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Volume and volatility in the FX market: Does it matter who you are?

by

Geir H. Bjønnes, Dagfinn Rime and Haakon O.Aa. Solheim

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Volume and volatility in the FX market: Does it matter who you are?[1]

Geir H. Bjønnes[2] Dagfinn Rime[3] Haakon O.Aa. Solheim[4]

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[2]Stockholm Institute for Financial Research and Norwegian School of Management (BI), email: geir.bjonnes@sifr.org.

[3]Norges Bank (Central Bank of Norway) and Stockholm Institute for Financial Research. email: dagfinn.rime@norges-bank.no.

[4]Norwegian School of Management (BI) and Statistics Norway. email: haakon.o.solheim@bi.no.

Abstract

The relationship between volume and volatility has received much attention in the literature on financial markets. However, due to the lack of data, few results have been presented for the foreign exchange (FX) market. Furthermore, most studies contain only aggregate series, and cannot distinguish between the impact of different participants or instruments. We study the impact of volume on volatility in the FX market using a unique data set of daily trading in the Swedish krona (SEK) market. The data set covers 95 percent of worldwide SEK trading, and is disaggregated on a number of reporting banks' buying and selling in five different instruments on a daily basis from 1995 until 2002. We find that volume in general shows a positive correlation with volatility. However, the strength of the relationship depends on the instrument traded and the identity of the reporting bank. In particular, we find that trading tends to concentrate around the largest banks during periods of high volatility. These banks are probably also best informed. This is especially the case when volatility is high. We interpret this as evidence that heterogeneous expectations are important to an understanding of the volume-volatility relationship.

Keywords: Volume-volatility relation, microstructure, exchange rates
JEL Classification: **F31**

1 Introduction

This paper studies the relationship between volume and volatility in the market for foreign exchange (FX) using a unique data set from the Swedish krona (SEK) market. The data is based on daily reporting from a number of primary dealers (market making banks), both Swedish and foreign, and covers as much as 95 percent of all currency trading in Swedish krona. Each primary dealer reports their total purchases and sales in five different instruments: (*i*) Spot; (*ii*) Outright forwards; (*iii*) Short swaps ("tomorrow-next"); (*iv*) FX swaps; and (*v*) options.[1]

Studies from a number of different market settings suggest that there is a positive relationship between volatility and volume (see Karpoff, 1987). Due to the lack of data there are few studies of the FX market, and those that include actual volume data have only had access to a limited part of total volume. The studies conducted by Goodhart and Figliuoli (1991) and Bollerslev and Domowitz (1993) both use the frequency of indicative quotes on the Reuters FXFX-screen as a proxy for volume. Grammatikos and Saunders (1986) and Jorion (1996) use the number of futures contracts traded at the Chicago Mercantile Exchange. Wei (1994) and Hartmann (1999) use the Bank of Japan's data set on brokered transactions in the Tokyo JPY/USD market. Galati (2000) uses data provided by the BIS on actual trading volume for seven developing countries. In general, these studies suggest a positive relationship between volatility and volume consistent with evidence from other markets. Compared with previous studies our data set has the following advantages: (*i*) It covers the entire market for the Swedish krona; (*ii*) FX volume is separated into different instruments; and (*iii*) FX volume is reported individually by each primary dealer.

An important question is why the volume-volatility relationship arises. Three central contributions on the theory of volume and volatility are Clark (1973), Epps and Epps (1976) and Tauchen and Pitts (1983). Clark (1973) introduces the mixture of distribution hypothesis, where the correlation between volume and volatility arises due to the arrival of new information that drives both exchange rate changes and volume. Epps and Epps (1976) provide a second, and complementary, explanation. They argue that the volume-volatility relationship is due to disagreement between traders when they revise their reservation prices. More heterogeneous beliefs should cause more volatility.

Tauchen and Pitts (1983) provide a model that combines these two features. They point out that volume might change over time for different reasons. There might be an increase in the number of traders, new information may arrive or there may be heterogeneous beliefs between different traders. A trend in volume due to an increase in the

[1] A short swap is a contract to be delivered within two days, e.g. before a spot contract.

number of traders should lead to lower volatility due to higher liquidity.

Foster and Viswanathan (1990) and Shalen (1993) presents models where the dispersion of beliefs creates both more price variability and excess volume. Shalen (1993) argues that uninformed traders increase volatility because they cannot differentiate liquidity demand from fundamental value change. The market microstructure literature (e.g. Glosten and Milgrom, 1985) emphasizes the role of heterogeneous beliefs in the pricing process.

This paper makes three contributions. First, we document a positive relationship between volume and volatility using data that covers almost all currency trading in SEK. Although a positive volume-volatility relationship is documented for the FX market in previous studies, this is to our knowledge the first time such a relationship has been documented for one of the ten largest currencies using such an extensive set of volume data.[2]

Second, we are able to separate total volume into different instruments. The standard assumption is that the spot market should be the important market for determining the exchange rate. However, previous studies have used data from both the spot market and the forward market. We show that it is indeed the spot volume that is most important. However, we also find some indications that option volume is correlated with spot exchange rate volatility.

Last, but maybe most importantly, we examine the role of heterogeneity in explaining volatility. This is possible since we have the volume of each of the reporting banks. That means that we have aggregates of volume that are actually observable in the market, although only to the reporting bank. This is truly private information. Since large banks have more customer orders and thus see more order flows, these banks are potentially better informed than smaller banks (Lyons, 2001). It is also likely that the composition of their order flows is different. Large banks may, for instance, have a larger proportion of financial customers than smaller banks (Lyons, 2001; Fan and Lyons, 2003). Another distinction that may matter is that between Swedish and foreign banks. All foreign reporting banks are large in the FX market, but they are not among the largest in the market for the Swedish krona.

Our results suggest that trading with large banks tend to have the strongest impact on volatility. This is especially the case in periods of high volatility. These results suggest that private information may be important in understanding the relationship between volume and volatility. Controlling for size, there is also evidence that trading by Swedish banks is more correlated with volatility than trading by foreign banks. Thus, we conclude that large Swedish banks have the highest correlation with volatility.

[2] According to the BIS (2002), the Swedish krona is the eighth most traded currency. The Swedish krona is for example larger than the emerging markets studied in Galati (2000).

Studies from other market settings also suggest that heterogeneity among market players may be important to understanding volatility (see e.g. Grinblatt and Keloharju, 2001). Bessembinder and Seguin (1993) and Daigler and Wiley (1999), both studying futures markets, document the importance of different types of traders for explaining the volume-volatility relationship. Daigler and Wiley (1999) find that trade-"speculators", i.e. traders located outside the actual market, tends to be more correlated with volatility than trade by investors in the market. Since these "outsiders" may be interpreted as noise-traders, this result is different from ours.

The paper is organized as follows. Section 2 gives a detailed presentation of our data. In Section 3 we present the results. Section 4 concludes.

2 Data

In this section we start by describing our volume data. We then present the macro variables (control variables) applied in the analysis.

2.1 Volume data

Sveriges Riksbank (the central bank of Sweden) receives *daily* reports from a number of Swedish and foreign banks (currently 10) on their *buying and selling* of *five different instruments.* The reported series is an aggregate of Swedish krona (SEK) trading against all other currencies, measured in krona, and covers 90–95 percent of all worldwide trading in SEK. Close to 100 percent of all interbank trading and 80–90 percent of customer trading is made in SEK/EUR. In our analysis, we will therefore focus on the SEK/EUR exchange rate.

Aggregate volume information is not available to the market. FX markets are organized as multiple dealer markets and have low transparency. The specific reporter will only know her own volume and a noisy signal on aggregate volume that is received through brokers. Reporting banks do obtain some statistical summaries of volume aggregates from the Riksbank, but only with a considerable lag. The data set used in this paper is not available to market participants.

The data set stretches from January 1, 1995 to June 28, 2002. Figure 1 shows the total gross volume in the spot market and the absolute returns in the exchange rate. There seems to be a relationship between volume and volatility, especially in periods of high volatility like 1996/97 and in the fall of 1998. We also note that there is no clear trend in the two series.

The five instruments are spot, forwards, options, short swaps and standard swaps.

Figure 1: Gross spot volume and absolute changes in SEK/EUR

Upper line shows gross spot volume, measured in 10 billion SEK. Lower line shows absolute changes in the log of SEK/EUR.

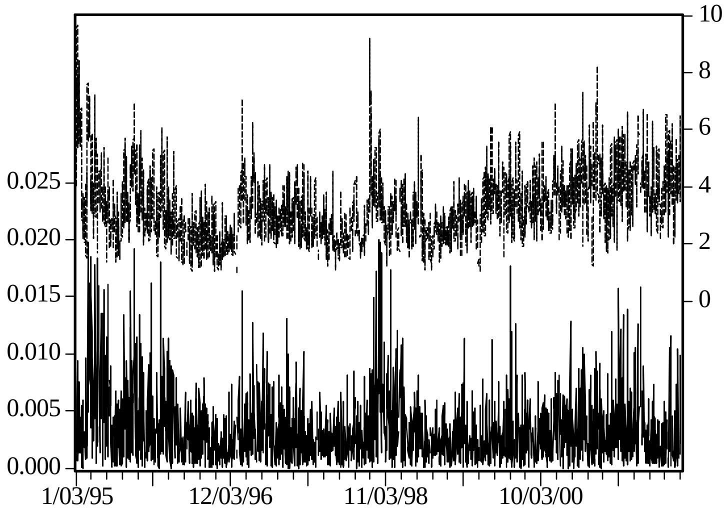

Table 1: The importance of different instruments. Sample: Jan. 1995–Jun. 2002

Table shows summary statistics of volume in the SEK market, divided by instrument. The first row shows the share of volume in each instrument of total volume. Short swap is a liquidity instrument with settlement within 7 days. All numbers are calculated on a daily basis. Volume is measured in units of 10 billion SEK.

	Spot	**Forward**	**Short swap**	**Swap**	**Option**
Share of tot. volume	0.27	0.06	0.37	0.27	0.03
Mean	3.14	0.73	4.72	3.53	0.41
Median	3.02	0.60	4.09	2.94	0.22
Std. Dev.	1.32	0.53	2.70	2.29	0.54
Skewness	0.43	1.62	0.73	1.21	3.09
Kurtosis	4.39	7.39	3.25	4.68	15.49
Correlation	**Spot**	**Forward**	**Short swap**	**Swap**	**Option**
Forward	0.58	1			
Short swap	0.40	0.59	1		
Swap	0.49	0.64	0.77	1	
Option	0.42	0.55	0.57	0.56	1

Short swaps are mainly used as a liquidity control instrument when cash with delivery in less than two days is required (the time of a standard spot transaction). Table 1 gives an indication of the relative usage of the different instruments. As a percentage of total volume in the market, short swaps is the largest category, followed by spot trading. Forward and option trading make up much smaller parts of total market volume.

The reporting banks are anonymized. However, we can distinguish between Swedish banks, foreign banks, and branches of foreign banks located in Sweden. The reporters are the main market makers in the SEK market. At most, there are 15 reporting banks active in the market. In total, 19 banks are represented in our data.

For confidentiality reasons, we can not display detailed information on the size of each bank. Two of the banks are clearly bigger than the others. These are Swedish banks. Their market share averages 44 percent, and does not vary much over the sample period. Other Swedish banks have a market share of 20 percent. The average market share of foreign reporters is 25 percent, while the market share of branches of foreign banks is 11 percent.

Table 2: The concentration of dealing with primary dealers. Sample: Jan. 1995–Jun. 2002

We divide the primary dealers into three groups. Large banks are the two largest primary dealers. Medium banks are the next seven largest banks. The remaining reporters in our sample are small banks, 10 in total.
The table shows summary statistics of volume in the SEK market. All numbers are calculated on a daily basis. Volume is measured in units of 10 billion SEK.

	Large	**Medium**	**Small**
Share of tot. spot volume	0.45	0.43	0.12
Mean	1.42	1.39	0.39
St.dev.	0.62	0.58	0.28
Skewness	1.35	0.59	1.61
Kurtosis	8.00	3.61	11.81
Correlation	**Large**	**Medium**	**Small**
Medium	0.67	1	
Small	0.42	0.61	1

We split our banks two ways. First we split by size. The two largest banks are categorized as “large banks”. Of the remaining 17 banks, we find seven banks that have an approximately equal trading volume (5-10 percent of total volume). These are categorized as “medium-sized banks”. The remaining banks are regarded as “small”. The group of small banks will include some banks that are in the sample for only short periods of time. The aggregate of small banks as a percentage of total volume is, however, relatively constant over the sample period. The average daily trading volume in the spot market is about 700 million SEK for the large banks, 200 million SEK for the medium-sized banks, and 40 million for the small banks. Some statistical properties are reported in table 2.

The banks are also split by nationality. We then look at Swedish banks and foreign banks situated outside Sweden but registered as reporters in the SEK market.

2.2 Macrodata

In the volatility regressions we use both the absolute value of changes and squared value of changes in the exchange rate measured from close to close in the Swedish market.[3] This is the most relevant exchange rate because the majority of the volume reported is carried out before the Swedish market closes. The reports are sent to the Riksbank right after the close. For the period prior to January 1, 1999, we use SEK/DEM. The exchange rate is indexed to EUR equivalent terms (SEK/DEM$\times$1.95583). Before 1999, DEM played the role now taken by EUR.

Figure 2: The log of the SEK/EUR exchange rate and the difference between Swedish and German 10-year bonds

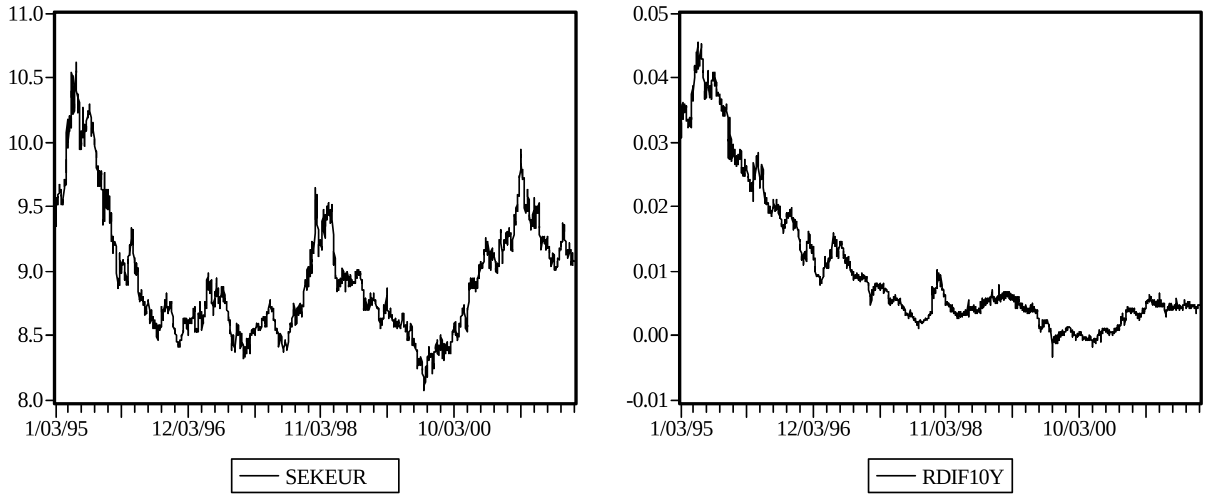

Figure 2 shows the exchange rate together with the 10-year bond spread between Sweden and Germany. From 1990 till November 1992, the SEK was pegged to the ECU. In November 1992, Sweden experienced a speculative attack, and the SEK was allowed to float and has been floating since then. Sweden introduced an inflation target in 1993. The current target is set by law at 2 percent, with a band of $\pm$ 1 percent. Sveriges Riksbank has no obligation to intervene in the foreign exchange market. A dummy is included to controll for days with interventions.

The krona appreciated sharply during 1995 and early 1996. A period of depreciation then followed the Russian moratorium in August 1998. Further, there was strong depreciationary pressure during 2000 and 2001. Over the period as a whole, the exchange rate

[3]Other potential measures for volatility is intra-day high-low or implied volatility from option prices. However, such data is not available for the SEK/EUR market.

has moved within a range of 27 percent from top to bottom. The standard deviation of daily changes over the period has been about 0.45 percent, with a maximum daily return of 2.0 percent. The bond spread gives an indication of the credibility of the inflation target and of macroeconomic developments in Sweden. It has fallen from nearly 4 percent in 1995 to a current spread fluctuating around zero.

According to the statistics from the BIS 2001 survey of the foreign exchange market, the Swedish krona is the eighth largest currency in the world. However, SEK is still a small currency compared to EUR, USD or JPY. An interesting question is to which extent the volatility in the SEK/EUR market is reflection of volatility in the relative price of SEK to EUR and to which extent it is the result of volatility in EUR on a broader scale. A movement in the USD/EUR rate might, for example, be expected to trigger expectations of a similar movement in the SEK/EUR rate. There is evidence of some correlation between the two series. The correlation over the period from January 1995 to June 2002 is 0.29. We include changes in USD/EUR in the regressions below, as a proxy of general volatility in the foreign exchange market.

2.3 Expected vs. unexpected volume

As pointed out above, Tauchen and Pitts (1983) differentiate between an increase in volume due to an increase in the number of traders and an increase in volume due to e.g. new information. An increase in volume due to an increase in the number of traders can be interpreted as “expected volume”. Expected volume should primarily increase liquidity, and should have little or negative impact on volatility. Bessembinder and Seguin (1992) and Hartmann (1999) document the importance of unexpected volume in explaining the volume-volatility relationship.

The standard method to distinguish between expected and unexpected volume is to identify systematic time-series behavior in the volume data, i.e. using an ARIMA-model. Using stationarity tests like the augmented Dickey-Fuller or the Phillips-Perron, we find no evidence of non-stationarity. However, when we estimate an ARMA-model on the volume series, the AR-root tends to be close to or outside the unit circle. At the same time we find that the MA coefficient is close to -1.

Similar observations have been made by Hartmann (1999). Hartmann has volume data reported from Tokyo-based brokers, covering trading in JPY/USD over the period from 1986 to 1994. He reports that the series are stationary according to standard tests, but the AR-roots have a unit root and the MA is close to -1. According to Hartmann, the fact that the MA is close to -1 might distort the stationarity tests. He therefore argues that one should treat the series as non-stationary.

Hartmann (1999) argues that an ARIMA(9,1,1) gives the best fit for his data. However, repeated tests on our sample do not seem to give any firm evidence of improvement when we move beyond an ARMA(2,2). We have run regressions using a number of different ARIMA specifications, and these do not seem to influence the results. Nor does it have any effect whether we use the level or the first difference in these regressions. We therefore choose to use a model that is as simple as possible.

Further, Hartmann argues that an ARCH(3) process removes ARCH/GARCH effects from his series. This feature can also be replicated in our data. However, again we find no improvement from using a GARCH(3,0) rather than the more standard GARCH(1,1). We therefore choose to use a GARCH(1,1).

To the ARMA(2,2) model we add a constant and dummies for each of first four days of the week. Chang, Pinegar, and Schachter (1997) document that there tend to be weekday patterns in volume data. Harris and Raviv (1993) have a model that predicts an increase in the volume on Mondays, as the dispersion of beliefs is higher after a period of closed markets. Foster and Viswanathan (1990) predict that volume on Mondays will be lower than Tuesdays, due to the fact that private information accrues over weekends, while public information does not. We find strong evidence in support of lower volume on Mondays, and some evidence in support of higher volume on Wednesdays. The predictions are in accordance with Foster and Viswanathan (1990). The results of the regressions are reported in table 12 in the appendix.

Our model of expected volume has a reasonable fit. For most series we find an R^2 between 30 and 60 percent. We use the fitted values as "expected", and the residual as "unexpected".

3 Results

In all our regressions a measure of volatility will be the dependent variable. We use two different measures. The first is absolute return, while the second is squared return. The second measure puts more emphasis on large changes than the first.

In the regressions we need to control for volatility that is expected, and hence can not be driven by new information or revisions in beliefs. To control for the expected volatility, all reported regressions are estimated using a GARCH(1,1)-M, meaning we include the squared root of the variance term in the regression as an estimate of conditional volatility.

We also take into account that volatility might be driven by the same underlying macro variables. It is therefore reasonable to include macro variables. These include absolute changes in the log of the USD/EUR, the log of a German stock index (DAX30), the log of a Swedish stock index (OMX16) and the 10 year and 3 month interest rate differential between Sweden and Germany. When the dependent variable is squared returns, these variables are included as squared changes. We also include a specific dummy that takes the value 1 in every period where Sveriges Riksbank reports an intervention. It is a notable result that this dummy is significant and positive in most regressions reported.

Theory suggests that it is unexpected volume that should be positively correlated with volatility. We estimate expected volume using ARMA(2,2) models. The residual from these models is defined as unexpected volume. Using generated regressors might bias the parameter estimates. All results should therefore be interpreted with care. We do, however, find that the results for the volume terms are stable with regard to choice of estimation methods.[4] Further, the important issue in our discussion is the comparison of volume from different groups—not the coefficient of volume itself. We have no reason to believe that a possible bias in the volume coefficient should be different between different groups.

The rest of this section provides results regressing volatility on volume in different instruments and volume from different reporters or groups of reporters.

3.1 Instruments

The most common approach to estimating the volume-volatility relationship would be to regress the volatility of spot exchange rates on some measure of spot volume. A reasonable a priori assumption is that a volume-volatility relationship for the spot exchange rate should be dominated by transactions in the spot market. Lyons (2001) describes the spot market as the driving force of the FX market. By comparison, a swap transaction has no "order flow" effect, as it is just two opposing transactions being made at the same time.

However, volume in other instruments than spot may reflect the arrival of new information or a dispersion of beliefs, and thereby also be informative about spot *volatility*. For instance, customers may take speculative positions by trading in forward contracts. In this case, the information effect might primarily be picked up by the forward volume, although this forward trading will trigger trading in the interbank spot market when the dealers try to off-load the effect on their inventories. Option volume may also reflect changes in beliefs about the true spot volatility, potentially due to new information. It may thus be interesting to see whether other instruments can also explain volatility.

Table 3 reports the estimations of volatility (absolute changes) on the volume for each of the five instruments. In the table, we focus only on the effect of expected and unexpected volume, although the regressions also include macro variables and predicted volatility. We see that the effect of expected volume is not significantly different from

[4] We have also used GMM and simple OLS regressions. There is no indication that this affects any of the results. Recursive regressions reveal that parameter stability in the volume parameters reported is good.

Table 3: Estimating $|\Delta log(SEK/EUR)|$. Sample: Jan. 1995–Jun. 2002. Daily observations

The table reports GARCH(1,1) regressions on the absolute value of changes in SEK/EUR. We only report results for the volume variables. Expected volume is the fit of an ARMA(2,2) model, while unexpected volume is the residual of this estimation. t-values are reported together with the regression coefficients, and ** and * indicates 1 percent and 5 percent significance levels. "R^2-adjusted (b)" reports R^2-adjusted with macro variables and the conditional variance but no volume. "R^2-adjusted (c)" is R^2-adjusted in a regression including only expected and unexpected volume.

	Spot			**Forward**			**Short swap**			**Swap**			**Options**		
unexpt.	0.0008	9.31	**	0.0004	2.38	*	0.0000	1.34		0.0001	3.11	**	0.0009	4.31	**
expt.	0.0001	0.75		0.0000	0.28		0.0001	2.33	*	0.0000	0.25		-0.0001	-0.75	
R^2**-adj.**	0.25			0.19			0.19			0.20			0.21		
DW-stat.	2.01			2.03			2.00			2.00			2.00		
R^2**-adj. (b)**	0.20			0.20			0.20			0.20			0.20		
R^2**-adj. (c)**	0.12			-0.02			-0.02			-0.02			-0.01		

Estimation includes the squared root of the conditional variance (ARCH-in-mean) and the following macro variable information (all as absolute changes): log(USD/EUR), German stock index, Swedish stock index, oil price, 10-year and 3-month interest differential between Sweden and Germany and a dummy that takes the value 1 on days when Sveriges Riksbank reports an intervention. Volume is measured in units of 10 billion SEK.

zero in four of the regressions. In the only regression with a significant coefficient on expected volume (short swaps), the coefficient is significantly positive and not negative. Theory predicts that the coefficient should be negative rather than positive since more expected volume from e.g. an increase in the number of dealers would typically mean higher liquidity.

For unexpected volumes we find positive and significant coefficients in four of the five regressions. As expected we see that spot volumes have the highest explanatory power. The table rows R^2-adj. (b) and R^2-adj. (c) report values for the regression only including macro variables and predicted volatility, and for the regression only including expected and unexpected volume, respectively. The table clearly shows that it is only the unexpected spot volumes that have an independent contribution to the explanatory power.

Table 4: Estimating volume and volatility. Sample: Jan. 1995–Jun. 2002. Daily observations

We estimate the absolute value and the squared value of $\Delta log(SEK(EUR)$ on unexpected volume (the residual of an ARMA(2,2)) and macro variables. The model is estimated using a GARCH(1,1). t-values are reported together with the regression coefficients.

	Abs.change			**Sq.change**		
SQR(GARCH)	1.01	12.05	**	0.54	1.39	
Const.	0.00	-2.14	*	0.00	-0.49	
Spot	0.0009	8.32	**	9.73E-06	6.54	**
Forward	-0.0003	-2.01	*	-3.61E-06	-0.72	
Short swap	-0.0001	-1.46		-1.43E-06	-1.03	
Swap	0.0000	-0.46		-7.39E-07	-0.48	
Options	0.0004	1.96	*	6.54E-06	1.73	
log(USD/EUR)	0.05	3.30	**	0.05	3.43	**
log(DAX30)	0.03	4.03	**	0.01	4.62	**
log(OMX16)	0.01	1.79		0.00	0.83	
log(Oil)	0.00	0.89		0.00	0.22	
$\left(r^{SWE} - r^{GER}\right)_{10Y}$	0.96	4.78	**	13.50	14.57	**
$\left(r^{SWE} - r^{GER}\right)_{3M}$	0.39	1.44		7.42	3.85	**
INT	0.00	2.68	**	0.00	1.93	
Var.eq.						
Const.	0.00	5.20	**	0.00	0.11	
ARCH(1)	0.05	5.50	**	0.15	5.70	**
GARCH(1)	0.94	97.55	**	0.60	32.66	**
R^2	0.26			0.20		
DW-stat.	2.01			1.84		

Volume is measured in units of 10 billion SEK.

Note 1: * 5 percent, ** 1 percent.

Note 2: INT - dummy that takes the value 1 on days when Sveriges Riksbank report an intervention.

Note 3: sqr(GARCH) - squared conditional variance (ARCH-in-mean).

Note 4: All macro variables are included as absolute changes in the regression on absolute changes, and squared changes in the regression on squared changes.

Table 4 reports regressions including the unexpected volume of all instruments. Since expected volume does not seem to be important in the single regressions presented in table 3, we only include unexpected volumes. We report regressions on both absolute changes and squared changes in the exchange rate. The results are qualitatively similar, although the explanatory power is a little less when using squared returns. We find that only spot trading enters with a significant and positive value at the five percent level in both regressions. The coefficient on option volume is significantly larger than zero at the five percent level in the regression with absolute returns as the dependent variable, but only at the ten percent level in the regression with squared returns as dependent variable. For forward, swap and short swap trading the coefficients are actually negative, however, not significantly different from zero except in one case. Short swaps are primarily liquidity instruments, while ordinary swaps are more interest rate related instruments. It is much harder to think about information releases that might trigger swap volume instead of spot volume, while still having implications for spot exchange rate, than it is with e.g. options. Given our results, we find it natural to focus on spot volumes only in later regressions.

Table 5: Relative effects on volatility. Sample: Jan. 1995–Jun. 2002.
"Percent of FX volatility" is the ratio of "Predicted effect" over the standard deviation of absolute returns in the SEK/EUR (measured in percent). "Predicted effect" is the predicted effect of a change of one standard deviation (multiply st.dev with parameter). All parameters are collected from table 4.

	St.dev.	**Parameter**	**Predicted effect**	**% of FX-volatility**
abs. change in SEK/EUR	0.0031			
Unexp. spot	0.9334	0.0009	0.00084	26.85
abs. change in USD/EUR	0.0043	0.05	0.0002	6.99
abs. change in RDIF10	0.0004	0.96	0.0004	12.76
SQR(GARCH)	0.0008	1.01	0.0008	24.95

The size effects of the parameter values in table 4 are not obvious. To give an indication of size effects, we perform an illustrative exercise in table 5. One standard deviation of absolute returns is 0.3 percent. If we multiply the standard deviation of the conditional volatility term (0.0008 or 0.08 percent) with the parameter value of 1.01 (in the case of the regression on absolute changes reported in table 4), we obtain 0.0008 (0.08 percent). Compared with the standard deviation of the absolute changes in SEK/EUR, we see that this variable is economically significant. A similar procedure for unexpected spot volumes gives a number of 0.00084 (or 0.084 percent). This indicates that the coefficient on unexpected volume is also economically significant. Interestingly, we see that the coefficient on absolute changes in USD/EUR is not so significant economically. A change of one standard deviation in the variable multiplied by the coefficient gives a value of only

0.0002 (or 0.02 percent). Thus, volatility in the most important currency pair (that is USD/EUR) is not a very important driver of volatility in SEK/EUR.

3.2 Reporters

Recent research from the microstructure approach to foreign exchange indicates that traders have different strategies and information (see e.g. Lyons, 1995; Bjønnes and Rime, 2000). It is also reasonable to assume that different banks will focus on specific types of trading strategies (Cheung and Chinn, 2001). However, banks are mostly unwilling to reveal their explicit strategies, so this is an area where few results have been published.

We have bank-specific volumes and can therefore test for differential impact from banks on volatility directly. A priori, it is not obvious that different reporters should be correlated differently with volatility. If the increase in number of transactions is due to the arrival of public information only, we should expect a simultaneous increase in trading from all reporters. However, if the dispersion of beliefs (different dealers interpret information differently) is important, or if different dealers are asymmetrically informed, then the trading volume of some reporters might be more closely correlated with volatility than the volume of other reporters.

Table 6: Estimating $|\Delta log(SEK/EUR)|$. Sample 01.1995–12.2001
The table reports GARCH(1,1) regressions on the absolute value of changes in SEK/EUR. We only report results for the volume variables. Expected volume is the fit of an ARMA(2,2) model, while unexpected volume is the residual of this estimation. Large banks are the two largest reporting banks in the sample. Medium banks are the seven following banks. Small banks are remaining reporters. t-values are reported together with the regression coefficients.

	Large			**Medium**			**Small**		
unexpt.	0.0016	8.39	**	0.0014	8.18	**	0.0027	5.62	**
expt.	0.0006	3.02	**	0.0001	0.87		-0.0001	-0.48	
R^2**-adj.**	0.25			0.23			0.22		
DW-stat.	2.01			2.01			2.03		

The issue of the size of the bank can be tested more thoroughly. In table 6 we have estimated the relationship by grouping reporting banks into three categories, small, medium, and large, according to size of volume. Aggregated, the two banks included in "large banks" on average control 45 percent of daily spot trading. In "medium-sized banks" we include seven banks that on average control 43 percent of trading in the spot market. "Small banks" are the remaining banks.

We see that for all groups there is a significant effect from unexpected volume. In fact the coefficient is clearly larger for small than for large banks. However, the adj. R^2s are highest for the regression with large banks. By studying table 7 a clear picture emerges. We see that the regression with only volume from large banks as the independent variable explains 15 percent of FX volatility, while the regression with medium banks explains

Table 7: Adjusted R^2. Sample: Jan. 1995–Jun. 2002

Table shows adjusted R^2 from three separate estimation:
"Macro": Estimation includes the squared root of the conditional variance and the following macro variable information (as absolute changes in regression on absolute changes, as squared changes in regression on squared changes): log(USD/EUR), German stock index, Swedish stock index, oil price, 10 year and 3 month interest differential between Sweden and Germany and a dummy that takes the value 1 on days when Sveriges Riksbank reports an intervention.
"Volume" includes expected and unexpected volume of the specified group. Volume is measured in units of 10 billion SEK.
"Macro & volume" is identical to the estimations in table 6.

Abs. changes	**Macro**	**Volume**	**Macro & Volume**
Large	0.20	0.15	0.25
Medium	0.20	0.06	0.23
Small	0.20	0.02	0.22
Sq. changes			
Large	0.16	0.13	0.22
Medium	0.16	0.06	0.18
Small	0.16	0.03	0.17

only 6 percent. Note that average total volume for medium banks is roughly similar to the total volume of large banks. The regression with only small banks explains only 2 percent. The difference in explanatory power is considerable, especially when considering that inter-dealer trades increase the correlation between the volumes of different groups.

In table 8 we report regressions including unexpected volume from all three categories. When we run this regression on absolute changes in SEK/EUR, we find that all groups are significant.

An interesting result becomes visible when we repeat the same regression on squared changes. In this case, only the volume of large banks is significant. Squared changes do of course put more weight on extreme observations than absolute changes. This result seems to indicate that when volatility is truly high, trading tends to coalesce around the largest banks.

A second indication of the importance of large banks can be found in table 9. Here we compare the effect of volume from each of the three groups for the regression with absolute change in SEK/EUR. By comparing predicted effects of a one standard deviation change in the independent variables, we see that the effect of large banks is much stronger than the effect of medium and small banks.

Table 10 tests whether differences in nationality matter. To be able to compare banks of similar size, we exclude the two largest (Swedish) banks. By also excluding branches of foreign banks located in Sweden, we think that the difference between Swedish and foreign banks should be as clear as possible. The group of Swedish banks (excluding the two largest) covers on average 20 percent of total volume, while the group of foreign banks covers 25 percent. In the regression with absolute changes in SEK/EUR as the dependent variable, we see that the coefficients of unexpected volumes are significantly

Table 8: Estimating volume and volatility — banks divided by size. Sample: Jan. 1995-Jun. 2002. Daily observations

We estimate the absolute value and the squared value of $\Delta log(SEK(EUR)$ on unexpected volume (the residual of an ARMA(2,2)) and macro variables. The model is estimated using a GARCH(1,1). Large banks are the two largest reporting banks in the sample. Medium banks are the seven following banks. Small banks are remaining reporters. t-values are reported together with the regression coefficients.

	Abs. change			Sq. change		
SQR(GARCH)	0.98	11.78	**	0.52	1.32	
Const.	0.00	-1.45		0.00	-0.42	
Large	0.0011	5.08	**	1.41E-05	4.07	**
Medium	0.0005	2.71	**	2.38E-06	0.49	
Small	0.0012	3.10	**	1.12E-05	1.22	
log(USD/EUR)	0.05	3.30	**	0.05	3.40	**
log(DAX30)	0.03	4.06	**	0.01	4.48	**
log(OMX16)	0.01	1.60		0.00	0.78	
log(Oil)	0.00	0.84		0.00	0.17	
$\left(r^{SWE}-r^{GER}\right)_{10Y}$	0.87	4.32	**	13.39	14.31	**
$\left(r^{SWE}-r^{GER}\right)_{3M}$	0.23	0.86		6.92	3.58	**
INT	0.00	2.75	**	0.00	1.93	
Var.eq.						
Const.	0.00	4.72	**	0.00	0.11	
ARCH(1)	0.05	5.43	**	0.15	5.58	**
GARCH(1)	0.94	93.43	**	0.60	30.93	**
R^2	0.26			0.20		
DW-stat.	2.02			1.84		

Volume is measured in units of 10 billion SEK.

Note 1: * 5 percent, ** 1 percent.

Note 2: int - dummy that takes the value 1 on days when Sveriges Riksbank reports an intervention.

Note 3: sq(GARCH) - squared conditional variance (ARCH-in-mean).

Note 4: All macro variables are included as absolute changes in the regression on absolute changes, and squared changes in the regression on squared changes.

Table 9: Relative effects on volatility. Sample: Jan. 1995–Jun. 2002.

"Percent of FX volatility" is the ratio of "Predicted effect" over the standard deviation of absolute returns in the SEK/EUR (measured in percent). "Predicted effect" is the predicted effect of a change of one standard deviation (multiply st.dev with parameter). All parameters are collected from table 8.

	St.dev.	Para-meter	Predicted effect	% of FX-volatility
abs. change in SEK/EUR	0.0031			
Large	0.4948	0.0011	0.0005	17.09
Medium	0.4266	0.0005	0.0002	6.97
Small	0.1875	0.0012	0.0002	7.09
abs. change in USD/EUR	0.0043	0.05	0.0002	6.97
abs. change in RDIF10	0.0004	0.87	0.0004	11.62
SQR(GARCH)	0.0008	0.98	0.0007	24.26

Table 10: Estimating volume and volatility. Sample: Jan. 1995–June. 2002. Daily observations

We estimate the absolute value and the squared value of d(log(SEK(EUR)) on unexpected volume (the residual of an ARMA(2,2)) and macro variables. The model is estimated using a GARCH(1,1). t-values are reported together with the regression coefficients.

"Swedish" are all Swedish reporters with the exception of the two largest banks, "foreigners" are all foreign reporters. "Swedish" make up approx. 20 percent of total volume, "foreigners" approx. 25 percent of total volume.

	Abs. change			**Sq. change**		
SQR(GARCH)	1.05	11.94	**	0.53	1.30	
Const.	0.00	-3.11	**	0.00	-0.49	
Swedish	0.0019	5.31	**	1.95E-05	4.06	**
Foreign	0.0010	5.09	**	7.81E-06	1.39	
log(USD/EUR)	0.06	3.87	**	0.05	3.61	**
log(DAX30)	0.03	4.28	**	0.01	4.76	**
log(OMX16)	0.01	1.79		0.00	0.83	
log(Oil)	0.00	1.15		0.00	0.28	
$\left(r^{SWE} - r^{GER}\right)_{10Y}$	1.01	4.72	**	14.29	15.42	**
$\left(r^{SWE} - r^{GER}\right)_{3M}$	0.30	1.13		7.50	3.67	**
INT	0.00	3.14	**	0.00	2.28	*
Var.eq.						
Const.	0.00	6.52	**	0.00	0.11	
ARCH(1)	0.05	5.13	**	0.15	5.45	**
GARCH(1)	0.94	86.46	**	0.60	33.98	**
R^2	0.23			0.18		
DW-stat.	2.02			1.86		

Volume is measured in units of 10 billion SEK.

Note 1: *-5 percent, **-1 percent.

Note 2: int - dummy that takes the value 1 on days when Sveriges Riksbank reports an intervention.

Note 3: sqr(GARCH) - squared root of conditional variance (ARCH-in-mean).

Note 4: All macro variables are included as absolute changes in the regression on absolute changes, and squared changes in the regression on squared changes.

positive for both Swedish and foreign banks. However, the size of the coefficient is almost twice the size for Swedish banks. When considering the regression with squared changes in SEK/EUR, the picture becomes even clearer. The coefficient on Swedish banks is highly significant, while the coefficient on foreign banks is insignificant.

Table 11: Estimating volume and volatility. Sample: Jan. 1995–Jun. 2002. Daily observations

We estimate the absolute value and the squared value of d(log(SEK(EUR)) on unexpected volume (the residual of an ARMA(2,2)) and macro variables. The model is estimated using a GARCH(1,1). t-values are reported together with the regression coefficients.

"Large Swedish" are the two largest banks, "other Swedish" are other Swedish banks. "Large Swedish" make up approx. 45 percent of total volume, "other Swedish" approx. 20 percent of total volume.

	Abs. change			**Sq. change**		
SQR(GARCH)	0.95	6.90	**	0.51	1.31	
Const.	0.00	-0.91		0.00	-0.41	
Large Swedish	0.0013	12.74	**	1.60E-05	4.35	**
Other Swedish	0.0007	3.25	**	3.78E-06	0.55	
log(USD/EUR)	0.06	5.33	**	0.05	3.44	**
log(DAX30)	0.03	5.38	**	0.01	4.42	**
log(OMX16)	0.01	2.36	*	0.00	0.81	
log(Oil)	0.00	1.00		0.00	0.16	
$\left(r^{SWE} - r^{GER}\right)_{10Y}$	0.85	7.38	**	13.34	14.26	**
$\left(r^{SWE} - r^{GER}\right)_{3M}$	0.14	0.88		6.95	3.54	**
INT	0.00	5.33	**	0.00	1.93	
Var.eq.						
Const.	0.00	2.14	*	0.00	0.11	
ARCH(1)	0.05	10.14	**	0.15	5.60	**
GARCH(1)	0.95	216.55	**	0.60	30.93	**
R^2	0.25			0.20		
DW-stat.	2.01			1.84		

Volume is measured in units of 10 billion SEK.
Note 1: * 5 percent, ** 1 percent.
Note 2: INT - dummy that takes the value 1 on days when Sveriges Riksbank reports an intervention.
Note 3: sqr(GARCH) - squared root of conditional variance (ARCH-in-mean).
Note 4: All macro variables are included as absolute changes in the regression on absolute changes, and squared changes in the regression on squared changes.

We also test whether Swedish banks of different size (large vs. small and medium-sized banks) had different effects (table 11). The results again suggest that size is important. To sum up, size is important when explaining volatility. This indicates that private information may be an important driver of FX volatility in SEK/EUR. The finding that Swedish banks (controlling for size) are more important when explaining volatility than foreign banks may suggest that volatility in SEK/EUR is primarily related to economic conditions in Sweden.

4 Conclusion

The literature on volume and volatility asks one primary question: why does the relationship arise? If everyone has the same expectations, and all groups behave similarly, the effect should be caused by more trading due to the arrival of new information. However, all rational agents should have the same opportunity to take advantage of the new information, and heterogeneity should be of less importance. On the other hand, if the volume-volatility relationship is the result of dispersion of beliefs or asymmetric information, then heterogeneity is certainly a central feature in the analysis.

This paper reviews evidence from a unique set of volume data from the Swedish FX market, covering five and half years of daily data. The Swedish market is a small market compared with e.g. the USD/EUR or USD/JPY market. However SEK/EUR is among the 10 most traded currency crosses in the world, and the market is well developed with high liquidity. For this market we find evidence to indicate that different agents have different effects on the volume-volatility relationship. In particular, we find that it is the volume of the largest banks that is most important. In the SEK market these banks are Swedish banks. There is reason to believe that the large Swedish banks are relatively well informed. This is in contrast with the findings of Daigler and Wiley (1999) from future markets that it is the volume of the least informed traders that creates the volume-volatility relationship. While the Daigler and Wiley result is about noise-traders, our result is one about information advantage. We also find that Swedish banks are more important when explaining volatility than foreign banks even when controlling for size. This suggests that volatility in SEK/EUR is primarily related to economic conditions in Sweden.

A Tables

Table 12: Estimating an ARMA(2,2) process on volume. Period: 01.95-6.02
Model is estimated to differentiate expected and unexpected volume. We treat the fit of the model as expected, and the residual as unexpected. The model is estimated using an GARCH(1,1).

	Total spot			Large banks			Small banks		
Const.	2.91	10.15	**	1.29	17.34	**	0.34	2.89	**
Monday	-0.39	-7.59	**	-0.19	-7.47	**	-0.04	-3.85	**
Tuesday	0.12	2.23	*	0.04	1.42		-0.01	-0.63	
Wednesday	0.23	4.03	**	0.10	3.33	**	0.01	1.51	
Thursday	0.14	2.58	**	0.05	1.60		0.02	1.77	
ZERO	-3.20	-23.32	**	-1.34	-29.61	**	-0.41	-10.89	**
AR(1)	1.58	22.90	**	1.52	16.45	**	1.37	7.52	**
AR(2)	-0.58	-8.56	**	-0.53	-5.86	**	-0.37	-2.06	*
MA(1)	-1.25	-15.83	**	-1.26	-12.41	**	-1.11	-5.91	**
MA(2)	0.29	4.11	**	0.30	3.37	**	0.19	1.20	
Variance Eq.									
Const.	0.05	2.04	*	0.01	2.31	*	0.00	0.56	
ARCH(1)	0.06	3.38	**	0.06	2.60	**	0.03	5.35	**
GARCH(1)	0.87	19.65	**	0.89	24.04	**	0.97	158.82	**
R^2	0.49			0.38			0.55		
DW-stat.	1.92			1.91			2.03		

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