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Asymmetric information in the interbank foreign exchange market

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Interbank Foreign Exchange Market[*]

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Abstract

This paper provides evidence of private information in the interdealer foreign exchange market. In so doing it provides support for the hypothesis that information is an important reason for the strong positive correlation between order flow and returns. It also provides evidence that information influences order-book structure. Our data comprise the complete record of interdealer trades at a good-sized Scandinavian bank during four weeks in 1998 and 1999, including bank identities. Our results indicate that larger banks have more information than smaller banks, that the relation between order flow and returns is stronger for larger banks than smaller banks, and that larger banks exploit their information advantage in limit-order placement.

JEL Classifications: G15; F31; F33

Keywords: Foreign exchange, microstructure, asymmetric information, liquidity premium

1 Introduction

It is by now well documented that order flow influences returns in major financial markets. Positive order flow – measured as the net of buyer-initiated and seller-initiated trades – brings permanently higher prices in equity markets (Shleifer 1986; Hasbrouck 1991), bond markets (Brandt and Kavajecz 2004) and foreign exchange markets (Evans and Lyons 2002). Understanding this relationship is essential for understanding key features of financial markets such as the price discovery process and the determinants of bid-ask spreads. This paper investigates the relationship between order flow and returns in the foreign exchange interbank market.

The microstructure literature stresses three reasons why order flow could influence prices: inventories, liquidity, and information. Inventory effects arise because dealers charge a spread as compensation for inventory risk (e,g., Stoll 1978). Since these effects are transitory they cannot explain the persistence of the relationship observed in financial markets.

The liquidity hypothesis (Shleifer 1986) suggests that order flow influences returns because the demand for currency has finite elasticity or, equivalently, is downward sloping. Exogenous shocks to net demand require price changes to elicit the required liquidity supply. The needed liquidity could emerge as investors respond to changed risk premiums or, in the foreign exchange market, as firms engaged in international trade respond to changed import or export values (Carlson *et al.* 2008).[1] The relevance of the liquidity hypothesis to foreign exchange is stressed in Berger *et al.* (2008).[2]

The information hypothesis (Glosten and Milgrom 1985, Kyle 1985) postulates a financial market with differentially informed traders in which prices move to reflect the information content of trades. Evans and Lyons (2007) assert that information is essential to the link between order flow and exchange-rate returns. The information hypothesis is potentially consistent with a supporting role for liquidity: if informed traders have strong net demand the size of the associated price move could depend on the elasticity of supply. By contrast, in its pure form the liquidity hypothesis rules out a significant role for information.

Distinguishing empirically between the pure-liquidity and information hypotheses has been difficult because they have the same first-order implication: stronger net purchases bring a stronger currency. Berger et al. (2008) present evidence that the effect of order flow on returns dims considerably after the initial move and suggest that this is inconsistent with the information

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[1] Import/export agents, who account for roughly one third of end-user trading (B.I.S. 2007), use currency as a means of exchange, unlike investors who use it as a store of value (Osler 2008).

[2] Note that liquidity here is distinct from the instantaneous liquidity provided by dealers; this is analyzed in Grossman and Miller (1988).

hypothesis. Their evidence is not conclusive, however, since the relationship remains significant and substantial even at their longest horizon of three months.

We implement tests based on the following relatively subtle contrast: Under the liquidity hypothesis the trading of all banks, whether informed or uninformed, should have the same relation to returns. Under the information hypothesis, by contrast, order flow from informed banks should have a stronger correlation with returns than order flow from uninformed banks. Similarly, the liquidity hypothesis implies no correlation between the trading of banks of different sizes, while the information hypothesis implies that trading should be positively correlated among informed banks and negatively correlated between informed and uninformed banks.

Our tests of these subtle contrasts are feasible since our transactions data, unusually, include counterparty identities. We examine the complete interdealer trading record of an active Scandinavian foreign exchange dealing bank over one week in 1998 and three weeks in 1999. We focus on dollar-mark trading in the first sample and, due to the adoption of the common currency in January 1999, euro-dollar in the second.[3] The trading records of a single active bank, like ours, can be thought of as representative of the wider market because most interbank trading takes place over electronic limit-order books in which counterparty identities are only revealed *after* trades. Since dealers cannot intentionally direct order flow to specific counterparties, order flow at banks with a continuous market presence, like ours, should reflect market-wide patterns.

Both surveys and previous evidence suggest that information in the foreign exchange market comes from customers. This implies that banks with the most customers (large banks) should have the most information. We therefore partition banks into four groups according to the contemporary size ranking in *Euromoney* magazine. At the top are the "Immense" banks, meaning the twenty biggest dealing banks. At the bottom are the "Small" banks, meaning those that *Euromoney* ranked below 100 or didn't rank at all.

To distinguish between the liquidity and information hypotheses we examine three properties of bank trades. First, we follow Anand *et al.* (2005) in noting that the trades of informed banks will anticipate returns while the trades of uninformed banks will not. We thus calculate average post-trade returns for banks in each size group. We find that aggressive trades from banks of all sizes typically anticipate returns but returns are larger after aggressive trades of larger banks. We infer that larger banks are better informed.

We next directly examine the dynamics of the price response to individual trades by running a structural vector autoregression (SVAR) between returns and order flow, following Hasbrouck

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[3]The 1998 data were previously studied by Bjønnes and Rime (2005).

(1991). We define order flow as net aggressive trades against our bank and disaggregate it by bank size group. We find that order flow from banks of all sizes has a positive price impact that is achieved within roughly five trades and persists thereafter. We also find that this price impact is more substantial for larger banks. The differential impact suggests, once again, that larger banks are better informed than small banks.

We also examine correlations among the trades of different bank groups. Consistent with the information hypothesis, there is a positive correlation between the order flow of the two largest bank groups and a negative correlation between the order flow of larger and smaller banks.

Our evidence complements other new evidence indicating that information is relevant to the nexus between order flow and contemporaneous returns. Indirect support for this hypothesis is presented in Evans and Lyons (2007), who show that the trading of Citibank's end users has predictive power for macroeconomic developments. Evans and Lyons (2005) shows that end-user order flow also has predictive power for exchange rates themselves. While Evans and Lyons (2007) focus on fundamental information, we take no position on the nature of the information on which banks are trading.

Our analysis also indicates that information influences order-book structure as well as order flow. Specifically, we use both average post-trade returns and SVARs to show that large banks perform better than small banks also when using limit orders. This suggests that banks exploit information when placing limit orders as well as when placing market orders. An informed dealer might rationally choose to place limit orders if he does not expect his information to affect prices immediately (Kandel and Liu 2006). Alternatively, a dealer that is typically informed might recognize, when he has no information, that picking-off risk is relatively low and limit-order placement correspondingly safe (Bloomfield, O'Hara, and Saar 2005). These results suggest that there may be information in the order book as well as in order flow (Anand and Subrahmanyam 2008).

Our evidence has implications for three further lines of inquiry within foreign exchange microstructure. First, it helps resolve an apparent inconsistency between two bank studies. Bjønnes and Rime (2005) finds that this same big bank earns substantial speculative profits, while Mende and Menkhoff (2006) finds that its relatively small bank profited little from speculative trades and earned most of its profits from customer spreads. Our evidence suggests that big and small banks operate under different business models. Big, informed banks profit substantially from both interdealer trading and servicing customers while small banks profit primarily from servicing customers.

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Our evidence also supports the strategic dealing hypothesis as applied to foreign exchange. This hypothesis states that dealers set narrow spreads to customers who are most likely be informed, to attract their trades and potentially infer their information. Support for this comes from Osler *et al.* (2007) and Ramadorai (2008). In order for such behavior to be rational there must be profitable uses for the information. Our paper shows that one profitable use is interbank trading, as postulated in Osler et al.

Finally, our evidence supports the price discovery hypothesis presented in Osler *et al.* (2007). This suggests that interbank prices move in the direction implied by customer information because dealers tend to place market orders in the interbank market parallel to the trades of their informed customers. Consistent with that hypothesis, our paper shows that the aggressive trades of banks in every size group carry more information than their passive trades, and that banks with more information rely relatively heavily on aggressive trades.

In the rest of the paper we present our data, describe our results, and conclude.

2 Data

Our data include detailed information on the interdealer transactions of three spot traders working for a large Scandinavian bank. We focus on the dealers' dollar-mark trades during March 2 through March 6, 1998, and their euro-dollar trades during August 2 through August 20, 1999.[4] We believe this is the first interdealer transactions dataset that includes counterparty identities.[5]

A Aggressive and Passive Trades: The Structure of the Interdealer Market

The foreign exchange market has two tiers. In one tier, customers trade with dealers at banks; in the other, dealers trade with each other. The customer-dealer trades are only observed by the parties to the trades and, since there are no disclosure requirements in foreign markets, banks do not report them.

Interdealer trading in the foreign exchange market can take two routes. Most commonly, dealers trade via brokers (which in our case are primarily electronic limit-order markets). During our sample periods these brokerage services were available exclusively to foreign exchange dealers. Dealers can also call each other directly and request quotes, just like a regular customer.

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[4]One of the dealers examined in Bjønnes and Rime (2005) is not included here because he had only a limited number of DEM/USD trades.

[5]Evans and Lyons (2007), Carpenter and Wang (2007) Bjønnes, Rime and Solheim (2005), and Osler et al. (2007) study customer data disaggregated into different groups, like financial and non-financial.

The possibility of both direct and indirect interdealer trading complicates our nomenclature. Most readers will be familiar with the simple dichotomy of limit-order markets: limit orders and market orders. In the foreign exchange setting, however, we must generalize these concepts to "aggressive trades" and "passive trades." The aggressor is the bank placing the market order or the bank that calls another bank directly. The passive counterparty is the bank placing the limit order or the bank that provides a quote when called directly by another bank.

B The Data

Our transactions data cover every dollar-mark or euro-dollar trade by the three dealers on whom we focus, including direct trades, trades with electronic brokers, trades with voice-brokers, trades within the bank (internal trades), and customer trades. For each trade we have the following information: the time of the transaction; the name of the counterparty; the trade initiator; the quantity traded; and the transaction price. Our analysis uses transaction time and trades are in correct chronological order.

The 1998 dataset includes 2,066 transactions in DEM/USD worth in aggregate roughly $4 billion; this amounts to a bit less than one transaction per minute of active trading. The 1999 dataset is substantially larger, with 7,591 transactions worth in aggregate $11 billion, which amounts to a bit more than one transaction per minute. In 1998, the three dealers active in dollar-mark traded with 259 counterparty banks. In 1999, the two dealers active in euro-dollar traded with 287 counterparty banks. In both years, over 90 percent of trades were entered electronically. Of these, the vast majority were executed through an electronic broker. Since this paper studies aggregate trades by all the relevant dealers taken together, distinguishing individual trader strategies is not central to our analysis. For the 1998-sample, such issues are addressed in Bjønnes and Rime (2005).

C Why Focus on Bank Size?

We group counterparty banks according to their size because the microstructure literature suggests that the foreign exchange banks with the most customers will have the most information. The idea that customers bring information to asset markets emerged in seminal papers by Kyle (1985) and Glosten and Milgrom (1985). Both papers develop equity-inspired models in which uninformed dealers trade with customers (never with each other), and some customers have private information.

The information structure of currency markets is clearly different from that of equity markets, since the relevant information – generally a country's aggregate macroeconomic condition – seems, at first glance, to be revealed in published statistics.[6] A casual observer might even wonder if private information is well defined in this market. Nonetheless, dealers go to great efforts to gather information from customer trades (Osler et al. 2007).[7] The evidence shows why: Evans and Lyons (2005) shows that customer order flow has predictive power for exchange rates and Evans and Lyons (2007) shows that customer order flow has predictive power for macroeconomic variables.

Since macro statistics arrive with a lag, some customers might profitably synthesize existing public information to generate private insights into upcoming developments such as macro statistical releases (Osler 2008). Such customers typically work for hedge funds or other levered investors. By contrast, the banks' "commercial customers" – traders at firms that import and/or export goods and services – are generally not permitted to speculate by their employers and therefore make little attempt to forecast exchange rates (Osler, 2008). Dealers confirm that they learn important information from the order flow of sophisticated financial customers but not from the order flow of most non-financial firms. The hypothesis that financial customers have private information is also supported by the robust econometric finding that cumulative financial-customer order flow, like cumulative interdealer order flow, is positively cointegrated with exchange rates while cumulative commercial order flow is not (e.g., Bjønnes, Rime, and Solheim 2005).

If financial customers bring private information to the market that is (partly) revealed by their trades, banks with the most financial customers should have the most information. These banks are usually the biggest banks: large asset managers often make very large trades, and to get credit lines big enough for such trades they need banks with large balance sheets.

According to published surveys (see e.g. Cheung and Chinn, 2001), foreign exchange dealers claim that large foreign exchange banks are better informed than others, and our dealers certainly agree. We asked the three foreign exchange dealers studied here to rank their counterparties on a scale of 1 to 5; banks assigned a 1 would be the best informed and banks assigned a 5 would be essentially uninformed. We limited the survey to the subset of counterparty banks with which our dealers dealt bilaterally. Our dealers strongly agreed with each other, as indicated by the high correlations among their individual information rankings (when a foreign

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[6]There are minor exceptions, such as inside information that a central bank is about to intervene.

[7]According to a Citibank manager in the *Financial Times*, April 29, 1991: "if you don't have access to the end user, your view of the market will be severely limited."

exchange bank is ranked by at least two dealers). All three of the pairwise correlations are statistically significant and are 0.90 or higher.

Each year *Euromoney*, a leading magazine in the trading community, surveys FX market participants and ranks the banks. We compared the average of the dealers' three ratings to each bank's size rank in the *Euromoney* overall assessment of the top 100 foreign exchange banks of 1998 (if a bank was not ranked in 1998, but was ranked in 1999, we use the 1999 ranking).[8] The Spearman rank correlation between the two is 0.82. The correlations between a bank's *Euromoney* ranking and the ranking assigned by each of the three DEM/USD dealers taken individually average 0.85.

In short, both the literature and our dealers indicate that bigger banks tend to be relatively well informed. To search for information asymmetries in the foreign exchange market we therefore group the banks into four size categories, relying on the *Euromoney* size estimates mentioned above. The banks labeled "Immense" includes those ranked from 1 to 20, inclusive, in *Euromoney*. The "Big" group includes banks ranked from 21 to 50, inclusive. We refer to the Immense and Big banks jointly as "larger banks." The "Medium" group includes banks ranked from 51 to 100, inclusive; the "Small" banks includes those ranked below 100 by *Euromoney* or not ranked at all. We refer to banks in the two lowest size categories as "smaller" banks.

A more concrete description of firms in each size group may be helpful. In *Euromoney*, the Immense banks include such household names as Deutschebank and Citibank, along with slightly less familiar names such as Standard Chartered Bank. Euromoney's Big banks include Dresdner Bank, Lloyds Bank, and Sumitomo. Euromoney's Medium banks include ANZ (Australia and New Zealand Bank), Bank of Nova Scotia, and Mitsubishi Trust Bank. According to a market insider unconnected to our bank, the Small bank group could include such institutions as the Landesbank of Rheinland, Moscow Narodny Bank, or the Maruitius Commerce Bank. (These specific banks may or may not be included in our sample; their names are included here purely for illustration.)

Our own bank would be a Big bank in this ranking. The same bank is studied in de Jong, Mahieu and Schotman (1998), which documents that it was then among the nine most active banks in posting indicative quotes on Reuters. While this is a noisy signal of size in today's market, during our sample period it was fairly reliable. Further, we have been told informally that our dealing bank ranked among the largest ten users of one electronic foreign exchange

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[8]We limit this comparison to the 1998 sample because the questionnaire survey was conducted in 1998.

broker and among the fifteen largest users of the other.[9] Since our results largely measure performance *relative to our bank*, the important quality for inference is that our bank is neither extremely large nor extremely small.

Table 1A provides descriptive statistics for electronic trades between our bank and the other banks in these four size categories. Unsurprisingly, the average number of trades per bank is monotonically related to size: during our 1999 sample our bank traded on average 121 times with each immense bank but only 11 times with each small bank.

Table 1B provides descriptive statistics for trade sizes. The median trade size is 1 million for all bank groups in both sample periods, confirming earlier evidence that trade size is fairly standardized around that value. As one might expect, mean trade size generally rises with bank size, though the differences are quite modest: the Immense banks' mean trade is only 16 percent larger than the Small banks' mean trade in the 1998 sample and 23 percent larger in the 1999 sample.

Table 1A also reveals how little concentrated the foreign exchange market was during this period (it is more concentrated today; *Euromoney* 2006). There were more banks in the Smallest category than the total number of banks in the larger three categories combined, and our bank made more trades with banks in the Smallest category than with any other group of banks. The lack of market concentration is also apparent in Table 1C, which shows the number of trades between our bank and banks in other cities. The total number of trades with banks in peripheral cities – such as Singapore, Bahrain, and Chicago – was close to the number of trades with banks in the five biggest trading centers. While this is not central to our purpose, it is a characteristic of this market that sets it apart from most others.

D Standard Order-Flow Regressions

To show that our data can reasonably represent the entire interbank market, despite their provenance at a single bank, we run standard order-flow regressions. Returns, the dependent variable, are measured as log changes in mid-quotes.[10] We measure order flow, the independent variable, as net aggressive buys from our bank (i.e., net purchases at our bank's quoted prices). We choose a half-hour time horizon, though this is immaterial: the results barely change if we choose an

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[9]Our bank would still not be counted as an Immense bank since its interbank activity is larger relative to its customer activity than is typical.

[10]Our data only contains traded prices. In order to create midquotes, to avoid bid-ask bounce in the estimation, we subtract (add) one pip from ask (bid) prices since the interbank quoted spread was between 2 and 3 pips in 1998 (see Bjønnes and Rime, 2005; Goodhart *et al.* 2002).

Table 1: Descriptive Statistics, Banks in Four Size Categories

Note: Table shows descriptive statistics for the complete dollar-mark or euro-dollar interdealer trading record of a Scandinavian bank during one week in 1998 and three weeks in 1999. Ranks are from *Euromoney* in 1998 or 1999.

Table 1A: Number of trades

		Trades/Bank	Num. Trades	Num. Banks
1998 Sample				
Immense	(Rank 1-20)	27.2	435	16
Big	(Rank 21-50)	17.0	357	21
Medium	(Rank 51-100)	18.8	432	23
Small	(Rank >100)	4.1	819	199
Total		7.9	2,043	259
1999 Sample				
Immense	(Rank 1-20)	120.9	2,176	18
Big	(Rank 21-50)	61.0	1,829	30
Medium	(Rank 51-100)	34.8	1,287	37
Small	(Rank >100)	11.4	2,299	202
Total		26.4	7,591	287

Table 1B: Trade sizes

	Mean	Median	Std. Dev.
1998 Sample			
Immense	1.74	1.00	1.19
Big	1.67	1.00	1.00
Medium	1.45	1.00	0.99
Small	1.50	1.00	0.88
1999 Sample			
Immense	1.79	1.00	1.87
Big	1.53	1.00	1.24
Medium	1.54	1.00	1.17
Small	1.45	1.00	1.15

Table 1C: Number of trades by location

	1998 Sample	1999 Sample
London	570	2,587
New York	219	931
Tokyo	23	103
Hong Kong	71	280
Frankfurt	65	273
Others	1,094	3,417
Total	2,042	7,591

hourly time horizon.[11] In Table 2, Panel A, all order flow is aggregated into a single variable; in Panel B, order flow from each bank category is included separately.

Table 2: Standard order-flow regressions

Note: Table shows coefficients and t-statistics (in parentheses) from a regression where the dependent variable is the half-hourly exchange-rate return (log change) and the independent variable(s) are other banks' net aggressive trades with our bank over half-hour intervals. Other banks' net aggressive trades are largely other banks' market orders that hit our bank's limit orders at electronic brokers. All coefficients are multiplied by 10,000. An entry of unity implies that one net buy order brings a currency appreciation of one basis point. Data comprise the complete dollar-mark or euro-dollar interdealer trading record of a Scandinavian bank during one week in 1998 and three weeks in 1999.

	1998 Sample	1999 Sample
Panel A		
All banks	0.97	0.51
	(4.52)	(5.00)
Adj.R²	0.20	0.11
DW Stat	1.94	1.75
Panel B		
Immense	1.05	0.79
(Rank 0-20)	(2.96)	(4.02)
Big	1.26	0.85
(Rank 21-50)	(2.02)	(2.98)
Medium	-0.11	0.13
(Rank 51-100)	(-0.17)	(0.31)
Small	0.72	-0.56
(Rank >100)	(1.04)	(-1.35)
Adj.R²	0.21	0.16
DW Stat	1.93	1.71

The results confirm that our data display the same positive relation between returns and contemporaneous order flow documented elsewhere (e.g., Evans 2002; Evans and Lyons 2002; Hau, Killeen and Moore 2002). We also replicate the typical finding that order flow can explain sizable amount of the variation in return. The estimated coefficients suggest that every additional net market buy order – each of which is typically worth between 1 and 2 million – strengthens the euro by around one basis point.

To motivate the subsequent analysis we also show results from regressions in which order flow from different-sized banks is included separately (Panel B). These indicate that order flow of Immense and Big banks has a strong and significant relation with contemporaneous returns while order flow from Medium and Small banks does not. Though this does suggest that bigger banks are relatively informed, it provides only weak support for the information hypothesis since it involves half-hour intervals. Euro-dollar trades more than once per second in the interbank

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[11]These results, suppressed to save space, are available upon request.

market, so any causal relationship between returns and order flow could be masked by feedback effects. To identify structural relationships it is necessary to tease out lead-lag relationships for individual transactions, and this in turn requires data on individual trades. The next section undertakes such an analysis.

3 Tests and Results

This section uses transaction-level data to provide evidence that larger banks have more information than smaller banks and that exchange rates respond to order flow because it carries information. Our evidence also suggests that the larger banks are primarily responsible for the positive contemporaneous correlations between returns and interbank order flow.

A Asymmetric Information in the FX Interdealer Market

Our first test, which focuses on the existence of private information in the interbank foreign exchange market, is based on this observation: If some banks are better informed than others, their trades should predict returns better than those of less informed banks. Following Anand *et al.* (2005), we calculate average signed post-trade returns (positive if the counterparty bank buys, negative otherwise) for banks in each size category. We measure returns as the log change in the bid (ask) quote if a trade is settled at the bid (ask) and use horizons of one and five minutes. The one-minute horizon is probably most appropriate for our market since active foreign exchange dealers consistently assert that their information is extremely short-lived. Indeed, dealers at our bank close their positions within thirty seconds, on average (Bjønnes and Rime 2005). The five-minute horizon permits comparisons with the results in Anand *et al.* (2005). We first carry out this analysis for all trades with our bank; we then repeat the analysis separately for other banks' aggressive trades against our bank and other banks' passive trades against our bank. The independent variable is always coded one (negative one) if a bank buys from (sells to) our bank.

The average signed returns following all trades, shown in Table 3A, vary dramatically across bank size groups. The Immense banks' net purchases (against our bank) tend to be followed by price increases while the smallest banks' net purchases tend to be followed by price decreases. This implies that big banks do have some information and that they have more of it than smaller banks. The difference between the Immense- and Small-bank coefficients, which is roughly one-half basis point, is highly statistically significant in almost every case.[12] These results suggest

[12]The difference is similar to the average return on speculative positions for our dealers, as measured in Bjønnes and

that private information exists in the foreign exchange interdealer market and that the banks with the greatest customer business have the most of it, consistent with the information hypothesis.

The literature shows that when traders have short-lived information their optimal strategy is to trade aggressively, thereby increasing the chance that they can exploit the information before it becomes embedded in price (Kaniel and Liu 2006). That is, the provision of liquidity varies in response to the state of information because agents in possession of information are less likely to place limit orders. Banks that are better-informed, on average, might thus be expected to rely more heavily on aggressive trades, on average. The final column of Table 3A shows that the share of aggressive trades among all trades varies monotonically with bank size: it exceeds 60 percent for Immense banks, falls just below 60 percent for Big, is close to 50 percent for Medium banks, and is below 40 percent for Small banks. This suggests, again, that bigger banks are better informed.

If indeed banks use aggressive trades relatively frequently when informed, those trades in isolation might get a clearer indication of which banks have the most information. We therefore recalculate post-trade returns using only aggressive trades, with the results shown in the first four columns of Table 3B.

We first note that the price impact of net aggressive purchases is consistently higher than the impact of all net purchases, which suggests that banks do indeed rely more heavily on aggressive trades when they have information. These results also provide further support for the hypothesis that larger banks are better informed than smaller ones. The average price impact of aggressive trades is consistently higher for the Immense and Big banks than for the Medium and Small banks in the more powerful 1999 sample. In the 1998 sample the three largest bank categories have higher price impact than the Small banks, and the Immense-Small bank difference is statistically significant. Perhaps because we only include aggressive trades, the difference between Immense and Small banks is only statistically significant in the 1999 sample. Since bigger banks tend to make bigger trades, one might wonder whether the bigger price impact is due solely to larger trade sizes. The price impact of Immense-bank trades at the one-minute horizon, however, is about twice as high as the price impact of Small-bank trades in the 1999 sample and eight times as high in the 1998 sample, while the Immense-bank trades are at most 23 percent bigger. Since the price impact of trades has a convex relationship with trade size (Berger et al. 2006), trade size is unable to account for the higher price impact of the Immense-bank trades.

Rime (2005).

Table 3: Returns immediately following a trade with our bank

Note: Table shows average (log) returns in the period immediately following trades. Since we can identify the trade initiator, we measure returns as the (log) change in the bid (ask) quote if a trade is settled at the bid (ask). All returns are multiplied by 10,000, so an entry of unity represents one basis point. "Share Aggressive" is the share of aggressive trades as a percent of all trades between our bank and banks of that size group. Data comprise the complete dollar-mark or euro-dollar interdealer trading record of a Scandinavian bank during one week in 1998 and three weeks in 1999.

Table 3A: Other banks' net purchases (aggressive or passive) from our bank

	A: 1998 Sample			B: 1999 Sample		
	Avg. return	t-stat.	Share Aggressive	Avg. return	t-stat.	Share Aggressive
1-Minute Horizon						
Immense	0.20	2.15	65.8	0.14	2.95	61.1
Big	-0.09	-0.78	51.5	0.06	1.05	58.2
Medium	0.00	0.01	53.7	-0.12	-1.92	52.4
Small	-0.57	-6.58	39.4	-0.43	-9.69	33.3
Immense−Small	0.77			0.57		
p-value	0.00			0.00		
5-Minute Horizon						
Immense	-0.09	-0.44		0.26	2.33	
Big	0.11	0.46		0.10	0.85	
Medium	0.39	1.71		-0.02	-0.14	
Small	-0.23	-1.39		-0.48	-4.79	
Immense−Small	0.14			0.73		
p-value	0.61			0.00		

Table 3B: Other banks' net aggressive purchases and net passive purchases

	Other banks aggressive trades				Other banks passive trades			
	1998 Sample		1999 Sample		1998 Sample		1999 Sample	
	Avg. return	t-stat.	Avg. return	t-stat.	Avg. return	t-stat.	Avg. return	t-stat.
1-Minute Horizon								
Immense	0.52	4.59	0.46	8.10	-0.37	-2.42	-0.55	-6.59
Big	0.36	2.20	0.44	6.91	-0.52	-3.66	-0.68	-7.61
Medium	0.62	3.64	0.29	3.76	-0.66	-3.78	-0.74	-6.95
Small	0.06	0.54	0.27	4.04	-0.95	-8.14	-0.90	-16.82
Immense−Small	0.46		0.19		0.58		0.35	
p-value	0.00		0.04		0.02		0.00	
5-Minute Horizon								
Immense	0.03	0.12	0.56	4.30	-0.32	-0.98	-0.39	-1.90
Big	0.36	0.93	0.55	3.59	-0.13	-0.44	-0.75	-3.85
Medium	0.97	3.34	0.37	1.94	-0.24	-0.69	-0.61	-2.74
Small	0.04	0.15	0.48	3.08	-0.39	-1.73	-1.13	-9.00
Immense−Small	0.00		0.07		0.07		0.74	
p-value	0.99		0.72		0.86		0.00	

One might wonder whether Small banks have any information worth trading on, but the price impact of aggressive trades is positive for the Small and Medium banks in both samples and statistically significant in the 1999 sample. This indicates that even small banks sometimes gather price-relevant information.

The last four columns of Table 3B show average returns following other banks' net passive purchases from our bank. At the one-minute horizon these average returns are all negative and significant, consistent with the possibility that when banks place limit orders they are often picked off by better-informed banks. Smaller banks apparently experience greater losses than larger banks following passive trades, from which we infer that banks use their information to structure passive trades as well as aggressive trades. The informed banks might rationally place limit orders when they expect their information to affect prices slowly (Kaniel and Liu, 2006). Alternatively, they might serve as liquidity providers – hoping to capture the spread – when their information indicates that the market is fairly priced and picking-off risk is relatively low (Bloomfield, O'Hara, and Saar 2004).

The literature suggests that location can substantially affect a trader's information. Hau (2001), for example, finds that asset managers located near a major financial center were better informed than those farther away. With respect to foreign exchange, Covrig and Melvin (2003) show that foreign exchange traders in Japan tend to lead the market in dollar-yen. Likewise, D'Souza (2008) shows that that traders in Canada and Australia are best informed in the markets for Canadian and Australian dollars, respectively. We examined whether location influences the information asymmetries in this market by testing whether banks located in London or New York, by far the two biggest trading centers, perform better than banks located either in the Euro area or elsewhere. Since London and New York banks tend to be bigger, this raises the possibility that the information advantage we have identified comes from location rather than size. To verify the contribution of size we run separate sets of SVARs for banks in London, New York, the Euro-zone, and anywhere else. To deal with the loss of power associated with further disaggregation, we create just two size groups, Immense plus Big and Medium plus Small, and use only the larger 1999 sample. The results indicate that trades by smaller banks have a lower estimated price impact than trades by larger banks, and the difference is statistically significant for banks located in London, New York, and the Euro-zone.[13]

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[13]These results, suppressed in the interest of space, are available upon request.

B Structural VARs

We next look more closely at how returns respond to order flow using Structural Vector Auto Regressions (SVAR). With order flow measured once again as aggressive purchases from our bank we run two SVARs, one for each sample. Each SVAR has a block-triangular structure with order flow from our four bank groups first and then the exchange-rate return.[14] The SVARs have two lags, with lag length chosen according to the Schwartz criterion. Following Hasbrouck (1991) and Payne (2003), every trade is one observation, so order flow for a specific bank group is always +1 (aggressive buy), -1 (aggressive sell), or 0 (no transaction).

These regressions permit a direct test of whether information helps explain the contemporaneous correlation between interbank order flow and returns (Payne 2003; Evans 2002; Evans and Lyons 2002; Hau, Killeen and Moore 2002). If the contemporaneous correlation stems only from liquidity effects then the dynamic relation between order flow and returns should be the same for banks of all sizes. If information asymmetries are important the relation should be stronger for better-informed banks. Further, if order flow carries fundamental information we should find that these relations are sustained over time.

The impulse-response patterns revealed by these regressions, shown in Figures 1A and 1B, are quite similar across our two sample periods (though the confidence intervals are narrower for the 1999 sample, as one would expect given its larger number of observations.) These results are consistent with our previous results, since returns respond positively to order flow from banks of all sizes and the strength of the response rises with bank size. The results indicate that an unexpected positive trade shock from the Immense banks increases the mid quote by 0.4 basis points. In unreported results we aggregate the banks and estimate just one SVAR between order flow and returns per sample period. The cumulative impact of a positive shock is between 0.5 and 0.6 basis points for both sample periods, which is comparable to the effect of 0.5 basis points found by Payne (2003) for the overall market.

The cumulative impact of Immense-bank order flow is significantly larger than the impact of the Small-bank order flow, which supports the hypothesis that exchange rates react to information in order flow. To ensure that order size is not driving these results we ran the SVARs with trade values, rather than trade direction, as the independent variable. For brevity we show only the results for the more-powerful 1999 sample (Figure 1C). These confirm our previous qualitative conclusions: even controlling for trade size, the trades of Immense banks have a bigger cumulative effect on price than the trades of Small banks. The information hypothesis

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[14]All overnight-returns are taken out of both samples.

Figure 1: SVAR Analysis of Price Response to Banks' Aggressive Trades
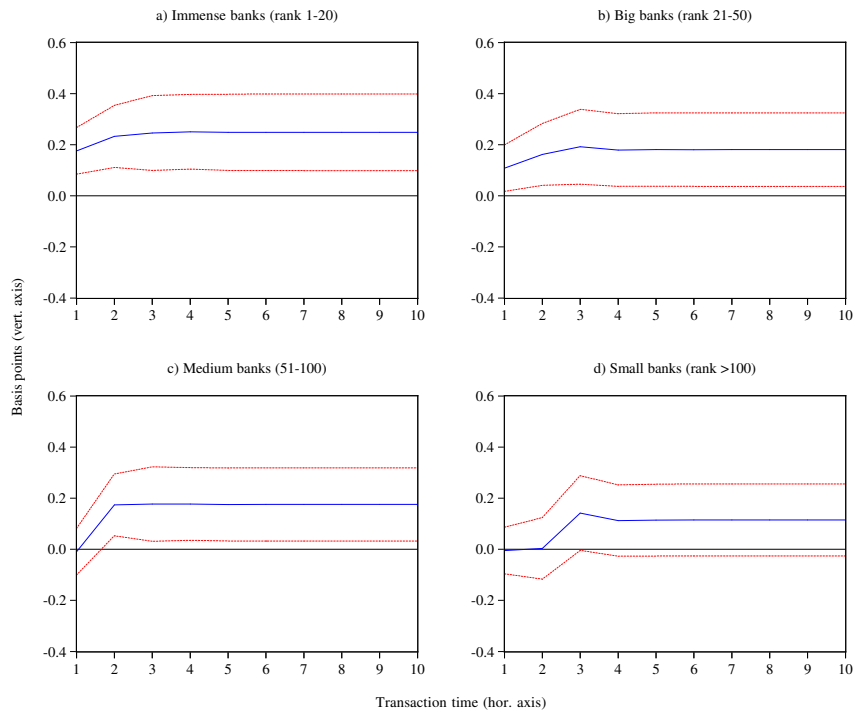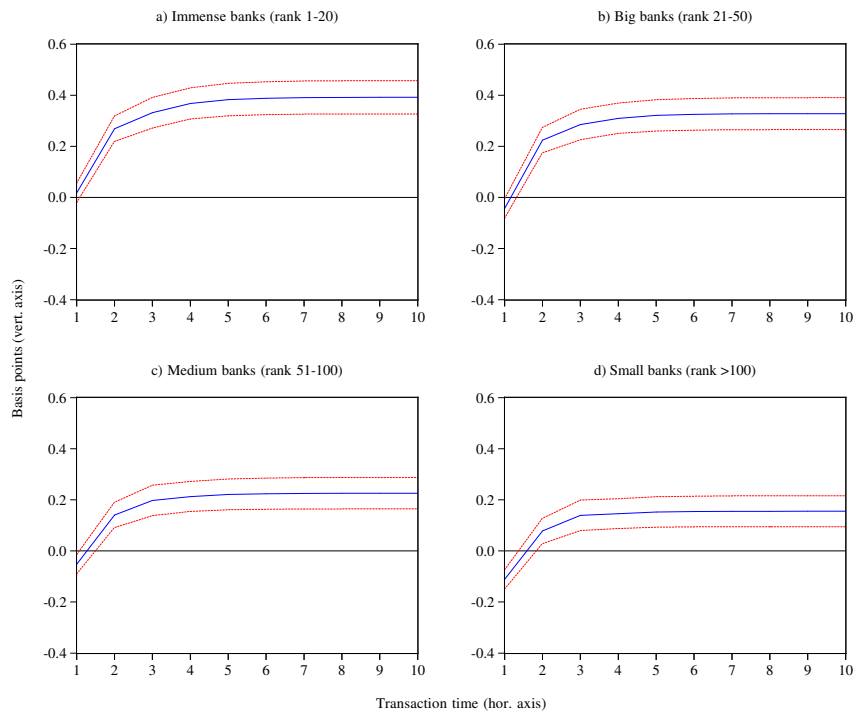
(a) 1998 Sample

(b) 1999 Sample

Note: Accumulated response of price to one-standard-deviation innovations in aggressive trades, together with two-standard-deviation bands. Return (times 100) is ordered last in a VAR together with the four order flows. Data comprise entire trading record for major Scandinavian bank over four weeks in 1998 and 1999. Individual banks are disaggregated into size groups according to contemporaneous Euromoney size rankings.

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Figure 1: 1999 Trade Volume Data
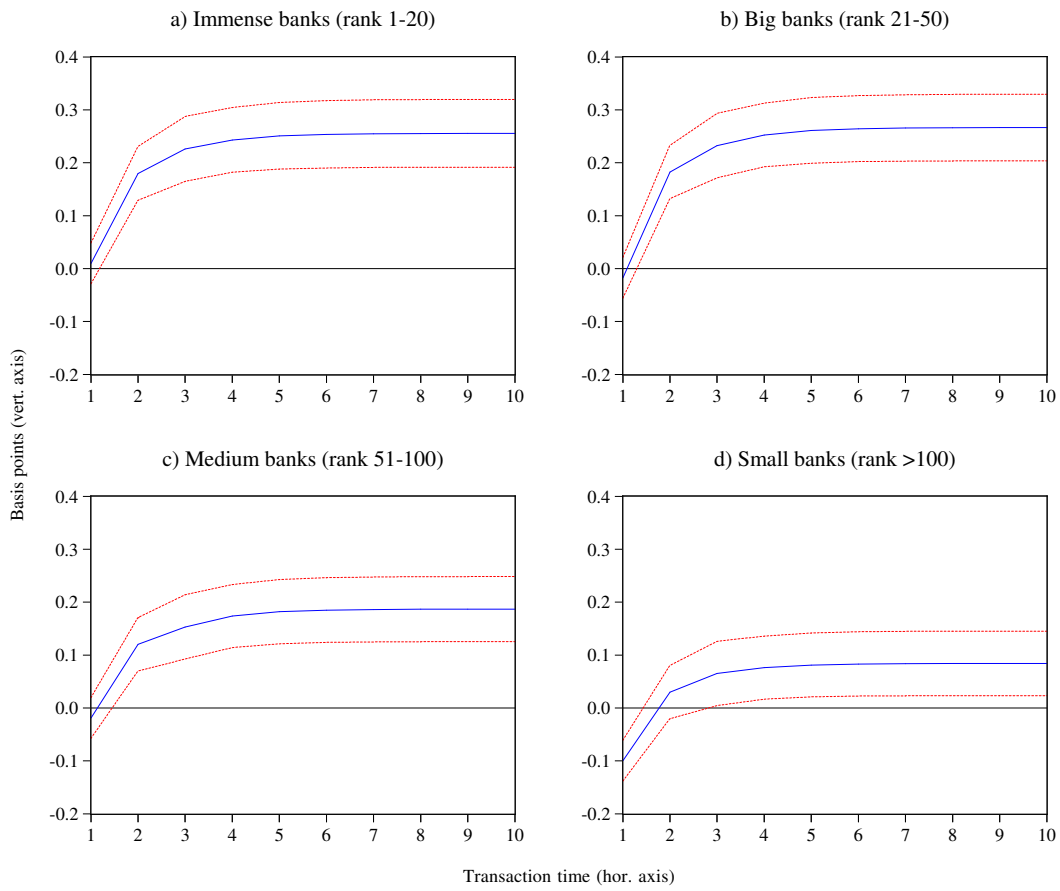
gains further support from the sustained nature of the response of returns to order flow. The response is initially small but rises quickly – usually within five transactions – to its sustained level. Since our bank trades roughly once per minute, on average, this suggests that the exchange rate responds fully to information within about five minutes.

The relevance of information for interbank dealing is indicated yet again by a complementary analysis of our own bank's aggressive trades (Figure 2).[15] As noted earlier, if the relation between order flow and returns is driven solely by liquidity these responses should not vary across bank size groups. We find, however, striking differences across bank size groups. The exchange rate initially moves adversely in every case but turns around after two or three transactions. The point estimates paint a consistent picture across both samples, though it is more clearly statistically significant in the larger 1999 sample. When our bank trades against Immense banks the initial adverse price move is most pronounced and the subsequent reversal still leaves our bank with a net loss. When our bank trades aggressively with other Big banks it usually comes out even after the price settles down. When our bank trades against Medium or Small banks it usually comes out ahead after the price settles down. All of this suggests, consistent with the information hypothesis, that our bank is less informed that Immense banks, equally informed as Big banks, and better informed than Medium and Small banks.

C   Correlated Trading

Our final set of tests examines whether our bank groups tend to trade in parallel or in opposite directions. We examine correlations between the net purchases of the four groups, using an hourly time horizon. The pure-liquidity hypothesis suggests no reason these correlations would be anything but zero. The information hypothesis, once again, predicts that these correlations should vary across bank size groups. To fix ideas, suppose two banks learn that the euro is likely to appreciate while all other banks remain uninformed. The uninformed banks, in their ignorance, will continue both buying and selling. The informed banks, by contrast, will avoid selling and try only to buy. The informed banks would be unlikely to trade with each other and would be more likely to trade with uninformed banks.

Given our earlier evidence that larger banks are better informed than smaller banks, the information hypothesis has three predictions for trading correlations. All three predictions are confirmed by the actual correlations across groups, as shown in Table 4.[16] As might be expected,

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[15]The 1998 impulse-response functions are qualitatively similar but less precisely estimated. These are available upon request.

[16]The strength of these patterns suggests that our sample is indeed representative of the broader market.

Figure 2: SVAR Analysis of Price Response to Our Bank's Aggressive Trades
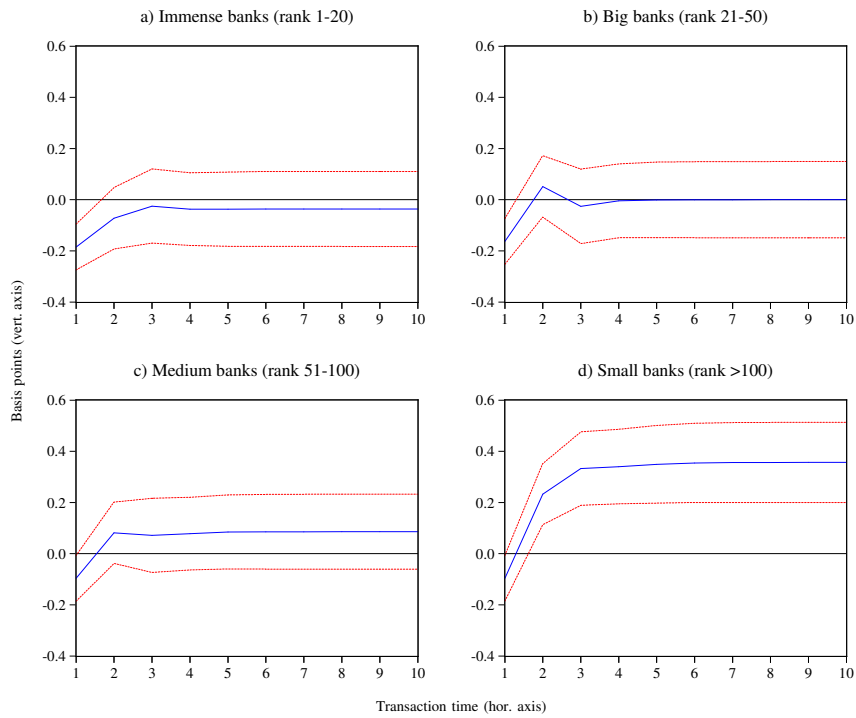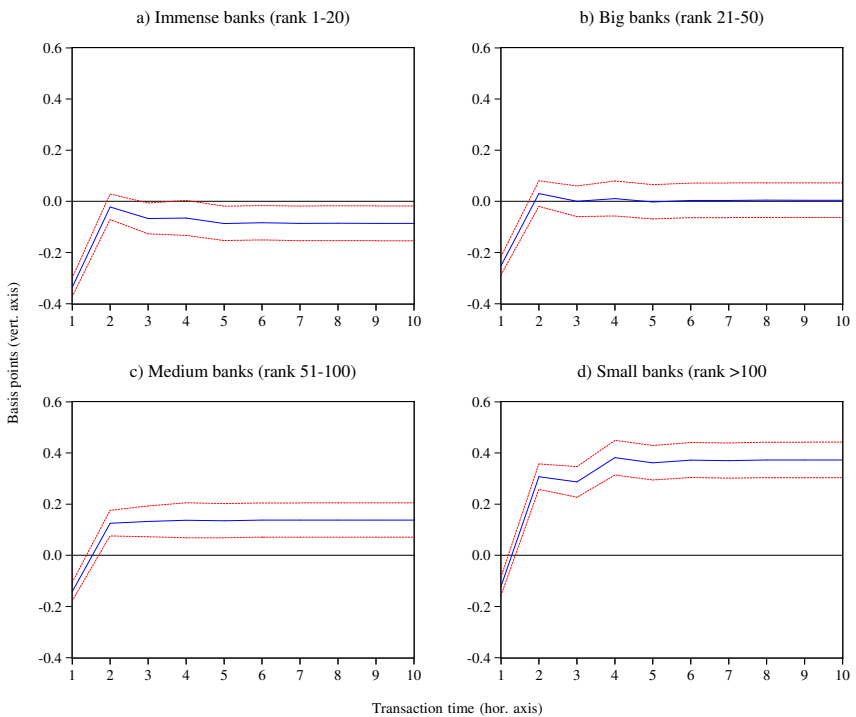

(a) 1998 Sample

(b) 1999 Sample

Note: Accumulated response of price to one-standard-deviation innovations in aggressive trades, together with two-standard-deviation bands. Return (times 100) is ordered last in a VAR together with the four order flows. Data comprise entire trading record for major Scandinavian bank over one week in 1998 (Fig. 2A) or three weeks in 1999 (Fig. 2B). Individual counterparty banks are disaggregated into size groups according to contemporaneous Euromoney size rankings. Vertical axis shows returns in basis points.

these patterns are most pronounced for the banks in the extreme size categories.

i. *Implication: Net purchases of informed banks should be positively correlated with each other.*

Finding: The correlation between the Immense and Big banks is positive in both samples and is statistically significant (at 0.29) in the 1998 sample.

ii. *Implication: Net purchases of the informed banks should be negatively correlated with net purchases of the uninformed banks.*

Finding: All the correlations between the Medium and Small banks with the Immense and Big banks are negative, and most of these are statistically significant. The negative correlation between banks in the extreme size categories is always statistically significant.

iii. *Implication: Net purchases of uninformed banks should be either uncorrelated with each other (since their trades are unrelated to information) or positively correlated with each other (since they will tend to trade against the informed larger banks).*

Finding: The correlation between Medium and Small banks is positive and significant in the 1998 sample while in the 1999 sample it is economically and statistically insignificant.

Table 4: Net purchases: Correlation across bank groups

Note: The table shows how net purchases for each group is correlated with net purchases of other groups. Net purchases is measured as the number of purchases minus the number of sales over hourly time intervals. Data comprise the complete dollar-mark or euro-dollar interdealer trading record of a Scandinavian bank during one week in 1998 and three weeks in 1999. Symbols *, ** and *** indicate significance at the 10%, 5% and 1% level, respectively.

	Immense (Rank 1-20)		Big Rank (21-50)		Medium (Rank 51-100)		Small (Rank > 100)
A. 1998 Sample							
Immense	1.00						
Big	0.29	**	1.00				
Medium	-0.66	***	-0.28	**	1.00		
Small	-0.79	***	-0.32	***	0.41	***	1.00
B. 1999 Sample							
Immense	1.00						
Big	0.11		1.00				
Medium	-0.06		-0.04		1.00		
Small	-0.42	***	-0.27	*	-0.01		1.00

It is also instructive to take a close look at our bank's counterparties when it is most likely to be informed. We take this to be when our bank expands an inventory position. Trades undertaken to expand an inventory position are likely to be speculative while interdealer trades

to reduce an inventory position could be either speculative or non-speculative.[17] Inventory-accumulating trades certainly appear to be informed, since they tend to be quite profitable. (The profitability of such trades is documented for the 1998 sample in Bjønnes and Rime (2005); profitability in the 1999 sample is comparable.)

Suppose our bank has information and makes an accumulating trade. Under the pure-liquidity hypothesis, the likelihood that it trades with banks of any given size should be the same as that group's share in any other type of trade. Under the information hypothesis, by contrast, it would trade relatively more frequently with smaller banks and less frequently with other large banks.

Table 5: Position-taking against other banks

Note: "Accumulating trades" are trades through which dealers at our bank build speculative position, while "Decumulating trades" are trades through which these dealers reduce speculative positions. "Percent of trades" shows the percent of trades with the different categories of counterparts. "P-Value: Accumulating−Decumulating" tests whether the percentage of accumulating trades is significantly different from the percentage of decumulating trades. Data comprise the complete dollar-mark or euro-dollar interdealer trading record of a Scandinavian bank during one week in 1998 and three weeks in 1999. Ratios in *italics* are statistically different from unity.

Counterparty Bank	Percent of Accumulating Trades	Percent of Decumulating Trades	p-Value: Accumulating-Decumulating	Ratio: Accumulating Over Decumulating
A. 1998 Sample				
Immense	17.00	27.20	0.00	*0.63*
Big	15.90	18.80	0.09	*0.85*
Medium	21.40	19.80	0.52	1.08
Small	45.80	34.30	0.00	*1.34*
B. 1999 Sample				
Immense	23.00	33.00	0.00	*0.69*
Big	22.00	25.00	0.00	*0.87*
Medium	16.00	18.00	0.04	*0.90*
Small	39.00	24.00	0.00	*1.65*

Table 5 shows the share of each group of banks in our bank's accumulating trades and also, as a point of reference, in our banks decumulating trades. The pattern conforms to the predictions of the information hypothesis. In 1998, for example, 46 percent of our bank's accumulating trades were with Small banks while Small banks accounted for only 27 percent of our bank's decumulating trades; similarly, Immense banks accounted for only 17 percent of our bank's accumulating trades but for a full 33 percent of our bank's decumulating trades. More broadly, the ratio of our banks accumulating trades to decumulating trades is inversely related to bank

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[17]In studying our dealers' accumulating trades, we noticed that occasionally the resulting position is immediately unwound via an offsetting customer trade or direct interbank trade. Since this type of inventory accumulation seems unlikely to represent speculation, we further narrow the set of trades on which we focus to those that are not immediately followed by a customer or direct interdealer trade of the opposite sign, though we continue to refer to these as "accumulating" trades.

size and the differences are statistically significant. Overall, these results support the idea that when our bank is informed it trades relatively frequently with smaller banks and relatively infrequently with other large banks, consistent with the information hypothesis.

4 Conclusion

This paper examines the forces driving short-run exchange-rate dynamics. Though macro-based exchange-rate models have not successfully identified these forces, close scrutiny of the market's microeconomics is proving fruitful. This microstructure approach, pioneered by Goodhart (1988) and Lyons and Evans (2002), shows that one important force driving returns is contemporaneous order flow. This paper examines why order flow has this influence using transactions data from a big Scandinavian bank during four weeks of 1998 and 1999.

Our analysis is designed to distinguish between the two most prominent explanations for the relation between order flow and returns. According to the pure-liquidity hypothesis advocated in Berger *et al.* (2008) and Breedon and Vitale (2004), order flow represents a demand for market liquidity and the price adjusts to elicit a corresponding supply. According to the information hypothesis of Glosten and Milgrom (1985) and Evans and Lyons (2007), returns on average reflect the private information conveyed by order flow. Under the pure-liquidity hypothesis there should be no asymmetries across banks in the relation between order flow and returns. Under the information hypothesis, by contrast, order flow from better-informed banks should have a stronger relation with returns than order flow from less-informed banks. Noting that larger banks get more customer business than smaller banks, and are therefore likely to be better informed, we disaggregate banks into four size groups.

Our results consistently indicate that there is a striking information asymmetry in the foreign exchange interdealer market: the most active banks are clearly better informed than the least active banks. We examine returns following individual trades and find that, though all banks have at least some information, the trades of larger banks carry more information than those of smaller banks. This conclusion holds even after controlling for trade size and for bank location.

Our results also indicate that private information is critical to the relation between interdealer order flow and returns. Using structural VARs to examine the dynamics of the relation between individual trades and returns, we find that the price impact of trades is significantly higher for larger banks than for smaller banks. Interestingly, we also find that full price response is typically realized within about five trades and is sustained thereafter.

Finally, we examine contemporaneous correlations among order flow of our size-based bank groups. There is a positive correlation between the order flow of large banks and a negative correlation between large-bank and small-bank order flow, which is consistent with the information hypothesis but not with the pure-liquidity hypothesis.

While our results highlight private information in the foreign exchange interdealer market, they do not indicate the nature of that information. Our results are consistent with a at least three possibilities suggested in the literature. Dealers claim in surveys that they do not trade on fundamental information (e.g., Cheung and Chinn 2001) but they often profit from knowledge of large trades moving through the market (Osler 2008). Alternatively, the information reflected in bank trades could reflect fundamental information that is originally dispersed among economic agents, as suggested in Evans and Lyons (2007) and Bacchetta and van Wincoop (2006). When such agents atomistically adjust their currency trades in response to the state of the economy, banks can infer the underlying information from trading patterns. Finally, the information carried by bank trades could be fundamental information actively gathered by members of the professional trading community, as suggested in Osler (2008). It is possible, of course, that all three types of information are relevant to the market. Future research could productively investigate the nature of private information in the foreign exchange market.

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