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Abstract

Though unambiguously outperforming all other financial markets in terms of liquidity, foreign exchange trading is still performed in opaque and decentralized markets. In particular, the two-tier market structure consisting of a customer segment and an interdealer segment to which only market makers have access gives rise to the possibility of price discrimination. We provide a theoretical foreign exchange pricing model that accounts for market power considerations and analyze a database of the trades of a German market maker and his cross section of end-user customers. We find that the market maker generally exerts low bargaining power vis-á-vis his customers. The dealer earns lower average spreads on trades with financial customers than commercial customers, even though the former are perceived to convey exchange-rate-relevant information. From this perspective, it appears that market makers provide interdealer market liquidity to end-user customers with cross-sectionally differing spreads.

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1 Introduction

The market microstructure literature generally suggests that market making is performed under informational asymmetry, implying that spreads include an adverse-selection component that compensates dealers for losses to privately informed counterparties (Glosten and Milgrom, 1985; Kyle, 1985). Based on this literature, it is now commonly accepted that adverse selection costs are the primary channel through which asymmetric information affects spreads. The adverse selection component of spreads would be expected to rise with the likelihood that a given counterparty has private information. In an anonymous trading framework, this spread component is supposed to vary positively with order size, since larger trades should be associated with higher adverse selection costs (Easley and O'Hara, 1987; Glosten, 1989). In real-world currency markets, however, dealing is not completely anonymous, as dealers maintain business relationships with major customers (Sager and Taylor, 2006). Within the broad group of customers, importers and exporters ('commercial customers') are considered less informed than other banks and hedge funds (jointly 'financial customers'). This is due to the fact that financial customers are using professional information systems and communicate intensively with a variety of market makers, while commercial customers are, in contrast, just responding to changes in relative prices in order to maximize profits from their real-side businesses. Commercial customers need to buy or sell foreign currency only occasionally and do not engage in substantial foreign exchange research. Thus, the standard models for understanding spreads under information asymmetry indicate that, other things being equal, currency spreads should be widest on financial customers' large trades and narrowest on commercial customers' small trades. Using various empirical models of FX trading such as Madhavan and Smidt (1991) and Huang and Stoll (1997), Osler et al. (2006) and Reitz et al. (2007) find, in contrast, that spreads of large deals are lower than spreads of small deals and that financial customers obtain narrower margins than commercial customers.

A possible explanation for this seemingly contradictory observation is based on the idea that commercial customers - in contrast to financial customers - generally stick to their dealer and do not spend resources on searching for the best available price, allowing the market maker to quote wider spreads. Of course, in a search-and-friction model of over-the-counter markets Duffie et al. (2005, 2007) show that bid-ask spreads are lower if investors can more easily find other investors, or have easier access to multiple market makers.[1] Thus, a lack of customers' information regarding current market conditions allows a dealer to exert market power. In a cross-section of customers, a relatively weak bargaining position vis-á-vis financial customers may be compensated by trades with commercial customers.

A low level of transparency as a prerequisite of price discrimination is prevalent in a number of markets, where trades are not transacted via a central marketplace, but occur in a decentralised 'over the counter' (OTC) fashion. OTC-markets are relatively opaque, at least with respect to a customer's knowledge about current quotes of every single dealer in the market. Hence, the bulk of market power studies investigate mainly OTC-markets. For example, Chakravarty and Sarkar (1999) study, among others, government bond markets, and Hong and Warga (2000) and Schultz (2001) investigate corporate bond trading. However, none of these studies explicitly focuses on market power considerations. Rather, they analyse bid-ask spreads with respect to specific features of the trade such as order size, which, in turn, can be indirectly related to market power. Based on theoretical considerations presented in Duffie et al. (2007), Green et al (2007), in contrast, explicitly investigate market power on the U.S. municipal bond market applying a stochastic frontier model. Dealer intermediation in this market resulted in a large retail price dispersion and unfavorable spreads for small investors. Dunne et al. (2008) investigate the European sovereign bond market consisting of an (electronic) competitive interdealer market and an (electronic) monopolistic customer market and find that dealer inventory management and market volatility are important for explaining spreads quoted to customers in the European bond market. Despite this work, however, the number of studies in the field is generally low, and to our knowledge there is currently no contribution dealing empirically

[1] The market-power hypothesis complements, and is consistent with the strategic-dealing hypothesis, where currency dealers strategically subsidize trades with privately informed customers in order to learn the direction and magnitude of those customers' trades (Osler et al., 2006).

with market power considerations in the foreign exchange market.

In this paper we model the market maker's transactions in the end-user segment of the foreign exchange market as an alternation offer game. The resulting transaction price appears to be a weighted average of the customer market price, which turns out to be a public information price corrected for adverse selection cost, inventory holding costs and trade execution costs, and the interdealer market price. The weights are given by the relative bargaining power of the counterparties. We test our model using a data base from a German bank's tick-by-tick end-user order flow and respective quotes and find that financial customers exert massive market power vis-á-vis the market maker, while market power of commercial customers is somewhat lower, but still strong. The results suggest that market power considerations may account for earlier findings contrasting with the adverse selection hypothesis. The remainder of the paper is organised as follows. In Section 2, we develop our microstructural model of the market maker's trading in a segmented foreign exchange market. In Section 3 we estimate the model and discuss the empirical results. A final section concludes.

2 Modelling the Foreign Exchange Market

2.1 Market structure

The foreign exchange market is decentralised in the sense that market participants are generally separated from one another and transactions take place through media such as telephone or computer networks. This is in contrast to major stock markets like the New York Stock Exchange where traders physically interact with one another. Two important implications of decentralisation are fragmentation and low transparency. The foreign exchange market is fragmented in the sense that transactions may (and do) occur simultaneously or near simultaneously in the market at different prices (Sarno and Taylor, 2001). It lacks transparency in the sense that the absence of a physical market place makes the process of price-information interaction difficult to observe and understand (Dominguez, 1999; Lyons, 2002). Within this market environment, two types of participants can generally be distinguished: dealers and customers. While customers' trading behaviour is derived mainly from their core businesses, financial or commercial, foreign exchange dealers (or market makers) can be thought of as exchange-designated specialists who stand ready to buy or sell foreign currency to other market participants. Among these market makers there has evolved a market segment with a considerable market share, the interdealer market. Though the daily market turnover of this interdealer market has declined somewhat in the recent years it still accounts for more than 40 percent of total foreign exchange market turnover (Bank of International Settlements, 2007).

Trading among market makers mostly occurs via electronic brokers like the Electronic Broking System (EBS) or Reuters D3000. Both systems were established in 1993 and were the primary facilitators of the subsequent marked increase in market liquidity. Their functionality is essentially equivalent, providing ex ante anonymous limit-order bid-ask pricing to dealers. The electronic brokers announce bid and ask prices in addition to the best bid and ask prices and their respective quantities. Prices and directions for all trades are communicated to the rest of the market (Bjønnes and Rime, 2005). As a result, market transparency is dramatically higher in brokered interdealer trading than in regular customer trading or even in direct (bilateral) interdealer trading. Due to the different degree of market transparency it is now commonly accepted that the pricing in the interdealer segment differs from that in the broader customer market with the implication that any theoretical and empirical work has to consider the two-tier structure of the foreign exchange market (Evans and Lyons, 2005; Osler et al., 2006).

2.2 Customer trading

In the broader customer trading segment, trading is assumed to be performed in the following way: A market participant is approached by another and asked for quotes at which he is willing to buy or sell foreign exchange. Of course, in actual foreign exchange markets the first participant will be an exchange trading bank and the second typically an end-user customer. For the moment, however, it will be useful to consider a situation where every customer market participant may contact another for trading but none will have access to the interdealer market. This implies that their trading may suffer from adverse selection, inventory holding costs and a broad range of execution costs. We follow - and subsequently extend - the analysis of Madhavan and Smidt (1991).

We consider a customer who wants to trade foreign currency and approaches another customer and asks for a two-way price. For concreteness, assume that first customer is trying to sell an open position to the second customer. The full-information price of foreign currency denoted by υ_t follows a random walk. Its current value is revealed immediately after trading when its increment is announced as a part of the flow of public information signals.[2] The fact that the full-information price is currently unobservable gives rise to adverse selection costs as the seller may possess private information. When additionally considering inventory control costs and execution costs, the price the buyer quotes to the approaching seller is

$$p_t^c = \mu_t - \gamma(I_t - I_t^*) + \psi D_t, \tag{1}$$

where p_t^c denotes buyer's quoted price, μ_t is the buyer's expectation about the true value of the exchange rate conditional upon his information at time t, $(I_t - I^*)$ is the deviation of current inventory from desired inventory, D_t is an indicator variable, where $D_t = -1$ represents the considered buy transaction and ψ measures execution costs.

The seller's pre-trade expectation of the foreign currency value m_t is a weighted average of the public information price y_t and a private signal w_t,

$$m_t = \theta w_t + (1 - \theta) y_t, \tag{2}$$

where the coefficient θ depends on the precision of the information sources. His order flow q_t results from the perceived mis-pricing of the buyer and an idiosyncratic liquidity shock x_t:

$$q_t = \alpha(m_t - p_t^c) + x_t, \tag{3}$$

where α is a positive constant. Following Glosten and Milgrom (1985), the buyer considers the fact that the order flow depends on a private signal. In order to quote prices

[2]For details of the exact trading protocol see Madhavan and Smidt (1991).

that are regret-free after the trade has occurred, the buyer has to infer the seller's private signal conveyed by the order flow. Bayesian updating gives a posterior mean μ_t of the true value of the exchange rate:

$$\mu_t = \pi y_t + (1-\pi)(p_t^c + \frac{1}{\alpha}q_t), \tag{4}$$

consisting of a weighted average of the public signal and the inferred private signal from the order flow. The parameter $\pi\epsilon(0,1)$ is the weight placed on prior beliefs and depends on the relative precisions of signals. Substituting equation (4) into equation (1) yields the price the buyer quotes to the seller

$$p_t^c = \pi y_t + (1-\pi)(p_t^c + \frac{1}{\alpha}q_t) - \gamma(I_t - I_t^*) + \psi D_t, \tag{5}$$

which can be regarded as a public information price corrected for adverse selection costs, inventory holding costs, and trade execution costs. Intense competition among foreign exchange customers will prevent prices from deviating too far from the derived price. Otherwise, we should (permanently) observe quoted prices below trading costs on the part of the quoting agent or systematically inferior prices on the part of the approaching agent cutting into his profits of real-side businesses. We refer to equation (5) as the customer market price of foreign currency.

2.3 Interdealer market

The interdealer market consists of only a subset of market participants called market makers who trade heavily via the market's electronic platforms. As briefly outlined in the sub-section 2.1, the interdealer market is characterized by substantially higher transparency than the customer market. Due to the trading protocol, the pricing in a brokered market depends heavily on information that is available to every market maker.[3] Thus, the exchange rate reflects market makers' individual information only when others assimilate that information, implying very low (if any) adverse selection costs.[4] Allowing for the

[3] Of course, this does not mean that dealers hold identical information sets. For more details see Evans and Lyons (2005).

[4] Bjønnes et al. (2008) provide empirical evidence from electronic interdealer trading revealing information asymmetries between small and large banks. However, reported interdealer spreads ranging between 2

fact that market orders are generally executed within a very short time period (Bjønnes and Rime; 2005; Sager and Taylor, 2006), we do not expect significant inventory holding costs since dealers are able immediately to unload any unwanted positions. Finally, given that fixed costs of introducing access to the interdealer market are realized, trade execution costs tend to be small. Taken together, it seems to be reasonable to assume that the price paid by a market maker deviates from the interdealer market price only by (small) transaction costs ϕ:

$$p_t^{mm} = p_t^{id} + \phi D_t, \tag{6}$$

where p_t^{id} denotes the interdealer market price and p_t^{mm} is the net price the market maker would receive or have to pay for an interdealer transaction.

2.4 Price discrimination and market makers

The fact that market makers have access to both the customer and the interdealer market together with customer market prices differing from the interdealer market prices, according to equations (5) and (6), gives rise to the possibility of price discrimination. The extent to which the market maker is able to exploit price differences and collect monopoly rents depends on the degree of his market power. Of course, the market power of dealers on quote-driven markets is heavily based on the knowledge of customers about current market conditions. In a search-and-friction model of over-the-counter markets, Duffie et al. (2005, 2007) show that bid-ask spreads are lower if investors can more easily find other investors or have easier access to multiple market makers. Regarding the different types of end-user customer in the foreign exchange market, it is widely accepted that commercial customers typically know far less about market conditions than financial customers. The trading of market makers with customers is a low risk business as the former may pass any order flow from the latter immediately onto the interdealer market. To this end market makers provide access to the interdealer market at cross-sectionally varying rents. We

and 3 pips (Bjønnes and Rime, 2005) are small compared to customer market spreads and declined further in the 2000s as competition in the market became fierce (Gallardo and Heath, 2009). This is consistent with the Evans and Lyons '(2005) results.

provide a more detailed description of this argument below.

For the sake of concreteness we continue to consider a selling customer asking for quotes.[5] As customers may choose among different counterparts, his lowest acceptable quote in this competitive but opaque segment is the customer market price derived in equation (5). Thus, we may define equation (5) as the reservation price of the customer. The market makers reservation price (and the decision to trade) will depend on his expectations about the price he will obtain on re-selling and the costs he anticipates in intermediating the trade. Within this framework the best price a selling customer can get from the market maker is the interdealer market price p_t^{id} less transaction costs. As a result, we interpret equation (6) as the reservation price of the market maker. Let p_t be the price the market maker offers to the seller. The market maker is risk-neutral with indirect utility function $p_t^{mm} - p_t$, i.e. the expected profit from selling foreign currency. The selling customer is also risk-neutral with indirect utility function $p_t - p_t^c$, i.e. the price he receives from the market maker less the reservation price.

The seller and market maker engage in an alternating offer game with possibility of breakdown, the solution of which can be described by the general Nash solution. Let ρ be the bargaining power of the market maker relative to that of the customer, where $\rho \in [0,1]$. If $\rho = 0$, the seller has all the bargaining power and the buyer none, vice versa if $\rho = 1$. The equilibrium transaction price p_t maximizes the generalized Nash product

$$\max_{p_t} (p_t^{mm} - p_t)^{\rho} (p_t - p_t^c)^{1-\rho}, \tag{7}$$

subject to the participation constraints

$$p_t^{mm} - p_t \geq 0 \tag{8}$$

$$p_t - p_t^c \geq 0. \tag{9}$$

The participation constraints can only be satisfied if there are positive gains from trade:

[5] The modelling strategy follows Green et al. (2007).

$$p_t^{mm} - p_t^c \geq 0. \tag{10}$$

If the gains from trade are not positive, the game ends and no trade takes place. The first-order condition when the gains from trade are positive is

$$(1-\rho)(p_t^{mm} - p_t) + \rho(p_t^c - p_t) = 0. \tag{11}$$

Solving (11) for p_t, the equilibrium offer price is

$$p_t = \rho p_t^c + (1-\rho)p_t^{mm}. \tag{12}$$

The transaction price is a weighted average of the customer's and the market maker's reservation prices. The weights are given by the relative bargaining power of the counterparties.

Substituting (5) and (6) into (12) gives

$$p_t = (1-\rho)(p_t^{id} + \phi D_t) + \rho[\pi y_t + (1-\pi)(p_t^c + \frac{1}{\alpha}q_t) - \gamma(I_t - I^*) + \psi D_t]. \tag{13}$$

Equation (13) cannot be estimated directly because y_t is unobservable. The Madhavan and Smidt (1991) solution to this problem is to approximate the pre-trade expectation about the true value of the exchange rate using the last reservation price adjusted for inventory effects and execution costs:

$$y_t = p_{t-1}^c + \gamma(I_{t-1} - I^*) - \psi D_{t-1} + \eta_t, \tag{14}$$

where η_t is the difference between the posterior mean at time $t-1$ and prior mean at time t and incorporates the public news signal. Note that, from (6) and (12), the customer's last reservation price can be expressed in terms of the bargained price and the inter-dealer market price:

$$p_{t-1}^c = \frac{1}{\rho}p_{t-1} - \frac{1-\rho}{\rho}(p_{t-1}^{id} + \phi D_{t-1}). \tag{15}$$

Substituting equations (15) and (14) in (13) we arrive at the following equation for the exchange rate change:

$$\begin{aligned}\Delta p_t &= (\tfrac{1}{\pi}-1)\rho\gamma I^* + (1-\rho)\Delta p_t^{id} + \tfrac{\rho(1-\pi)}{\alpha\pi} q_t - \tfrac{\rho\gamma}{\pi} I_t + \rho\gamma I_{t-1} \\ &\quad + \tfrac{\rho\psi+(1-\rho)\phi\pi}{\pi} D_t - [\rho\psi + (1-\rho)\phi] D_{t-1} + \rho\eta_t.\end{aligned} \tag{16}$$

The exchange rate dynamics inherent in equation (16) provide two main innovations over the standard Madhavan and Smidt (1991) model.[6] First, the change of the interdealer exchange rate is introduced as a direct measure of the customers' relative market power vis-á-vis the market maker: in the case of a customer with high market power, the price quoted by the market maker should follow closely the interdealer market price. Second, the coefficients of the otherwise unchanged variables exhibit a market power effect. For example, when interpreting the third term on the right-hand side of (16) we find that the contribution of order flow to the change of the exchange rate is diminished when the market maker exhibits low market power. A similar argument can be put forward when investigating the coefficients of the direction dummies. Since the standard Madhavan and Smidt (1991) model does not account for market power, the coefficient of the lagged direction dummy has been interpreted by empirical researchers as the effect of spreads varying adversely with the cross section of customer counterparties. From the perspective of our model, however, lower spreads quoted to informed financial customers may be the result of the low market power of the market maker vis-á-vis this customer type.[7] As these are important issues in a number of recent empirical contributions (Bjønnes and Rime, 2005; Osler et al., 2006; Reitz et al., 2007), we discuss this point in more detail when we present our estimation results below.

[6]Technically, the Madhavan and Smidt (1991) model is nested in the above generalized model for $(1-\rho) = 0$. The interpretation is that the Madhavan and Smidt (1991) model does not contain an interdealer market providing a better quote. This lack of alternatives leaves end-users with competitive quotes from the customer market.

[7]Since trading costs ϕ in the interdealer market are small and their impact is further diminished by $(1-\rho) < 1$, the estimated coefficient of the lagged direction dummy now approximates the combined impact of market power and transaction costs.

3 Empirical Evidence

Our data set consists of all foreign exchange transactions of a German bank that occurred between October 1, 2002 and September 30, 2003, covering a period of 254 trading days and nearly 12,000 observations, and was kindly supplied to us directly by the bank concerned. While a large cross-section of dealers and currencies appears in the raw data, we examine the most active dealer in the EUR/USD market. We follow Lyons (1995) and set the inventory equal to zero at the beginning of each trading day. Our sample is similar to other proprietary data used in Lyons (1995) and Bjønnes and Rime (2005), with the exception of two distinguishing features. As in the data analysed by Osler et al. (2006), each counterparty has a unique customer code, which allows us to classify trades according to their origin. This contrasts with Lyons (1995), where the dealer has no customer order flow and earns profits by continually "shading" his quotes to induce interbank trades. Bjønnes and Rime (2005) only distinguish between customer trading and interbank trading. Second, the length of our sample is very much longer than that of Lyons (which was five trading days), Bjønnes and Rime (also five days) and Osler et al. (87 days). Each trade record contains the following information: (1) currency pair, (2) date and time stamp of the trade, (3) direction, (4) transaction price, (5) interdealer market price from EBS, (6) deal size, (7) counterparty, and (8) the initiator of the trade. Incoming trades are generally initiated by customers for which the dealer will always be the supplier of liquidity. Order flow variables are calculated from the perspective of the deal initiator, implying that customers' buy orders have a positive sign, and sell orders have a negative sign.

Equation (16) is estimated using Hansen's (1982) generalized method of moments (GMM). The estimated standard errors are adjusted for heteroscedasticity and serial correlation with the Newey-West (1987) covariance matrix correction. The introduction of the change of the interdealer market price may give rise to an endogeneity problem. Of course, from the microstructure literature it is concluded that customer order flow ultimately drives exchange rates in the interdealer market and not vice versa. In market microstructure models like Evans and Lyons (2004), however, the incorporation of order flow information into interdealer prices tends to be slowly in market setups where a large number of competitive dealers trade among each other simultaneously. The reason is that every dealer accounts for only a small fraction of the entire customer order flow making his trade a very noisy signal of market-wide dynamics. In real-world interdealer markets an information hierarchy may exist in the sense that large banks represent a substantial fraction of the entire customer order flow implying that their trades exhibit a significant price impact. Empirical support for this view is provided by Bjønnes et al. (2008) showing that trades by smaller banks have a lower, often statistically insignificant, estimated price impact than trades by large banks. Given the average size of our bank, interdealer exchange rates are used by the dealer as described above. Econometrically, this implies that price changes of our dealer should not Granger-cause price changes in the interdealer market, which is confirmed by the data.[8] Since the focus of this paper is to investigate the importance of cross-sectional differences in customer order flow, Table 1 provides estimation results of the baseline model, the model including deal size and counterparty-type dummies.

[Table 1 about here]

The coefficient on deal size is statistically significant and has the appropriate sign in the baseline model. At first glance the data set seem to provide evidence in favour of the standard hypothesis that, due to asymmetric information, a dealer increases spreads in response to a larger order and moves prices accordingly. When disaggregating the order flow by means of deal size dummies and counterparty dummies, however, we find the relationship between deal size and price movements to be concentrated on small deals with commercial or internal customers. This is surprising, because order flows from these types of customers are generally not regarded as very informative since these customers trade currencies for hedging and liquidity purposes. Moreover, the statistical insignificance of deal size parameters within the group of large deals and within the group of financial

[8] Results of the Granger causality tests are available on request.

customers indicates that there is no residual linear variation of spreads according to deal size. Consistent with the results reported in Bjønnes and Rime (2005) our findings suggest that deal size is relatively unimportant. The statistical insignificance of the deal size parameters may be due to traders' response to the strategy of dealers inferring information from order flow (Huang and Stoll, 1997).

In line with recent studies such as Bjønnes and Rime (2005) and Osler et al. (2006), we find that existing inventories have little influence, particularly when accounting for trade size or counterparty type on prices our dealer quotes to customers. This contrasts with earlier studies of interdealer trading, where evidence is provided that dealers did engage in inventory-based price shading towards other dealers (Lyons, 1995). Obviously, the dealer mostly used electronic brokered trades to unload undesired inventory because it is less expensive and faster than price shading.

The estimated coefficient of the lagged direction dummy implies an average half-spread of 6.2 pips, which is quite large compared to those reported in Bjønnes and Rime (2005) (2.95 pips) or Lyons (1995) (0.92 pips).[9] We suggest that this result reflects fixed processing costs in a dealing environment dominated by small deal sizes. Support for this interpretation can be provided by re-estimating the model using binary variables for small and large deal sizes and binary variables for counterparty types. In the case of orders with a deal size smaller than EUR 0.5 million, the estimated half-spread is 10.4 pips, while orders with a deal size greater than EUR 0.5 million were executed at an average half-spread of 1.8 pips. When order flow is differentiated by counterparty type, the half-spread is just 1.58 pips for financial customers, but 9.8 (15.3) pips if the counterparty is a commercial (internal) customer.[10]

So far, the numbers presented in Table 1 appear to be reasonable compared to those reported in previous studies. Regarding the innovation of the paper, we find strong evidence in favour of our approach. Measuring customers' relative market power vis-á-vis the market maker by the fraction of the exchange rate change which is explained by the change

[9] With the exchange rate defined as dollars per euro, a pip is equal to one hundredth of a US cent.

[10] The estimated half-spreads are quite close to those reported in Osler et al. (2006) implying that the order flow investigated here seems to be representative for customer trading in foreign exchange.

of the interdealer market price leads to statistically significant and economically meaningful coefficients. We find that financial customers exert massive market power vis-á-vis the market maker, while market power of commercial and internal customers is somewhat lower, but still strong. This implies that even in case of commercial customers trading in the foreign exchange market leaves little room for market maker's price discrimination. It seems that market makers in a competitive two-tier market environment post quotes that follow quite closely developments in the interdealer market.[11]

Our results provide an explanation for some earlier findings on foreign currency pricing. In particular, the estimated coefficients of the direction dummies along the lines of the standard Madhavan and Smidt (1991) model have been proven to be contradictory to the standard adverse selection argumentation as the potential information content - measured by trade size or counterparty type - and customer spreads are negatively correlated (Osler et al., 2006; Reitz et al., 2007). Of course, a statistically significant negative relationship between trade size and spreads is observed in other quote-driven markets, too. For example, Harris and Piwowar (2006) find that spreads average 2.23 percent for small trades and 0.10 percent for large trades in the municipal bond market. A similar result is found for the U.S. corporate bond market (Goldstein et al., 2007) and for the London Stock Exchange (Hansch et al., 1999). From the perspective of our model, wider spreads paid by less well informed customers can be explained, in large part, due to relatively low market power. This becomes obvious when analysing the theoretical coefficient of the lagged direction dummy in equation (16). The second term of the coefficient is negligible as it represents transaction costs in the interdealer market corrected by relative market power of customers. When extracting transaction costs in the customer market using the estimated coefficients of counterparty-type market power, we find that $\psi = 69.64$ in the case of commercial customers and $\psi = 52.66$ in the case of financial customers - i.e. they are in a similar range.[12] These results are confirmed by empirical contributions investigat-

[11] These results provide empirical evidence for the Evans and Lyons (2005) model of information aggregation in a two-tier foreign exchange market. There, a market maker trading in the customer market segment posts quotes based on interdealer market prices.

[12] The remaining differences may be attributed to fixed costs per trade as comparable differences occur between large and small trades.

ing transparent markets with little or no opportunity of price discrimination. For example, Harris and Hasbrouck (1996), Bernhardt and Hughson (2002), Peterson and Sirri (2003) find spreads to be positively related to transaction size on the (more transparent) floor-trading New York Stock Exchange. Moreover, the negative relationship between trade size and FX customer spreads does not extend to the FX interbank market either, for which Lyons (1995) finds a positive relationship between trade size and spreads, and Bjønnes and Rime (2005) find little or no relationship. Thus, the empirical evidence from different asset markets supports our view that it is price discrimination that primarily determines the sign of the relationship between the potential information content and spreads of trades.

In standard applications of the Madhavan and Smidt (1991) model the ratio of the lagged and current direction coefficient gives the average weight put on prior information (π). Although the ratio may only give a slightly biased measure due to market power considerations, we find that the coefficient π is generally close to unity implying that the dealer does not perceive his order flow to be very informative. This is in line with the interpretation of our results regarding the deal size q_t.

4 Conclusion

In this paper we provide a new pricing model which allows for a heterogeneous market structure. In contrast to most microstructural models of financial markets, our approach accounts for the existence of two-tier market structure consisting of a customer segment and an interdealer segment. Because separated market segments give rise to the possibility of price discrimination our model incorporates market power considerations. We analyze a database of a German dealer and his cross section of end-user customers' order flow in the foreign exchange market. We compute measures of the dealer's bargaining power and find that financial customers exert massive market power vis-á-vis the market maker, while the market power of commercial customers is somewhat lower, but still strong. Consequently, the dealer earns lower average spreads on trades with financial customers than with commercial customers. The dealer tolerates lower spreads in trades with well informed customers because he is able immediately to unload order flow into the interdealer market. From this perspective, market makers provide interdealer market liquidity to end-user customers with cross-sectionally differing spreads. The results suggest that price discrimination is important when modelling dealers' trading behavior in two-tier markets.

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Table 1: Spread variation across deal size and counterparty type

254 trading days between October 1, 2002 – September 30, 2003 (11,830 obs.)

	Baseline MS	Size Dummies		Counterparty Dummies	
Constant	0.03 (0.03)		0.02 (0.03)		-0.01 (0.27)
Deal Size Q_{it}	0.33 (0.12)***	Large	0.01 (0.02)	Financial	0.05 (0.04)
		Small	21.1 (1.72)***	Commercial	0.94 (0.16)***
				Internal	0.33 (0.12)***
Inventory I_t	0.03 (0.01)*	Large	- 0.006 (0.015)	Financial	- 0.006 (0.018)
		Small	0.004 (0.015)	Commercial	0.001 (0.017)
				Internal	0.037 (0.044)
Lagged Inventory I_{t-1}	– 0.04 (0.01)**	Large	0.005 (0.015)	Financial	0.005 (0.017)
		Small	– 0.007 (0.014)	Commercial	– 0.003 (0.016)
				Internal	- 0.096 (0.04)**
Direction D_t	6.46 (0.15)***	Large	1.62 (0.12)***	Financial	1.49 (0.11)***
		Small	11.9 (0.21)***	Commercial	9.84 (0.15)***
				Internal	15.4 (0.99)***
Lagged Direction D_{t-1}	- 6.18 (0.22)***	Large	- 1.79 (0.11)***	Financial	- 1.58 (0.11)***
		Small	- 10.4 (0.20)***	Commercial	- 9.75 (0.14)***
				Internal	- 15.3 (1.03)***
Interdealer price Δp_t^{id}	0.92 (0.02)***	Large	0.97 (0.02)***	Financial	0.97 (0.02)***
		Small	0.86 (0.03)***	Commercial	0.86 (0.04)***
				Internal	0.87 (0.09)***
R^2	0.58		0.69		0.70

Notes: The dependent variable is the change of the currency price measured in pips between two incoming deals. The set of instruments equals the set of regressors implying that the parameter estimates parallel OLS estimates (see Bjønnes and Rime, 2005). * (**, ***) denote significance at the 10% (5%, 1%) level.