Information shares in a two-tier FX market

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Abstract

Using several popular measures of information share, we examine price discovery across the inter-dealer and dealer-customer market tiers in the foreign exchange market. We generally find that the information share of the inter-dealer tier is higher than that of the dealer-customer one for non-financial sector trades and is lower than the dealer-customer tier for financial sector trades. In the forward market, we find that the dealer-customer tier generally has the greater information share. Our results indicate the market where customers' trades are the most informative and how exogenous events can affect price discovery across markets and market tiers.

JEL Classification: G14; G15

Keywords. Foreign exchange market microstructure; FX derivatives; Information share; Price discovery

1 Introduction

The foreign exchange (forex or FX) market is a two-tier market with no central clearing house. The two tiers consist of dealers trading with their customers, referred to as the dealer-customer market, and dealer trading with other dealers, referred to as the inter-dealer market. Despite the large volumes and sophisticated market participants, since there is no clearing house and low transparency in the forex market, the market is referred to as a 'dark' one (Menkhoff, et al., 2016). Thus, price discovery and information shares[1] in such dark markets are more important than they are in common public markets where price formation is relatively known and accessible to the public.

Recent price discovery studies on currency markets have examined the information share between the spot market and the forward market (Chen and Gau, 2010; Rosenberg and Traub, 2008). Special attention has also been given to the process of price discovery in the two FX market tiers (Osler, Mende, and Menkhoff, 2011; Bjønnes and Rime, 2005). Lyons (1995) argues that customer order flow serves as a source of private information for FX dealers in the inter-dealer market. Recent studies that examine information shares across the various FX trader types include Osler, Bjønnes, and

[1]Successful information shares impound new information into market prices efficiently and quickly. This means that among various markets or sectors that simultaneously trade the same asset, the one that impounds the new true information (permanent shocks) most quickly and with the least noise (transitory shocks), has the largest information share.

Kathitziotis (2016), Chen and Gau (2014), Chang, et al. (2013), and Evans and Lyons (2005). These studies find that: (a) Financial customer trades convey more information than corporate customer trades. This in turn is reflected by dealers offering narrower bid-ask spreads (hereafter referred to as the spread) to the former in order to 'pay' for their private information. (b) Large international banks benefit the most from their large scale customer bases. (c) There is no definitive evidence as to whether the spot market or the forward market has the greater information share. Whether the spot or forward market dominates in price discovery depends on the country, the level of volatility during the sample period, the channel type of trades (e.g., electronic versus non-electronic), and the relative composition of speculators versus hedgers in the markets. In spite of the growing number of studies on the influence of various sectors on both exchange rates and information shares, to the best of our knowledge there is no study that explicitly examines the two-tier information share in the spot versus forward market. We seek to fill this gap using proprietary disaggregated customer and dealer data, provided by the Bank of Israel.

Our paper's contribution is threefold. First, we estimate the information share of the local banks, who serve as dealers or market makers, in the ILS/USD exchange rate versus various sectors (corporates, financial companies, foreign investors, non-levered institutional investors, households, and all customers). Such a disaggregation enables us to learn about the information share of inter-dealer trades versus dealer-customer trades, which is more

informative than the commonly used speculator-hedger disaggregation or a basic comparison of the information share measures (hereafter ISMs) between multiple markets. Second, the ISMs that we use include Hasbrouck (1995) (H), Gonzalo and Granger (1995) (GG), Lien and Shrestha (2014) (LS), and Yan and Zivot (2010) and Putniņš (2013) (PYZ). Using these measures together allows us to shed brighter light on the bilateral importance of markets versus studies that employ one or two measures, only. Third, we examine the assessed ISMs over time, particularly around a unique exogenous economic episode (hereafter referred to as 'the episode') in which foreign investors massively purchased short-term instruments and in turn caused frictions between the spot and forward markets.

Using spot and forward ILS/USD exchange rate trades by the various customer types, we find that, first, the ISMs of inter-dealer trades in the spot market are higher than any non-financial dealer-customer trades (corporates, non-levered institutional investors [2], and households), but lower than dealer trades with financial customers (financial companies and foreign investors). Second, the ISMs for the inter-dealer tier in the forward market are generally lower than those of the dealer-customer tier. This means that the hypothesis that dealers attain private information through their respective customer trades to use in inter-dealer trade holds for the Israeli spot FX

[2] We refer to these Israeli investors as non-financial ones since their trade patterns are characterized by relatively few trades and for long terms. However, they can be categorized also as financial customers based on their relatively small spreads.

market, but not for the forward FX market. Third, assessing the various ISMs of spot trades versus forward trades within each sector attains mixed results. The ISMs of banks, foreign investors, and households in the spot market are higher than their respective ISMs in the forward market, while the ISMs of corporates, financial companies and all banks' customers are higher in the forward market. Fourth, the spreads offered to financial companies, foreign investors, and institutional investors are, on average, close to 0, while those of corporates and especially households are much larger. This finding is similar to that of Osler, Mende, and Menkhoff (2011) which shows that dealers are willing to 'pay' their customers that are perceived to be informed for their order flow. In addition, the information content of trades by corporates, institutional investors, and 'all customers' is revealed on the buy (ask) side in both markets while the opposite is true with foreign investors. Fifth, H and LS_{GIS} ISMs are autocorrelated for the non-financial sectors. Finally, positions and volatility explain, in some cases, the four ISMs and we develop bootstrap techniques (described in Appendix B) for testing ISMs for statistical significance.

The remainder of the paper is structured as follows: Section 2 briefly surveys the related literature. Section 3 describes the FX markets in Israel and the data. Section 4 provides the information share measures cross sectionally and over time. Section 5 concludes.

2 Related Literature

Our paper falls within the literature that examines price discovery in two-tier financial markets. In a two-tier market, customer order-flow provides a source of private information for dealers to use in their future trades with other dealers (Lyons, 1995). Consistent with Lyons (1995), in the foreign exchange market, Evans and Lyons (2002), Evans and Lyons (2008), Love and Payne (2008), Osler, Mende, and Menkhoff (2011), and King, Osler, and Rime (2013) find that FX order flows contribute significantly to price discovery. Order flows have also been shown to significantly contribute to price discovery in the bond market (Valseth, 2013), in the stock market (Hasbrouck, 1995; Gyntelberg, Loretan, and Tientip, 2015), and in the U.S. treasuries market (Brandt and Kavajecz, 2004; Menkveld, Sarkar, and van der Wel, 2012). An important question, that remains unanswered, is as to where price discovery originates in two-tier markets. Anand and Subrahmanyam (2008) find that the information share of intermediaries account for greater price discovery than other institutional and individual investors in Toronto Stock Exchange. Valseth (2013) finds that customer order flow only explains 1% of the yield variation in the Norwegian government bond market, compared to 25% by dealer order-flow. Osler, Mende, and Menkhoff (2011) report that forex dealers offer narrower spreads to their customers that they perceive to be the most informed in order to use that private information in the FX inter-dealer market. The literature is yet to provide empirical evidence as to whether

customer-dealer prices lead inter-dealer prices or vice-versa, however. This is an important question, since the foreign exchange market is a dark two-tier one, without a central clearing house, where different prices are transacted at in the two market tiers. Our paper differentiates itself from previous studies by examining the information share of the two tiers by viewing each tier as a distinct market. This allows us to uniquely estimate whether customer-traded prices lead inter-dealer prices or vice-versa.

3 The Israeli Currency market and Data

The currency market in Israel is characterized as a free floating one, except for the Central Bank's periodic interventions. Almost all transactions in the spot foreign exchange market are done through the banking system where the U.S. dollar is the most heavily traded currency. Our data, provided by the Bank of Israel, contain daily disaggregated spot and forward trades in the U.S. dollar (USD) and Israeli Shekel (ILS) currency pair for the January 1, 2009 to March 31, 2014 period. Data are collected, on a daily basis, from the local banks (the dealers) and contain all transaction prices, volumes, and additionally trader types (whether it is a dealer-customer trade or an inter-dealer trade).[3] The forward trades are all cash settled at the "representative" exchange rate published by the Bank of Israel during afternoon hours each

[3] There are also FX option trades in the OTC market, but their transaction size and frequency are small compared to the spot and forward trades. For a description of the OTC FX options market, see Piccotti and Schreiber (2015).

trading day.[4] Following Piccotti and Schreiber (2015), Lien and Shrestha (2014), Grammig and Peter (2013), and Anand and Chakravarty (2007), we use data at the daily frequency only, due to data availability. We do not believe, however, that using daily data will bias our results, since the OTC market is not a high-frequency one. The mean transaction volume (in both the inter-dealer and dealer-customer markets) per day is 586 and 174 for spot and forward trades, respectively (see Table 1). For a discussion on the trade-off between daily data and ultra-high frequency data, see Grammig and Peter (2013).

The disaggregated data contain 7 sectors. (1) 'bank' - local banks who serve as dealers. This sector includes inter-dealer trades, only. (2) 'corp' - mainly exporters and importers (non-financial corporates) of goods and services. (3) 'fin' - financial companies including hedge funds, asset management companies, and index and mutual funds' managers. (4) 'for' - all kinds of foreign investors (except foreign households). We do not distinguish, however, between foreign financial and non-financial investors, due to our data's granularity. (5) 'inst' - long-term (non-levered) institutional investors (i.e., pension funds, provident and compensation funds, and study funds). (6) 'hous' - local and foreign households. (7) 'cust' - all bank customers above (corp, fin, for, inst, hous) and undefined customers. This detailed disaggregation allows us to analyze which customer sectors lead inter-dealer trades

[4] The representative rate is calculated by sampling the exchange rate that prevailed among local banks around noon hours.

(or led by them) in the Israeli two-tier FX market. To this end, we follow Gyntelberg, Loretan, and Tientip (2015) and King, Osler, and Rime (2013) and divide the above sectors into financial ones (financial companies and foreign investors) and non-financial sectors (corporates, non-levered institutional investors, and households).

In order to examine price discovery in the local two-tier FX market, we exclude days and sectors with less than two buy or sell trades or with missing data from the raw data. Basic statistics of the data set are presented in Tables 1-2. These tables present the number of trades, order flows (#buy - #sell), and the spreads [5], for the spot and forward markets, respectively.

[Enter Table 1 here]

The mean net order flow[6] for the inter-dealer spot market points to the banks' functioning as dealers. This is true also for financial firms, though to a lesser extent. In contrast, corporates buy spot more than they sell, on average. The foreign investors' fraction of total trades is about 42% (247.6/(452+134.6)), while both institutional investors and households trade much less frequently (about 4% and 5%, respectively). Note that institutional

[5] Spreads are calculated as $(Ask - Bid)/[(Ask + Bid)/2]$ where Ask (Bid) is the sell (buy) price of the ILS/USD exchange rate. As our data contain only actual trades, Ask and Bid prices are daily trade means of the various sectors against the local banks.

[6] Evans and Lyons (2002) show the power of the entire market's order flows in forecasting the future exchange rate, while Evans and Lyons (2005) disaggregate the entire market's order flows into sectors. Thus, the order flows of the various sectors can be used to assess the potential impact of each sector on the exchange rates. However, this is beyond the scope of our paper.

investor trades are for long-term horizons while households have a negligible impact on the market due to their small size (Galai and Schreiber (2013)). Finally, the spreads in the inter-dealer market are the smallest at 0.2 basis points, which compares to the spread offered to households and corporates of 57.6 and 14.2 basis points, respectively. Such differences are found in Galai and Schreiber (2013) and they are consistent with the extent of informed customer trading in the two-tier FX market. Osler, Mende, and Menkhoff (2011) argue that in a two-tier market, dealers are willing to 'pay' informed investors for the information they convey and thus, they attract them by quoting a narrower spread. We find this effect also in the spreads offered to financial companies, which are perceived to be informed investors versus corporates and households who are perceived to be uninformed and usually react to news rather than precede it (see King, Osler, and Rime (2013)).

[Enter Table 2 here]

A similar picture to the spot market (Table 1) is also found in the forward market (Table 2), although less significantly. In general, there are less trades and less trading days in the forward market, compared to the spot one. Here too, the net daily order flow is close to 0 for financial sectors (bank, fin, and for), while the mean net daily order flow is largely positive for corporates. In contrast with the spot market, the percentage of total trades attributable to foreign investors is only 21%, which means that they are relatively more active in the spot market. Moreover, the variability of trading activity among corporates and foreign investors is higher than it is in the other sectors (the

standard deviations are 67.2 and 76.6 for daily total trades, respectively). The large order flow of corporates indicates that they may use the forward market to hedge against their exchange rate exposure. This can be seen by the ratio of forward to spot total trades which is much higher for corporates than all other sectors except institutional investors - inst (1.09 versus 0.33 of all customers - cust). Finally, the spreads ranking in the forward market is similar to those in the spot market. Corporates, and particularly households, face the largest spreads, while financial companies face the smallest ones. The differences between the characteristics of the various sectors in the spot and forward markets call for a rigorous examination of which sector is the leading one and whether inter-dealer trades convey information more quickly and accurately than dealer-customer trades. Such an examination is conducted in the next section.

4 Empirical Results

In this section, we examine the bilateral information share measures across sectors, markets, spot versus both short-term and long-term forward contracts, and the buy side versus the sell side. The sector or market that impounds new information most quickly and efficiently (avoids noise) has the larger information share. This allows us to examine which sectors, markets, and trade side contribute the most to price discovery. Finally, we examine the information shares over time and focus on an exogenous economic episode

(Section 4.3) that occurred during 2011 and asymmetrically influenced the spot and the forward markets.

4.1 Price Discovery Across Sectors

In all tables and figures, we estimate the information shares (H_{Mean}, H_{MIS}, LS_{GIS}, GG, and PYZ), which are described in Appendix A. We find the leading trades, in terms of 'the first to move' (the Hasbrouck (1995) measure, which is denoted by H) and 'the most accurate' trades (the Gonzalo and Granger (1995) measuere, which we denote by GG). In addition, we calculate whether the various information shares are statistically significant (i.e., significantly different from 0.5) by forming 95% statistical confidence intervals by employing the bootstrap techniques, which are described in Appendix B.

[Enter Table 3 here]

Table 3 presents the information share results for the inter-dealer market (bank-sel/buy/total) versus the dealer-customer market. We find a clear-cut distinction between the information share of financial versus non-financial sectors. Trades in the inter-dealer market are more informative than those of non-financial sectors (i.e., corporates, households, and non-levered institutional investors), which are characterized by relatively long-term investment horizons. This finding is true for both sell, buy, and total trades, although the information content of inter-dealer sell trades is less significantly greater than dealer-customer sell trades as compared to the case of buy trades. Be-

tween inter-dealer trade and dealer-financial company trade, however, there is no decisive information leader. The information shares of financial company trades are not significantly different from those of inter-dealer trades for sell, buy, or total orders. An interesting case is that of foreign investors' trades. They contribute to price discovery significantly more than dealers' sell trades, significantly less for buy trades, and not significantly different for total trades. Finally, against all sectors (cust), the inter-dealer trades are more informative than dealer-customer trades, but only significantly so for buy orders. These results are in line with our hypothesis that financial companies' order flows convey valuable information to their dealers. Therefore, financial companies' spreads are the lowest among all customers and the information content of their tradaes is not significantly different from inter-dealer market trades. In contrast, the information shares of dealers are greater than the respective trades of non-financial sectors (corporates, households, and non-levered institutional investors), as their contribution to price discovery is limited (King, Osler, and Rime (2013)). The information shares of foreign investor trades can be explained by the natural short U.S. dollar position of foreign investors who sell U.S. dollars to the local banks. Thus, their information is revealed through their international portfolio re-balancing (particularly in the local FX market). This evidence is corroborated by their negative average daily order-flow (-7.6, see Table 1).

[Enter Table 4 here]

Table 4 presents the information share results for the forward market. In

Table 4, the inter-dealer market contributes less to price discovery than it does in its dominant role in the spot market. This can be seen by the information shares of bank trades against those of non-financial sectors (corporates, households, and non-levered institutional investors). In Table 3, these three sectors were significantly led by the local banks in the spot market, while in the forward market there is no clear-cut leader. Particularly, the information shares of corporate buy trades are greater than those of bank trades, while the opposite is true for corporate sell trades. This can be explained by the relatively larger export firms being the primary ones that hedge their currency exposure. These results are also supported by the lower mean spreads offered to corporates in the forward market compared to the respective figure in the spot market (2 basis points in the forward market versus 14.2 basis points in the spot market). However, these lower spreads are inconsistent with King, Osler, and Rime (2013) who argue that non-financial firms do not convey ***any*** valuable information to the dealers. Moreover, the information share of all customers (cust) trades are significantly higher than those of inter-dealer trades, which indicates that the inter-dealer market tier does not lead the dealer-customer market tier in the forward market. In addition, the information content of dealer-financials trades is greater than that of inter-dealer trades, while in the spot market there is no decisive price discovery leader. Finally, the information shares of bank trades are generally greater than those of foreign investors, which indicates that the latter do not look to the forward market for price discovery as they do regarding the spot market.

Comparing the information shares of the various sectors in the spot market versus the forward market confirms that inter-dealer and dealer-financials trades are the information leaders in the spot market and that the forward is generally used for passive hedging demands.

[Enter Table 5 here]

Table 5 examines information shares across the spot and forward market for each trader type. The results in the table are consistent with our earlier evidence in that the sectors that are found to be leaders in the spot or forward markets (Tables 3-4) continue to be found to be price leaders in the same market. For example, the inter-dealer market leads in the spot market (Table 3), but not in the forward market (Table 4). Thus, banks' spot trades lead their forward trades. Corporate trades are led by inter-dealer trades in the spot market, but lead in the forward market. Thus, their forward trades significantly lead their spot trades. This is also the case with foreign investors; though, insignificant for sell trades. Finally, financial companies' trades, which decisively lead inter-dealer trades in the forward market, do not lead them in the spot market. Hence, financial companies' forward trades lead their spot trades. These results point to the different roles that banks fulfill in these two markets, with regard to price discovery. In the spot market, banks serve as true market makers thus, their information shares are higher than those of non-financial sectors (as well as those of all customers); although, against financial sectors (financial companies and foreign investors), there is no decisive leader. In the forward market, however,

the inter-dealer market tier usually does not lead the dealer-customer market tier and, as a result, the information share of their spot trades is greater than that of their forward ones.

[Enter Table 6 here]

Table 6 compares the information shares of the spot and forward markets by differing forward contract horizons. We define long-term forward contracts as contracts that have in excess of 220 trading days-to-expiration (over one calendar year) and examine the information shares of total trades, only. Since the short-term forward market is more similar to the spot market as compared to the long-term forward market, we hypothesize that the leading trades will be more decisive for spot trades versus long-term forward trades relative to spot trades versus short-term forward trades. Table 6 confirms that the inter-dealer spot market information share is significantly greater than the inter-dealer long-term forward market. This is also the case, though with the opposite direction, for corporates' trades and for financial companies' trades.

[Enter Table 7 here]

To further examine price discovery, Table 7 presents, for both markets, which side of the trade: buy (ask prices) or sell (bid prices), leads the other. The results in Table 7 are consistent with the results in Tables 3-4. The sectors that have been found to be leaders on the sell or buy side in the spot/forward markets generally continue to be found as leaders on the same side (sell or buy). For instance, banks' buy orders are more informative than

their sell orders in the spot market. Additionally, corporates' buy orders are more informative than their respective sell orders in both spot and forward markets, while the opposite is true for foreign investors. Contrary to our earlier tables, financial sectors do not behave differently from non-financial sectors in this regard.

4.2 Price Discovery Over Time

In this section, we examine how the contributions to price discovery by each trader type and market tier evolve over time.

[Enter Figure 1 here]

Figure 1 presents the disaggregated spot market dealer-customer information shares against the inter-dealer market, based on total trades only. The information shares are estimated using a rolling one-year window (220 trading days) with the innovation in the roll being one month (22 trading days). In most cases, the dealer-customer information shares are below 0.5, which means that the inter-dealer market leads the dealer-customer market. While all non-financial sectors' information shares are generally below 0.5, indicating that they convey little new information to the banks, financial companies' and foreign investors' trades lead the inter-dealer market in several sub-periods. Guided by the literature (for example, King, Osler, and Rime (2013)) and our results, especially Table 3, these two sectors appear to transfer private information to the banks, which is used later in the inter-

dealer spot market.

[Enter Figure 2 here]

The information share results in the forward market are very different than in the spot market. Over most of the sample period, the information share of dealer-customer trades is greater than the inter-dealer one, except for foreign investors, in which case the dealer-foreign information shares are below 0.5 for the majority of the sample period. That dealer-foreign trades have a greater information share in the spot market than the inter-dealer trades and have a lower information share in the forward market than inter-dealer trades points to the main difference between foreign investors and other customer sectors. The former supply foreign currency to the market, while the latter are generally on the demand side (except for exporters). The differing behavior of the information shares of the spot market versus those in the forward market is most prominent for non-financial sectors. The differing behavior is particularly apparent for households who are perceived to be the smallest and the least sophisticated investors in FX markets (Galai and Schreiber (2013)). Figure 2 shows that even the households' trades are contributing more to price discovery than the inter-dealer market, in some short sub-periods. Another difference is the co-movement of almost all dealer-customer sectors to lead the inter-dealer market in the middle of 2011.

4.3 The Episode

As monetary policy became less and less expansionary, the interest rate gap between Israel and the developed countries widened, and the inflow of capital increased. From August 2009 until April 2011[7], the value of the asset portfolio held by foreign investors grew by 700%. Most of the activity of foreigners was concentrated in the money market - Makam (similar to U.S. Treasury bills) and short-term government bonds. The share of foreign investor holdings in the Makam and short-term government bonds grew from 1.8% and 0% in August 2008 to 34.5% and 17.2% in May 2011, respectively. This activity is depicted in Figure 3.

[Enter Figure 3 here]

During 2011, the Bank of Israel took steps to restore equilibrium short-term rates by imposing a reserve requirement on local banks of 10% against foreigners' transactions in foreign currency derivatives (January), as well as a reporting requirement on various transactions (July). At the same time, the Ministry of Finance canceled nonresident investors' capital gains tax exemption in investments in makam and short term government notes, in order to moderate speculative capital flows. These steps reduced foreigners' positions in Makam to almost zero by 2013. One consequence of the foreign activity was a reduction of short-term interest rates (the Makam), and a

[7] For a detailed description of the episode, see the "Bank of Israel monetary report for 1-6/2011": http://www.boi.org.il/deptdata/general/infrep/eng/inf-11-2e.pdf.

segmentation of the spot market from the forward market. This latter market friction was reflected by a gap between Makam and Telbor (similar to Libor) rates and the opening of a cross currency basis which is inconsistent with the covered interest rate parity (CIP). This parity apparently holds in the FX market where there are no arbitrage opportunities thus, deviations from the CIP can indicate a lack of liquidity, credit risk, or other frictions in the markets. Yet, Du, Tepper, and Verdelhan (2016) argue that since the sub-crime crisis such a non-zero basis, which reflects arbitrage opportunities, is found in many markets and is the result of both global imbalances between high yield and low yield countries and additional regulatory requirements on financial institutions. The cross-currency basis is defined in this paper as:

$$basis_t = \frac{F_t}{S_t} - \frac{i_t - i_t^*}{1 + i_t^*} \approx (f_t - s_t) - (i_t - i_t^*) = FP_t - IRD_t \qquad (1)$$

where, F_t and S_t are the nominal spot and the one year forward rates at time t, respectively, i_t and i_t^* are the local and the US short-term interest rates, respectively, s_t and f_t are logs of the spot and the one year forward rates, $FP_t = f_t - s_t$ is the forward premium and $IRD_t = i_t - i_t^*$ is the interest rate differential. If CIP holds, then $basis_t = 0$ for any t; however, this is not the case, especially during the Episode time, as Figure 4 shows.

[Enter Figure 4 here]

Figure 4 depicts the ILS/USD exchange rates, the one year forward rate, and the cross-currency basis which is based on both the 12-month Makam and

Telbor rates (both are symbolized as i in equation 1). The basis is negative with a peak (-2%) around the Episode time, then it converges to zero starting from 2012. Moreover, the massive demand for Makam by foreigners during the Episode is reflected in the gap between the bases; once with the Makam (the upper red line) and the other with the Telbor (the lower green line). The result of the massive demand for the Makam was, therefore, lower yields and a less negative basis (the upper red line) compared to the basis which is based on the Telbor (the lower green line). While Du, Tepper, and Verdelhan (2016) report on a non-zero basis since the sub-crime crisis, the Episode is a local phenomenon; it started in 2010 and ended with the (successful) authorities' steps in 2011.

The Episode as an event study is also reflected in the co-movement of the information share in the forward market for all sectors with the largest effect being for those customers on the demand side for foreign currency (Figures 1 and 2). For example, the information share of corporates in the spot market, which is led by the inter-dealer market over the sample period, crosses above 0.5 by some measures in the spot market and by all measures in the forward market during 2011 (Figure 2). This means that, around the Episode of 2011, most sectors' dealer-customer trades were contributing more to price discovery than the inter-dealer market's trades. In contrast, the high contribution to price discovery of most bank-customer sectors' trades in the forward market remained high until the end of the sample period.

The next natural step is to examine the co-movement of the various measures.

this is done in Table 8.

[Enter Table 8 here]

Table 8 presents the correlation matrices for the various IMSs. The ISMs are calculated based on all trades and using 220 trading days as the window size and a movement of 22 days between two consecutive windows (similar to Figures 1 and 2). Correlation coefficients among ISMs in the forward market are larger than the respective coefficients in the spot market and those among financial sectors (fin and for) are larger than non-financial sectors (corp, inst, and hous) in the spot market.[8] The moderate correlation coefficients among the various ISMs, especially among the spot market, suggest that they are presumably not true substitutes, since their setup and underlying assumptions are different.

5 Conclusion

In this paper, we examine the information shares of the inter-dealer and dealer-customer market tiers in the foreign exchange market. Using disaggregated dealer-customer data we find that the information share of the inter-dealer market is higher than that of the dealer-customer market, which includes non-financial sectors such as corporates, non-levered institutional

[8] Excluding the Episode sub-period from the data did not change the results, substaintially.

investors, and households and lower than that of financial sectors (e.g., financial companies). Additionally, local banks behave more like dealers in the spot market, rather than in the forward market. Our results are consistent with financial sectors' trades conveying private information to the dealers who further exploit that information in the inter-dealer market. Our findings point to the market and the customer type where private information is dissipated into prices. Examining price discovery across sectors over time uncovers a unique episode around 2011. During that sub-period, the information share derived from all sectors' trades changed as a result of massive foreign investor purchases of short-term instruments and as a result caused temporary frictions between the spot and the forward markets. That episode enables us to examine the sensitivity of the market tier and the customer type information shares to exogenous events.

Appendix A Methodology

1 Hasbrouck (1995) Information Share measure (H)

The first measure used in this paper is the Hasbrouck (1995) measure. The true, $\mathbf{s}_t^*$, which is a latent variable and the observed exchange rate, $\mathbf{s}_t$ are assumed to evolve as following:

$$\mathbf{s}_t = \boldsymbol{\iota}_2 s_t^* + \mathbf{e}_t, \tag{A1}$$

$$s_t^* = s_{t-1}^* + \omega_t, \tag{A2}$$

where $\mathbf{s}_t = (s_{1,t}, s_{2,t})'$ is a (2×1) vector of observed exchange rates in the two-tier market (hereafter, we refer to the inter-dealer market as market 1 and the dealer-customer market as market 2 or the spot market as 1 and the forward market as 2), s_t^* is the true unobservable exchange rate, $\boldsymbol{\iota}_2$ is a (2×1) vector of ones, $\mathbf{e}_t = (e_{1,t}, e_{2,t})'$ is a (2×1) vector of disturbance terms resulting in pricing errors, and ω_t is the innovation to the true exchange rate. Innovations in the true exchange rate, ω_t, are serially uncorrelated and independent from the vector of pricing error disturbances.

Eqn. (A1) implies that the exchange rates in the two-tier markets are co-integrated and that there is one co-integrating vector. The corresponding

vector error correction model (VECM) is:

$$\Delta \mathbf{s}_t = \boldsymbol{\alpha}\boldsymbol{\beta}'\mathbf{s}_{t-1} + \sum_{j=1}^{q-1} \boldsymbol{\Gamma}_j \Delta\left(\mathbf{s}_{t-j}\right) + \mathbf{u}_t, \tag{A3}$$

where $\boldsymbol{\alpha}$ is a (2×1) vector of error correction (adjustment) coefficients, $\boldsymbol{\beta} = (1, -1)'$ is the assumed co-integration vector, $\boldsymbol{\Gamma}_j$ is a (2×2) matrix of coefficients, and $\mathbf{u}_t$ is the (2×1) residual vector.

Note that the matrix $\boldsymbol{\alpha}\boldsymbol{\beta}'$ is decomposed in such a way that $\boldsymbol{\beta}'\mathbf{s}_{t-1}$ consists of the difference between observed exchange rate prices in inter-dealer trades and customer-dealer trades in our study. The innovation vector, $\mathbf{u}_t$, has a mean of 0 and variance-covariance matrix $\boldsymbol{\Sigma}_{\mathbf{u}} = \mathbf{E}\left(\mathbf{u}_t, \mathbf{u}_t'\right)$. Following Stock and Watson (1988), we transform eqn. (A3) into a vector moving average (VMA) as follows: $\Delta s_t = \Psi\left(L\right)\mathbf{u}_t$, or in levels:

$$\mathbf{s}_t = \mathbf{s}_0 + \Psi\left(1\right)\sum_{i=1}^{t} \mathbf{u}_i + \Psi^*\left(L\right)\mathbf{u}_t, \tag{A4}$$

where $\Psi\left(1\right) = \sum_{k=0}^{\infty} \Psi_k$, $\quad \Psi_k^* = -\sum_{j=k-1}^{\infty} \Psi_j$, and $\Psi^*\left(L\right)u_t \sim I\left(0\right)$. The matrix $\Psi\left(1\right)$ contains the cumulative impact of the innovations, $\mathbf{u}_t$, on all future exchange rates, and thus represents the long-run impact of new information coming to the markets. Co-integration of exchange rates in the two-tier markets implies that $\boldsymbol{\beta}'\Psi\left(1\right) = \mathbf{0}$ and $\Psi\left(1\right)\boldsymbol{\alpha} = \mathbf{0}$. As $\boldsymbol{\beta}' = (1, -1)$, the rows of $\Psi\left(1\right)$ are identical and the long-run impact of a current innovation on both series is identical (Lehmann, 2002).

Denote $\psi = (\psi_1, \psi_2)'$ to be the common row vector of $\Psi(1)$ so that $\psi' \mathbf{u}_t = \psi_1 u_{1,t} + \psi_2 u_{2,t}$ represents the long-run impact of both series. Hasbrouck (1995) proposes the following measure for the contribution of each market to price discovery by calculating the relative contribution of that market's volatility to the total volatility of the long-run impact or the permanent effect:

$$H_i = \frac{([\psi' \mathbf{F}]_i)^2}{\psi' \mathbf{\Sigma_u} \psi}, \qquad i \in \{1, 2\}, \tag{A5}$$

where $[\psi' \mathbf{F}]_i$ is the i'th element of the row matrix, $[\psi' \mathbf{F}]$, and $\mathbf{F}\mathbf{F}' = \mathbf{\Sigma_u}$, where $\mathbf{F}$ is a lower triangular matrix (the Cholesky decomposition) and by construction $H_1 + H_2 = 1$. As the resulting H depends on the ordering of the variables, one obtains, in the case of two markets, an upper bound and a lower bound for the information share. This may cause an indecisive result regarding the leading market if the lower (upper) bound of the information share of the first market is not higher (lower) than the respective upper (lower) bound of the second market.

In order to cope with such a problem, Lien and Shrestha (2009) suggest a unique modified information share (MIS) measure that is independent of the ordering in the variance-covariance matrix. They decompose the correlation of the innovation matrix, $\mathbf{\Sigma_u}$, by using an eigenvalue-eigenvector decomposition. Denote the diagonal matrix containing the eigenvalues of the correlation (rather than the covariance) matrix by $\mathbf{\Lambda}$ and denote $\mathbf{G}$ as

the matrix with columns containing the corresponding eigenvectors. Let $\mathbf{S}$ be the diagonal matrix with the innovation standard deviations on the diagonal: $\mathbf{S} = diag\left(\sqrt{\mathbf{\Sigma_u}_{,11}}, \sqrt{\mathbf{\Sigma_u}_{,22}}\right)$. Thus, the unique modified information share is:

$$MIS_i = \frac{\left(\psi_i^M\right)^2}{\psi' \mathbf{\Sigma_u} \psi}, \qquad i \in \{1, 2\}, \tag{A6}$$

where ψ_i^M is the i'th element of ψ^M, $\psi^M = \psi \widehat{\mathbf{F}}'$, $\widehat{\mathbf{F}} = \left[\mathbf{G}\mathbf{\Lambda}^{-1/2}\mathbf{G}'\mathbf{S}^{-1}\right]^{-1}$, and $\widehat{\mathbf{F}}\widehat{\mathbf{F}}' = \mathbf{\Sigma_u}$. In the main text, we present the mean of the upper and lower bounds of the Hasbrouck (1995) measure (see Baillie (2002)) and the MIS developed by Lien and Shrestha (2009). We refer to these two information share measures as H_{Mean} and H_{MIS}, respectively.

2 Lien and Shrestha (2014) Generalized Information Share (LS_{GIS})

A caveat of using the basic Hasbrouck information share measure is that the co-integration matrix $\boldsymbol{\beta}$ assumes that exchange rates in the two tiered foreign exchange market have a one-to-one co-integrating relationship. This assumption, however, may be unreasonable if the prices of the traded assets in the two markets are not equal in the long run, possibly due to segmented markets or different micro structures. To allow for this effect, we also estimate the generalized information share (GIS) measure of Lien and Shrestha (2014) where $\boldsymbol{\beta}$ is $\boldsymbol{\beta}^{(GIS)} = (1, -\theta)'$, such that $s_{i,t} - \theta_{i,j} s_{j,t}$ is stationary. The long-run

equilibrium relationship between s_i and s_j for $i \neq j$, $\theta_{i,j}$, is estimated as in Engle and Granger (1987) by the following ordinary least squares regression:

$$s_{i,t} = a_{i,j} + \theta_{i,j} s_{j,t} + \varepsilon_{i,j,t}. \tag{A7}$$

The estimated $\boldsymbol{\beta}^{(GIS)}$ matrix, $\widehat{\boldsymbol{\beta}}^{(GIS)}$, is then used in eqn. (A3) and eqns. (A4)-(A6) to get the LS_{GIS} measure.

3 Gonzalo and Granger (1995) Component Share (GG)

Gonzalo and Granger (1995) model market prices to follow a permanent-transitory (PT) process:

$$\mathbf{s}_t = \mathbf{A}_1 f_t + \mathbf{A}_2 z_t, \tag{A8}$$

where, $f_t \sim I(1)$ is a vector of permanent common factors and $z_t \sim I(0)$ is a transitory vector component. Under the assumption that z_t does not Granger cause f_t in the long-run, Gonzalo and Granger show that:

$$f_t = \gamma' \mathbf{s}_t, \qquad z_t = \boldsymbol{\beta}' \mathbf{s}_t, \tag{A9}$$

where $\gamma = (\boldsymbol{\alpha}'_\perp \boldsymbol{\beta}_\perp)^{-1} \boldsymbol{\alpha}'_\perp$ and $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are defined in eqn. (A3). $\perp$ denotes the vector orthogonal meaning that $\boldsymbol{\alpha}_\perp$ and $\boldsymbol{\beta}_\perp$ are (2×1) vectors such that $\boldsymbol{\alpha}'_\perp \boldsymbol{\alpha} = 0$ and $\boldsymbol{\beta}'_\perp \boldsymbol{\beta} = 0$. As $\boldsymbol{\beta} = (1, -1)'$, one choice for $\boldsymbol{\beta}_\perp$ is $\mathbf{1} = (1, 1)'$ so that $\gamma = (\boldsymbol{\alpha}'_\perp \mathbf{1})^{-1} \boldsymbol{\alpha}'_\perp$. Thus, the permanent exchange rate component,

f_t, is a weighted average of the exchange rates in the inter-dealer and the customer-dealer markets with the component share (GG) of the i'th market being:

$$\gamma_i = GG_i = \frac{\alpha_{\perp,i}}{\alpha_{\perp,1} + \alpha_{\perp,2}}, \qquad i \in \{1, 2\}. \tag{A10}$$

Note that $GG_1 + GG_2 = 1$ by construction.

4 Yan and Zivot (2010) and Putnins (2013) structural information share (PYZ)

Yan and Zivot (2010) show that H measures the response of one market to permanent shocks only under strict conditions. They re-interpret the H and GG measures in terms of the underlying structural innovations: permanent information-related innovations ($\boldsymbol{\eta}_t^P$) due to the arrival of news and transitory information-unrelated innovations ($\boldsymbol{\eta}_t^T$) due to trading frictions. They show that both measures adjust for the relative avoidance of transitory shocks, but that only H captures the relative informativeness of a given market. They suggest, therefore, the joint use of H and GG to distinguish $\boldsymbol{\eta}_t^P$ from $\boldsymbol{\eta}_t^T$ in order to obtain a sound interpretation regarding the question of which market is the leading market. In the context of this paper, Yan and Zivot propose a structural representation of the H and GG measures as follows (given that the inter-dealer market is market 1 and customer-dealer market

is market 2):

$$\infty \geq YZ = \left| \frac{H_1}{H_2} \frac{GG_2}{GG_1} \right| \geq 0. \tag{A11}$$

There are four possible outcomes:

1. If $H_1 > 0.5$ and $YZ > 1$, then the inter-dealer market leads,
2. If $H_1 < 0.5$ and $YZ < 1$, then the customer-dealer market leads,
3. If $H_1 > 0.5$ and $YZ < 1$ it is not clear that one market leads the other,
4. If $H_1 < 0.5$ and $YZ > 1$ it is not clear that one market leads the other.

Finally, Putniņš (2013) simulates different combinations of noise and the speed of impounding new information. Based on the simulation results, he argues that calculating H and GG can be misleading, since noise can distort the conclusion as to which market leads. Instead, he recommends using a metric based on YZ that takes into account both parameters and yields an information share measure between 0 and 1:

$$PYZ_i = \frac{ILS_i}{ILS_1 + ILS_2}, \qquad i \in \{1, 2\}, \tag{A12}$$

where $ILS_1 = YZ$ and $ILS_2 = \left| \frac{H_2}{H_1} \frac{GG_1}{GG_2} \right|$. Notice that by construction $PYZ_1 + PYZ_2 = 1$, while the YZ measure lacks such a characteristic. We refer to the Putnins' measure, which is based on YZ, as PYZ.

Appendix B The bootstrap technique for confidence interval calculations

We describe here the bootstrap technique that we use to calculate the 95% confidence intervals used in Tables 3-7. These techniques are helpful when the distribution of the estimated parameter is not known as is the case for the information share measures in this study. After obtaining the point estimates of the VECM in eqn. (A3), which is the basic equation for most information share measures, we simulate a new time series as follows. The first observation and the increment, s_0 and Δs_1, respectively are simulated first. Then, the following increments $\Delta s_t \, (t = 2, ..., T + 100)$ are calculated sequentially, according to eqn. (A3), where the error terms u_t are simulated from a bivariate normal distribution using the estimated VECM residual variance-covariance matrix, $\hat{\mathbf{\Sigma}}_{\mathbf{u}}$. The first 100 observations are removed (used as a burn-in period) in order to mitigate dependencies on the initial values. The VECM parameters are then estimated from the simulated series (for H and LS) as well as the parameters for the GG and PYZ measures. We simulate 500 samples in order to obtain an empirical distribution for the model estimated parameters. We use the 2.5% and 97.5% critical values from the empirical distribution as the 95% confidence interval. Thus, if an information share is statistically significant it means that 0.5 (the break even point for leading) is not included in the confidence interval. The series is either significantly above 0.5 (leads the other series) or significantly below

0.5 (led by the other series).

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Table 1: Spot Market Summary Statistics

sector	mean	median	max	min	sd	#days
Panel A: Total Trades						
bank	134.6	128.0	445.0	11.0	67.9	1,253
corp	87.8	87.0	378.0	6.0	47.5	1,278
fin	76.5	79.0	271.0	4.0	42.4	1,240
for	247.6	238.5	768.0	5.0	122.5	1,270
inst	22.3	20.0	101.0	4.0	13.0	947
hous	28.2	23.0	105.0	4.0	18.3	1,172
cust	452.0	464.0	1164.0	18.0	210.5	1,276
Panel B: Net Daily Order Flow						
bank	-0.6	0.0	67.0	-66.0	12.3	1,253
corp	22.8	20.0	176.0	-99.0	29.4	1,278
fin	-3.0	-2.0	80.0	-96.0	17.5	1,240
for	-7.6	-5.0	348.0	-250.0	55.4	1,270
inst	1.8	1.0	38.0	-31.0	7.7	947
hous	5.0	3.0	55.0	-29.0	10.2	1,172
cust	18.1	15.0	361.0	-288.0	64.6	1,276
Panel C: Bid-Ask Spreads (spreads)						
bank	0.2	0.0	52.2	-43.0	6.4	1,253
corp	14.2	10.9	778.8	-710.8	35.4	1,278
fin	-0.9	0.0	87.3	-136.8	11.8	1,240
for	0.4	0.0	53.7	-37.5	7.5	1,270
inst	0.0	0.0	700.3	-80.6	26.3	947
hous	57.6	57.4	191.0	-591.3	48.6	1,172
cust	14.3	14.7	172.0	-234.0	15.8	1,276

This table presents summary statistics for variables of interest in the spot market. Data is at the daily frequency. #days denotes the number of days that at least one trade occurred on. Order flow is the difference between the number of buy trades and the number of sell trades, and spreads are the ILS/USD exchange rate bid-ask spreads, $[(ask - bid)/[(ask + bid)/2]$, which are denominated in basis points (10,000 basis points = 1 USD). Since the data contain only actual trades, Ask and Bid prices are daily trade means of the various sectors against the local banks. Thus, negative spreads are possible. 'bank' denotes local banks (the inter-dealer market), 'corp' - corporates, 'fin' - financial companies, 'for' - foreign investors, 'inst' - institutional investors, 'hous' - households, and 'cust' - all customers. The sample period is January 1, 2009 to March 31, 2014.

Table 2: Forward Market Summary Statistics

sector	mean	median	max	min	sd	#days
Panel A: Total Trades						
bank	24.1	10.0	348.0	4.0	39.7	786
corp	96.1	81.0	600.0	4.0	67.2	1,239
fin	17.8	11.0	230.0	4.0	24.9	625
for	37.3	15.0	522.0	4.0	76.6	492
inst	24.7	20.5	135.0	4.0	17.9	544
hous	18.4	15.0	108.0	4.0	13.6	980
cust	149.8	122.0	1082.0	7.0	125.3	1,279
Panel B: Net Daily Order Flow						
bank	0.8	0.0	41.0	-24.0	5.9	786
corp	28.2	22.0	413.0	-450.0	70.5	1,239
fin	-1.2	-1.0	30.0	-202.0	10.6	625
for	-3.0	0.0	146.0	-260.0	22.7	492
inst	-3.1	-2.0	40.0	-69.0	14.4	544
hous	1.1	1.0	74.0	-48.0	10.4	980
cust	23.6	16.0	467.0	-454.0	76.9	1,279
Panel C: Bid-Ask Spreads (spreads)						
bank	1.0	0.0	120.6	-61.0	12.3	786
corp	2.0	5.7	95.3	-520.4	31.5	1,239
fin	7.5	5.3	246.4	-122.7	25.0	625
for	1.5	0.0	430.3	-111.6	28.3	492
inst	0.3	0.6	367.9	-178.2	34.8	544
hous	35.5	30.1	287.9	-692.3	47.3	980
cust	11.7	10.5	113.3	-166.8	20.4	1,275

This table presents summary statistics for variables of interest in the forward market. Data is at the daily frequency. #days denotes the number of days that at least one trade occurred on. Order flow is the difference between the number of buy trades and the number of sell trades, and spreads are the ILS/USD exchange rate bid-ask spreads, $[(ask - bid)/[(ask + bid)/2]$, which are denominated in basis points (10,000 basis points = 1 USD). Since the data contain only actual trades, Ask and Bid prices are daily trade means of the various sectors against the local banks. Thus, negative spreads are possible. 'bank' denotes local banks (the inter-dealer market), 'corp' - corporates, 'fin' - financial companies, 'for' - foreign investors, 'inst' - institutional investors, 'hous' - households, and 'cust' - all customers. The sample period is January 1, 2009 to March 31, 2014.

Table 3: Information Shares by Customer Type and Order Type: Spot market

Sector	H_{Mean}	H_{MIS}	LS_{GIS}	GG	PYZ
Panel A: Sell Orders					
corp	0.248†	0.271†	0.276†	0.060†	0.001†
fin	0.500	0.510	0.521	0.491	0.554
for	0.527†	0.647†	0.646†	0.838†	0.971†
inst	0.289†	0.234†	0.238†	0.049†	0.000†
hous	0.389†	0.381	0.363	0.151†	0.007†
cust	0.464	0.439	0.438	0.278	0.098
Panel B: Buy Orders					
corp	0.408	0.300	0.356	0.130†	0.000†
fin	0.467	0.399	0.409	0.084	0.014
for	0.454†	0.371†	0.376†	0.074†	0.007†
inst	0.438†	0.305†	0.316†	0.179†	0.022†
hous	0.308†	0.181†	0.243†	0.169†	0.003†
cust	0.435†	0.311†	0.356†	0.131†	0.000†
Panel C: Total Orders					
corp	0.400†	0.307†	0.343†	0.035†	0.001†
fin	0.486	0.453	0.467	0.229	0.129
for	0.496	0.483	0.487	0.364	0.271
inst	0.386†	0.266†	0.273†	0.145†	0.010†
hous	0.390†	0.257†	0.291†	0.148†	0.005†
cust	0.462	0.360	0.392	0.095	0.000

This table presents the information share results between the inter-dealer market tier and the dealer-customer market tier within the FX spot market, partitioned by customer type. An information share less than 0.5 indicates that the inter-dealer market is the leading market tier. H_{Mean} refers to the mean of the Hasbrouck (H) upper and lower bounds, H_{MIS} refers to the modified information share measure of Lien and Shrestha, LS_{GIS} refers to the general information measure (GIS) of Lien and Shrestha, GG refers to the Gonzalo and Granger measure, and PYZ refers to the Putniņš, and Yan and Zivot measure. Total orders is the mean of buy and sell trades. For the sectors' representation, see Table 1. † denotes statistical significance at the 5% level of the confidence interval, using the bootstrap techniques presented in Appendix B. The sample period is January 1, 2009 to March 31, 2014.

Table 4: Information Shares by Customer Type and Order Type: Forward market

Sector	H_{Mean}	H_{MIS}	LS_{GIS}	GG	PYZ
Panel A: Sell Orders					
corp	0.421†	0.401	0.407	0.262†	0.068†
fin	0.564	0.692	0.668	0.929	1.000
for	0.484	0.454	0.454	0.321	0.161
inst	0.490	0.476	0.479	0.408	0.320
hous	0.478	0.496	0.474	0.379	0.173
cust	0.543	0.610	0.605	0.756	0.921
Panel B: Buy Orders					
corp	0.574†	0.679†	0.697†	0.980†	1.000†
fin	0.582†	0.712†	0.708†	0.938†	0.998†
for	0.402†	0.266†	0.269†	0.110†	0.006†
inst	0.514	0.564	0.569	0.675	0.852
hous	0.509	0.532	0.568	0.521	0.685
cust	0.580†	0.694†	0.707†	0.990†	1.000†
Panel C: Total Orders					
corp	0.545	0.607	0.621	0.748	0.949
fin	0.576†	0.730†	0.715†	0.843†	0.988†
for	0.452†	0.331†	0.334†	0.102†	0.007†
inst	0.515	0.569	0.573	0.745	0.919
hous	0.509	0.527	0.538	0.547	0.655
cust	0.562†	0.653†	0.659†	0.927†	0.998†

This table presents information share results between the inter-dealer market tier and the dealer-customer market tier within the FX forward market, partitioned by customer type. An information share less than 0.5 indicates that the inter-dealer market is the leading market. H_{Mean} refers to the mean of the Hasbrouck (H) upper and lower bounds, H_{MIS} refers to the modified information share measure of Lien and Shrestha, LS_{GIS} refers to the general information measure (GIS) of Lien and Shrestha, GG refers to the Gonzalo and Granger measure, and PYZ refers to the Putniņš, and Yan and Zivot measure. Total orders is the mean of buy and sell trades. For the sectors' representation, see Table 1. † denotes statistical significance at the 5% level of the confidence interval, using the bootstrap techniques presented in Appendix B. The sample period is January 1, 2009 to March 31, 2014.

Table 5: Information Shares by Customer Type and Order Type: Forward versus spot trades

Sector	H_{Mean}	H_{MIS}	LS_{GIS}	GG	PYZ
Panel A: Sell Orders					
bank	0.454	0.412	0.436	0.222	0.092
corp	0.588†	0.588	0.594	0.646†	0.878†
fin	0.531†	0.649†	0.648†	0.911†	0.993†
for	0.486	0.477	0.502	0.370	0.355
inst	0.582†	0.651	0.664	0.803†	0.978†
hous	0.458	0.448	0.460	0.374	0.231
cust	0.512	0.544	0.557	0.553	0.683
Panel B: Buy Orders					
bank	0.381†	0.248†	0.274†	0.116†	0.002†
corp	0.551†	0.624†	0.619†	0.918†	0.992†
fin	0.510	0.556	0.576	0.619	0.844
for	0.409†	0.320†	0.338†	0.030†	0.003†
inst	0.470	0.402	0.448	0.123	0.110
hous	0.562	0.63†	0.621†	0.678	0.863
cust	0.520	0.583	0.596	0.758	0.952
Panel C: Total Orders					
bank	0.420†	0.329†	0.355†	0.001†	0.002†
corp	0.556†	0.606†	0.609†	0.699†	0.899†
fin	0.528†	0.633†	0.644†	0.985†	0.997†
for	0.449	0.369	0.396	0.054	0.015
inst	0.512	0.549	0.585	0.636	0.916
hous	0.496	0.508	0.507	0.47	0.429
cust	0.521	0.579	0.595	0.709	0.923

This table presents information share results between the FX spot market and the FX forward market, partitioned by trader type. An information share greater (smaller) than 0.5 indicates that the FX spot (forward) market is the leading market. H_{Mean} refers to the mean of the Hasbrouck (H) upper and lower bounds, H_{MIS} refers to the modified information share measure of Lien and Shrestha, LS_{GIS} refers to the general information measure (GIS) of Lien and Shrestha, GG refers to the Gonzalo and Granger measure, and PYZ refers to the Putniņš, and Yan and Zivot measure. Total orders is the mean of buy and sell trades. For the sectors' representation, see Table 1. † denotes statistical significance at the 5% level of the confidence interval, using the bootstrap techniques presented in Appendix B. The sample period is January 1, 2009 to March 31, 2014.

Table 6: Information Shares by Customer Type and Order Type: Spot Vs. short/long term forward trades

Term	H_{Mean}	H_{MIS}	LS_{GIS}	GG	PYZ
Panel A: Banks					
short	0.500	0.510	0.542	0.501	0.716
long	0.428†	0.289†	0.330†	0.186†	0.010†
Panel B: Corporates					
short	0.533	0.859	0.900	0.552	0.652
long	0.550	0.607†	0.610†	0.692	0.888
Panel C: Financials					
short	0.504	0.733	0.675	0.520	0.564
long	0.527	0.630	0.642	1.000	0.998
Panel D: Foreigners					
short	0.486	0.373	0.434	0.331	0.055
long	0.455	0.381	0.413	0.097	0.036
Panel E: Institutions					
short	0.527	0.695	0.815	0.667	0.730
long	0.518	0.564	0.601	0.733	0.981
Panel F: Households					
short	0.504	0.544	0.550	0.851	0.990
long	0.500	0.519	0.518	0.489	0.476
Panel G: All Customers					
short	0.516	0.760	0.943	0.557	0.583
long	0.520	0.578	0.594	0.704	0.917

This table presents information share results between the FX spot market and the FX forward market, partitioned by trader type and forward term. An information share greater (smaller) than 0.5 indicates that the FX spot (forward) market is the leading market. H_{Mean} refers to the mean of the Hasbrouck (H) upper and lower bounds, H_{MIS} refers to the modified information share measure of Lien and Shrestha, LS_{GIS} refers to the general information measure (GIS) of Lien and Shrestha, GG refers to the Gonzalo and Granger measure, and PYZ refers to the Putniņš, and Yan and Zivot measure. For the sectors' representation, see Table 1. Short (long) refer to forward trades whose time to expiration is less than a year (220 business days). Spot trades are not shown in the table as their value is equal to 1-ISM. † denotes statistical significance at the 5% level of the confidence interval, using the bootstrap techniques presented in Appendix B. The sample period is January 1, 2009 to March 31, 2014.

Table 7: Spot Vs. Forward Information Shares: buy (Ask) Vs. sell (Bid) prices

Sector	Action	H_{Mean}	H_{MIS}	LS_{GIS}	GG	PYZ
Panel A: Spot market's sell Vs. buy trades						
bank	sel	0.463†	0.364†	0.366†	0.009†	0.000†
corp	sel	0.276†	0.268†	0.259†	0.090†	0.001†
fin	sel	0.512	0.562	0.564	0.781	0.941
for	sel	0.534†	0.614†	0.609†	0.933†	0.993†
inst	sel	0.323†	0.238†	0.240†	0.078†	0.002†
hous	sel	0.574	0.629	0.568	0.599	0.687
cust	sel	0.486	0.480	0.448	0.391	0.142
Panel B: Forward market's sell Vs. buy trades						
bank	sel	0.522	0.581	0.580	0.777	0.933
corp	sel	0.344†	0.292†	0.287†	0.025†	0.000†
fin	sel	0.533	0.599	0.582	0.841	0.947
for	sel	0.582†	0.731†	0.727†	0.856†	0.987†
inst	sel	0.481	0.466	0.464	0.371	0.224
hous	sel	0.484	0.500	0.456	0.448	0.256
cust	sel	0.478	0.457	0.436	0.316	0.088

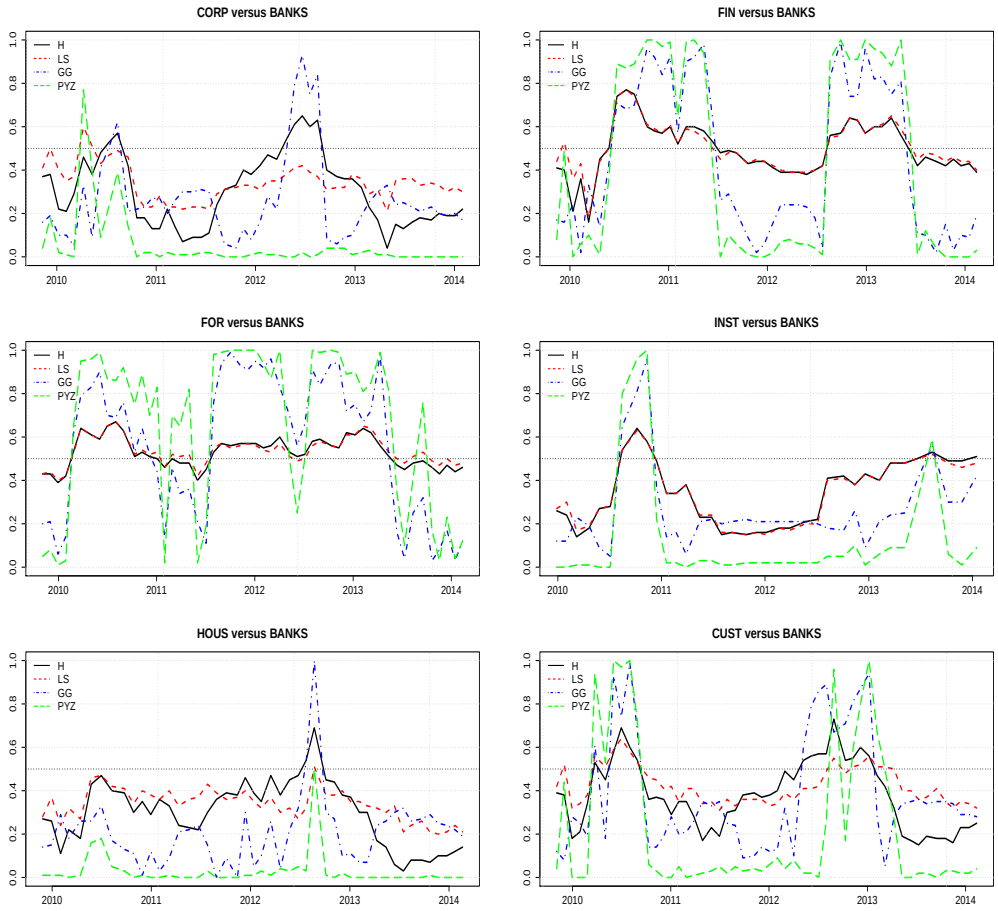
This table presents information share results between the FX spot and forward markets and buy and sell orders, partitioned by trader type. An information share greater (smaller) than 0.5 indicates that sell (buy) orders by a particular trader type have a greater information share. H_{Mean} refers to the mean of the Hasbrouck (H) upper and lower bounds, H_{MIS} refers to the modified information share measure of Lien and Shrestha, LS_{GIS} refers to the general information measure (GIS) of Lien and Shrestha, GG refers to the Gonzalo and Granger measure, and PYZ refers to the Putniņš, and Yan and Zivot measure. For the sectors' representation, see Table 1. The figures in the table are for buy trades (refer to Ask prices) and are from the viewpoint of the dealers (Ask > Bid). † denotes statistical significance at the 5% level of the confidence interval, using the bootstrap techniques presented in Appendix B. The sample period is January 1, 2009 to March 31, 2014.

Table 8: Coefficient correlations among ISMs in the spot and forward markets

	Spot				Forward			
ISM	*H*	*LS*	*GG*	*PYZ*	*H*	*LS*	*GG*	*PYZ*
Panel A: Corporates (corp)								
H	1.00	0.68	0.53	0.32	1.00	0.98	0.98	0.89
LS	0.68	1.00	0.24	0.70	0.98	1.00	0.97	0.95
GG	0.53	0.24	1.00	0.11	0.98	0.97	1.00	0.93
PYZ	0.32	0.70	0.11	1.00	0.89	0.95	0.93	1.00
Panel B: Financial companies (fin)								
H	1.00	0.97	0.74	0.80	1.00	0.98	0.77	0.82
LS	0.97	1.00	0.72	0.82	0.98	1.00	0.84	0.87
GG	0.74	0.72	1.00	0.96	0.77	0.84	1.00	0.97
PYZ	0.80	0.82	0.96	1.00	0.82	0.87	0.97	1.00
Panel C: Foreigners (for)								
H	1.00	0.97	0.82	0.83	1.00	1.00	0.95	0.89
LS	0.97	1.00	0.73	0.82	1.00	1.00	0.95	0.88
GG	0.82	0.73	1.00	0.90	0.95	0.95	1.00	0.96
PYZ	0.83	0.82	0.90	1.00	0.89	0.88	0.96	1.00
Panel D: Institutional investors (inst)								
H	1.00	1.00	0.64	0.66	1.00	1.00	0.94	0.93
LS	1.00	1.00	0.64	0.67	1.00	1.00	0.93	0.92
GG	0.64	0.64	1.00	0.95	0.94	0.93	1.00	0.98
PYZ	0.66	0.67	0.95	1.00	0.93	0.92	0.98	1.00
Panel E: Households (hous)								
H	1.00	0.75	0.20	0.53	1.00	0.99	0.98	0.97
LS	0.75	1.00	0.08	0.50	0.99	1.00	0.97	0.97
GG	0.20	0.08	1.00	0.73	0.98	0.97	1.00	0.97
PYZ	0.53	0.50	0.73	1.00	0.97	0.97	0.97	1.00
Panel F: All customers (cust)								
H	1.00	0.76	0.62	0.71	1.00	1.00	0.96	0.91
LS	0.76	1.00	0.59	0.88	1.00	1.00	0.94	0.90
GG	0.62	0.59	1.00	0.62	0.96	0.94	1.00	0.96
PYZ	0.71	0.88	0.62	1.00	0.91	0.90	0.96	1.00

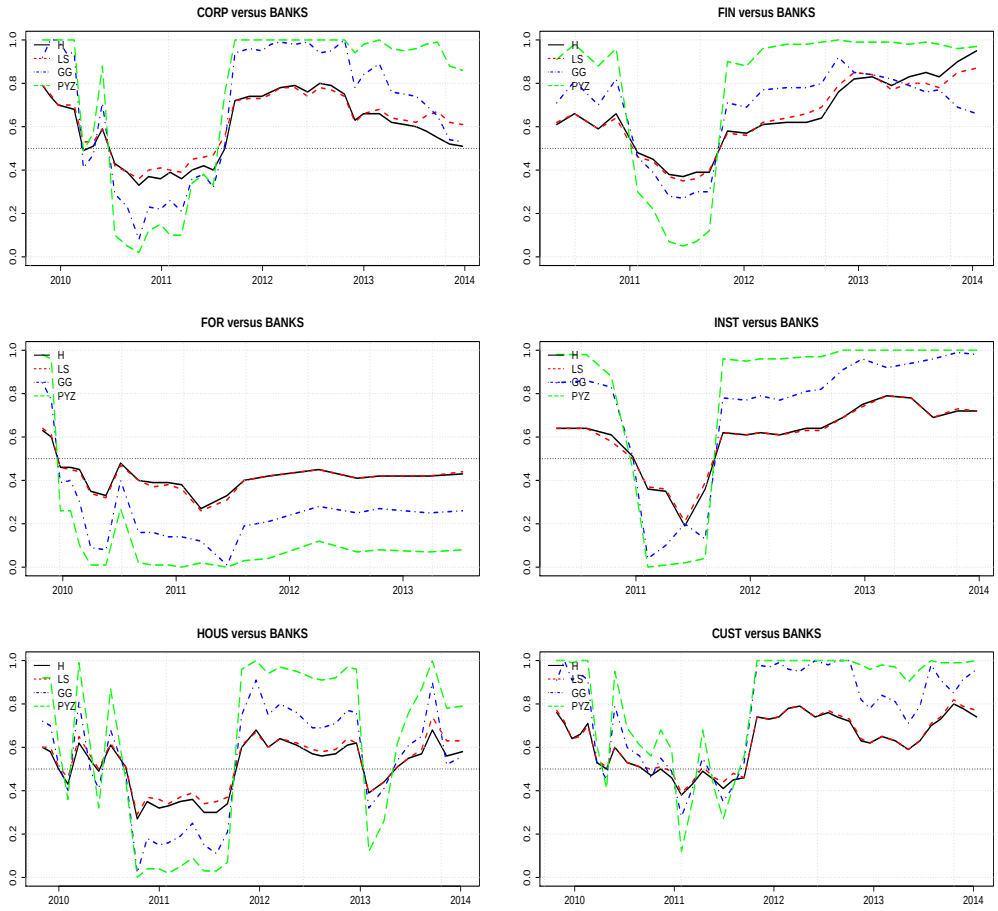
This table presents correlation coefficients among the four information share measures. H_{Mean} refers to the mean of the Hasbrouck upper and lower bounds (H), LS_{GIS} refers to the general information share measure (GIS) of Lien and Shrestha, GG refers to the Gonzalo and Granger measure, and PYZ refers to the Putniņš, and Yan and Zivot measure. The information share measures (ISMs) are the same as in Figures 1 and 2; they are calculated based on all trades using 220 trading days as the window size and a movement of 22 days between two consecutive windows. Generally, the correlation coefficients among ISMs in the forward market are larger than the respective coefficients in the spot market, and those among financial sectors (fin and for) are larger than non-financial sectors (corp, inst, and hous) in the spot market. The sample period is January 1, 2009 to March 31, 2014.

Figure 1: Information Shares of dealer-customer trades: spot market



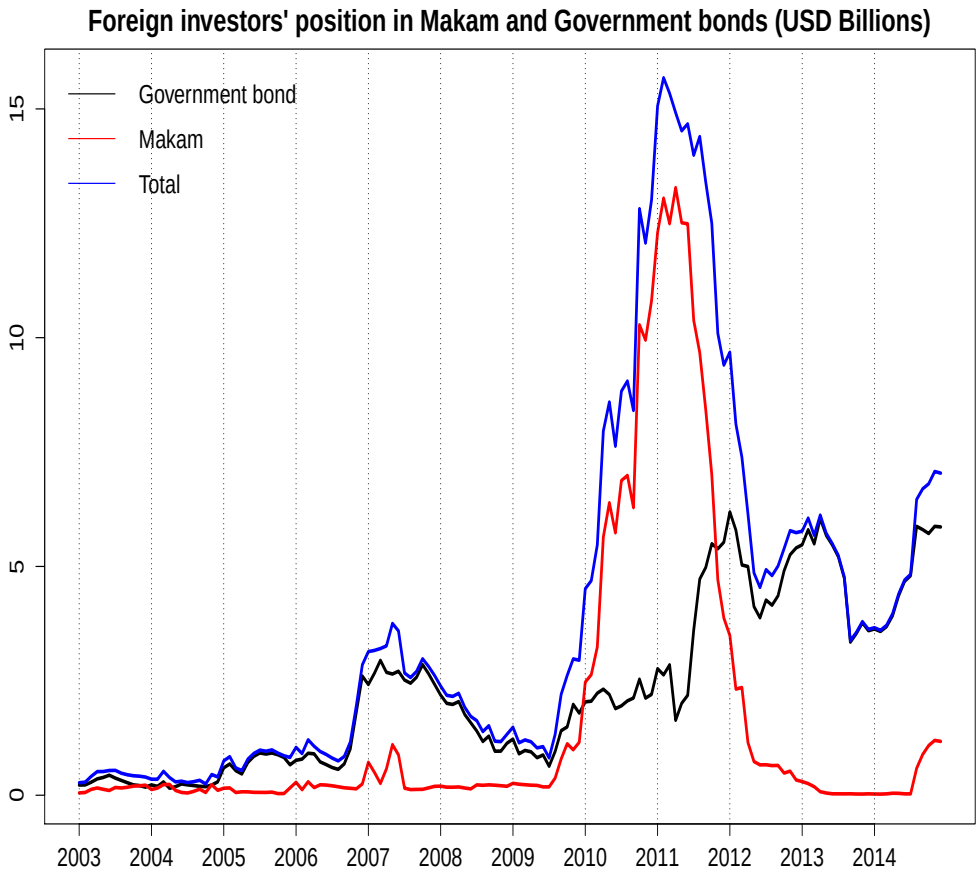
H_{Mean} refers to the mean of the Hasbrouck (H) upper and lower bounds, LS_{GIS} refers to the general information measure (GIS) of Lien and Shrestha, GG refers to the Gonzalo and Granger measure, and PYZ refers to the Putniņš, and Yan and Zivot measure. The sectors are represented by: corp (corporates), fin (financial companies), for (foreign investors), inst (institutional investors), hous (households), and cust (all bank customers). 'banks' refers to inter-dealer trades. Figures below the dashed line (at 0.5) mean that the information share of the inter-dealer market is higher than that of dealer-customer trades for a particular sector.

Figure 2: Information Shares of dealer-customer trades: Forward market



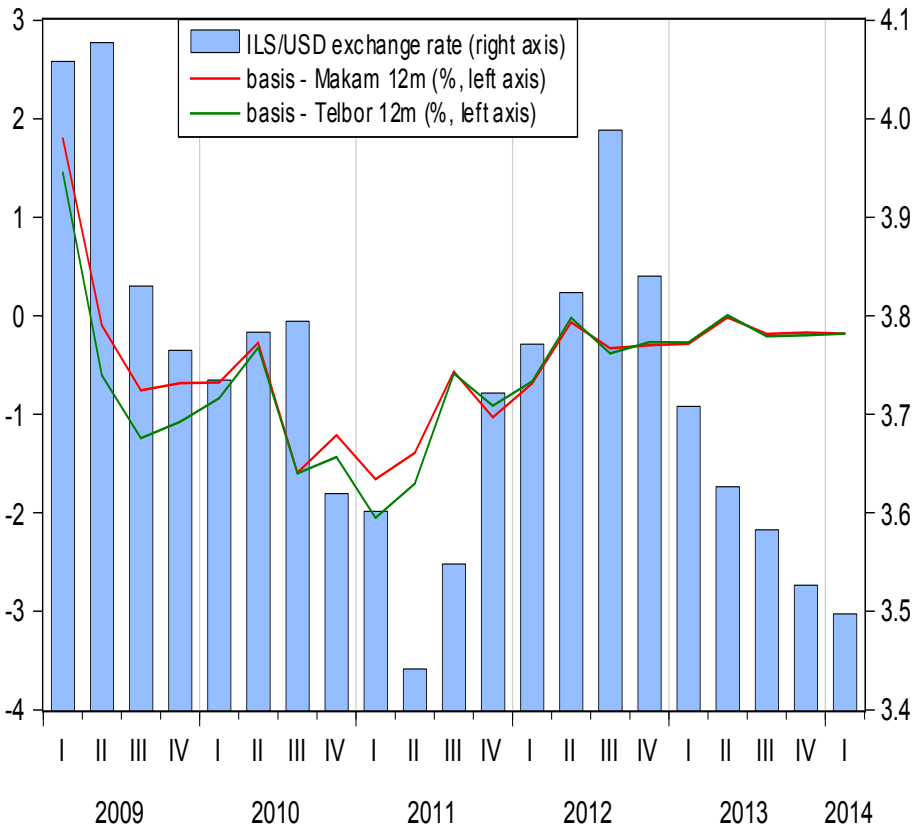
H_{Mean} refers to the mean of the Hasbrouck (H) upper and lower bounds, H_{MIS} refers to the modified information share measure of Lien and Shrestha, LS_{GIS} refers to the general information measure (GIS) of Lien and Shrestha, GG refers to the Gonzalo and Granger measure, and PYZ refers to the Putniņš, and Yan and Zivot measure. The sectors are represented by: corp (corporates), fin (financial companies), for (foreign investors), inst (institutional investors), hous (households), and cust (all bank customers). 'banks' refers to inter-dealer trades. Figures below the dashed line (at 0.5) mean that the information share of the inter-dealer market is higher than that of dealer-customer trades for a particular sector.

Figure 3: Foreign investors' positions in Makams and Government Bonds



This figure plots the development of the foreign investors' net position in the government bond (black line), the Makam (red line), and a sum of the two (blue line). The Makam is a short-term government bill (similar to the U.S. Treasury bill).

Figure 4: Cross-currency basis and the ILS/USD exchange rate



The figure shows the cross-currency basis once with the 12 month Makam rates (red line) and once with the 12 month Telbor rates (green line) and the ILS/USD exchange rate (blue bars). The Makam is a short-term government bill (similar to the U.S. Treasury bill) while the Telbor is a short term security with its value (and the respective interest rate) being determined in the FX market. Positive or negative basis (see eqn. (1)) points to a deviation from the covered interest rate parity (CIP) and an arbitrage opportunity.