frequency data such as in Melvin and Melvin (2003) or Cai *et al.* (2008).

We test the accuracy of our measures to detect liquidity problems in the FX market on daily data from 2000 to 2009. Moreover, we screen liquidity problems to better understand the impact across currencies and over time. Our methodology presents some similarities with the Kaminsky, Lizondo and Reinhart (1997) signals approach that tries to predict which countries are more likely to suffer from currency crises. Here, we focus precisely on liquidity problems on the FX market: we show that our liquidity indicators are able to identify liquidity pressures during specific episodes in the early 2000s (internet crash, September 2001) and during the recent financial turmoil.

The remainder of the paper is organized as follows. In Section 2, we describe the main features of the FX market and the database. In Section 3, we develop several classic liquidity measures. We introduce and explain a new liquidity indicator that we compare with the liquidity benchmarks. In Section 4, we propose a signalling approach to screen liquidity problems on the FX market. Section 5 concludes the paper.

2. DESCRIPTION OF THE FX MARKET

2.1. Main features of the global FX market

Foreign exchange trading is dispersed throughout the world. As a result, there is no precise location and no complete recording of activity. Trading in FX markets is unregulated, contrary to trading in other markets such as stocks or bonds. The customer market is quite opaque. Quotes and transactions are private information for the two parties involved, i.e. the customer and the dealer. Trading is located in three regions: North America, Asia and Europe within which several FX markets exist. Quotes and trades take place from Sunday (9pm GMT) through to Friday (9pm GMT) on a continuous basis. The activity corresponds to the opening of the main financial markets in Tokyo, London and New York. Each market has its specific opening and closing hours even though the FX market never really closes. Furthermore, there are some overlapping segments where several financial markets are open simultaneously in different regions involving a high degree of activity.

The vast majority of trading on the FX market is concentrated on less than ten currencies. The dollar is the most traded currency: it is involved in 86.3% of the total traded operations in 2007 (see Table 1 in Appendix A). The euro is involved in 37% of the trading operations on the market. This share remains the same since the creation of the European currency in 1999. The yen and sterling are involved in 16.5% and 15% respectively of trading operations. The euro-dollar is the most traded exchange rate (27% of the total turnover by currency pair in 2007 after 28% in 2004). The yen-dollar has been decreasing over the last decade: the average daily turnover dropped from 20% in 2001 to 17% in 2004 and 13% in 2007.

2.2. Players and developments on the FX market

The foreign exchange market comprises two segments. In the first segment, dealers trade primarily with each others: the interdealer market forms the core of the market. In the second segment, dealers trade with customers. Dealers divide their customers into two main groups: the first one is composed of financial customers and includes asset managers (hedge funds), mutual funds, real money funds, non-dealing banks and central banks. They accounted for about 40% of all FX trading in 2007 (against 22% in 1998). The second group includes the corporate customers: commercial firms that purchase currency as part of on-going real production activities or for financial purposes.

Growth in interbank transactions has sharply increased over the last decade: the daily average turnover rose from USD 728 billions in 1995 to USD 936 in 2004 and USD 1319 in 2007; the interbank market accountted for almost one third of the growth in aggregate turnover[6]. Transactions between reporting dealers and other financial institutions experienced the most sustained increase between 2004 and 2007, reaching USD 1235 billions on a daily average basis (see Table in the Appendix). Overall, the share in this segment has doubled from 20% in 1995 to 40% in 2007. Several factors explain the strong turnover in this specific segment. First, risk-adjusted returns were particularly attractive in an environment in which activity was increasing and financial market volatility was low (Galati and Heath (2007)). Second, the development of electronic trading platforms contributed to higher turnover in this segment. In particular, it allowed large financial institutions to set up algorithmic trading systems[7]. Third, institutional investors with longer-term investment horizons adapted their strategies to hold more internationally diversified portfolios. Coss-border transactions have sharply increased over the past decade: they tripled - from USD 613 to 1896 billion on a daily average between 1995 and 2007 - whereas local transactions doubled during the same period (see Table 2 in Appendix A).

2.3. Electronic Dealing Technology: development and implications

Through the mid-1990s, the FX market was primarily reliant on phone-based technology. The phone-based network of direct relationships between banks was the principal component of the interbank market, and the central source of liquidity in the FX market. During the past decade, these interbank dealing arrangements began to shift to electronic protocols. Reuters Dealing and EBS (Electronic Broking Services) both introduced interbank electronic trading platforms in 1993. An increasing share of overall FX trading volume is traded on electronic platforms: in 2001, less than 40% of interbank dealing was transacted through EBS and Reuters. In 2007, between 75% and 90% of all the interbank dealings channeled through these two systems. The two trading systems

[6]The share of the interbank market in total turnover has fallen from 53% to 43% between 2004 and 2007, largely because the growth in turnover in this segment was outpaced by the expansion in the other segments.

[7]However, the BIS survey notes that the share of trade transacted through electronic systems in this segment varies considerably accross countries.

are specialized in certain exchange rates: the main exchange rates (EUR-USD, USD-JPY, EUR-JPY, USD-CHF and EUR-CHF) are traded on EBS. The exchange rates involving GBP, CAD and AUD are traded through Reuters D-3000. Overall, the share of transaction dealt through EBS is higher than on Reuters platforms: in 2006, the daily volume of EBS was USD160 billions for EBS compared to USD 105 billions for Reuters. However, it should be noted that others platforms have been put in place recently, such as the multibank portal *FXall* launched in 2001 leading to a decrease in dealing costs for end users. They have an increasing role in the market: in 2006, *FXall* traded about USD 50 billions on an average daily basis.

The structure of interdealer trading changed substantially after the introduction of electronic brokerages in early 1990s. As noted by Barker (2007), the price discovery process on Reuters Dealing and EBS differs from the phone-based model of direct dealing in several aspects:

1. Banks participating on these platforms are not obliged to provide two-sided price quotes to other banks on demand.

2. The minimum deal size allowed on these portals is much smaller than the standard wholesale amounts used in the traditional direct-dealing relationships between banks. Furthermore, from 2005, trading on the electronic brokerages was not only restricted to dealers but broadened to some hedge funds and some automated trading programs on EBS for example.

3. These electronic portals provide a live price stream that aggregate all bids and offers posted on the system. This interbank price is continuously displayed to all market participants. However, as mentioned by Osler (2008), contrary to most other limit-order markets, the FX market has low pre- and post-trade transparency. In fact, pre-trade information is limited to the best bid and ask quotes and post-trade information is a listing of transaction prices while traded volumes are not published.

3. FX LIQUIDITY ANALYSIS

The analysis of market liquidity is sometimes difficult due to the unavailability of some data such as volumes or quotes for example. This is typically the case for exchange rates that are mainly traded over-the-counter. However, as previously mentioned, trading platforms for exchange rates are developing and a non-negligible share of trading actually takes place on such anonymous platforms. The main advantage of these platforms, like EBS for instance, is the ex post[8] availability of

[8] We mean by "ex post" that even if market participants trading on EBS do not have real-time traded volumes on their screens, data are recorded and available for expost analyses.

data such as transaction prices, traded volumes or posted quotes.

3.1. Data and preliminary assessments

In this paper, we use a dataset provided by Reuters data tick history comprising all quotes and trades from January 1 2000 to December 31 2009 on the EBS Dealing Electronic Systems[9]. The data concern firm quotes and trades on a tick-by-tick basis for the spot exchange rates. Contrary to the indicative quotes of FXFX screens, the quotes on EBS are firm in the sense that agents are committed to trade at the price that they have quoted.

Precisely, two types of orders are possible on EBS platform: quotes and hits. Quotes enter the order book until they reach a counterpart. Hits are orders that are directly fulfilled, if a counterpart is standing in the order book, or immediately cancelled otherwise.

The dataset thus includes all transactions and quoted prices as well as traded volumes. Furthermore, we have information concerning the volumes on hold, which give indications about the depth of the market. The traded volume is expressed as unit of millions of the base currency, i.e. the currency appearing first in the denomination. For example for USDJPY the base currency for volumes are millions of USD. For EURUSD the base currency for volumes are millions of euro. Appendix B presents an example of the raw EBS dataset for only three seconds of trading on April 2 2009.

The "type" column states if the reported information is a deal, "D", or a quoted price, "P". Then we have the "Bid price" column, the "Offer price" column and finally the "Bid" and "Offer" volumes. When the type is "D", the volume recorded is the traded one. When the type is "P", the mentioned volumes are those standing at the bid and ask prices.

Concerning EURJPY for example, we have a buy initiated trade at 133.77 yen per euro for 1 million euro in line 3. We have a sell initiated trade of EURUSD in line 35 at 1.345 USD per euro for a volume of 1 million euro. In the remaining analysis, we focus on the three main exchange rates: EURUSD, USDJPY and EURJPY, ending up with more than 1 billion observations.

3.2. Regional and historical liquidity analysis on the FX market

As a first step, we consider the regional and historical evolution of liquidity conditions. By historical, we mean that we picture liquidity in an historical perspective by considering all the data

[9]Ito and Hasimoto (2006) analyse EBS data for EURUSD and JPYUSD on a shorter period of time (1999-2001) and Berger et al. (2008) between 1999 and 2004 but at the one minute frequency.

available between January 2000 and June 2009. By regional, we mean that we separate the trading activities into 4 time zones, as presented in Figure 2 (Appendix C), called regions of open trading sessions. This segmentation is also justified by the intraday pattern of liquidity indicators, with a concentration of activities on some specific parts of the day.

Region 1 considers Asian trading; region 2 is the period when Europe is open and the US closed. During the third, both the US and Europe trade and finally region 4 is US only activity.

Figure 3 in Appendix C displays the average intraday pattern for the number of transactions for the EURUSD, USDJPY and EURJPY exchange rates. For the three exchange rates, we clearly see two peaks related to the opening hours of the European and American markets. The activity increases during the overnight period, around midnight, with the opening of the Japanese market. The second aspect of the figures shows that the number of transactions have significantly risen between 2000 and 2009, illustrating the increasing importance of the EBS platform for these exchange rates.

3.2.1. Standard liquidity indicators

Considering these four regions, we now focus on four indicators: the relative spread, the Amihud statistics, the number of transactions and the traded volumes.

Spread: This term characterizes the gap between bid and ask prices. We calculate the relative spread for comparability reasons. Indeed, the raw spread has the drawback of being in unit of currency, which is not the case for the relative one. Its wideness is directly associated with the level of competition on the buy and sell sides of the market: the larger the spread, the more illiquid the market. The **relative spread** for currency i at transaction n recorded at time t_n is:

$$S^{relative}_{i,t_n} = \frac{p^{Ask}_{i,t_n} - p^{Bid}_{i,t_n}}{M_{i,t_n}}, \tag{1}$$

where $M_{i,t_n} = \left[\frac{p^{Ask}_{i,t_n}+p^{Bid}_{i,t_n}}{2}\right]$, i.e. the midpoint between the ask and bid prices. We consider "regional" average spreads by month. Note that the "averaging" aggregation pattern is not optimal, even if it is the only solution, since the pattern is smoothed and may not reveal occasional illiquidity problems over time. Graphs are shown in Appendix D.

Figure 4 shows that EURJPY has the largest spread, followed by USDJPY and EURUSD. Looking at the broad trend, we note, for all currencies, a decrease indicating that liquidity improves over the sample. Looking at the regional patterns, Region 4 presents the strongest liquidity problems. Nevertheless, this region is also the one that shows the fastest decrease to a low spread level with some kind of convergence to the level usually observed in Regions 2 and 3, i.e. Europe and US opening times.

Indeed, for all currencies it appears that Regions 2 and 3 are the most immune against liquidity problems. This is not surprising since it corresponds to business hours both in Europe and in the United States. Not surprisingly, Region 1 - the Asian opening time period, is the only region that changes from active (USDJPY) to quiet (EURJPY, EURUSD) depending on the currency pair. Obviously, the end of the period is particularly marked by the 2008 crisis with peaks in spreads for all regions and all the exchange rates. Such a general increase, for all the regions and exchange rates, could suggest that the liquidity problems are broad-based and not region-specific.

Number of transactions and volumes: The number of transactions has been often used as a proxy for the traded volume since volume data were not available. Over the sample, the most active currency pair is the EURUSD with around 300, 000 transactions per month[10], followed by the USDJPY with 220, 000, and the EURJPY with 100, 000 (see Figure 5). The number of transactions is the highest for Regions 2 and 3 which correspond to the opening time of Europe and the United States. However, even during the overnight period, the activity on EURUSD remains sustained as the number of transactions in Regions 1 and 4 is around 40, 000 on average per month.

If the volume per trade is stable, the number of transactions is a good proxy for volume. However, some variations in the traded volumes, with the alternation of periods with large and small traded volumes, i.e. when investors need to split orders for example, make volume per trade complementary and essential to really capture market liquidity. As we can see in Figures 5 and 6, while the two indicators show very similar patterns, some differences appear in Regions 2 and 3 for EURUSD.

The number of transactions and the traded volume are linked to market depth and illustrate how markets are able to absorb large transactions without implying a huge price impact.

Based on these measures, EURUSD is ranked first, followed by USDJPY and EURJPY[11]. Overall, we note an increase in the traded volume in all regions and for all currencies. However, these

[10]This 300, 000 transactions per month is the sum of the number of transactions per month of the four regions (Region 1 : 40, 000 ; Region 2 : 80, 000 ; Region 3 : 120, 000 ; Region 4 : 40, 000).

[11]Note that for comparison purposes, all the volumes have been converted into euro at the exchange rate prevailing at the date of the trade.

upward trends seem to have reach a peak in 2008 and we observe a sharp decrease thereafter coupled with higher volatilities. This decrease is relatively strong irrespective of the region considered. In particular, even for Regions 2 and 3, which are assumed to be the most liquid ones, we observe such problems.

Amihud ILLIQ: Amihud (2002) proposes an indicator of liquidity based on daily returns and traded volumes. This indicator is perceived to be an aggregated price impact measure, such that the larger this indicator, the lower the liquidity. This indicator called $ILLIQ$ is defined as follows:

$$ILLIQ_{i,m} = \frac{1}{N_m} \sum_{d=1}^{N_m} \frac{|R_{i,d,m}|}{V_{i,d,m}}, \tag{2}$$

where $|R_{i,d,m}|$ is the absolute return value and $V_{i,d,m}$ is the volume in dollars for day d in month m for the currency pair i. This indicator is computed monthly for each currency pair. It represents the price variations per traded unit of assets or the impact of a trade given the market depth. To compare the statistics between the three currencies, we convert the raw statistics - the return per volume in the reference currency - into return modifications by millions of euro.

The Amihud indicator, plotted in Figure 7 confirms previous results. It is the highest for EURJPY followed by USDJPY and finally EURUSD is the most liquid (see Figures in Appendix D). The EURJPY shows a clear downward trend between 2000 and 2007, in particular in the least liquid region. Such a downward trend is also observed to a lesser extent for the two other exchange rates. Similarly to the spread, there is a clear difference between regions, indicating that the price impact is higher in the segments where some financial markets are closed: for instance, the $ILLIQ$ measure is important, and has a greater volatility, in Regions 1 and 4 for the EURUSD, i.e. during the overnight period in Europe. We also observe a sharp rise in the $ILLIQ$ indicator for the different exchange rates in 2008 in relation to the financial crisis.

3.2.2. *Understanding these indicators*

To summarize, following the four indicators we come to the conclusion that the most liquid regions are Regions 2 and 3. The most illiquid is Region 4 followed by Region 1. However, each of them shows peaks at different dates. Their volatility can be rather different and their ranking can also change with the indicator. In fact, these four standard indicators are imperfect proxies for market liquidity. Moreover, they do not all represent market liquidity, but some of them represent also market illiquidity. This depends on the definition and even sometimes on the period. For example, the number of trades can both represent market liquidity and illiquidity. Let us consider a rise in the number of transactions. This may come from the fact that investors, fearing a high liquidity risk and a high price impact, are splitting their orders. Another possible explanation is that there are more liquidity providers on the market so that liquidity is increasing. A third explanation would be that some traders are actively using private information to trade on this market, so that they are liquidity consumers. This simple example shows how these indicators may be ambiguous. This is confirmed by the correlations between the indicators given in Tables in Appendix E: they vary in level but also in signs.

In our cases, we observe that spread is positively related with $ILLIQ$ and negatively related to the volumes for the three exchange rates. However, it is not clear that higher spreads mean less transactions. The correlation between $S_{i,t}^{relative}$ and $V_{i,t}$ is typically negative whereas the correlation between $S_{i,t}^{relative}$ and $N_{i,t}$ is sign varying, ranging from -0.17 to 0.26. The traded volumes, for example are also negatively correlated with $ILLIQ$, so that high traded volumes contribute to lowering the price impact. Finally, the relation between the number of trades and volumes is positive and ranges from 0.77 for the EURUSD to 0.98 for the EURJPY.

This simple analysis clearly shows the importance of crossing the several market liquidity dimensions. However, data availability is often an obstacle to such analysis. If price data are usually available, volume data are rare. At a disaggregated level, volume data is even scarcer. $ILLIQ$ is a response to this scarcity of intraday volumes, but volume data are required. However, it seems that the analysis based on daily data does not allow to identify properly liquidity accidents. Intraday data appears to be necessary in order to make a good assessment of liquidity dynamics.

3.3. A new liquidity indicator

3.3.1. Motivation

Liquidity is defined as the ability to trade rapidly large volumes with a small price impact. As such, liquidity is usually associated with four market characteristics known as *immediacy, depth, tightness and resiliency* (see Idier, Jardet and Le Fol (2009)). "Immediacy" mainly considers time and delay between transactions or quotes so that all transaction data are required. "Depth" considers the market's ability to absorb traded volumes without a significant impact on market dynamics. In order to do so, many authors consider volume-related indicators (e.g. volume per trade, global turnover, or VNET from Engle and Lange (2001)). "Tightness" is associated with trading cost related to the existence of bid-ask spreads reflecting information asymmetries, inventory constraints, or some discounts linked to the need for immediacy. Finally, "Resiliency" considers the price impact of transactions and is usually captured by volatility measures and bid-ask spread variations.

While this definition is commonly accepted there is no consensus on how liquidity should be measured (see Goyenko *et al.* (2009)). A good liquidity measure is a measure that is simple to implement on any market and to aggregate at any frequency. This measure should also be easy to translate into cost. Spread measures are quite appealing in this respect but as mentioned before they do not aggregate easily and are related to the size of the tick which may differ between markets and assets. Moreover, it is common knowledge that spreads do not only widen due to liquidity problems but also due to information asymmetries. As mentioned by Acharya and Pedersen (2005) the spread is a good measure of the cost of selling only a small volume of the asset. Concerning the $ILLIQ$ measure, these authors explained that it does not measure directly the cost of trade.

Here, we propose a new measure that meets all the criteria. Our indicator is:

- based on transaction prices that are available on any market;
- a sum of returns and as such can easily be aggregated to any frequency;
- a measure of market resiliency and/or temporary price impact. It reflects a liquidity cost if we disregard information price moves to concentrate on liquidity price moves.

Moreover, our indicator corresponds to what Grossman and Miller (1988) call "the price of immediacy" and is related to their measure of illiquidity. In this model, investors hold securities but have to sell them to obtain cash when facing a liquidity event. If many investors have to sell at the same time because of a liquidity event, the price will drop to attract buyers even though the cash flows of the security is unchanged. This drop in price will attract new buyers that will supply the missing liquidity. These investors are called suppliers of liquidity in Grossman and Miller (1988) or liquidity arbitragers in Darolles, Le Fol, Mero (2010). They supply liquidity to capture the liquidity premium later on by liquidating their positions. In markets where there is a large supply of immediacy, the arrival of a large number of sellers has little or no impact on prices. Markets that are liquid are markets where the price of immediacy is low. Grossman and Miller (1988) and Darolles, Le Fol and Mero (2010) show that this price impact - due to a temporary order imbalance - is usually compensated within a day or less. It depends on the temporary order imbalance, the risk of having a new piece of information hitting the market before the resolution of the liquidity problem and the number of liquidity arbitragers. In their model, information has an impact on prices at any frequency while the impact of illiquidity is only observable at an intraday frequency: the daily price impact of illiquidity vanishes. However, suppliers of immediacy have limited capital and/or their actions might be restricted by regulation eventually inducing a long lasting illiquidity problem and creating serial correlation in liquidity.

3.3.2. Définition

Our new indicator, called BIL, considers only price impacts that are reversed within a period called the information horizon. It is constructed from transaction data and is defined for day t as:

$$BIL_t = \frac{1}{N_t}\left[\mathbb{1}_{[r_t<0]}\sum_{n=1}^{N_t} r_{t_n}^{+} + \mathbb{1}_{[r_t>0]}\sum_{n=1}^{N_t} - r_{t_n}^{-}\right], \tag{3}$$

with N_t being the number of intra-periods. $\sum_{n=1}^{N_t} r_{t_n}^{+}$ and $\sum_{n=1}^{N_t} r_{t_n}^{-}$ are the sums of positive and negative tick-by-tick returns respectively over period t. r_t is the daily return assumed to be the information horizon. By definition, BIL is positive or zero. The idea behind this formula is relatively simple. BIL focuses on the price variations that are compensated throughout the day, i.e. all variations not induced by information arrivals[12]. We assume the information to be represented by the entire period return r_t, i.e. the permanent change in price over the day. This approach is closely related to the approach found in the literature concerning realized volatility. While sampling methods to compute realized volatility aim at eliminating the price variation due to the microstructure noise, the aim of BIL is to keep everything else but the information cumulated in r_t. In other words, it represents the "tatonnement" process to converge to the true price of the asset, i.e. the mispricing or the additional cost paid by market participants due to missing liquidity. The more the price diverges towards the true value of the asset, the higher the BIL indicator. One key underlying assumption is that the asset converges to its true value by the end of the day. Moreover, we can consider this

[12]Figure 8 in Appendix F displays a simple illustration of the intra-period variations that are considered in order to compute this indicator. In this example, the entire period return r_t is positive, as a consequence, we consider the negative intra-periods returns (r_1, r_2, r_3) in order to compute the BIL indicator.

indicator computed on the four intraday regions presented previously. In this case, we get:

$$BIL_t^{region} = \frac{1}{N_t^{region}} \left[\mathbb{1}_{[r_t<0]} \sum_{n=1}^{N_t^{region}} r_{t_n}^{+} + \mathbb{1}_{[r_t>0]} \sum_{n=1}^{N_t^{region}} - r_{t_n}^{-} \right] \tag{4}$$

where N_t^{region} is the number of intra-returns for day t in a particular region and r_t the daily return.

The BIL indicator measures the degree of market frictions. The more illiquid the market, the larger the temporary variations due to market frictions, and the larger the value of BIL.

Moreover, one additional advantage of this is that BIL is directly comparable between assets denominated in different currencies since it represents the "inefficient" returns per trade to converge to the true value of the asset.

3.3.3. *Application to exchange rate data and comparisons*

The suggested indicator aggregates out very easily to any frequency by just summing up the days t. For a given month, based on every transaction, the monthly indicator is the sum of the daily ones. The day still being the information horizon, the monthly BIL is the aggregation of all daily compensated price variations for month m as:

$$BIL_m = \sum_{d=1}^{D_m} BIL_d \tag{5}$$

where D_m is the total number of trading days in a given month[13]. For instance, any BIL close to zero means that every price variation is part of the price discovery process, while any positive BIL means that the price discovery process is blurred by the liquidity process. Obviously, the ability to filter between the information and liquidity process relies on the hypothesis of information revelation horizons. Here, we take the day as the information revelation horizon. The corresponding monthly time series are reported in Appendix E.

From Figure 8, we see that BIL ranks the currencies like the other indicators: EURUSD is the most liquid, then come USDJPY and EURJPY. Like the spread indicator, BIL ranks the regions 4-1-2-3 (USA, Asia, Europe, Europe/USA) for EURUSD and EURJPY and 4-3-2-1 (USA, Europe/USA, Europe, Asia) for USDJPY from illiquid to liquid. Moreover, BIL shows a regular improvement of the liquidity conditions until the drastic deterioration of the end of the sample. Overall, it seems that

[13]Note that the regional BIL for a month m is also the sum of the BIL_t^{region} from equation 4.

BIL is less volatile than the other indicators while it reacts more strongly to the crisis episode.

To compare this BIL indicator with the previous ones, we consider sample correlations between indicators as it is often the case in the literature (Amihud (2002) or Sadka (2006)). The following table presents correlations for the three considered currencies.

	$BIL_t/EURUSD$	$BIL_t/EURJPY$	$BIL_t/USDJPY$
$S_{i,t}^{relative}$	0.95	0.72	0.96
$N_{i,t}$	0.58	0.20	0.35
$V_{i,t}$	-0.01	0.05	0.01
$ILLIQ_{i,t}$	0.79	0.81	0.81

Table 4: Correlation between liquidity indicators and BIL (2000-2009) for each currency pair

On the one hand, Table 4 shows low correlations between BIL and the number of transactions and BIL and the volume. On the other, the correlations between BIL and the two others indicators are large and even reach 0.96. This first result suggests that the BIL indicator accurately measures liquidity. These results are particularly interesting as the BIL indicator relies solely on price data for its computation and does not rely on volume data as does the Amihud (2002) one. Furthermore, as explained above, the BIL indicator measures a cost and is not affected by the shortcomings of measures such as spread and $ILLIQ$.

3.3.4. Robustness check

Sensitivy test on the BIL indicator One main hypothesis to compute our new *BIL* indicator is the definition of the information horizon. In the previous section, we consider the end of the day as the information revelation horizon. However, when we compute a regional *BIL*, we may also consider the regional closing time of trade as the information horizon. In particular in the first case, the BIL is

$$BIL_t^J = \frac{1}{\left[\sum_{h=1}^{H} N_h\right]} \sum_{h=1}^{H} \left[\mathbb{1}_{[r_J<0]} \sum_{n=1}^{N_h} r_{t_n}^{+} + \mathbb{1}_{[r_J>0]} \sum_{n=1}^{N_h} - r_{t_n}^{-} \right] \tag{6}$$

with N_h is the number of trades for region h, H is the number of regions and r_J the return over the entire day J. In this formula, we consider $\mathbb{1}_{[r_J<0]}$ as the dummy variable. However, in the second case, the daily BIL with information revelation at the end of each region would be

$$BIL_t^H = \frac{1}{\left[\sum_{h=1}^{H} N_h\right]} \sum_{h=1}^{H} \left[\mathbb{1}_{[r_h<0]} \sum_{n=1}^{N_h} r_{t_n}^{+} + \mathbb{1}_{[r_h>0]} \sum_{n=1}^{N_h} - r_{t_n}^{-} \right] \tag{7}$$

where r_h is the return over the region h, using $\mathbb{1}_{[r_h<0]}$ as the dummy variable.

From a quantitative point of view, it appears that the two BIL are very close[14]. Notably, it does not change the correlations (as reported in Appendix G) with the other indicators.

Comparison of liquidity indicators between electronic platforms. One main issue for liquidiy analysis is the degree of order fragmentation between several alternative platforms. In the case of our three exchange rates, two electronic platforms may be considered: EBS and Reuters D-3000. These two platforms do not present the same degree of expost trade transparency, or at least data availibility on traded volumes for example. One advantage of BIL is that it is computable from the only price series, and without volumes, even if, as mentionned previously, it ends up being very close to the Amihud trade-impact measure.

The two electronic platform EBS and Reuters D-3000 tend to be specialized in specific FX parities even though few trades are observed in both platforms for EURUSD in particular. As a consequence, the degree of liquidity for EURUSD on Reuters D-3000 is far lower than that on EBS platforms. We expect our indicator to reflect this platform segmentation and the low degree of liquidity even for the same currency pair. To compare the liquidity conditions for EURUSD on the two electronic platforms, we compute the relative spread, the BIL indicator and the number of trades for the period January 2005- May 2009. Graphs are reported in Appendix G.

The number of trades on EBS is, on average, sixteen times the number of trades on Reuters D-3000. Over the sample, this proportion clearly increased during the turmoil in 2007 and in the 2008 crisis. This relates to the higher concentration of trades during crises. In particular, when liquidity is scarce on the global market, trades concentrate on the most liquid platform marginalizing the less liquid ones. This is further confirmed by the two other indicators. Even if, on average, the spread on D-3000 is only three times that on EBS, during the turmoil this increased up to 22. This gap between the two spreads for the same currency pair, during a period of scarce liquidity clearly illustrates this concentration principle of liquidity. Turning to our new BIL indicator, it also appears

[14]We have analyzed the specific features of the errors between the two formula: technical details are available upon request.

very sensitive to this crisis-liquidity-concentration dynamic. On average, the BIL on D-3000 is 12 times greater than the EBS one, and is also nearly 55 times that on EBS during the crisis. We note that our indicator is the most sensitive to this liquidity gap between the two platforms, especially during crisis episodes. In this sense, it also appears quite accurate to illustrate the fragmentation impact of liquidity between trading platforms during crisis episodes.

4. DETECTION OF LIQUIDITY CRISES ON THE FX MARKET: A SIGNAL APPROACH

4.1. Signal methodology

In this section, we test the accuracy of our measures to detect liquidity problems in the FX market. Moreover, we screen liquidity problems to better understand the impact accross currencies and over time. In order to do so, we consider the main financial crises that have occured during our complete sample, January 2000 to December 2009. For the first part of our sample, we rely on the identification of crisis periods proposed by Rigobon (2003). In his paper, Rigobon identifies the following crises : the Internet Crash (March 2000 - May 2000), the Argentinean crisis (October 2000 - December 2001), September 11, 2001 and the WorldCom accounting problems (June 2002 - October 2002)[15]. We complete the sample by considering the financial turmoil that started in 2007. Concerning these events, we could identified three episodes: the 2007 subprime mortgage crisis (August 2007 - January 2008), the Bear Stern problem and the global financial crisis that was triggered by the Lehman Brother failure (September 2008 - November 2008).

From a methodological point of view, we caracterize a liquidity problem as abnormal values of our liquidity measures. Abnormal values lie outside the 95% quantile. As shown in Figures 5 and 6, the volume and the number of trades are upward trended which reflects the development and the specialization of the EBS platform for this three currencies. Furthermore, variables such as the relative spread show some downward trends during the first part of our sample for all the currencies indicating the improvement of liquidity conditions on the EBS platform. In fact, at the beginning of the sample, the EBS platform was not widely used which could introduce a bias into our analysis. To account for trends in liquidity measures observations, we calculate 4-year-moving quantiles[16]. For the Amihud, BIL and the spreads a deterioration in liquidity unambiguously reflects

[15] Rigobon (2003) identifies crisis periods for the 1990s; as our sample starts in 2000, we cannot include them in our analysis.

[16] Until the first of January 2004, the quantile is calculated using all the observations from the first of January 2000 to the last day of december 2003. After that date, we take a 4-year-moving quantile. As a consequence, we compute the quantile with approximately 1000 observations.

a rise in the indicators. We therefore consider the appropriate 95% quantile. For the number of trades and the volumes measures, the relation between liquidity dry-ups and the development of the two indicators is ambiguous, as discussed on Page 10. As a consequence, we select the dates at which these two indicators fall outside the [2.5%-97.5%] quantiles. With such an identification procedure, extreme values of the indicators should indicate liquidity tensions on the FX market. This methodology presents some similarities with the Kaminsky, Lizondo and Reinhart (1997) signal approach that tries to predict which countries are most likely to suffer from currency crises.

We first analyze the extent to which our set of liquidity indicators is a useful tool for analyzing the liquidity problems related to the financial crises identified by Rigobon (2003) during the early 2000s; then we focus in particular on the consequences of the financial turmoil of 2007-2008.

4.2. Liquidity problems on the FX market during the crisis episodes of 2000-2002

From Figure 13, we detect liquidity problems for the three exchange rates mainly during the internet crash and the Sept. 2001 episodes. During the internet crash, the spread indicator computed on USDJPY signals liquidity problems 31.3% of the time, which corresponds to 20 days out of 64. The internet crash and the Sept. 2001 events had global consequences and their impact on the FX market could be viewed as the consequences of international asset reallocation during these crises by market participants.

Concerning the Argentinean and the WorldCom crises, the detection appears to be more limited. However, it should be noted that these periods of crisis are identified on an extended period of time (see Figure 13).

Concerning the 2000-2001 period that covers the Internet crash and the Argentinean crisis, the indicators detect liquidity tensions that are more directly related to FX issues: in particular, our signalling approach suggest liquidity pressures on the EURUSD during the period September - November 2000. Such pressures could be related to the several official ECB interventions of September and November 2000 aiming at reducing the overshoot of the euro. Furthermore, our set of liquidity indicators suggest very few liquidity problems during 2001, with the exception of September.

Our liquidity indicators detect very few days of liquidity pressures during the WorldCom accounting crisis problem considered on the complete sample (5 months of data). Nevertheless, this crisis culminated in the discovery of improper accounting of $3.8 billion in expenses on June 25 2002 and the bankruptcy protection that the firm filed for one month later (July 21). Note that the liquidity indicators show tensions on the USDJPY exchange rate on 26 and 28 of June. Concerning EURUSD, liquidity pressures appear only through the volume and the number of trades measures. Both of them signal problems on June 25 and 26. The number of trades and the volumes have abnormal values of 7 and 8 times respectively between June 25 and July 24. No sign of tensions are detected on the EURJPY during this period.

4.3. Liquidity problems on the FX market during the financial turmoil (2007-2009)

The financial crisis that started in the summer of 2007 and intensified in the autumn of 2008 exposed financial assets to extreme price variations linked to some particular liquidity conditions. As described by Melvin and Taylor (2009), the financial crisis has affected the FX market through "shocking events" since August 2007. Melvin and Taylor (2009) describe in detail the crisis timeline and the consequences on the FX market. According to them, four specific episodes have had significant impact on the FX market.

- 16 August 2007: first wave of carry trade unwind in relation with the contagion from other asset classes,
- 7 November 2007: second wave of carry trade unwind,
- March 2008: rumor of Bear Stearn's demise,
- September 2008: failure of Lehman Brothers.

Figures 14 to 16 display the BIL and the relative spread indicators aggregated to obtain daily data for the period 2007-2009 for the three exchange rates. As mentioned by Melvin and Taylor (2009), financial market problems have impacted FX liquidity through major shocks. The Bear Stearn's episode is one of these shocks during which the two indicators surge transitorily. However, it should be noted that this surge in illiquidity is short-lived: this contrast with the impact of the Lehman Brother episode. During this event, we could observe a long-lasting increase in illiquidity that started in early September 2008 for the three parities.

Figure 17 in the Appendix displays the results for the 4 selected periods mentionned by Melvin and Taylor (2009)[17].

With our set of liquidity indicators, we are able to detect liquidity problems during the four

[17] In Figure 17, the marker 1 indicates that the liquidity indicator falls into the 95% empirical quantile (the marker -1 used for the Volume and the number of trades indicates that these indicators falls oustside the [2.5%-97.5%] quantile).

periods. In November 2008, liquidity tensions seem concentrated on the JPY parities. Extreme values for the volumes and the number of trades are detected for these two exchange rates. In particular, the BIL indicator shows liquidity pressures on USDJPY during two days. Concerning the Bear Stern episode, the BIL and the volumes indicators are the first to signal tensions on the JPY parities as of March 7. Starting on March 13, most of the indicators signal liquidity problems for the three exchange rates. However, concerning EURJPY, the spread indicator sends a signal of liquidity pressures only on March 21, more than 6 working days after the Amihud and the BIL.

Concerning the Lehman Brother bankruptcy, the Amihud illiquidity indicator is the first to signal pressures on the EURUSD (since August 28) and on the USDJPY (on September 1). Starting on September 3 and 4, most of the illiquidity variables take extreme values for the three exchange rates, suggesting sustained liquidity pressures on the FX market. It should be noted that the spread, the Amihud and the BIL continued to show extreme values until the end of 2008 for the three currencies considered, indicating that the liquidity pressures on the FX market have been long-lasting (see Figures 14 to 16). This may suggest some freeze in international operations and a country segmentation due to the high degree of uncertainty.

5. CONCLUSION

The aim of the paper is to understand the role, if any, of liquidity in the FX market. Even though this market is one of the most liquid, our analysis highlights that liquidity problems have occurred during the last decade for the three major exchange rates (EURUSD, USDJPY and EURJPY), and should not be ignored. Several important finding are brought to light in our paper.

First, the trading organisation of the FX market has substantially changed over the last 15 years moving from a bilateral OTC market, to the intensive used of electronic trading platforms such as EBS. This migration to a centralized electronic trading platforms has several implications concerning the functioning of FX market and allows for a monitoring of liquidity conditions and its impact on the price discovery process.

Second, we use several standard liquidity indicators - spread, number of transactions, volumes and Amihud - to obtain an assessment of liquidity dynamics in the FX market. We complete the picture by proposing a new liquidity indicator that meets all the criteria that a liquidity indicator should fulfill. BIL is close to a market impact indicator, with the main advantages of relying only on price data for its computation, and being directly comparable between currencies. Moreover, this indicator is statistically close to the relative spread and the Amihud indicators, meaning that even if this indicator is based on traded prices, it is close to order-based and volume-based measures.

All the indicators we use show a general improvement in liquidity between 2000 and the beginning of 2007 on the three exchange rates considered. However, this overall trend could be affected by isolated liquidity problems (accidents) that affect on a one-off basis specific exchange rates. From our results, it appears that EURUSD is the most liquid exchange rate, followed by USDJPY and then EURJPY, but that the USDJPY exchange rate seems to be the most driven by liquidity conditions. Furthermore, from an intraday point of view, liquidity variables have a specific pattern in relation with the opening of business hours: regions where only European market and European-American markets are open are the most liquid (and therefore the most immune against liquidity problems).

Finally, from our signal approach methodology, it appears that liquidity pressures have occurred during several financial crises of the last decade and our measures are able to capture them. In particular, the main events that have had significant impacts on the liquidity of EURUSD and EURJPY during the last decade have been: the internet crash, September 2001, Bear Stearn and the Lehman Bothers failure. USDJPY has been impacted by the same set of events and also by the WorldCom accounting problems. Focusing on the turmoil that started in 2007, several indicators - the relative spread, the Amihud *ILLIQ* and our BIL indicator - highlight liquidity problems for the three exchange rates. However, for some specific events, like August 2007, Amihud and our BIL indicators are able to detect pressures on the FX market contrary to the relative spread. Nevertheless, contrary to the Amihud indicator, the BIL indicator uses solely on price data series that are more easily available for FX markets than volume data; as a consequence, it seems particularly appropriate for assessing liquidity conditions on this specific market.

References:

Acharya V. and L. Pedersen (2005), "Asset pricing with liquidity risk", *Journal of Financial Economics*, 77, 375-410.

Aitken M., C. Comerton-Forbe (2003), "How should liquidity be measured?", *Pacific-Basin Finance Journal*, 11, 45-59.

Amihud Y. (2002), "Illiquidity and Stock Returross-Section and Time Series Effects", *Journal of Financial Markets,* 5(1), 531-56.

Barker W. (2007), "The Global Foreign Exchange Market: Growth and Transformation", *Bank of Canada Review*, Autumn, 3-12.

Bank for International Settlements (2007) "Foreign exchange and derivatives market activity in 2007", Triennial Central Bank Survey.

Berger D., A. Chaboud, S. Chernenko, E. Howorka, and J. Wright (2008), "Order flow and exchange rate dynamics in electronic brokerage system data", *Journal of International Economics* 75(1), 93-109.

Cai F., E. Howorka and J. Wongswan (2008), "Informational linkages across trading regions: Evidence from foreign exchange markets", *Journal of International Money and Finance*, 27(8), December, 1215-1243.

Darolles S., G. Le Fol and G. Mero (2010), "When Market Illiquidity Generates Volume", working paper available at SSRN: http://ssrn.com/abstract=1102089.

Engle R., and and Lange J., (2001), "Predicting VNET: A model of the dynamics of market depth", *Journal of financial markets*, vol 4, 113-142.

Evans M. and R. Lyons (2002), "Order Flow and exchange rate dynamics", *Journal of Political Economy*, 110(1), 170-180.

Fleming M.J. (2003), "Measuring Treasury Market Liquidity", *FRBNY Economic Policy Review*, September.

Galati G. and A. Heath (2007) "What drives the growth in FX activity? Interpreting the 2007 triennial survey," *BIS Quarterly Review*, December.

Goyenko R., C. Holden and C. Trzcinka (2009), "Do liquidity measures measure liquidity?", *Journal of Financial Economics*, 80, 309-349.

Grossman, S. J. & M. H. Miller (1988), " Liquidity and Market Structure", *Journal of Finance*, American Finance Association, vol. 43(3), 617-37.

Idier J., C. Jardet and G. Le Fol (2009), "How markets are liquid : an application to stock markets", *Bankers, Markets and Investors,* 103, November-December.

Ito T. and Y.Hasimoto (2006), "Intraday seasonality in activities of the foreign echange markets: evidence from the electronic broking system", *Journal of the Japanese and International Economies*, 20(4), 637-664.

Kaminsky, G., S. Lizondo and C. Reinhart, (1998), "Leading indicators of currency crises", International Monetary Fund Staff Papers 45, 1–48.

Melvin M. and B.P. Melvin (2003), "The global transmission of volatility in the foreign exchange market", *The Review of Economics and Statistics*, 85(3), 670-679.

Melvin M. and M.P. Taylor (2009), "The crisis in the foreign exchange market", *Journal of International Money and Finance*, 1-14.

Osler C. (2008), "Foreign Exchange Microstructure: a survey of the empirical literature", Springer Encyclopedia of Complexity and System Science, forthcoming.

Rigobon R. (2003), "Identification through heteroskedasticity", *Review of Economics and Statistics*, 85(4): 777–792.

Sadka R. (2006), "Momentum and post-earnings-announcement drift anomalies: The role of liquidity risk", *Journal of Financial Economics* 80, 309-349.

Westerhoff F. and S. Manzan (2004), "Does liquidity in the market depend on volatility?", *Economics Bulletin*, 6(10), 1-8.

Appendix A. FX market turnover:

	1992	1995	1998	2001	2004	2007
US Dollar	82.0	83.3	87.3	90.3	88.7	86.3
Euro	.	.	.	37.6	37.2	37.0
Deutsche Mark	39.6	36.1	30.1	.	.	.
French Franc	3.8	7.9	5.1	.	.	.
Japanese Yen	23.4	24.1	20.2	22.7	20.3	16.5
Pound Sterling	13.6	9.4	11.0	13.2	16.9	15.0
Swiss Franc	8.4	7.3	7.1	6.1	6.1	6.8
Australian Dollar	2.5	2.7	3.1	4.2	5.5	6.7
Canadian Dollar	3.3	3.4	3.6	4.5	4.2	4.2

Table A-1: Currency distribution of foreign exchange market turnovers (percentage shares of average daily turnover), source BIS 2007.

	1995		1998		2001		2004		2007	
	Amount	%	Amount	%	Amount	%	Amount	%	Amount	%
With reporting dealers	728	64	908	64	689	59	936	53	1319	43
With other financial institutions	230	20	279	20	329	28	585	33	1235	40
With non-financial institutions	179	16	242	17	156	13	252	14	527	17
Total	1137	100	1429	101	1174	100	1773	100	3081	100
Local	526	46	657	46	499	43	674	38	1185	38
Cross-Border	613	54	772	54	674	57	1099	62	1896	62

Table A-2: FX Market turnover by counterparty (daily averages in April, in billions of USD and percent), source BIS 2007.

Appendix B. Dataset example from EBS trading platform recordings.

line	date	time	currency	type	bid price	offer price	bid size	offer size
1	02-Apr-09	15:00:06	AUD/USD	P	0.717	0.717	3	1
2	02-Apr-09	15:00:06	EUR/JPY	P	133.73	133.78	1	1
3	02-Apr-09	15:00:06	EUR/JPY	D	.	133.77	.	1
4	02-Apr-09	15:00:06	GBP/JPY	P	146.59	146.65	1	1
5	02-Apr-09	15:00:06	GBP/USD	P	1.474	1.474	1	1
6	02-Apr-09	15:00:06	USD/CHF	P	1.133	1.134	1	6
7	02-Apr-09	15:00:06	USD/JPY	P	99.48	99.49	5	1
8	02-Apr-09	15:00:06	XAG/USD	P	12.76	12.808	50	50
9	02-Apr-09	15:00:07	AUD/JPY	P	71.29	71.32	1	1
10	02-Apr-09	15:00:07	AUD/USD	P	0.717	0.717	3	1
11	02-Apr-09	15:00:07	BKT/RUB	P	.	38.54	0	3
12	02-Apr-09	15:00:07	EUR/CHF	D	1.524	.	1	.
13	02-Apr-09	15:00:07	EUR/JPY	P	133.73	133.78	1	2
14	02-Apr-09	15:00:07	EUR/RUB	P	44.875	44.945	5	5
15	02-Apr-09	15:00:07	EUR/USD	P	1.345	1.345	6	2
16	02-Apr-09	15:00:07	GBP/JPY	P	146.59	146.66	1	1
17	02-Apr-09	15:00:07	USD/CHF	P	1.133	1.134	5	10
18	02-Apr-09	15:00:07	USD/CHF	D	1.133	.	1	.
19	02-Apr-09	15:00:07	USD/JPY	P	99.48	99.49	6	1
20	02-Apr-09	15:00:08	EUR/GBP	P	0.912	0.913	1	1
21	02-Apr-09	15:00:08	EUR/JPY	P	133.73	133.78	1	1
22	02-Apr-09	15:00:08	EUR/USD	P	1.345	1.345	6	3
23	02-Apr-09	15:00:08	GBP/JPY	P	146.59	146.65	1	1
24	02-Apr-09	15:00:08	GBP/USD	P	1.474	1.474	1	1
25	02-Apr-09	15:00:08	USD/CAD	P	1.244	1.245	1	5
26	02-Apr-09	15:00:08	USD/CHF	D	1.133	.	1	.
27	02-Apr-09	15:00:08	USD/JPY	P	99.48	99.49	1	1
28	02-Apr-09	15:00:08	USD/JPY	D	99.48	.	5	.
29	02-Apr-09	15:00:08	USD/MXN	P	13.808	13.823	1	1
30	02-Apr-09	15:00:08	XAG/USD	P	12.76	12.808	100	50
31	02-Apr-09	15:00:09	AUD/JPY	P	71.29	71.34	1	1
32	02-Apr-09	15:00:09	AUD/USD	P	0.717	0.717	1	1
33	02-Apr-09	15:00:09	EUR/JPY	P	133.75	133.8	1	28
34	02-Apr-09	15:00:09	EUR/USD	P	1.345	1.345	5	1
35	02-Apr-09	15:00:09	EUR/USD	D	1.345	.	1	.
36	02-Apr-09	15:00:09	GBP/JPY	P	146.58	146.67	1	1
37	02-Apr-09	15:00:09	GBP/USD	P	1.473	1.474	1	2
38	02-Apr-09	15:00:09	USD/CHF	P	1.133	1.134	5	9
39	02-Apr-09	15:00:09	USD/JPY	P	99.49	99.5	2	18
40	02-Apr-09	15:00:09	USD/JPY	D	99.49	99.49	2	1
41	02-Apr-09	15:00:09	XAG/USD	P	12.755	12.8	100	50

FIG. 1 Example of EBS database during 3 seconds of trading on 2 April 2009

Appendix C. Regional segmentation of FX trading activity

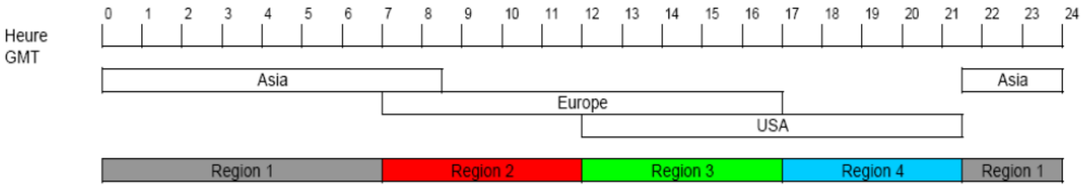

FIG. 2 Regional segmentation on FX markets

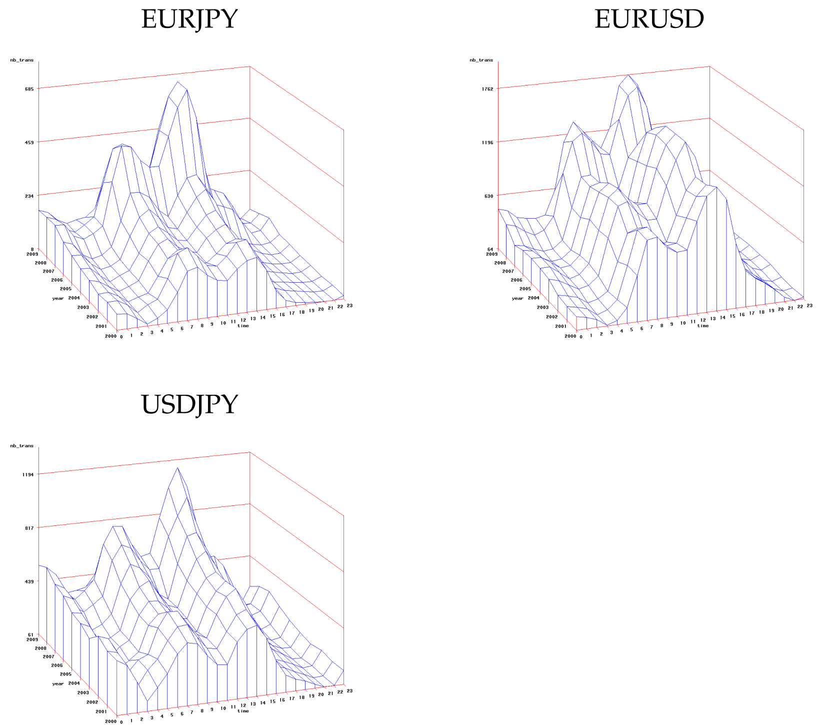

FIG. 3 Hourly intraday patterns of the number of transactions (mean per year)

Appendix D. Standard liquidity indicators by currency pair and region.

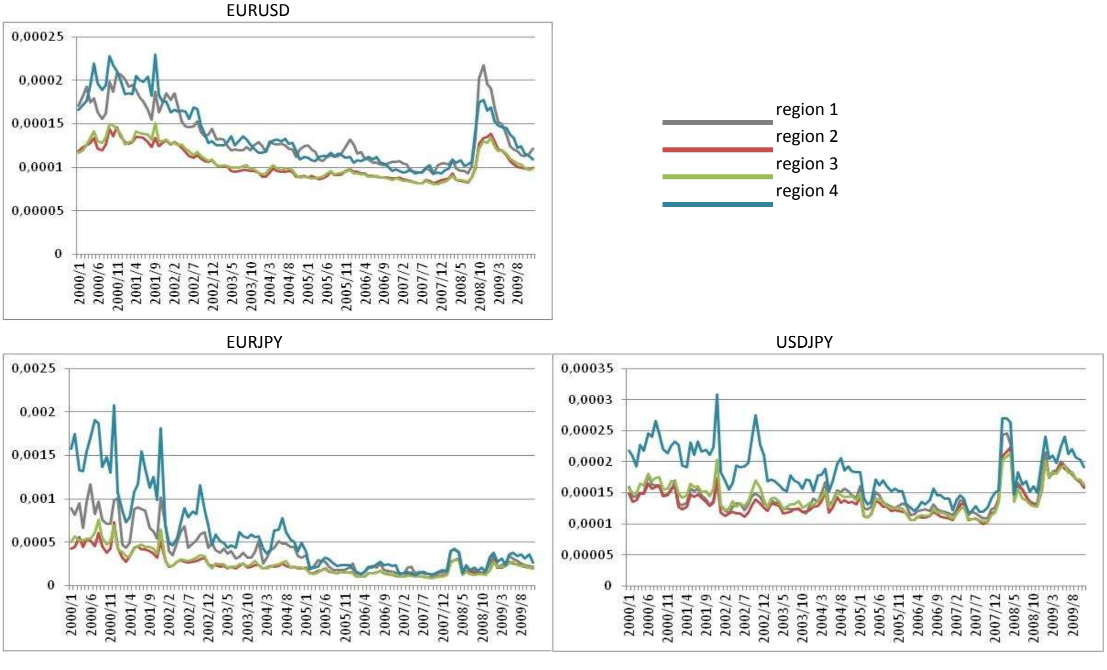

FIG. 4 Relative spread by exchange rates and by regions (mean per month) (2000-2009)

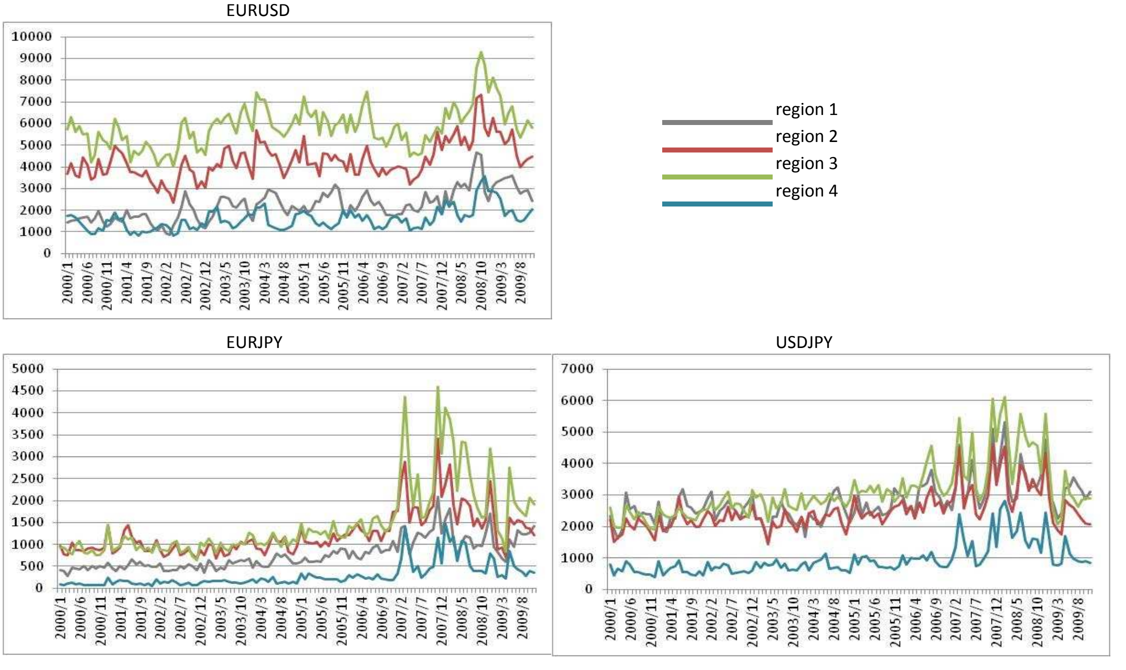

FIG. 5 Daily Number of transactions by currency and by region (mean per month)

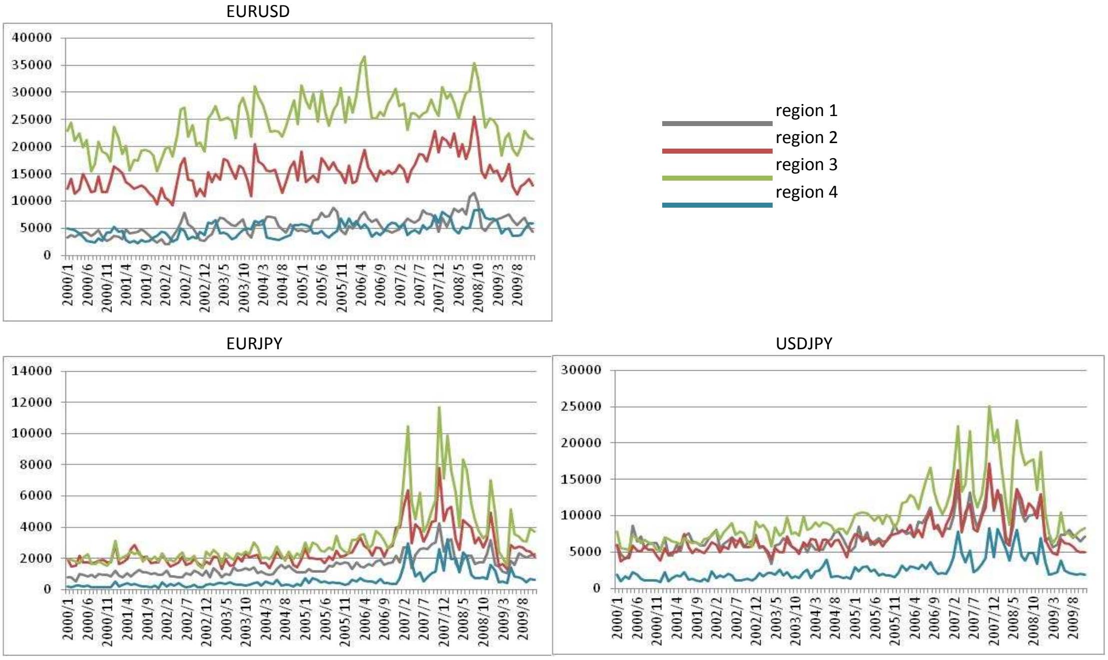

FIG. 6 Daily Volume by currency and by region (mean per month)

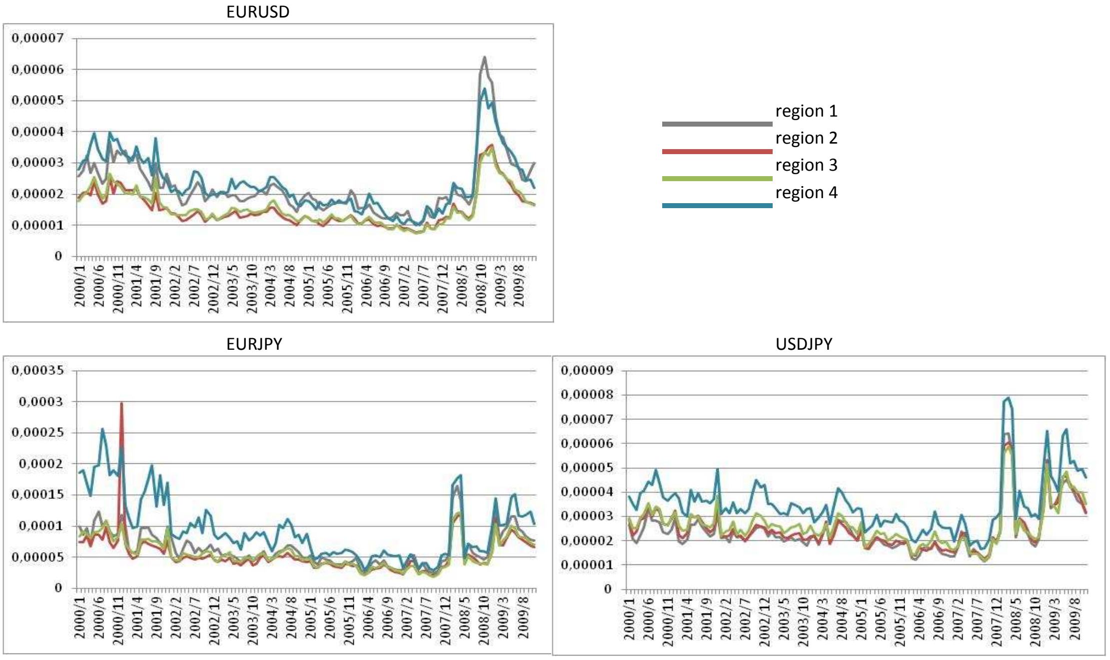

FIG. 7 Amihud (2002) illiquidity, by currency and by region (mean per month)

Appendix E. Correlation between liquidity indicators.

	$S^{relative}_{i,t}$	$N_{i,t}$	$V_{i,t}$	$ILLIQ_{i,t}$
$S^{relative}_{i,t}$	1	0.42	-0.18	0.84
$N_{i,t}$		1	0.77	0.26
$V_{i,t}$			1	-0.32
$ILLIQ_{i,t}$				1

Table E.1: Correlation between liquidity indicators (2000-2009) for EURUSD

	$S^{relative}_{i,t}$	$N_{i,t}$	$V_{i,t}$	$ILLIQ_{i,t}$
$S^{relative}_{i,t}$	1	-0.34	-0.43	0.88
$N_{i,t}$		1	0.98	-0.17
$V_{i,t}$			1	-0.28
$ILLIQ_{i,t}$				1

Table E.2: Correlation between liquidity indicators (2000-2009) for EURJPY

	$S^{relative}_{i,t}$	$N_{i,t}$	$V_{i,t}$	$ILLIQ_{i,t}$
$S^{relative}_{i,t}$	1	0.21	-0.16	0.86
$N_{i,t}$		1	0.91	-0.01
$V_{i,t}$			1	-0.32
$ILLIQ_{i,t}$				1

Table E.3: Correlation between liquidity indicators (2000-2009) for USDJPY

Appendix F. The BIL indicator

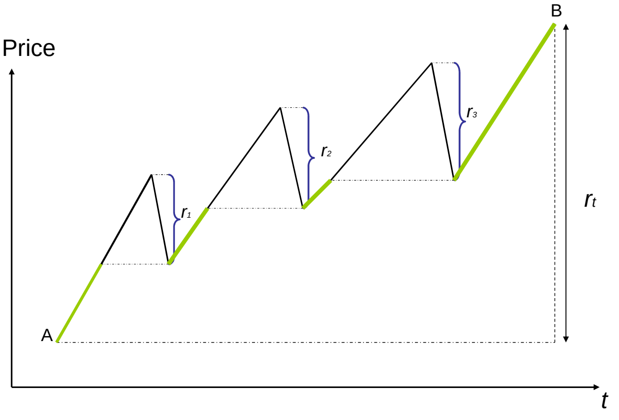

FIG. 8 Example of BIL computation

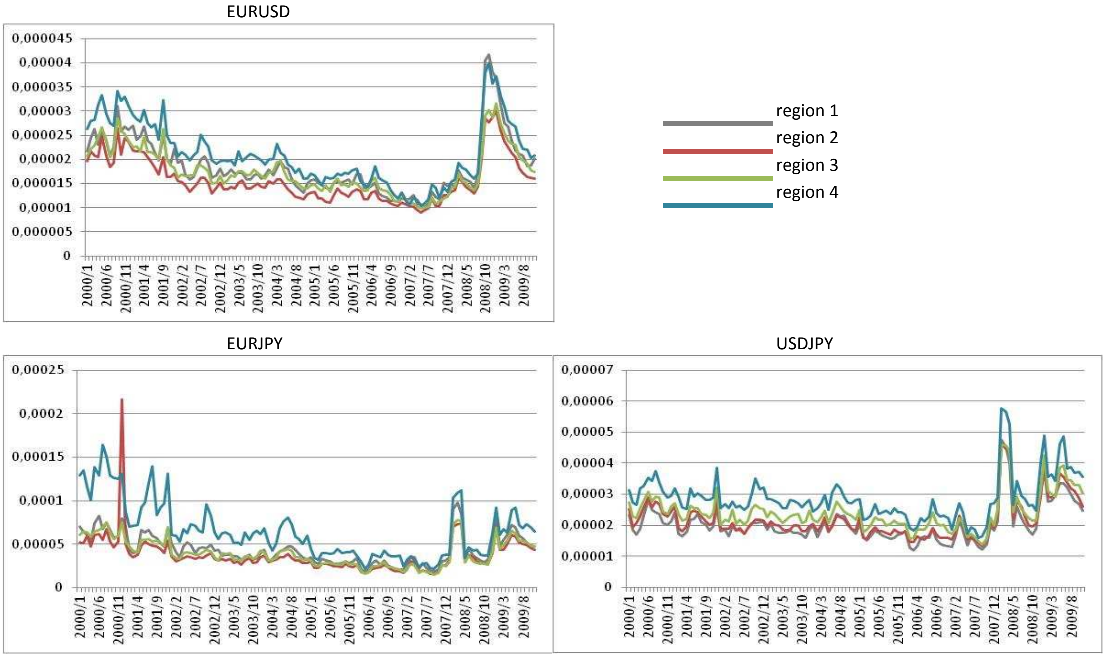

FIG. 9 BIL statistics, by currency and by region

Appendix G. Robustness check

	BIL_t^H	BIL_t^J
Spread	0.8425	0.8382
Amihud	0.9635	0.9626

Table G.1: Correlation between alternative measures of BIL and illiquidity indicators : EURUSD

	BIL_t^H	BIL_t^J
Spread	0.5917	0.5796
Amihud	0.9950	0.9939

Table G.2: Correlation between alternative measures of BIL and illiquidity indicators : EURJPY

	BIL_t^H	BIL_t^J
Spread	0.8990	0.8955
Amihud	0.9816	0.9805

Table G.3: Correlation between alternative measures of BIL and illiquidity indicators : USDJPY

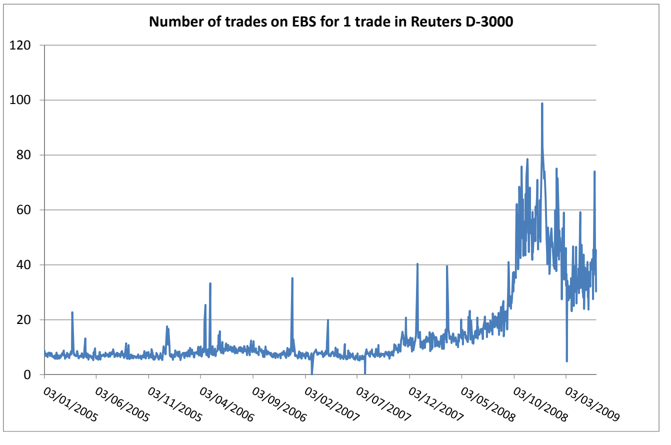

FIG. 10 Comparison of the number of trades between electronic platforms: EBS vs. Reuters D-3000

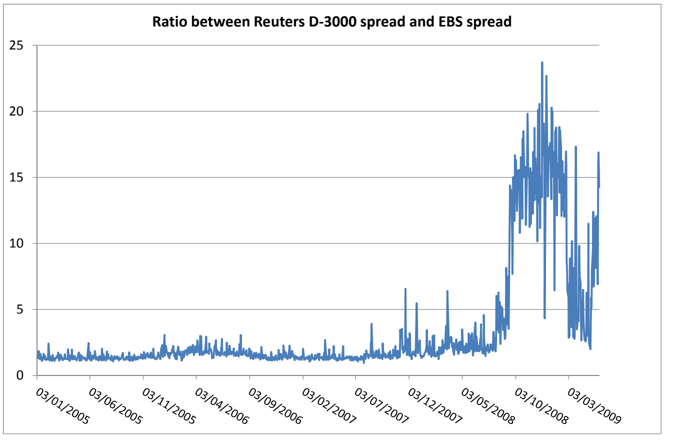

FIG. 11 Comparison of the Bid-Ask spreads between electronic platforms: EBS vs. Reuters D-3000

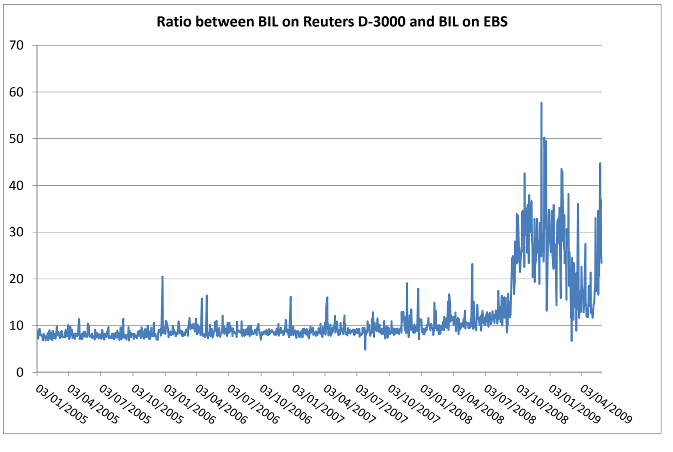

FIG. 12 Comparison of the BIL indicators between electronic platforms: EBS vs. Reuters D-3000

FIG. 13 Identification of liquidity problems during identified crisis (2000-2002)

Day proportion of liquidity problems during crisis episodes as defined by Rigobon (2003)

USDJPY	Number of 'crisis days'					
		spread	amihud	bil	volume	nb_trade
Internet Crash	64	31,3%	39,1%	39,1%	4,7%	4,7%
Argentinean crisis	301	4,3%	2,7%	2,0%	3,7%	4,0%
September 2001	14	57,1%	64,3%	57,1%	14,3%	14,3%
World Com acc. Pb.	108	2,8%	1,9%	1,9%	7,4%	9,3%

EURUSD	Number of 'crisis days'					
		spread	amihud	bil	volume	nb_trade
Internet Crash	64	6,3%	18,5%	20,0%	4,6%	4,6%
Argentinean crisis	301	8,9%	6,6%	4,9%	3,0%	3,6%
September 2001	14	28,6%	42,9%	42,9%	7,1%	7,1%
World Com acc. Pb.	108	0,0%	0,0%	0,0%	12,0%	8,3%

EURJPY	Number of 'crisis days'					
		spread	amihud	bil	volume	nb_trade
Internet Crash	64	27,0%	33,3%	30,2%	3,2%	3,2%
Argentinean crisis	301	4,0%	3,0%	2,7%	6,6%	7,0%
September 2001	14	42,9%	28,6%	42,9%	21,4%	14,3%
World Com acc. Pb.	108	0,0%	0,0%	0,0%	5,6%	5,6%

Day proportion of liquidity problems outside crisis episodes as defined by Rigobon (2003)

		spread	amihud	bil	volume	nb_trade
USDJPY		6,5%	5,0%	5,0%	8,8%	9,6%
EURUSD		9,6%	7,3%	8,5%	5,4%	6,9%
EURJPY		8,5%	7,7%	8,1%	10,8%	11,5%

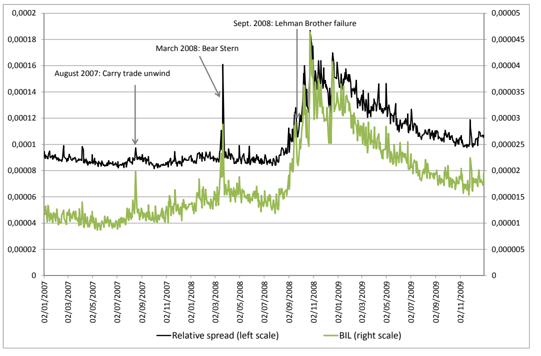

FIG. 14 EURUSD: daily illiquidity indicators during the financial turmoil (2007-2009)

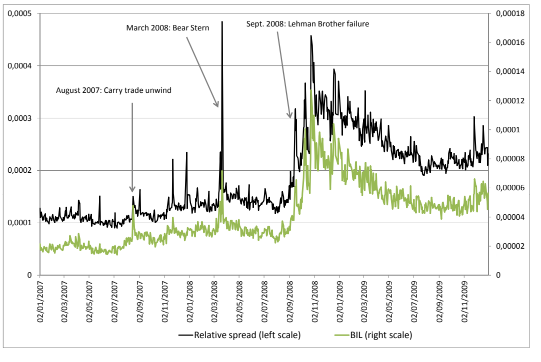

FIG. 15 EURJPY: daily illiquidity indicators during the financial turmoil (2007-2009)

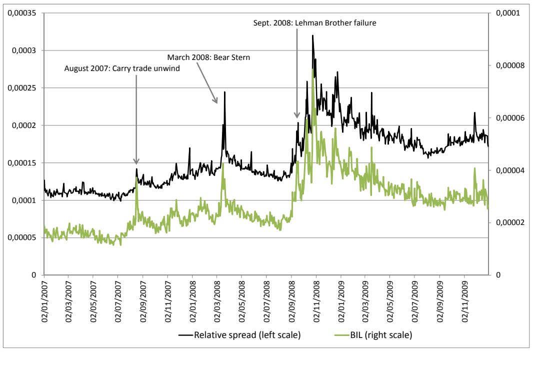

FIG. 16 USDJPY: daily illiquidity indicators during the financial turmoil (2007-2009)

FIG. 17 Detection of liquidity problems on the FX market -2007-2008 (selected episodes)

	EURUSD					EURJPY					USDJPY				
	spread	amihud	bil	vol.	trades	spread	amihud	bil	vol.	trades	spread	amihud	bil	vol.	trades
09/08/2007	0	0	0	1	0	0	0	0	1	1	0	0	0	1	1
10/08/2007	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1
13/08/2007	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
14/08/2007	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1
15/08/2007	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1
16/08/2007	0	0	0	1	1	0	0	0	1	1	0	1	1	1	1
17/08/2007	0	1	1	1	1	0	1	1	1	1	0	1	1	1	1
20/08/2007	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1
01/11/2007	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1
02/11/2007	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
05/11/2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06/11/2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07/11/2007	0	0	0	1	1	0	0	0	1	1	0	0	0	1	1
08/11/2007	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1
09/11/2007	0	0	0	0	1	0	0	0	1	1	0	0	1	1	1
12/11/2007	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1
13/11/2007	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1
14/11/2007	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1
15/11/2007	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1
16/11/2007	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
19/11/2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07/03/2008	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0
10/03/2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11/03/2008	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0
12/03/2008	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
13/03/2008	0	1	0	0	1	0	1	1	0	0	1	1	1	1	1
14/03/2008	0	1	1	0	1	0	1	1	0	0	1	1	1	1	1
17/03/2008	1	1	1	0	1	0	1	1	0	0	1	1	1	1	1
18/03/2008	0	1	1	0	1	0	0	0	0	0	1	1	1	1	1
19/03/2008	0	1	1	0	1	0	1	1	0	0	1	1	1	0	1
20/03/2008	0	1	1	0	1	0	1	1	0	0	1	1	1	0	0
21/03/2008	1	1	1	-1	-1	1	1	1	-1	-1	1	1	1	-1	-1
24/03/2008	0	1	1	0	0	0	1	0	0	0	1	1	1	0	0
25/03/2008	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
28/08/2008	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
29/08/2008	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
01/09/2008	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0
02/09/2008	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
03/09/2008	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0
04/09/2008	1	1	1	1	1	0	1	1	0	0	1	1	1	0	0
05/09/2008	1	1	1	0	1	0	0	1	0	0	0	1	1	0	0
08/09/2008	1	1	1	1	1	0	1	1	0	0	0	1	1	0	0
09/09/2008	1	1	1	1	1	0	1	1	0	0	0	1	1	0	0
10/09/2008	1	1	1	1	1	0	1	1	0	0	1	1	1	0	0
11/09/2008	1	1	1	0	1	0	1	1	0	0	1	1	1	0	0
12/09/2008	1	1	1	1	1	0	1	1	0	0	0	1	1	0	0
15/09/2008	1	1	1	1	1	1	1	1	0	0	1	1	1	0	1
16/09/2008	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1
17/09/2008	1	1	1	1	1	1	1	1	0	0	1	1	1	0	1
18/09/2008	1	1	1	1	1	1	1	1	0	0	1	1	1	0	1
19/09/2008	1	1	1	1	1	0	1	1	0	0	1	1	1	0	0
22/09/2008	1	1	1	1	1	0	1	1	0	0	1	1	1	0	0