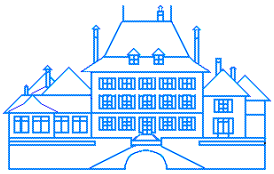

STUDIENZENTRUM GERZENSEE

STIFTUNG DER SCHWEIZERISCHEN NATIONALBANK

Price Clustering in the FX Market:

A Disaggregate Analysis using Central Bank Interventions

Andreas M. Fischer

Working Paper 04.04

Price Clustering in the FX Market:

A Disaggregate Analysis using Central Bank Interventions*

Andreas M. Fischer†

June 2004

Abstract

Price clustering is a well-documented regularity of foreign exchange transactions. In this paper, I present new empirical evidence of price clustering for central bank interventions. A feature of the price clustering in Swiss National Bank (SNB) transactions is market dependency. Evidence of clustering in the broker market is considerably smaller than in the dealer market. The empirical analysis for Swiss interventions uses a disaggregate approach to test the hypothesis whether intervention strategy matters. The most important determinants of price clustering are bank size and transaction volume. While the regression evidence for customer transactions is consistent with the efficiency hypothesis, the clustering results for intervention trades are not influenced by the SNB's intervention tactics.

Keywords: Central Bank Interventions, Intervention Strategy, Clustering
JEL Classification Number: E31, E33

† Study Center Gerzensee and CEPR, Postfach, 3115 Gerzensee, Switzerland
telephone (+41 31) 780 31 05, FAX (+41 31) 780 31 00
e-mail: andreas.fischer@szgerzensee.ch

* Without implicating them, I would like to thank Bruno Biais, Kathryn Dominguez, Charles Goodhart, Elmar Mertens, Carol Osler, and Marcel Zimmermann for helpful comments and discussion.

Introduction

Price clustering is a well-documented regularity of foreign exchange transactions. Sopranzetti and Datar (2002), Grossman *et al.* (1997), and Goodhart and Curcio (1991) find that indicative quotes for currencies end mostly with either a 'zero' or a 'five'. Goodhart and Figliuoli (1991) observed that round numbers are disproportionately represented in bid-ask spreads for major currencies. Osler (2000) notes that published support and resistance levels used for technical analysis of the major currencies are frequently numbers that end in zero or five. In a later study, Osler (2003) documents strong evidence of price clustering in currency stop-loss and take-profit orders.

This paper's objective is to extend the price clustering analysis in the foreign exchange market to central bank interventions. A first task is to determine whether central bank interventions suffer from clustering behavior? Although the intervention literature surveyed by Edison (1993) and Taylor and Sarno (2001) is silent on the issue of price clustering and central bank intervention, Grossman *et al.* (1997) and others have identified price clustering with increased market volatility through larger spreads. If so, then price-clustered interventions may amplify uncertainty; thus generating the opposite effect intended by central banks. Such activity is consistent with

the empirical evidence in Dominguez (1998). She finds that central bank interventions heighten exchange rate volatility.[1]

A further issue concerning the intervention-clustering nexus is intervention tactics. Chiu (2003), Lecourt and Raymond (2004), and Neely (2001), in their surveys on intervention practices, note that the monetary authorities pursue heterogeneous intervention tactics. If central bank interventions exhibit price clustering, does this arise endogenously because of market conditions at the time of an intervention or are there elements of the intervention strategy (i.e., timing, transaction size, or trades with specific banks) that influence the degree of rounding? In the latter case, if central banks are concerned about price clustering and the consequences of heightened exchange rate volatility, market microstructure argues that certain tactical decisions could influence the degree of clustering observed in intervention trades. For example, Harris (1991) argues that large sized transactions motivates the incentive to search for finer prices. This implies in the extreme case that high volume interventions are traded at finer prices than small volume transac-

[1]There is a large literature on exchange rate volatility and central bank interventions. The the references can be found in Humpage (2003) and Dominguez (2004). See also the information based model of Naranjo and Nimalendran (2000) that links unexpected interventions with wider spreads to unexpected interventions.

tions. This would be one channel where intervention design influences the degree of price clustering. Alternatively, if price clustering found in intervention trades is strictly endogenous to the timing of the intervention, then the intervention tactics defined by intervention size or other factors should have no influence.

To shed light on the question whether intervention tactics influence the level of price clustering in central bank transactions, the empirical analysis of Swiss interventions from 1986 to 1995 uses a disaggregate approach. While central banks are frequently pricetakers in the dealer market when executing their intervention trades, the disaggregate regressions are able to determine if price clustering is associated with non-price elements that the central bank controls during an intervention trade: i.e., counterparty, transaction volume, timing, location, or repeated interventions. The disaggregated data are from the official transaction slips of the Swiss National Bank (SNB).[2] Although the study's focus is on interventions, customer transactions are also used to highlight distinct features between the dealer and the broker market.

[2]Transaction prices and volume have been used in numerous studies, which examine the effectiveness of SNB interventions: Fischer (2003a, 2003b), Fischer and Zurlinden (1999), Paine and Vitale (2003), and Pasquariello (2002). New is the information on the counterparty bank of the SNB trades.

The paper is organized as follows. Section one discusses institutional issues and the transactions data used to test for price clustering. Descriptive evidence of price clustering is also offered in the same section. Thereafter in section two, the empirical strategy is defined and the testable hypotheses for the intervention strategy are specified. The regression results of the disaggregate approach are presented in section three. Section four concludes.

1. SNB Transactions in the FX Market: 1986 to 1995

The empirical analysis considers two types of SNB transactions: foreign exchange interventions and customer transactions. Both types of transactions are discussed in detail in the next sub-section. This is then followed by preliminary evidence used to motivate the empirical framework in section three.

SNB Transactions: Some Institutional Features

The SNB intervenes to influence the trend of the exchange rate or to counteract market disturbances. Solidarity with other central banks has also been an important motive in the past because almost all interventions were coordinated. This motive is further underscored by the observation that the scale of the SNB interventions tended to be small and SNB governors

have expressed skepticism on several occasions about the effectiveness of such operations. This however does not imply that the SNB has always followed the lead of the Federal Reserve and the Bundesbank. These two central banks have intervened more frequently than the SNB has.

SNB interventions are conducted via telephone correspondence in the dealer market with foreign and domestic commercial banks operating in several Swiss cities.[3,4] It is common for the SNB's trading desk to gather *binding* quotes from commercial banks before executing an intervention transaction. The SNB's activity in the dealer market is limited and should be treated as a pricetaker. Supportive evidence of pricetaking behavior is observed by comparing intervention trades with bid-ask quotes retrieved from the work notes of SNB dealers: in every instance the SNB trades were executed at the ask price on orders to buy dollars and at the bid price on orders to sell dollars.[5]

[3]The major city is Zurich followed by Basel, Geneva, and Lugano. Other locations on a minor scale include Zug and St. Gallen.

[4]Telephone correspondence represents the norm. Neely (2001) in his survey of operational issues for 22 central banks finds that most central banks conduct their interventions through telephone correspondence. Other possibilities include electronic brokers (i.e., Reuters 2002 or EBS) or direct dealing with counterparties via electronic communication.

[5]The (unofficial) work notes of the SNB dealers are available only from 1992 to 1995

The SNB communicates its interventions directly with the counterparty. After the intervention trade has been completed, the SNB informs the trader of the commercial bank that the transaction is an intervention. According to SNB officials, the intervention announcement spreads swiftly across the dealer market. The SNB makes no formal declaration to news agencies that it is intervening. The SNB in most cases will be asked by a newswire service if it has intervened, in which case an SNB spokesman will confirm or refute the intervention claim.

The SNB's intervention strategy may be described as following a shotgun tactic. An intervention session is characterized by numerous intervention transactions of small volume. The volume per transaction is most often either \$5 or \$10 million.[6] The sessions, which begin with trades with the Big Banks, followed by small Swiss banks and then foreign banks domiciled in Switzerland, are generally completed within 10 to 30 minutes.[7] With this tactic, the intervention's news is disseminated in the dealer market.

---

and cover only 36 trades.

[6]Only on rare occasions was the transaction's size over \$20 million.

[7]Big Banks is an expression frequently used in Switzerland to denote a select group of large Swiss banks. For the analyzed sample they include Union Bank of Switzerland, Credit Suisse, Swiss Bank Corporation, and Volksbank.

The second type of SNB trades is customer transactions.[8] These are purchases of U.S. dollars triggered by the Swiss government's request for foreign currency. If the government needs other foreign currencies, the SNB buys these currencies with U.S. dollars in the market. The government's currency requests thus result in a dollar outflow. In turn, the SNB compensates this outflow by repurchasing U.S. dollars against Swiss francs either directly from small domestic banks or through the BIS.

Customer transactions, as opposed to interventions, are brokered transactions via telephone correspondence. This means, unlike for the intervention trades, no quote gathering process takes place. It is thus not the SNB's intention to influence the Swiss franc with these type of transactions. The SNB has some scope in timing the customer transaction. As such, customer transactions are more likely to be performed when exchange rate volatility is low as opposed to interventions. Further, customer transactions are not split up as are interventions. It is only on rare occasions that the SNB will conduct more than one customer transaction per day. This means they are

[8]This is the term coined by Fischer and Zurlinden (1999). It is somewhat unconventional, because the actual customer transaction is the purchase of (other) foreign currencies for dollars on behalf of the government.

generally large volume transactions. Under these procedural arrangements (i.e., speed of transaction, counterparty type, transaction volume), it may be expected that customer transactions are less subject to price clustering than are interventions.

Descriptive Evidence of Price Clustering in SNB Transactions

Descriptive evidence of price clustering in SNB transactions is offered to motivate the disaggregate approach. The sample, as in the empirical regressions of section three, is from 1986 to 1995. The sample's size is determined by data availability. The SNB's records for its transactions do not go beyond 1986 and the last SNB intervention was conducted on 15 August 1995.[9]

Table 1 documents the evidence for the last digit of SNB transactions in the CHF/USD exchange rate. The upper half of the table provides evidence for interventions, whereas the lower half is for customer transactions. The former should reflect clustering in the dealer market, whereas the latter in the brokerage market. Price clustering is the result of the use of a coarse pricing set in which only a small fraction of the full set of potential prices are actually used. The evidence of price clustering in the odd and even ending

[9]A further consideration is the definition of customer transactions. Shortly after 1995, the SNB booked differently its customer transactions with the federal government.

digits is not as pronounced as those ending in zero or five. Hence, the analysis will focus on the latter form of clustering.

The evidence of price clustering in zeros and fives is considerably stronger for SNB interventions than for SNB customer transactions. The percentage for total interventions in Table 1 finds that roughly 80% of the transacted exchange rates end in either a zero or a five, whereas for total customer transactions the percentage is 40%. These percentages for the zero and five digits are not as high as the 91% found by Pasquariello (2002) for the CHF/USD exchange rate quotes in the dealer market. Moreover, he finds that the zero quotes (78%) dominate the five quotes (13%) by a margin of six to one, implying that there is clustering for even ending-digits as opposed to odd-ending digits. The evidence in Table 1 does not support such asymmetric behavior of SNB transaction prices.

Table 1 also divides the price clustering evidence along several dimensions. The first is interventions into purchases and sales of U.S. dollars. The same cut for customer transactions is not made since all of these transactions are dollar purchases. The results show that the direction of the intervention does not influence the price clustering result. Also of interest is the clustering of

refused bid-ask quotes during the intervention sessions from 1992-1995.[10] Although the number of observations is limited (and therefore the evidence should be treated with caution), it says that the SNB does not discriminate between the zero and five ending digits versus the others in accepting or refusing offers during the intervention round. This can be interpreted as weak evidence that the clustering of intervention trades is dependent on market conditions in the dealer market and is not influenced by intervention tactics.

A further sign of clustering in intervention transactions is that none of the end digits is close to the expected 10% level. The percentages for the digits '2', '3', '7' and '8' lie below 5% followed by the digits '1', '4', '6', and '9', which border '0' and '5', are even below 1%. This information is consistent with the resolution hypothesis of Ball, Torous, and Tschoegl (1985), which says that price clustering is the achievement of an optimal degree of price resolution.

[10]The sample of 33 refused bid-ask quotes in Table 1 do not represent all the refused quotes in the 1992-1995 period. The quotes stem from the (unofficial) work notes of the SNB dealers and should not be regarded as complete. Again, direct comparison with customer transactions is not possible for quote gathering does not take place for customer transactions.

If the price resolution theory were correct, one would find symmetry between odd and even final digits and that the ranking of the final digits would be 0, 5, (2=3=7=8), and (1=4=6=9). This result is supported by the sign tests for interventions (but not for customer transactions) recorded in Table 2. The result for interventions is at odds with the evidence in Goodhart and Curcio (1991) for exchange rate quotes.

An issue in many empirical studies is that price clustering varies over time. Gwilym, Clare and Thomas (1998), for example, show that intraday price clustering is strongest during the opening and closing of the futures market for FTSE 100 index contracts. These are the hours when trading is most intense. Figure 1 shows the same intraday information for SNB transactions. The hourly breakdown finds that the zero and the five frequencies are quite stable throughout the day. An exception is the lower clustering frequency of late hour trades in customer transactions. One explanation is the low number of customer transactions in the late afternoon: 68% of the customer transactions were conducted in the morning hours from 8:00 am to 12:00 am o'clock.

An alternative form of time variation that influences the degree of price clustering is along the calendar domain. Figure 2 shows annual frequency

patterns of the zero and five end digits. The clustering frequency for interventions rises slowly between 1986 and 1992 and is volatile thereafter. The high volatility at the tail end of the sample is marked by the fact that the SNB did not intervene in 1993 and that few interventions were carried out in 1994 and 1995.[11] Also, the frequency of price clustering in customer transactions appears to be time varying. It falls noticeably in the years from 1989 to 1994.

The descriptive analysis finds strong evidence of price clustering for intervention trades, whereas the level of clustering for customer transactions is less pronounced. To determine whether the clustering of interventions is influenced through intervention tactics determined by counterparty type, time, or volume an empirical framework handling the disaggregate data is first outlined in the next section.

2. The Empirical Framework

A probit model is used to test competing hypotheses that explain the

[11] Grossman *et al.* (1997) also present evidence of increased price clustering over time. They show an increase in the use of odd-eighth quotes for Nasdaq securities from 1 January 1993 to 31 December 1994.

clustering phenomena of SNB transactions in the CHF/USD currency market. The disaggregated specification defined for interventions is as follows (A similar variant of equation (1) is considered for customer transactions):

$$\begin{aligned} S_t &= b_0 + b_1 BigBank_t + b_2 DomBank_t + b_3 Loc_t \\ &\quad + b_4 Repeat_t + b_5 Time_t + b_6 Vol_t + \epsilon_t, \end{aligned} \tag{1}$$

where the dependent variable, S_t, is +1 if the transacted exchange rate ends in a zero or a five, 0 otherwise. Next, the explanatory variables are defined as follows: $BigBank_t$ is +1 if a Big Bank is the counterparty to the transaction, 0 otherwise; $DomBank_t$ is +1 if the transaction is with a Swiss bank, 0 if it is with a foreign bank; Loc_t is +1 if the counterparty bank is located in Zurich, 0 otherwise; $Repeat_t$ is +1 if the transaction is repeated in the same day, 0 if it is the first intervention; $Time_t$ is the time of the transaction; and Vol_t is the size of the transaction. Last, ϵ_t denotes the error term.

Under the null hypothesis that intervention tactics of a pricetaking central bank should not matter, this implies the non-price elements that the central bank controls should have no bearing on the level of clustering. To reject the null hypothesis, a set of coefficients in equation (1) need to be significant

and stable across the different regressions.

Interlinked in this discussion of intervention tactics and transaction type is the negotiation efficiency hypothesis by Harris (1991) and Grossman *et al.* (1997). The efficiency hypothesis says that if buyers and sellers are eager to speed up the negotiation process of their transactions, then they will not quibble over small increments in price. In a similar manner, the central bank in its intervention operations prefers to choose round numbers to minimize time and error in their communication with dealers.[12] In the SNB's intervention strategy, the quick dissemination of news is an important prerequisite for a successful intervention. Once the patterns of communication are established, Osler (2003) argues that rounding may be self-reinforcing even in the presence of rational speculative activity.

For interventions and customer transactions, the efficiency hypothesis says that there should be no observable difference in the timing, type of commercial bank, and location for transactions of the same size. Hence, these variables should not be significant in equation (1). However, as the

[12]This evidence would also be supported by the hypothesis that agents prefer certain numbers for purely behavioral reasons, see Yule (1927), possibly because they are easiest to process, cognately.

transaction's volume increases, the incentives of the pre-established pricing pattern defined under the efficiency hypothesis diminish. Smaller transactions should thus observe a larger occurrence of rounding (i.e., $b_6 < 0$ in equation (1)), because larger transactions would benefit the most of precise pricing. Because speed and timing are important features of interventions as opposed to customer transactions, it is expected that the volume impact defined by the efficiency hypothesis is stronger for customer transactions than for interventions.

3. Empirical Results of Foreign Exchange Clustering

The regression results confirm the descriptive evidence offered in Figure 1 and Table 1. The clustering result with SNB transactions holds for the dealer and the broker market, however the importance of the transaction's attributes differs across markets. For the intervention trades, the tactical factors are either not significant or give mixed results across the different regressions. I interpret this as evidence that the non-price elements under the control of the central bank have no influence on clustering in intervention trades. For customer transactions, however, the disaggregate regressions find stable coefficients for transaction volume and brokered trades with the BIS.

These results are consistent with the efficiency hypothesis.

Table 3 summarizes the regression results for SNB interventions. The analysis depends on disentangling the directional effects of transaction's characteristics on price clustering. For example, a negative coefficient for the volume variable, β_6 in equation (1), suggests that increasing volume size will decrease the probability of price clustering in SNB transactions; a positive value implies the opposite.

The main observations are the following. First, location, time, and repeated interventions are not statistically significant in the different variants of equation (1).[13] This suggests that tactical choices of geographical location, timing, and frequency of interventions are not associated with rounding.

A second observation is that as intervention volume increases so does clustering in the final zero digit. This variable is positive and significant for the final zero digit, but negative and insignificant for the five digit. The combined impact for the zero and five digits is also positive and significant. Sopranzetti and Datar (2002) find similar evidence for indicative quotes for

[13]The insignificance of the variable $Repeat_t$ is also true for alternative definitions of $Repeat_t$, i.e., +1 after 5 minutes after the first intervention. Hourly dummy variables in place of the time variable were also considered. These were also insignificant.

six currencies against the US dollar. This result for Vol_t is not consistent with the efficiency hypothesis, which would expect a finer price setting to occur as intervention volume increases.

An open issue is whether the positive correlation between intervention volume and clustering arises from increased intervention intensity. In this case, a positive correlation and not a negative correlation would still be consistent with the efficiency hypothesis, because greater intervention activity requires greater speed in transacting. Three checks were carried out. The first test was to determine if the positive correlation held even after dropping the three intervention days in which the SNB intervened on its own. This meant dropping 67 observations from the sample's 706. The second was to rerun the regression of the first check but without the first intervention for the 63 intervention days. The third was to discard days when intervention volume exceeded the sample's median of $100 million; i.e., 23 intervention days. For all tests, no change in the coefficient's sign was observed. This confirms the view that the efficiency hypothesis is inconsistent with price clustering in SNB interventions.

The third observation drawn from Table 3 regards the influence of bank structure on price clustering. The role of Big Banks does not appear to

matter, but the domestic bank variable, $DomBank_t$, gives mixed signals. In most regressions for the zero digit, $DomBank_t$ enters negatively and significantly. The opposite result holds for the five digit. In this case, domestic banks demonstrate a tendency to round. Whether this difference in behavior reflects alternative practices of strategic pricing between foreign and domestic banks is a question that cannot be answered. In the case for zero or five digits, the two forces cancel each other.

Next, the comparative results from the broker market using customer transactions are presented in Table 4. The choice of variables is slightly different from those previously discussed in Table 3. The counterparty variable, BIS_t, now defines the bank structure. This is because small domestic commercial banks were primarily the counterparty in customer transactions, except for those with the BIS. This made the location variable redundant, because almost all transactions were conducted with small commercial banks located in Zurich, except those with the BIS in Basel.

The results show that the BIS variable mitigates the degree of price clustering in all regressions. This suggests possibly that the SNB obtains finer price offers through the BIS. Also for all regressions in Table 4, the coefficient for the volume variable is negatively signed. Volume is significant in the final

zero digit and the combined case of zero or five. This evidence for customer transactions is consistent with the efficiency hypothesis. As in the case for interventions, the variables capturing timing effects and same day effects are found to be insignificant in most regressions.

4. Concluding Remarks

The paper's contribution is to present new evidence of price clustering in the foreign exchange market using transactions data from the Swiss National Bank. Intervention trades and to a lesser extent customer transactions exhibit price clustering in the foreign exchange market. The SNB evidence is consistent with results found in Goodhart and Figliuoli (1991) using bid-ask spreads, Osler (2000) using published support and resistance levels for technical analysis, and Osler (2003) using stop-loss and take-profit orders. Despite the recognition that the objectives motivating the central bank transactions differ from those generated by profit-oriented commercial banks, similar pricing properties are observed.

The pronounced evidence of price clustering in the dealer market compared to the broker market raises the issue if clustering in intervention trades are strictly endogenous to the timing of the intervention or if the central bank

is able to dampen the level of price clustering? If price-clustered interventions are determined by market conditions, then any intervention strategy may amplify uncertainty through clustering rather than instill the intended calm in the FX markets. Alternatively, if the timing, size, or counterparty type matters, then the central bank's intervention strategy may have some bearing on the level of price clustering.

The disaggregated regressions find that transaction volume and bank structure are the most important factors explaining the clustering in SNB trades. While the influence of transactions volume is found to be stable in the regressions for customer transactions and is therefore consistent with Harris' (1991) efficiency hypothesis, this is not the case for intervention trades. I interpret the latter result as being consistent with the view that the price clustering in intervention trades is not influenced by SNB intervention tactics. This suggests that the clustering outcome is determined by market conditions in the dealer market.

References

Ball, C, W. Torous, A. Tschoegl (1985) 'The Degree of Price Resolution: The Case of the Gold Market,' *Journal of Futures Markets* 5, 29-43.

Chiu, Priscilla (2003) 'Transparency versus constructive ambiguity in foreign exchange intervention,' BIS Working Papers N0 144.

Dominguez, Kathryn M. (2004) 'When Do Central Bank Interventions Influence Intra-Daily and Longer-Term Exchange Rate Movements,' *Journal of International Money and Finance* forthcoming.

Dominguez, Kathryn M. (2003) 'The Market Microstructure of Central Bank Intervention,' *Journal of International Economics* 59, 25-45.

Dominguez, Kathryn M. (1998) 'Central Bank Intervention and Exchange Rate Volatility,' *Journal of International Money and Finance* 17(1), 161-190.

Edison, Hali J. (1993) 'The Effectiveness of Central Bank Intervention: A Survey of the Literature After 1982,' Special Papers in International Economics, No 18, Princeton, Priceton University.

Fischer, Andreas M. and Mathias Zurlinden (1999) 'Exchange Rate Effects of Central Bank Interventions: An Analysis of Transaction Prices,' *Economic Journal* 109, 662-676.

Goodhart, Charles and Luigi Figliuoli (1991) 'Every Minute Counts in Financial Markets,' *Journal of International Money and Finance* 10(1), 23-52.

Goodhart, Charles and Riccardo Curcio (1991) 'The Clustering of Bid/Ask Prices and the Spread in the Foreign Exchange Market,' LSE Financial Markets Group Discussion Paper No. 110.

Grossman, Sanford J., Merton H. Miller, Kenneth R. Cone, and Daniel R. Fischel (1997) 'Clustering and Competition in Asset Markets,' *Journal of Law and Economics* 40(1), 23-60.

Gwilym, Owain ap, Andrew Clare, and Stephan Thomas (1998) 'Extreme Price Clustering in the London Equity Index Futures and Options Markets,' *Journal of Banking and Finance* 22, 1193-1206.

Harris, Lawrence (1991) 'Stock Price Clustering and Discreteness,' *Review of Financial Studies* 4(3), 389-415.

Humpage, Owen F. (2003) 'Government Intervention in the Foreign Exchange Market,' Federal Reserve Bank of Cleveland, Working Paper 03-15.

Lecourt, Christelle and Helene Raymond (2004) 'Central Bank Interventions in the light of Survey Results,' mimeo.

Naranjo, Andy and M. Nimalendran (2000) 'Government Intervention and Adverse Selection Costs in Foreign Exchange Markets,' *Review of Financial Studies* 13(2), 453-477.

Neely, Christopher J. (2001) 'The Practice of Central Bank Intervention: Looking Under the Hood,' Federal Reserve Bank of St. Louis, *Review* 83(3), 1-10.

Payne, Richard and Paolo Vitale (2003) 'A Transaction Level Study of the Effects of Central Bank Intervention on Exchange Rates,' *Journal of International Economics* 61(2), 331-352.

Pasquariello, Paolo (2002) 'Informative Trading or Just Noise? An Analysis of Currency Returns, Market Liquidity, and Transaction Costs in Proximity of Central Bank Interventions,' Stern School of Business, NYU, November.

Osler, Carol L. (2003) 'Currency Orders and Exchange-Rate Dynamics: An Explanation for the Predictive Success of Technical Analysis,' *Journal of Finance* 58(5), 1791-1820.

Osler, Carol L. (2000) 'Support for Resistance: technical Analysis and Intraday Exchange Rates,' *FRBNY Economic Policy Review*, July 53-68.

Sarno, Lucio and Mark P. Taylor (2001) 'The Microstructure of the Foreign-Exchange Market: A Selective Survey of the Literature,' Princeton Studies in International Economics No. 89 (May).

Sopranzetti, Ben J. and Vinay Datar (2002) 'Price Clustering in Foreign Exchange Spot Markets,' *Journal of Financial Markets* 5(4), 411-417.

Yule, G. Undy (1927) 'On Reading a Scale,' *Journal of the Royal Statistical Society* 90, 570-579.

Figure 1: Intraday Distribution of SNB Transactions

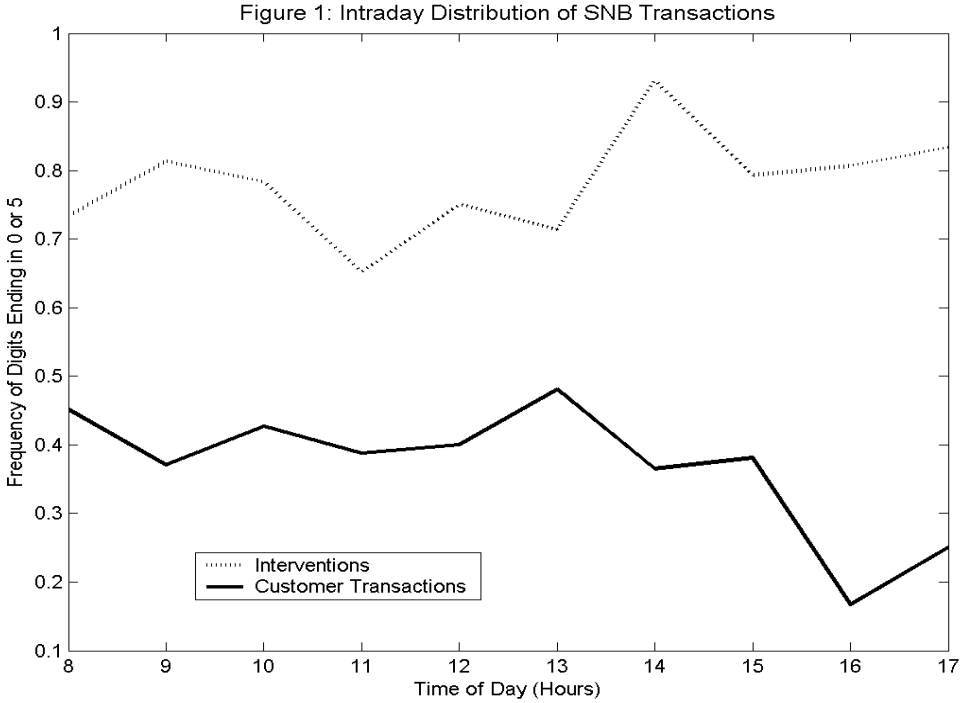

Figure 2: Price Clustering of SNB Transactions from 1986 to 1995

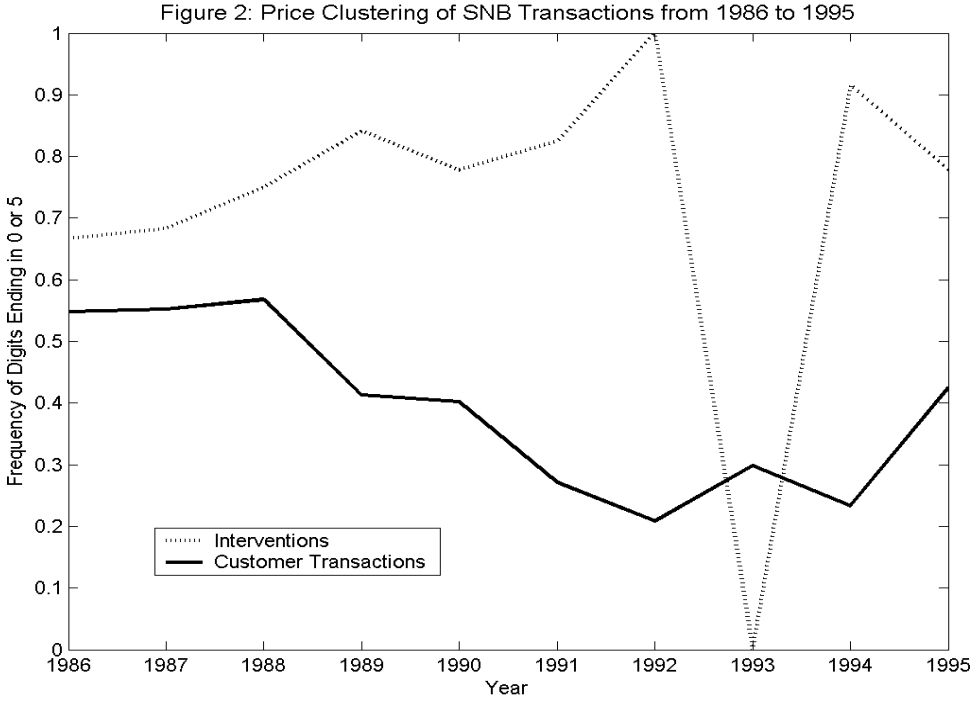

Table 1: Price Rounding in SNB Transactions (in Percent)

SNB Intervention Trades

fourth digit	Total Trades	Dollar Purchases	Dollar Sales	Refused Offers (Bid)	Refused Offers (Ask)
0	45.33	38.02	49.14	51.52	57.58
1	0.42	1.24	0.00	3.03	0.00
2	3.68	4.96	3.02	6.06	0.00
3	4.53	4.55	4.53	9.09	6.06
4	0.71	0.00	1.08	0.00	0.00
5	34.41	36.36	33.41	27.27	24.24
6	0.71	0.41	0.86	0.00	3.03
7	4.67	8.68	2.59	3.03	3.03
8	4.82	4.55	4.96	0.00	3.03
9	0.71	1.24	0.43	0.00	3.03
0 and 5	79.74	74.38	82.55	78.79	81.82
Even ticks	55.25	47.94	59.08	57.58	63.64
Odd ticks	44.74	52.07	40.96	42.42	36.36
NOB	706	242	464	33	33

Notes: Price clustering is for the fourth digit in the Swiss franc/U.S. dollar exchange rate. NOB refers to number of observations. All values are in percent.

Table 1: (*continued)* Price Rounding in SNB Transactions

SNB Costumer Transactions

fourth digit	Total
0	21.57
1	5.23
2	8.89
3	7.97
4	4.05
5	17.65
6	9.15
7	8.63
8	10.98
9	5.62
0 and 5	39.22
Even ticks	54.64
Odd ticks	45.10
NOB	765

Notes: Price clustering is for the fourth digit in the Swiss franc/U.S. dollar exchange rate. NOB refers to number of observations. All values are in percent.

Table 2: Sign-Rank Tests for the Fourth Digit (1986-1995)

Fourth Digit	'0'='5'	'3'='7'	'8'='2'	'4'='6'	'1'='9'
Interventions	0.001	1.000	0.366	1.000	0.727
	(0.001)	(0.901)	(0.302)	(1.000)	(0.547)
Customer Trans.	0.000	0.723	0.224	0.000	1.000
	(0.000)	(0.657)	(0.194)	(0.000)	(1.000)

Notes: Fourth digit is the y digit of the CHF/USD exchange rate 'x.xxxy'. Values are the significance of a 0.01% test of the null hypothesis that the median difference between two matched series is zero. Values given in parentheses are significance levels of the Wilcoxian sign test.

Table 3: Regression Results - Price Clustering of SNB Interventions

Ending in '0'					
Constant	-0.4039	-0.3824	-0.4500	-0.4623	-0.5220
	(0.2367)	(0.2368)	(0.3115)	(0.3125)	(0.4763)
$DomBank_t$	-0.3487	-0.5204*	-0.5182*	-0.5104*	-0.5147*
	(0.2101)	(0.2457)	(0.2458)	(0.2462)	(0.2469)
$BigBank_t$		0.2510	0.2543	0.2434	0.2362
		(0.1851)	(0.1853)	(0.1864)	(0.1871)
$Repeat_t$			0.0730	0.0625	0.0713
			(0.2180)	(0.2188)	(0.2195)
Loc_t				0.1150	0.1143
				(0.2090)	(0.2097)
$Time_t$					-0.0023
					(0.0279)
Vol_t	0.0577*	0.0546*	0.0548*	0.0550*	0.0657*
	(0.1829)	(0.0184)	(0.0184)	(0.0184)	(0.0205)
Log L	-479.56	-478.64	-478.58	-478.42	-474.26
Cases correct	417	418	418	418	405
NOB	706	706	706	706	701

Notes: Table continues on next page.

Table 3: (*continued*) Regression Results - Price Clustering of SNB Interventions

Ending in '5'					
Constant	-1.0367*	-1.0372*	-0.9800*	-0.9849*	-1.2120*
	(0.2644)	(0.2648)	(0.3364)	(0.3372)	(0.5060)
$DomBank_t$	0.7084*	0.7120*	0.7102*	0.7135*	0.7078*
	(0.2442)	(0.2752)	(0.2753)	(0.2757)	(0.2762)
$BigBank_t$		-0.0054	-0.0083	-0.0127	-0.0015
		(0.1876)	(0.1879)	(0.1890)	(0.1898)
$Repeat_t$			-0.0621	-0.0664	-0.0801
			(0.2251)	(0.2260)	(0.2266)
Loc_t				0.0468	0.0458
				(0.2182)	(0.2188)
$Time_t$					0.0242
					(0.0292)
Vol_t	-0.0247	-0.0246	-0.0247	-0.0246	-0.0338
	(0.0179)	(0.0180)	(0.0180)	(0.0180)	(0.0207)
Log L	-449.29	-449.29	-449.26	-449.23	-445.07
Cases correct	463	463	463	463	460
NOB	706	706	706	706	701

Notes: Table continues on next page.

Table 3: (*continued*) Regression Results - Price Clustering of SNB Interventions

Ending in '0' or '5'					
Constant	0.4736	0.5118	0.4692	0.4383	0.1095
	(0.3032)	(0.3034)	(0.4008)	(0.4023)	(0.5832)
$DomBank_t$	0.3334	0.1037	0.1049	0.1211	0.1098
	(0.2423)	(0.2791)	(0.2793)	(0.2799)	(0.2803)
$BigBank_t$		0.3536	0.3558	0.3341	0.3405
		(0.2208)	(0.2212)	(0.2222)	(0.2227)
$Repeat_t$			0.0445	0.0244	0.0124
			(0.2729)	(0.2737)	(0.2740)
Loc_t				0.2642	0.2634
				(0.2751)	(0.2752)
$Time_t$					0.0286
					(0.0286)
Vol_t	0.0738*	0.0682*	0.0684*	0.0693*	0.0662*
	(0.0287)	(0.0287)	(0.0288)	(0.0289)	(0.0292)
Log L	-350.18	-348.92	-348.91	-348.42	-347.63
Cases correct	563	563	563	563	558
NOB	706	706	706	706	701

Notes: The dependent variable is a dummy variable equal to +1 if the end digit is '0', '5' or '0' and '5'; otherwise 0; $DomBank_t$ is a dummy variable that the SNB intervention was transacted with a Swiss commercial bank; $BigBank_t$ is the same as Domestic Bank but is applied to Switzerland's big four banks; $Repeat_t$ is a dummy variable controlling for successive same day interventions; Loc_t is a dummy variable controlling for the location of the counterparty; $Time_t$ is time of transaction; Vol_t is the interventions size in US dollars. Values in parentheses are standard errors and * denotes significance at the 5% level.

Table 4: Regressions: Price Clustering of SNB Customer Transactions

Ending in '0'			
Constant	-1.4591*	-1.5939*	-1.5995*
	(0.2166)	(0.2286)	(0.2474)
BIS_t	-0.7867*	-0.7592*	-0.7127*
	(0.2027)	(0.2037)	(0.2112)
$Repeat_t$		0.3884*	0.4076*
		(0.1821)	(0.1870)
$Time_t$			0.0337
			(0.0329)
Vol_t	-0.0186*	-0.0189*	-0.0188*
	(0.0066)	(0.0066)	(0.0072)
Log L	-381.67	-379.41	-360.27
Cases correct	600	600	560
NOB	765	765	718

Notes: Table continues on next page.

Table 4: (*Continued*) Price Clustering of SNB Customer Transactions

Ending in '5'			
Constant	-2.5436*	-2.4689*	-2.5239*
	(0.2166)	(0.2538)	(0.2722)
BIS_t	-1.4964*	-1.5140*	-1.5361*
	(0.2478)	(0.2485)	(0.2597)
$Repeat_t$		-0.2293	-0.2270
		(0.2036)	(0.2102)
$Time_t$			0.0112
			(0.0369)
Vol_t	-0.0021	-0.0023	-0.0100*
	(0.0046)	(0.0046)	(0.0047)
Log L	-332.81	-332.17	-313.44
Cases correct	630	630	590
NOB	765	765	718

Notes: Table continues on next page.

Table 4: (*Continued*) Price Clustering of SNB Customer Transactions

Ending in '0' or '5'			
Constant	-1.0913*	-1.1435*	-1.1983*
	(0.1696)	(0.1791)	(0.1941)
BIS_t	-1.4172*	-1.4075*	-1.3929*
	(0.1711)	(0.1714)	(0.1776)
$Repeat_t$		0.1530	0.1744
		(0.1619)	(0.1671)
$Time_t$			0.03535
			(0.0311)
Vol_t	-0.0122*	-0.0122*	-0.0107*
	(0.0043)	(0.0043)	(0.0045)
Log L	-464.58	-464.13	-438.16
Cases correct	507	507	478
NOB	765	765	718

Notes: The dependent variable is a dummy variable equal to +1 if the end digit is '0', '5' or '0' and '5'; otherwise 0; BIS_t is a dummy variable if the SNB customer transaction was transacted with the BIS; $Repeat_t$ is a dummy variable controlling for successive same day transactions; $Time_t$ is time of transaction; Vol_t is the interventions size in US dollars. Values in parentheses are standard errors and * denotes significance at the 5% level.