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Price clustering in foreign exchange spot markets☆

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Abstract

This paper documents the existence of price clustering in the foreign exchange spot market for the German mark, the Japanese yen, the United Kingdom pound, the French franc, the Italian lira, and the Swedish krona. The U.S. dollar exchange rate indicative quotes for these currencies tend to exhibit clustering around right-most digits that end in either a "zero" or a "five." The tendency for exchange rates to cluster has *increased* with increases in trading volume and volatility. Moreover, the tendency for exchange rates to cluster differs across currencies.

JEL classification: F3; G2

Keywords: International financial markets; Currency; Foreign exchange

Price clustering is the tendency for securities prices to congregate around some specific set of values, for example whole digits ($6.00) or half digits ($6.50). Standard theories of pricing do not imply the coarse pricing intervals manifested as clustering.[1] Given the proliferation of derivative contracts that are being written against spot currencies and current spot transactions volume of over $1.2 trillion per *day*, price

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[1] Moreover, the existence of price clustering may be especially problematic for (1) valuing derivative securities that are written on assets whose prices exhibit clustering and, in a related context, (2) individuals who are attempting to hedge against adverse price movements in these assets.

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clustering in the spot currency market might have significant consequences. This paper contributes to the growing literature on price clustering by documenting the tendency for indicative quotes for dollars quoted in the German mark, the Japanese yen, the United Kingdom pound, the French franc, the Italian lira, and the Swedish krona to cluster on "even-ending" prices, where an "even-ending" price is defined to be one whose right-most digit is either a "zero" or a "five" (e.g., \$6.00, \$6.05, \$6.10,... \$6.95.)[2] We focus on the foreign currency/US dollar exchange rates since the US dollar is involved in over 80% of all transactions.[3]

Goodhart and Curcio (1990) also observe the clustering phenomenon in spot exchange rates, however our study investigates a broader sample period as well as more currencies; and more importantly, our study goes beyond Goodhart and Curcio (1990) by exploring the factors that influence clustering in this market.

The structure of the article is as follows. Section 1 provides a brief description of the structure of currency markets. Section 2 reviews the existing literature on price clustering. Section 3 provides evidence of price clustering in spot currency markets. Section 4 empirically examines the factors that influence clustering. Section 5 concludes the paper.

1. Institutional structure of currency spot markets

The spot market for foreign exchange is a highly decentralized, relatively opaque, multiple dealer market.[4] Unlike other markets, such as the New York Stock Exchange, there is no physical place where foreign currency traders meet and trade currencies. Although the trading volume in the FX market is tremendous, most of the volume occurs between dealers. The ten largest players are responsible for a dominant proportion of the order flow. Dealers trade with each other in two primary ways. The first is called an interdealer trade. The second way is by using a broker.[5] Unlike an interdealer trade, which is transparent, the use of a broker protects anonymity.

In the FX market, dealers provide two-way quotes, but quotes typically are available in two types: indicative quotes and firm quotes. Indicative quotes (those examined in this paper) are non-binding quotes that have been posted by individual banks to the electronic data networks. They are non-binding in the sense that if market conditions suddenly change, the posting bank can choose not to transact at

[2] As will be discussed more fully in the data section, the prices that are examined in this paper are taken from indicative quotes, which are non-binding quotes–offered by banks–that are sent out over electronic networks, such as Bloomberg, Reuters, etc. Unlike firm quotes, banks are not obligated to transact at prices for which they have made indicative quotes.

[3] *Source*: Bank for International Settlements, *Central Bank Survey of Foreign Exchange and Derivative market Activity*, Basle, March 1996.

[4] In this section, the authors rely heavily on R.K. Lyon's excellent book on futures market microstructure, *The Microstructure Approach to Exchange Rates*, MIT Press, forthcoming.

[5] In the FX market, brokers are involved almost exclusively in dealer to dealer transactions. They rarely trade for their own accounts.

its quoted price. Firm quotes, however, are binding.[6,7] When a bank is telephoned by a FX trader and it gives that trader a firm quote, then the quoting bank must be prepared to transact at that quoted price regardless of market conditions.

2. Review of the literature on price clustering

Even price clustering is pervasive in financial markets. Colwell et al. (1994) and Palmon et al. (1998) document even clustering in residential real estate transaction prices. Kahn et al. (1999) find it in bank deposit interest rates. An even greater number of studies have documented the existence of the even pricing phenomenon with respect to the stock market. For example, Osborne (1962), Neiderhoffer (1965), Harris (1991), and Christie and Schultz (1994) all provide evidence that confirms the tendency for prices to cluster on even fractions in the stock market. Lastly, Ball et al. (1985) find evidence of even price clustering in the gold market. Moreover, they link price clustering to both trading volume and volatility.

Two theories have arisen that attempt to explain the existence of even price clustering in financial markets. The first is the collusion theory, which argues that traders intentionally collude to set non-competitive bid-ask spreads.[8] However, since the foreign exchange market is populated mainly by large commercial banks that trade foreign currency denominated deposits with one another, it is difficult to fathom why these banks would collude to set hefty bid-asked spreads when they are trading currencies for their own accounts.

The other theory of even pricing, the efficiency theory, argues that traders intentionally set prices at even fractions to minimize negotiating costs and improve the speed of transactions.[9] However, since indicative quotes are not negotiated prices, but instead merely a prelude to negotiation, the minimization of negotiating costs seems a weak reason why these quotes would cluster.

3. Evidence of even clustering in currency markets

Our data consists of daily foreign exchange rate indicative quotes for the German mark, the Japanese yen, the United Kingdom pound, the French franc, the Italian lira, and the Swedish krona over the period January 1, 1971 to December 31, 1993.[10,11] The data were compiled from quotes by the Federal Reserve Bank of New

[6] Since firm quotes are generally unavailable to the public (until recently there was no "screen" that consolidated all firm dealer quotes in the FX market) they have not been studied extensively in the literature.

[7] Two-sided firm inter-dealer quotes are typically available for only three seconds.

[8] See Christie and Schultz (1994) and Christie et al. (1994).

[9] The efficiency theory is attributable to Harris (1991) and was formally modeled by Brown et al. (1991).

[10] For example, marks/dollar, yen/dollar, dollar/pound etc.

[11] The reader should not infer that our price clustering results using indicative quotes extend to firm quotes: their clustering patterns are different.

Table 1
Frequency distribution of the last digit of the US dollar denominated exchange rate quotes for the German mark, the Japanese yen, the United Kingdom pound, the French franc, the Italian lira, and Swedish krona from January 1, 1971 to December 31, 1993. The quotes are the median of a representative sample of noon offer rates in New York City, which have been collected by the Federal Reserve Bank of New York. Figures are the percent of total observations that end in that particular digit.

	German mark	Japanese yen	U.K. pound	French franc	Italian lira	Swedish krona
0	31.99	33.97	41.21	57.44	59.74	53.27
1	4.14	4.73	1.51	2.45	3.53	3.13
2	5.95	5.78	5.00	3.10	2.78	2.34
3	6.80	6.37	4.76	4.09	3.72	4.77
4	3.75	3.47	2.00	3.01	3.10	3.13
5	25.38	25.61	32.90	18.95	15.35	21.84
6	4.52	3.91	1.52	3.16	3.29	2.85
7	6.81	6.29	4.41	2.77	3.37	3.02
8	7.16	6.21	2.25	2.64	2.19	2.88
9	3.45	3.55	1.40	2.35	2.86	2.72
0 and 5	57.37	59.58	74.11	76.39	75.09	75.11

York and published in its H.10 release, which contains daily foreign exchange rates for major currencies. At noon each day, the Federal Reserve Bank of New York sampled indicative quotes that were posted on the electronic network for currency buying rates in New York.[12] They then took the median of the sampled rates and recorded them in a daily series. It is this daily series of median rates that describes our sample.[13]

In the absence of clustering, one would expect the distribution of the right-most digit of the quoted exchange rates to be uniform. Thus the probability of a number ending with a "zero" would be identical to the probability of one ending with a "six", a "two", or any other single digit: ten percent. Our data demonstrate that this is clearly not the case for spot exchange rates. Table 1, which presents frequency distributions for the last digit of each currency, documents that the actual proportion of exchange rates ending in "zero" and "five" was much greater than the uniform 10%. A last digit of "zero" occurred 31.99% of the time for the German mark, 33.97% of the time for the yen, 41.21% of the time for the pound, 57.44% of the time for the franc, 59.74% of the time for the lira, and 53.27% of the time for the krona, and a last digit of "five" occurred 25.38%, 25.61%, 32.90%, 18.95%, 15.35%, and 21.84% of the time for these currencies respectively. The null hypothesis that the last digit is uniformly distributed is rejected easily at the one percent level. Thus the data provide strong support for the claim that spot currency

[12] The rates in our sample are certified by the Federal Reserve Bank of New York for customs purposes, as required by Section 522 of the amended Tariff Act of 1930.

[13] We thank Charles Goodhart for pointing out that the distribution of the last digit for the median of a sample is almost identical to the distribution of the last digit of the individual elements of the sample itself.

exchange rate indicative quotes tend to cluster around prices that end in either a "zero" or a "five".

4. Factors influencing clustering

Ball et al. (1985) document a link between price clustering and trading volume in the spot gold market. They argue that if traders use even-ending price quotes in order to improve transaction efficiency, then one would expect that tendency for exchange rates to cluster at these even-ending prices would increase as the volume of orders that the traders must process increases. Ball et al. (1985) further document a link between price clustering and price volatility. They find that gold price clustering is less pervasive when prices are consistently trading within a tight band than when they are more highly volatile.

We employ a probit analysis to examine the factors that impact the propensity for exchange rates to cluster on even digits. The dependent variable, the probability that prices cluster, is unobservable, so we employ a more readily observable proxy. We create a binary dependent variable, CLUSTER, that equals one if the right-most digit of the exchange rate is either a "0" or a "5", and zero otherwise. The goal is to test whether trading volume or exchange rate volatility affects the propensity for exchange rates to cluster.

Fig. 1 provides evidence of the rapid increase in spot market trading volume that has been observed over the period 1977–1992. Our volume proxy, LNVOL, is the

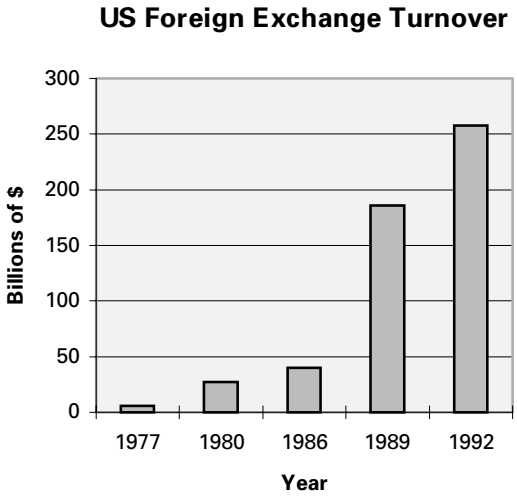

Fig. 1. Daily US foreign market turnover in billions of dollars, April 1992. Taken from the Summary of Results of the U.S. Foreign Exchange Market Survey Conducted in April 1992, Federal Reserve Bank of New York.

Table 2
Probit analysis for the propensity for the two right-most digits of US dollar denominated exchange rate quotes to end in an integer multiple of "five", e.g. {00, 05, 10,... 90, 95} regressed on a proxy for the standard deviation of the daily rate of return of the exchange rate, and the natural logarithm of aggregated annual FX volume in New York, a proxy for volume. The data consists of daily foreign exchange rates quoted in U.S. dollar units for the German mark, the Japanese yen, the United Kingdom pound, the French franc, the Italian lira, and Swedish krona over the period January 1, 1971 to December 31, 1993. The quotes are the median of a representative sample of noon offer rates in New York City, which have been collected by the Federal Reserve Bank of New York. Reported values are elasticities evaluated at the sample means. *t*-statistics are in parentheses.*

Currency in U.S. dollars	SIGMA	LNVOL	Likelihood ratio test
German mark	0.0704*	5.6682*	1352.6 with 2 d.f.
	(5.08)	(3.56)	
Japanese yen	0.0725*	6.5381*	478.2 with 2 d.f.
	(6.99)	(2.88)	
United Kingdom pound	0.0865*	3.2153*	257.1 with 2 d.f.
	(8.52)	(3.11)	
French franc	0.0034*	2.1458*	3548.1 with 2 d.f.
	(2.31)	(2.67)	
Italian lira	0.0563*	4.9852*	3768.1 with 2 d.f.
	(4.51)	(5.12)	
Swedish krona	0.0143	3.2574*	3342.8 with 2 d.f.
	(0.57)	(2.13)	

*Significance at the 5% level.

natural logarithm of the annual trading volume for all currencies in New York.[14] Note, this is an aggregated measure: the sum of all the volume in New York for all of the currencies combined. Our expectation is that if clustering is increasing with volume, then the coefficient on LNVOL should be positive. Our proxy for volatility, SIGMA, is the absolute value of the daily price change for the currencies in our sample.

Table 2 presents the results of the probit analysis for the factors that affect the propensity for exchange rates to cluster. The coefficients on SIGMA, the volatility proxy, are all positive and statistically significant at the five percent level for every currency except for the Swedish krona. The coefficients on LNVOL, the volume proxy, are all positive and all statistically significant at the five percent level. Thus as volume and volatility increases so does the tendency for indicative quotes to cluster.

Thus far, we have examined the factors that influence the tendency for a given foreign exchange rate to cluster. It might be interesting to compare the tendency for exchange rates to cluster across currencies. Do some currencies exhibit a greater degree of price clustering than others? Table 1 shows the observed frequency distribution of the last digit of each of the currencies in our sample. We will focus our

[14] Since the individual currency trading volumes were unavailable, we also employed an alternative volume proxy. Since volume has monotonically increased over time, we proxied for volume by using the variable YEAR, the year of the exchange rate observation. The results were qualitatively similar.

discussion on the last row in Table 1, which delineates the actual proportion of exchange rates for each currency that end in either the digits "zero" or "five". The results indicate that the degree of clustering does differ substantially across currencies with less clustering for the mark and the yen relative to the other currencies: 57.37% of the observations for the German mark ended in either the digit "zero" or "five" compared with 59.58% for the Japanese yen, 74.11% for the U.K. pound, 76.39% for the French franc, 75.09% for the Italian lira, and 75.11% for the Swedish krona.

5. Conclusion

This paper has documented the existence of price clustering in the foreign exchange spot markets for the German mark, the United Kingdom pound, the Japanese yen, the French franc, the Italian lira, and the Swedish krona. The dollar exchange rate quotes for each of these currencies tend to have right-most digits that end in either a "zero" or a "five". Moreover, the tendency for exchange rates to cluster generally increases with increases in trading volume and volatility. We also find that the propensity for exchange rates to cluster differs across currencies. Clustering is more prevalent in the indicative quotes for the French franc, Italian lira, UK pound, and Swedish krona, and less prevalent in the indicative quotes for the German mark and Japanese yen.

References

Ball, C., Torous, W., Tschoegl, A., 1985. The degree of price resolution: the case of the gold market. Journal of Futures Markets 5, 29–43.

Brown, S., Laux, P., Schachter, B., 1991. On the existence of an optimal tick size. Review of Futures Markets 10, 50–72.

Christie, W., Schultz, P., 1994. Why do NASDAQ market makers avoid odd-eighths quotes? Journal of Finance 49, 1813–1840.

Christie, W., Harris, J., Schultz, P., 1994. Why did NASDAQ market makers stop avoiding odd-eighths quotes? Journal of Finance 49, 1841–1860.

Colwell, P., Rushing, P., Young, K., 1994. The rounding of appraisal estimates. Illinois Real Estate Letter, Summer/Fall.

Goodhart, C., Curcio, R., 1990. Asset price discovery and price clustering in the foreign exchange market. Working paper, London School of Economics.

Harris, L., 1991. Stock price clustering and discreteness. Review of Financial Studies 4, 389–415.

Kahn, C., Pennacchi, G., Sopranzetti, B., 1999. Bank deposit rate clustering: theory and empirical evidence. Journal of Finance 54 (6), 2185–2214.

Neiderhoffer, V., 1965. Clustering of stock prices. Operations Research 13, 258–265.

Osborne, M.F.M., 1962. Periodic structure in the Brownian motion of stock prices. Operations Research 10, 345–379.

Palmon, O., Smith, B., Sopranzetti, B.J., 1998. Clustering in real estate prices: patterns and impacts on demand. Working paper, Rutgers, The State University of New Jersey.