

This PDF is a selection from an out-of-print volume from the National Bureau of Economic Research

Volume Title: The Microstructure of Foreign Exchange Markets

Volume Author/Editor: Jeffrey A. Frankel, Giampaolo Galli, Alberto Giovannini, editors

Volume Publisher: University of Chicago Press

Volume ISBN: 0-226-26000-3

Volume URL: <http://www.nber.org/books/fran96-1>

Conference Date: July 1-2, 1994

Publication Date: January 1996

Chapter Title: Bid-Ask Spreads in Foreign Exchange Markets: Implications for Models of Asymmetric Information

Chapter Author: David A. Hsieh, Allan W. Kleidon

Chapter URL: <http://www.nber.org/chapters/c11362>

Chapter pages in book: (p. 41 - 72)

2 Bid-Ask Spreads in Foreign Exchange Markets: Implications for Models of Asymmetric Information

David A. Hsieh and Allan W. Kleidon

The term *market microstructure* was coined in 1976 by Mark Garman to define “moment-to-moment trading activities in asset markets.” With the stated goal of providing insight and testable implications regarding the transaction-to-transaction nature of realistic exchange processes, Garman examines dealership and auction models of marketmakers where the stream of market orders from a collection of market agents is depicted as a stochastic Poisson process. The resulting insights concern bid-ask spreads (based on standard microeconomic analysis), inventories of marketmakers, and the effects of some market power on the part of marketmakers.

A more recent microstructure literature is based on information asymmetries among economic agents. In a recent literature review, Admati (1991) defines the area of market microstructure as “the literature on asset markets with asymmetric information and especially on trading mechanisms” (p. 347); Garman is noted as an example of “earlier market microstructure literature” in which “information issues were not typically modelled” (p. 355, n. 11). Two reasons are given for the popularity of asymmetric information models: policy implications of different trading processes, as exemplified by the 1987 crash, and empirical results such as various patterns in trading volume, variances, and returns over the trading day. The belief is that better insights into both issues will be achieved by examining information asymmetries. Moreover, observed empiri-

David A. Hsieh is professor of finance and economics at the Fuqua School of Business of Duke University. Allan W. Kleidon is vice president at Cornerstone Research and a consulting professor of law (in finance) at the School of Law of Stanford University.

Support for this research has been provided by Cornerstone Research. The authors are grateful for helpful comments from Jeffrey Frankel, Paul Pfleiderer, Antti Suvanto, currency traders at Citibank and at Wells Fargo–Nikko Investment Advisors (Jeffrey Hord and Vikas Srivastava), two anonymous referees, seminar participants at the Haas School of Business, University of California, Berkeley, and participants at the conference on the microstructure of foreign exchange markets.

cal results are believed to "call for theoretical explanations beyond what can be obtained by traditional models (in which informational asymmetries are not present)" (p. 348).

In some ways, foreign exchange data have institutional features that are ideal for testing these now "standard" asymmetric information models. The market is very liquid and is linked around the world by computerized information systems, and the commodity is essentially the same in all markets. Standard information models have been applied to foreign exchange data in Bollerslev and Domowitz (1993), particularly to the behavior of bid-ask spreads and volume around the open and close of trading in regional markets. Bollerslev and Domowitz conclude that data for smaller banks that "operate mainly within regional markets with well-defined market openings and closings" (p. 1422) show the relation between trading activity and spreads that is implied by standard asymmetric information models.

In this paper, we further examine how well standard asymmetric information models can explain the behavior of volatility, bid-ask spreads, and volume around the open and close of trading in foreign exchange markets.¹ We conclude that the standard information models are unable to explain these data.

Our analysis differs from most previous studies in that we examine the implications of standard information models for the behavior of data *across* markets that are open simultaneously, rather than looking at markets in isolation. In particular, a feature of standard information models is that high volatility is associated with trades by privately informed traders whose trading activity incorporates their information into prices and quotes. Within this class of model, if new information results in high volatility of quotes for a trader located in London, then the quotes for a trader who is physically located in New York but who observes the London quotes will also show high volatility.

We exploit the fact that foreign exchange transactions occur virtually around the clock, with overlap between the trading day for traders in London and New York. Consequently, the open of trade in New York and the close of trade in London correspond to times when the other market has been trading for some time. We find that the high volatility that shows up at the open in New York and the close in London appears to be unrelated to the concurrent volatility in the other market, even though both sets of quotes appear on exactly the same trading screens at exactly the same time.

This volatility cannot be due to new information reaching one market but not the other, within the standard information models. Either these markets that are ostensibly closely linked are segmented in important ways not recognized in standard models, or some phenomenon other than the incorporation

1. Trading patterns at the open and close of trade have been extensively studied within asymmetric-information models, primarily with respect to the New York Stock Exchange (NYSE), but also in the context of cross-country listings and foreign exchange (see, e.g., Admati and Pfleiderer 1988; Subrahmanyam 1991; Freedman 1989; Barclay, Litzenberger, and Warner 1990; and Bollerslev and Domowitz 1993). For an excellent survey of the literature, see Admati (1991).

of private information must be responsible for the behavior of quotes. Given the high degree of integration of the international foreign exchange market, we conclude that the observed periodicity of volatility is not due to the incorporation of private information as envisioned by standard asymmetric information models. One way of stating the problem is that if no new information is reaching the international foreign exchange market—which is implied by the absence of unusual volatility in quotes generated by traders in one physical location—then quotes generated by traders in another market show excess volatility relative to that implied by standard information models.

This is not a new phenomenon. For example, the crash of October 1987 is an example of a large change in stock prices that does not appear to have been caused by new information reaching the market as a whole. However, a recent class of model has been developed that explains such phenomena as the crash in terms of imperfect information aggregation and learning by market participants rather than new information reaching the market as a whole. These models differ from standard asymmetric information models by relaxing the assumption that each trader has perfect knowledge about the structure of the market, that is, about the preferences and beliefs of all traders in the market.²

While this is a different type of model from standard asymmetric information models, it is possible that at least some of the observed behavior in foreign exchange markets may be attributable to this type of information asymmetry. We examine this possibility below, after closely examining the standard asymmetric information models. It appears that some form of learning about the market structure is important at the start of trading, which results in wide and volatile quotes when traders first enter the market. This process may be as informal as the posting of wide quotes with little expectation of trading during the initial period of learning.

At the close of trading, standard information models are again unable to explain the foreign exchange data. We conclude that inventory management by marketmakers in the closing market appears to be the most likely explanation.

The paper proceeds as follows. Section 2.1 discusses the institutional features of our data and presents our empirical results. Section 2.2 examines the standard asymmetric information models of intraday price and volume of Admati and Pfleiderer (1988) and Subrahmanyam (1989, 1991) and the current application of these models to foreign exchange data in Bollerslev and Domowitz (1993).³ Section 2.3 examines alternate explanations of the results in

2. These issues are addressed in Gennotte and Leland (1990), Jacklin, Kleidon, and Pfleiderer (1992), Kleidon (1992, 1995), and Romer (1993).

3. Foster and Viswanathan (1990) present a related asymmetric information model that focuses on interday rather than intraday variations in price and volume. Although it can be argued that foreign exchange trading is not tied to any particular "day," our current focus is on behavior between the open and the close of usual trading hours for traders within the geographic markets of London and New York. Foster and Viswanathan examine the behavior of trading *across* days, particularly the effects of weekends on Monday trading.

section 2.1, namely, recent learning models based on asymmetric information and other market microstructure models that place more emphasis on the roles of market power and inventory management of marketmakers. Section 2.4 contains concluding remarks.

2.1 Data and Results

This section examines the behavior of spreads and quote volatilities across different regional foreign exchange markets at the same point in time. We demonstrate that a key implication of standard asymmetric information models is *rejected* in foreign exchange data, namely, that periods of high variance correspond to periods of high concentration of informed trading. When one regional market has high variance (i.e., open and close of the regional market with concurrent high bid-ask spreads), other markets simultaneously have *low* variance (and low bid-ask spreads), even though the traders from different markets are connected by computer terminals with all quotes appearing simultaneously on all terminals. In section 2.2, we interpret these results as showing that whatever the explanations for these phenomena—and we suggest possibilities in section 2.3 below—they are not consistent with current standard models of asymmetric information.

2.1.1 Data

The foreign exchange market can be roughly divided into two groups.⁴ The first group comprises marketmakers or the interbank market, which accounts for most foreign exchange trading.⁵ Marketmakers deal with each other through a very active computerized market that trades virtually around the clock, either directly or through interdealer brokers. The second group comprises the retail market or customers who approach a local broker or bank and are offered retail foreign exchange quotes by that retail bank.

The interbank foreign exchange market, from which our data are obtained, comprises a network of major trading banks throughout the world that are linked interactively via computer screens (either Reuters or Telerate systems). We use data from the Reuters indications system which transmits computerized quotes among interbank dealers. When a trading bank individually updates its quotes, the new quotes directly appear on the screens of all traders around the world. Actual trades are consummated via telephone,⁶ and price and

4. For an excellent description of the markets, see Burnham (1989). See also Goodhart (1990), Goodhart and Figliuoli (1991), Lyons (1992, 1993, 1995), and Bollerslev and Domowitz (1993).

5. Lyons (1993, 2), citing the New York Federal Reserve Bank, states that over 80 percent of trading volume is between marketmakers.

6. Lyons (1995) examines data for a single marketmaker from the Reuters Dealing 2000 System that allows screen trading, although direct telephone communication was necessary for all traders when our data were collected. Since our approach requires cross-market comparisons, the new data set is insufficient for our purposes. It will be useful to replicate our study using data from the new Reuters system, if sufficient data ultimately become available.

volume for direct interdealer trades are not publicly revealed. Some information about brokered interdealer trades, namely, price, quantity, and whether the trade is at the bid or the ask, is publicly disseminated to dealers via an intercom system. Major trading banks often perform both interbank and retail roles, with a dedicated foreign exchange desk within the bank linked to the interbank market and with retail customers who are offered quotes that consist of the dealers' interbank quotes plus an additional markup.

The deutsche mark/dollar data that we use were originally captured from a Reuters data feed by Charles Goodhart and cover the eighty-two days from 9 April to 30 June 1989. These are the same data used by Bollerslev and Domowitz (1993), who provide valuable descriptions of the characteristics of these data.⁷ For our purposes, we concentrate on two markets—London and New York—but our analysis applies to the other markets documented in Bollerslev and Domowitz. Figures 2.1a and 2.1b document the time periods in which significant trading activity takes place in London and New York, respectively. These figures give the average number of quote arrivals on Reuters' screens, per five-minute intervals, from traders based in London and New York.⁸ Each location has activity beginning around 7:00 A.M. (local time) and lasting until about 6:00 P.M. (local time).⁹ Figure 2.2 integrates the London and New York data by converting the Eastern Standard Time (EST) New York times to Greenwich Mean Time (GMT) and plotting both figures 2.1a and figure 2.1b together. As noted by Bollerslev and Domowitz (1993, 1426), trading activity (as measured by the number of quote arrivals) in London begins high, declines until New York opens, then increases until the close of London trade. Activity in New York roughly follows that of London but continues strongly after the London close as New York becomes the major open market.

We wish to highlight several aspects of these data that make them excellent for studying models of asymmetric information. First, the interbank market is the closest to an ideal twenty-four-hour market of which we know. It is very liquid, especially by comparison with stock markets, in terms of both volume of trade and number of traders; individual traders have continuous access to the market via computer terminal; and some trader is active virtually around the clock (including the markets in the Far East). Second, the commodity is essentially the same in all markets: the deutsche mark and the dollar are the same irrespective of trader location, and settlement issues are trivial by comparison with, say, transactions on the New York Stock Exchange (NYSE) ver-

7. The data were kindly forwarded to us by Tim Bollerslev and Ian Domowitz. For details of the data capture, error screens, and data characteristics, see Goodhart (1990) and Goodhart and Figliuoli (1991).

8. We exclude quotes from Saturday and Sunday since there is almost no trading on these days (except the last hour on Sunday).

9. There are isolated quotes at times outside this interval, but they are negligible in frequency, and we ignore them in subsequent analysis. Note also that in London there is one period shortly before 6:00 P.M. (GMT) in which there are no quotes; this is reflected in figures 2.4a and 2.6 below by a "zero" spread at that time.

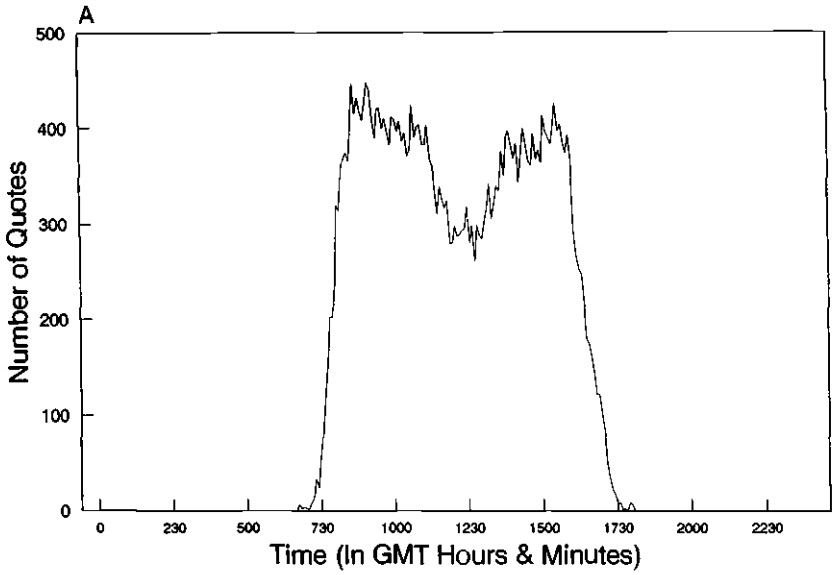


Fig. 2.1a Number of quotes per five-minute interval, London

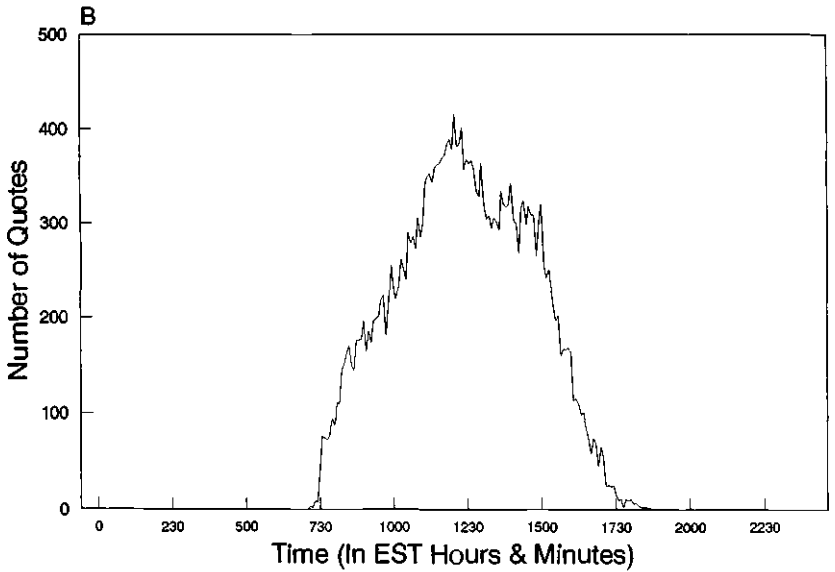


Fig. 2.1b Number of quotes per five-minute interval, New York

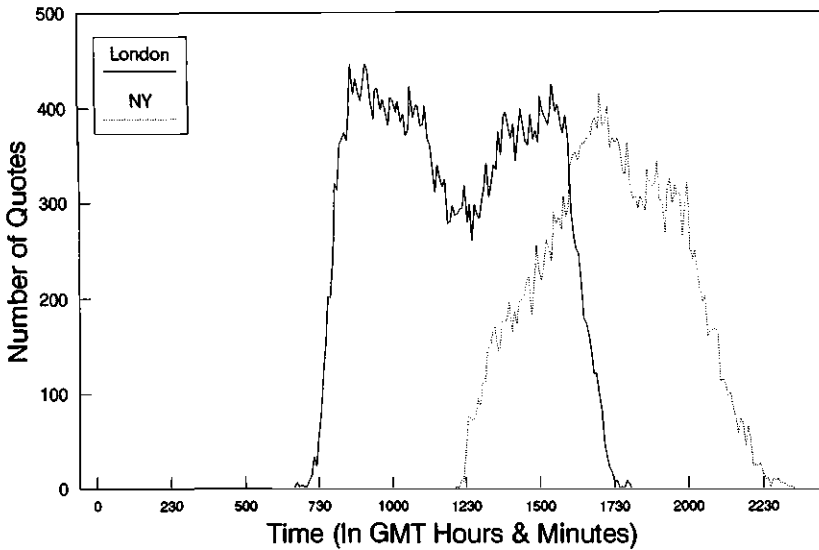


Fig. 2.2 Number of quotes per five-minute interval, London and New York

sus those on the International Stock Exchange (ISE) in London (see Bumham 1989, 21).

Third, the facts of twenty-four-hour trading and the very size and nature of the foreign exchange markets suggest that standard models of asymmetric information may find it difficult to explain persistent temporal patterns since there may be less systematic private information in these markets compared with, say, a small NYSE-listed stock that has few followers. Lyons (1995) concludes that interpretation of “information” in the foreign exchange market must be broader than that in standard models of equity markets since there are no “insiders” in the foreign exchange market. Our discussion of learning models in section 2.3 below provides such a broader concept of information.

2.1.2 Results

London and New York: Individual Markets

We first document that volatility in the foreign exchange markets follows the same U-shaped pattern from the open to the close of trade as on, say, the NYSE. This is important because it is precisely this result that supports the conclusions of Admati and Pfleiderer (1988) and Subrahmanyam (1989) that there is heavy activity by informed traders at the open and close of trade on the NYSE, which results in the higher variances of returns at those times.

Return variances are calculated as follows. The day is first divided into one-minute intervals. At the end of each minute, the last quote (bid/ask) is averaged. If no new quotes occur during that minute, the observation is deleted. Between

two minutes (if both have quotes), the one-minute rate of return is computed as the discrete rate of change of the average bid/ask between the two minutes. The standard deviation of each half hour (beginning at 7:30 A.M. local time) is computed as the standard deviation of these one-minute returns during the interval. For robustness, we present the medians of these half hourly standard deviations over all days in our sample.

Figures 2.3a and 2.3b plot these average (median) standard deviations per half hour interval, from 7:30 A.M. (local time) to 6:00 P.M. for London and New York, respectively. The results are striking. The average variances are much higher at open and close in both markets than during other times of the trading day, confirming the apparent U shape in volatility that has been previously documented in other markets.¹⁰ Figures 2.4a and 2.4b present the average spreads (in pfennig per dollar) by minute over the trading periods indicated by trading activity in figures 2.1a and 2.1b above for London and New York, respectively. These figures confirm the general U-shaped pattern of spreads particularly documented in Bollerslev and Domowitz for smaller regional banks (1993, 1428ff.).

London and New York: Integrated Markets

Figure 2.5 shows the standard deviations of both London and New York returns on the same (GMT) time scale. There appears to be no correspondence between the striking volatility patterns across these two markets, which are virtually instantaneously linked in terms of quote information.

Not surprisingly given the results in figure 2.5, figure 2.6 shows that changes in the bid-ask spread documented for London and New York separately do not provide any coherence when viewed at the same time across markets. While the average spread is roughly equal in London and New York when both markets are open, there is no apparent effect of the high spreads associated with the open or close of one market on the other market.

Table 2.1 presents a test of the difference in spreads between London and New York, by fifteen-minute intervals from noon GMT to 5:30 P.M. GMT. The test assumes that samples are uncorrelated, with the result that the t -statistic for the difference of average spreads in each interval is downward biased if there is in fact positive correlation across the samples (which would be expected if information affected both sets of quotes throughout the day). The results confirm the impressions from figure 2.6 above and demonstrate that the (indicated) spreads in New York are consistently significantly higher than those in London, except for London close, when London spreads are higher

10. Note that, since we delete observations if no quote update occurs, and since we require consecutive observations to calculate a one-minute rate of return, there will be typically fewer observations for any given time interval than one observation per minute times the number of days in the sample. In particular, there are fewer observations in our sample at the open and close of trading than during periods of active trading. Table 2.3 below presents formal tests of the differences in variances.

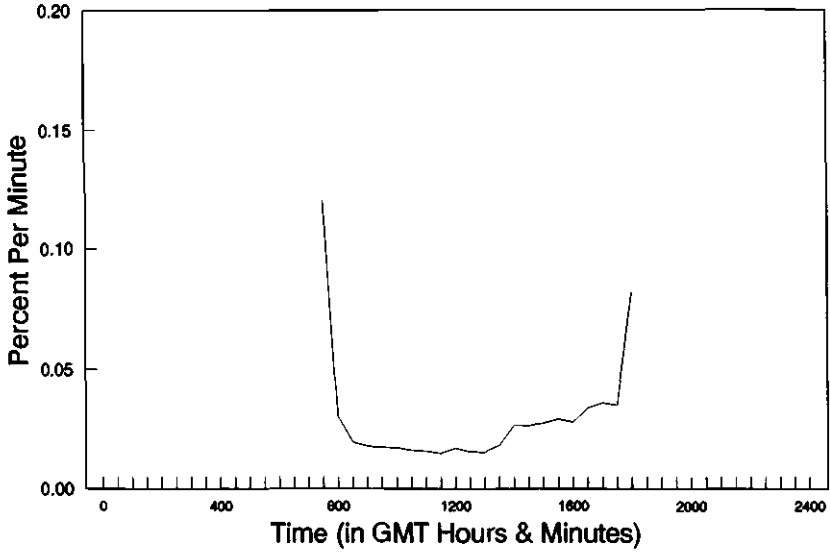


Fig. 2.3a Standard deviation per thirty-minute interval, London

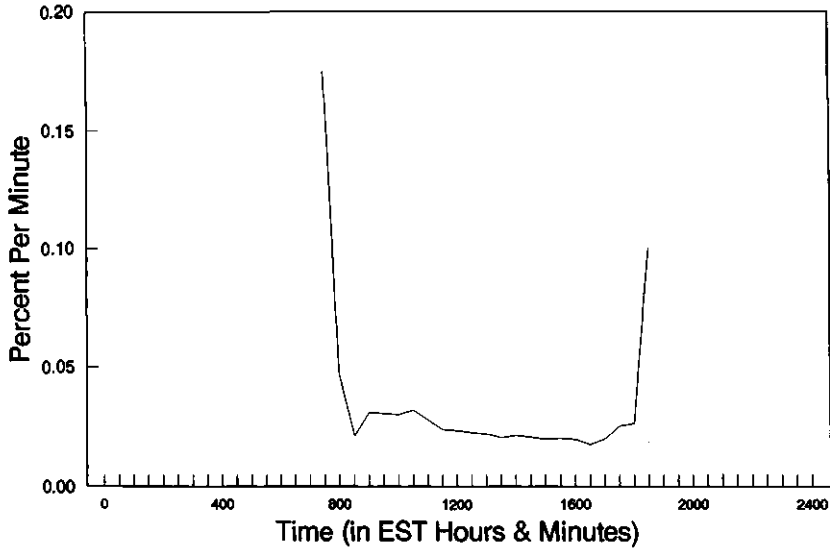


Fig. 2.3b Standard deviation per thirty-minute interval, New York

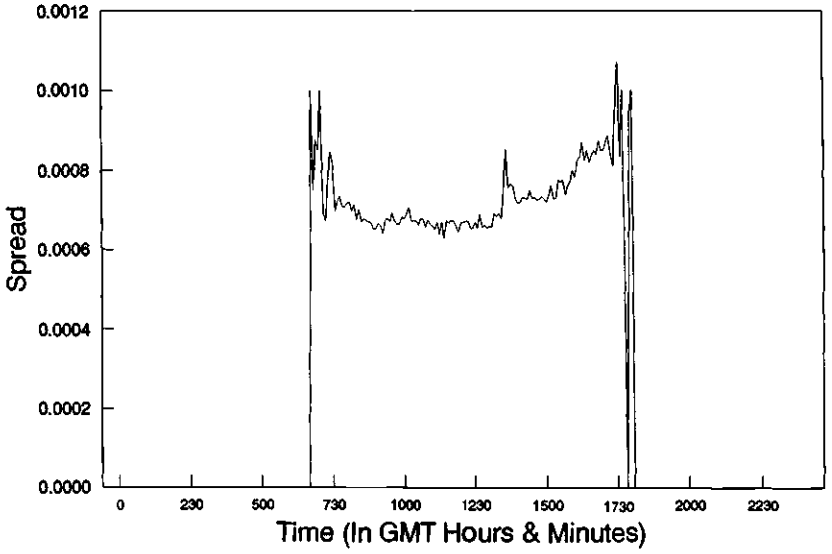


Fig. 2.4a Distribution of the spread over the day, London

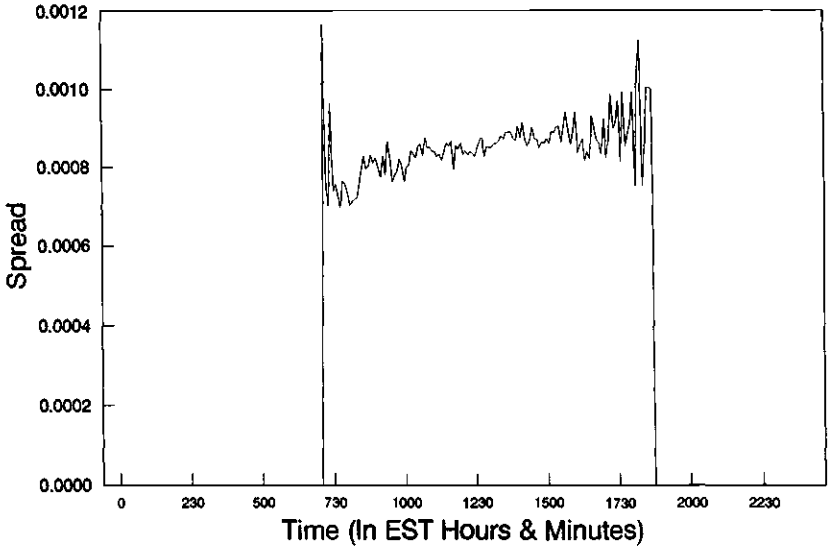


Fig. 2.4b Distribution of the spread over the day, New York

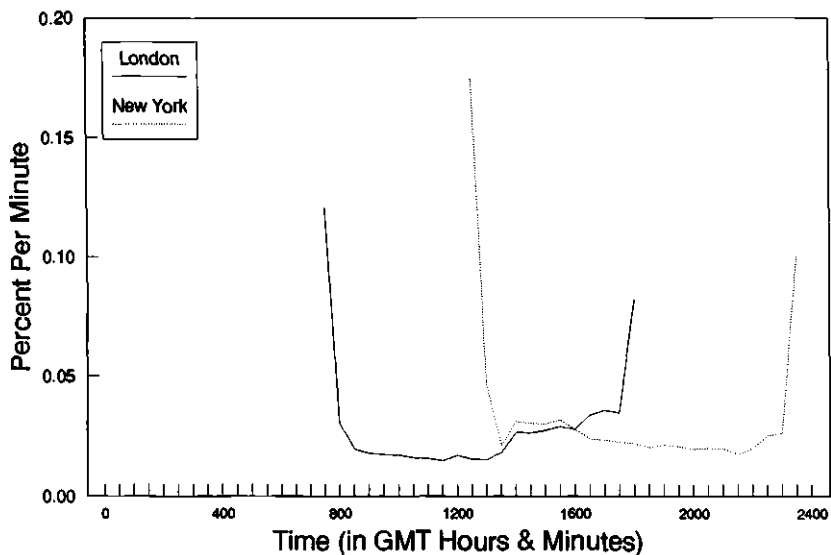


Fig. 2.5 Standard deviation per thirty-minute interval, London and New York

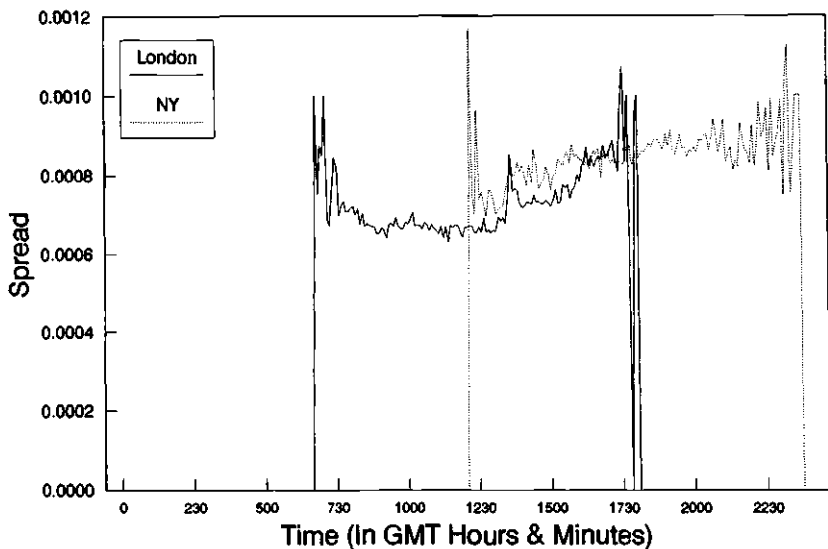


Fig. 2.6 Distribution of the spread over the day, London and New York

Table 2.1 Test of Difference in Spreads, London and New York (by fifteen-minute interval)

Time (GMT)	London		New York		<i>t</i> -Stat. ^c
	Spread ^a	<i>N</i> ^b	Spread ^a	<i>N</i> ^b	
Noon	.0669	873	.1000	5	-2.34
12:15	.0659	905	.0763	57	-2.34
12:30	.0668	836	.0725	222	-3.10
12:45	.0657	867	.0751	258	-5.61
1:00	.0677	958	.0710	367	-2.25
1:15	.0706	964	.0757	482	-3.05
1:30	.0789	1,059	.0808	470	-.93
1:45	.0735	1,168	.0821	549	-5.99
2:00	.0725	1,091	.0799	524	-4.95
2:15	.0735	1,153	.0823	596	-5.80
2:30	.0728	1,118	.0775	620	-3.54
2:45	.0727	1,105	.0795	699	-5.28
3:00	.0742	1,197	.0816	712	-5.70
3:15	.0759	1,207	.0836	783	-5.89
3:30	.0758	1,184	.0854	833	-7.34
3:45	.0784	1,128	.0846	890	-5.09
4:00	.0840	811	.0832	1,042	.63
4:15	.0831	642	.0837	1,065	-.44
4:30	.0841	477	.0837	1,104	.28
4:45	.0859	343	.0852	1,151	.42
5:00	.0868	166	.0833	1,183	1.66
5:15	.0909	46	.0833	1,124	1.71
5:30	.0792	12	.0863	1,088	-.99

^aMean spread in London (S_{LON}) and New York (S_{NY}) times 100.

^bNumber of observations.

^c*t*-statistic for ($S_{LON} - S_{NY}$), assuming uncorrelated samples.

than earlier in the London trading day and on average are higher than those in New York.

Table 2.2 tests for the difference between quote midpoints in London and New York, as opposed to the spreads. Although table 2.1 above shows that the indicated spreads in New York are significantly higher than those in London except at London close, table 2.2 shows that this pattern does not carry over to mid-quotes. Although on average the London mid-quotes are greater than the New York mid-quotes, the difference is typically not statistically significant, at least assuming uncorrelated samples.

Table 2.3 examines the difference between mid-quote to mid-quote variances for London and New York, again by fifteen-minute intervals beginning at noon GMT. The results from figure 2.5 above are supported in table 2.3. From noon until 3:15 P.M., the variance in New York consistently exceeds that in London with the largest average variances in New York at the start of New York trading (although not all periods are individually significant at conven-

Table 2.2 Test of Difference in Mid-Quotes, London and New York (by fifteen-minute interval)

Time (GMT)	London		New York		<i>t</i> -Stat. ^c
	Mid-Quote ^a	<i>N</i> ^b	Mid-Quote ^a	<i>N</i> ^b	
Noon	1.9508	873	1.9496	5	.07
12:15	1.9504	905	1.9553	57	-.73
12:30	1.9461	836	1.9414	222	1.18
12:45	1.9472	867	1.9383	258	2.44
1:00	1.9466	958	1.9425	367	1.28
1:15	1.9430	964	1.9421	482	.31
1:30	1.9424	1,059	1.9377	470	1.57
1:45	1.9412	1,168	1.9401	549	.39
2:00	1.9386	1,091	1.9332	524	1.88
2:15	1.9393	1,153	1.9384	596	.33
2:30	1.9411	1,118	1.9361	620	1.83
2:45	1.9420	1,105	1.9354	699	2.52
3:00	1.9423	1,197	1.9408	712	.58
3:15	1.9418	1,207	1.9359	783	2.38
3:30	1.9423	1,184	1.9423	833	.00
3:45	1.9447	1,128	1.9396	890	2.10
4:00	1.9370	811	1.9381	1,042	-.43
4:15	1.9370	642	1.9360	1,065	.38
4:30	1.9392	477	1.9393	1,104	-.03
4:45	1.9466	343	1.9378	1,151	2.73
5:00	1.9431	166	1.9395	1,183	.81
5:15	1.9477	46	1.9430	1,124	.63
5:30	1.9549	12	1.9448	1,088	.61

^aMean mid-quote ($(\text{bid} + \text{ask})/2$) for London (MQ_{LON}) and New York (MQ_{NY}).

^bNumber of observations.

^c*t*-statistic for $(MQ_{\text{LON}} - MQ_{\text{NY}})$, assuming uncorrelated samples.

tional levels based on the conservative assumption of uncorrelated samples).¹¹ However, the variance in London increases toward the close of London trading and significantly exceeds that in New York in the later part of the London trading period. The (conservative) *t*-statistics are strongly significant at conventional levels in all periods between 4:00 P.M. and 5:30 P.M. (GMT) (the *t*-statistics range from 2.64 to 5.53). Even in the last fifteen-minute interval (to 5:45 P.M.) in which there were only twelve observations in London, the *t*-statistic is 1.73. Thus, these results clearly document a change in variance in one market that is not simultaneously observed in the other market.

The cross-market variance results in figure 2.5 and table 2.3 and the cross-market spread results in figure 2.6 and table 2.1 constitute a challenge for standard asymmetric information models as applied to foreign exchange data.

11. The earliest intervals in New York (and the latest intervals in London) also have few observations (see n. 10 above).

Table 2.3 Test of Difference in Mid-Quote to Mid-Quote Variance, London and New York (by fifteen-minute interval)

Time (GMT)	London		New York		<i>t</i> -Stat. ^c
	SD ^a	<i>N</i> ^b	SD ^a	<i>N</i> ^b	
Noon	.0253	873	.0442	2	-1.40
12:15	.0203	905	.0905	30	-1.27
12:30	.0206	836	.0445	202	-2.56
12:45	.0174	867	.0280	253	-3.72
1:00	.0241	958	.0301	367	-1.56
1:15	.0276	964	.0327	482	-1.50
1:30	.0477	1,059	.0727	470	-1.62
1:45	.0310	1,168	.0429	549	-2.11
2:00	.0330	1,091	.0397	524	-1.52
2:15	.0329	1,153	.0408	596	-2.19
2:30	.0293	1,118	.0348	620	-2.41
2:45	.0301	1,105	.0315	699	-.63
3:00	.0321	1,197	.0385	712	-1.57
3:15	.0333	1,207	.0374	783	-1.42
3:30	.0317	1,184	.0309	833	.53
3:45	.0336	1,128	.0308	890	1.35
4:00	.0372	811	.0278	1,042	4.90
4:15	.0375	642	.0284	1,065	4.01
4:30	.0437	477	.0276	1,104	4.46
4:45	.0451	343	.0266	1,151	5.53
5:00	.0453	166	.0261	1,183	5.21
5:15	.0652	46	.0258	1,124	2.64
5:30	.0853	12	.0265	1,088	1.73

^aStandard deviation of mid-quote changes for London (SD_{LON}) and New York (SD_{NY}) times 100.

^bNumber of observations.

^c*t*-statistic based on method of moments test for equality of the variances, assuming uncorrelated samples.

2.2 Current Asymmetric Information Models

This section examines the standard asymmetric information literature as applied to the open and close of trade in foreign exchange markets. The general importance of asymmetric information has long been recognized. Bagehot (1971) argues that the marketmaker loses in trades with better-informed traders, with the result that trades with uninformed liquidity traders must make sufficient profit to cover those losses plus costs. This notion is formalized in subsequent work (see Admati 1991), the most relevant for our current purposes being Admati and Pfleiderer (1988) and Subrahmanyam (1989, 1991). Boller-lev and Domowitz (1993) explicitly interpret much of the foreign exchange behavior that we discuss in terms of the models of Admati and Pfleiderer and Subrahmanyam.¹²

12. Lyons (1993, 1995) develops microstructure models in the context of the foreign exchange market but does not examine cross-market data as in Bollerlev and Domowitz (1993).

An initial problem with this literature is an inability of the theoretical model of Admati and Pfleiderer (1988), and the extension of this model by Subrahmanyam (1989, 1991), simultaneously to account for the observed empirical phenomena of volume, volatility, and bid-ask spreads on the NYSE (the market that these models were originally intended to explain).¹³ We then demonstrate that the cross-market foreign exchange results from section 2.1 above are inconsistent with standard asymmetric information models.

2.2.1 Admati and Pfleiderer (1988)

A model of endogenous trading volume is provided by Admati and Pfleiderer (1988), who extend Kyle (1984). They assume three types of agents: informed traders, who will trade only on terms advantageous to them given their superior information; discretionary liquidity traders, who must trade over a given day but who choose when to trade during the day on the basis of trading costs (i.e., they trade in those periods of lowest cost); and nondiscretionary liquidity traders, who must trade at a given time during the day regardless of cost. In this model, trading costs arise solely because of the activity of the informed, whose profits are paid by the uninformed liquidity traders.

Given their assumptions, Admati and Pfleiderer show that it is possible to obtain concentrations of volume at arbitrary trading times because in equilibrium these high volume periods attract both informed traders and discretionary liquidity traders. The informed are attracted because there will be more uninformed liquidity traders behind whom they can camouflage their trades. The discretionary liquidity traders are attracted because, in this model, the increased activity of informed traders implies sufficiently increased competition among them that the cost of trading to the uninformed is *lowered* relative to other periods.

Admati and Pfleiderer relate their results to observed empirical behavior, especially to volume and variance at the open and close of a day's trading on the NYSE, and show "that the patterns that have been observed empirically can be explained in terms of the optimizing decisions of these traders" (1988, 4). Their primary motivation is the high volume and concurrent high variance at open and close. Volume is explained by their concentration equilibrium outlined above; high variance follows directly from the increased activity by informed traders at open and close since more (previously private) information is thus incorporated into prices.

2.2.2 Subrahmanyam (1989, 1991)

The key result in Admati and Pfleiderer (1988)—namely, that increased activity by informed traders lowers the costs to the uninformed, who must pay the price of the presence of the informed—is not intuitively obvious. Subrahmanyam (1989, 1991) builds on the model of Admati and Pfleiderer and shows

13. Much of this discussion follows Brock and Kleidon (1992, sec. 4.3).

that their result depends on the assumption of risk-neutral informed traders. If the informed traders are risk averse, then increased activity on their part can increase the trading costs of liquidity traders. Subrahmanyam (1989, 18) cites Foster and Viswanathan (1989) as showing that the adverse selection component of bid-ask spreads is highest at the beginning of the day, which "contrasts with the model of Admati and Pfleiderer [1988], which predicts that spreads should be *lowest* at the beginning of the day." Brock and Kleidon (1992, sec. 4.1) also provide evidence that appears inconsistent with the key result in Admati and Pfleiderer since spreads follow the same U shape as volume: highest volume is associated with highest, not lowest, costs.¹⁴

Subrahmanyam (1989) interprets this result as consistent with his extension of Admati and Pfleiderer to the case of risk-averse informed traders since then more trading by informed traders results in lower market liquidity and higher costs. To do this, he requires the additional assumption that "more individuals are informed at the beginning of the day than at other times during the day" (p. 17). For this model to be a full explanation of the relation between spreads and volume, he presumably requires that the informed also trade more heavily at close.

2.2.3 Bollerslev and Domowitz (1993)

Bollerslev and Domowitz (1993) examine the same data as in this paper, namely, continuously recorded quotes on the deutsche mark/dollar exchange rate in the interbank foreign exchange market. They document quote arrivals and bid-ask spreads over the trading day, across geographic locations, and across trading participants. The analytic focus is on two main areas: first (which is most relevant for this paper), an evaluation of the predictions of the asymmetric information models of Admati and Pfleiderer (1988) and Subrahmanyam (1989) and, second, time-series modeling of means and conditional variances.

Bollerslev and Domowitz conclude that their evidence "is encouraging with respect to the ability to validate and discriminate between theoretical models of trading activity using intraday information on foreign exchange trading" (1993, 1439). They suggest that periodic nondiscretionary liquidity trading around open and close will intensify the results of Admati and Pfleiderer, while round-the-clock trading will weaken them, and conclude that the U-shaped patterns of trading activity from open through close, well documented for the

14. The model of Admati and Pfleiderer (1988) and Subrahmanyam (1989, 1991) assumes sequential batch auctions rather than the continuous auctions associated with bids and asks on the NYSE. However, Admati and Pfleiderer regard their results as applying to the volume behavior on the NYSE, and Subrahmanyam (1989) explicitly equates the costs in Admati and Pfleiderer (which are the same as in his model) with bid-ask spreads. We follow this approach. Further, as Grossman and Miller (1988, 628) point out, transactions costs should be measured by the difference between the price paid now and the price expected to be paid by waiting; but, if the average spread falls after opening and rises at close, one would expect a priori that a given liquidity trader would expect higher transactions costs in such periods.

NYSE and addressed by Admati and Pfleiderer (1988), is apparent only in the European markets (p. 1426, n. 8).

Bollerslev and Domowitz also find that, for traders who restrict their trading to regional markets within well-defined openings and closings (as opposed to international firms with traders in multiple regional markets), the activity pattern (quote volume) "typically shows a U-shape, as does the distribution of their own spreads over the course of the day" (1993, 1428). Since these traders "operate more like the stock market traders usually modeled in much of the theoretical literature, with behavior influenced by openings and closings" (p. 1429), Bollerslev and Domowitz interpret this evidence as confirming the model of Admati and Pfleiderer (1988), although they note that the "daily patterns of the spread and market activity suggest risk-averse behavior on the part of these traders" (p. 1439). This modification is tied to "Subrahmanyam's (1989) extension of the Admati and Pfleiderer model to include risk-averse behavior [that] predicts that more trading by informed risk-averse participants brings about higher costs" (p. 1426, n. 9).

2.2.4 Foreign Exchange Quote Data and Standard Information Models

We conclude that the asymmetric information models of Admati and Pfleiderer and Subrahmanyam are *not* consistent with the foreign exchange data on spreads and volatility, for two reasons. First, close examination of Subrahmanyam's extension of the Admati-Pfleiderer model shows that, although he can account for high spreads at times of high informed trading, the cost is that he loses the major result of the Admati-Pfleiderer model, namely, the concentrated trading equilibrium relied on by Admati and Pfleiderer to account for simultaneous high volume and high volatility. Second, the results from section 2.1 above show that volatilities (and spreads) across markets that trade simultaneously do not show the congruence implied by either the Admati-Pfleiderer or the Subrahmanyam models.

On the first point, note that Subrahmanyam's model implies that discretionary liquidity traders who can time their trades will avoid the high-cost, high-volume periods that he links to high levels of informed trading. However, this breaks the concentration of trading relied on in Admati and Pfleiderer's equilibrium. This in turn makes it difficult to explain the observed high volume in terms of discretionary liquidity traders and informed traders, since the former will avoid the high-cost open and close and the number of informed traders must be "sufficiently small" (Subrahmanyam 1989, p. 18) for the result to go through. Further, were the increased volume due to a very large increase in the number of informed traders (sufficient both to offset the departure of discretionary liquidity traders and to account for the total increase in volume), one wonders who takes the other side of their trades, especially since they receive correlated signals in this model.

Presumably, the burden falls, once again, on the luckless nondiscretionary liquidity traders, who in these models have zero elasticity of demand and must

trade at these times regardless of price or cost. That is, the empirical results on spreads and volume—which the Admati-Pfleiderer and Subrahmanyam models attempt to explain—imply that within those models there must be an increase in nondiscretionary liquidity trading at open and close sufficient to offset the departure of discretionary traders in the face of higher transactions costs. Admati and Pfleiderer (1988, 34) conjecture that the orders of nondiscretionary traders may cluster around open and close because of market closure; however, this is not part of their formal model, and they rely on such periodic demand as simply a timing catalyst for their endogenous clustering that requires low trading costs at open and close to attract discretionary traders.

The second problem with these asymmetric information models relates to the cross-market results from section 2.1 above. These results show that the observed behavior in spreads and variances cannot be explained within standard information models. It is true that, looking at the two markets individually, the variance results appear similar to those from the NYSE used to motivate the asymmetric information model of Admati and Pfleiderer. At first blush, then, these results may appear to provide confirmation of the conclusion that activity at the open and close of trading in foreign exchange markets is heavily influenced by concentrations of informed traders at those times, resulting in high variances.

The results obtained from looking at London and New York separately are highly misleading, however, in terms of evidence concerning any tracks left in the data by privately informed traders. Recall that these quotes appear directly on the Reuters' screens of traders in all locations. Assume that the high variance (and high spread) at close of trade in London is indeed caused by an unusually high concentration of informed traders at that time, which in turn causes rapid changes in quotes and, consequently, high variance. Traders in New York observe directly and simultaneously these London quote revisions that are ostensibly caused by the incorporation of previously private information. Since the commodity is the same whether the quotes are posted in London or New York, it must be the case that the incorporation of new information into the London quotes must virtually simultaneously show up in New York quotes, resulting in simultaneous high variance in New York quotes.

The results in table 2.3 and figure 2.5 above clearly refute this implication. Note that the New York opening—which is ostensibly replete with private information, causing the New York variance of returns to rise dramatically—causes scarcely a ripple on the London market! Similarly, the London market closes with dramatic local effects in terms of variance but with no effect on New York. Similarly, table 2.1 and figure 2.6 above show an apparent lack of integration across these two markets with respect to spreads.

2.3 Evaluation of Results

We regard the results from section 2.2 as striking evidence that, whatever is causing the patterns in variances and spreads at the open and close of trading

in the foreign exchange market, it is *not* the incorporation of previously private information through the heavy trading of informed traders at the open and close of trading in London and New York. This is particularly evident from the comparison of volatility patterns across London and New York in figure 2.5 and table 2.3 above.

We consider two main alternative explanations for these results. First, we consider a broader class of information models that has recently been proposed to explain related forms of apparent excess volatility in stock prices, namely, models that relax the assumption in standard information models that traders have perfect knowledge about the preferences and beliefs of other traders in the market. These new models, based on imperfect information aggregation and subsequent learning by market participants, can be linked to experimental results in the behavioral literature and have proved successful in accounting for such difficult phenomena as the crash of October 1987. The second explanation that we consider, which is particularly relevant for behavior at the close of a market, returns to inventory models such as Garman (1976).

2.3.1 Models of Imperfect Information Aggregation: The Open of Trade

Our results at the open of New York and the close of London trading show that no new information is reaching the international foreign exchange market as a whole since there is an absence of unusual volatility in quotes generated by traders in London when New York opens and, conversely, at London close. One way to view these results is that quotes generated by traders in the volatile market show excess volatility relative to that implied by standard information models.

Others have noted the difficulty in explaining foreign exchange data in terms of standard information models. For example, Frankel and Froot (1990) emphasize heterogeneity of expectations across traders in foreign exchange markets and suggest three possible implications of the high trading volume in these markets for price movements: (1) greater depth means more efficient processing of fundamental information; (2) there is no relation between trading volume and prices since the market is "already perfectly efficient"; and (3) there may be "excessive volatility" caused by trading based on "noise" rather than "news" (p. 182). Frankel and Rose (1994) explore the third possibility in some detail, with emphasis on the possibility of "endogenous speculative bubbles" in foreign exchange markets.

The special nature of our cross-market data implies a high hurdle for potential explanations since such an explanation must account for both the systematic behavior within markets and the lack of congruence across markets around open and close. Thus, for example, if the explanation is to be "noise" rather than "news," it appears that London is not affected by noise when New York opens with high volatility; but at London close, the roles are reversed, with London displaying high volatility but New York now immune from any noise affecting London. This appears to be more complicated than is implied by the noise-trading models cited in Frankel and Rose (1994) or by models of learn-

ing currently applied to foreign exchange markets such as Lewis (1989a, 1989b).

One recent approach that shows promise in this context focuses on imperfect, although rational, information aggregation.¹⁵ There are two extreme views on price formation. One assumes that all private information is instantly aggregated and revealed to market participants through prices. The other assumes that price changes are capricious and irrational. One attempt to find a middle ground assumes that prices are formed as some average of these two types of behavior, an approach similar to the noise-trading models cited in Frankel and Rose (1994, 37). The approach of imperfect information aggregation also supplies a middle ground between the extremes, but in a very different way.

It is well known from behavioral laboratory experiments that, under certain conditions, asset prices can be readily generated that display systematic deviations from those predicted by fully revealing rational expectations models. These deviations display both apparent excess volatility and the characteristics often associated with speculative bubbles. The conditions needed to generate these phenomena in experimental laboratories are revealing: market participants must lack common knowledge about other traders' preferences or beliefs, or there must be insufficient traded instruments to theoretically allow traders to invert from prices to infer information. Significantly, if traders have common knowledge about preferences and beliefs, then the consistent result is that prices quickly converge to the fully revealing rational expectations equilibrium if there are sufficient traded assets given the sources of information uncertainty and if the traders have trading experience in the market.¹⁶

While standard information models typically assume common information among market participants about traders' preferences and beliefs, we regard this assumption as unrealistic in many settings, including the foreign exchange market. When traders first begin trading at the open of their local market, a commonly described issue is that they need to get the "feel" of the market at that time.¹⁷ The most important elements of this "feel" are the participants in the market at that point in time and what their trading behavior has been in the immediately prior trading period.

Clearly, current prices are not sufficient statistics for these items. Traders attempt to obtain this information by contacting traders who have been trading for some time; for example, New York traders will have contacts in London (not necessarily in the same bank) whom they will call to obtain a sense of the current market. Our interpretation of this phenomenon is consistent with the importance of knowledge about the preferences and beliefs of other traders to allow information aggregation across traders. In the more limited view of an

15. For a detailed discussion of this approach, see Kleidon (1995). This general approach has been examined in the context of foreign exchange markets by Crnja (1993).

16. For details, see Kleidon (1995, sec. 2).

17. This is not restricted to the foreign exchange market. This phenomenon has been consistently described to us in conversations with both equity and foreign exchange traders.

individual trader, the question is the interpretation of current trading behavior in the market. For example, is a request for a bid on a certain sized trade likely to be followed by the same trader for another? If so, then that will affect the terms offered for the first trade.

Significantly, traders report that, until they have got the feel of the market, they are uncertain of their "view" and hence, for example, of whether they will be going long or short one or another currency in their early trading during the day. This translates into initial high spreads, with rapidly changing quotes as traders develop their view for the current trading period.

This, of course, appears to correspond to the evidence that we presented in section 2.1 above at the open of trade. The market that has been trading for some time (London, at New York open) does not show any "excess volatility" relative to surrounding times, and the new traders (in New York) rapidly get the feel of the market, that is, assimilate important information about the current market structure that is not contained in the current price. While there is little documented evidence about the mechanisms that traders use to get the feel of the market, conversations with traders indicate that they include perusal of overnight information from various sources beyond the trading history of the particular currency being traded, as well as more formal arrangements with counterparts at overseas banks who agree to provide specific information about the market to the "novice" who is just starting to trade. One possibility consistent with our data (and not addressed by standard information models) is that the new dealers set wide spreads while they gather this information and then narrow the spreads once they are ready to trade.

However formal or informal the mechanism for obtaining information about the market structure, the level of spreads and the volatility of quotes settle down once traders get the feel of the market, and the markets trade in an integrated fashion until the next major disruption—the close of trading on one of the markets.

2.3.2 Inventory-Based Models: Close of Trade

A large proportion of foreign exchange trading, including most of that done by smaller, regional banks, is "day trading," in which traders start and end the day with flat positions. While this does not cause any particular problems at the start of the day since positions can be accumulated during the trading day that has just begun, the inventory problem for day traders becomes increasingly acute as the close of trading approaches. In the limit, a trader who *must* close out a position by the end of the day has increasingly inelastic demand to trade and will be more willing to accept a relatively poor price to accomplish the trade.¹⁸

18. Brock and Kleidon (1992) exploit differences in trading demand at open and close to predict higher spreads at these times if a marketmaker such as a monopolist specialist has the ability to price discriminate at these times of inelastic demand to trade. This idea may have some application in foreign exchange markets, particularly with respect to quotes by regional banks to customers who have peak foreign exchange trading demands at open and close.

The effects of inventory on prices and quotes are well discussed in market microstructure literature beginning with Garman (1976) (see also Amihud and Mendelson 1980; Ho and Stoll 1981, 1983; O'Hara and Oldfield 1986; and Son 1991). Recent empirical work in equity dealer markets in London (see Hansch, Naik, and Viswanathan 1993) and the United States (see Chan, Christie, and Schultz 1995) documents strong inventory effects, and Lyons (1995) documents inventory effects in the foreign exchange market. Discussions with traders in the foreign exchange market confirm that high quote volatility and spreads at close are linked by traders to the activities of day traders who are attempting to close out their positions.¹⁹

2.4 Conclusions

In this paper, we have explored the implications of foreign exchange markets for alternate models of intraday price and volume behavior. There are empirical difficulties in reconciling current asymmetric information models with stock price data in individual markets, but it is possible for some form of these models to be consistent with NYSE prices and volume, assuming that liquidity traders have strong demand to trade at open and close for reasons that are not motivated within the information models. Our choice of the foreign exchange market is motivated by the ability to test whether any form of the current asymmetric information models can explain prices and volumes in this market.

The advantages of foreign exchange data are that the market extends around the clock and that traders from any location have equal access via computer terminal to the posted quotes of all traders from all locations. If new information is the cause for revisions in quotes for traders in, say, London, then those quote revisions are immediately indicated to all other traders. Moreover, since there is an overlap between the trading days of traders in London and New York, we can observe whether the quote behavior is integrated in the fashion implied by the asymmetrical information models.

The results are inconsistent with these models. If London and New York are examined individually, they display the same patterns of spread and volatility from "open" to "close" as does the NYSE, which may indicate similar forces in each market. However, when New York foreign exchange traders begin their day, with attendant high volatility and spreads, London has been trading for hours and is still trading. There is no effect on London quotes, in either volatility or spreads, of the striking New York quote behavior. Similarly, although London "closes" its day with high variances and high spreads, this does not cause a ripple on the quotes of New York traders. This is inconsistent with standard sources of asymmetric information being the fundamental cause of this behavior.

19. A related feature of the New York close is the decrease in depth of the market as traders stop trading, with a consequent increase in spreads.

Our primary conclusion is that the current models of asymmetric information appear inadequate to explain our results. This raises questions concerning their application in other markets as well. Indeed, our findings are not limited to quotes in the foreign exchange market. Kleidon and Werner (in press) demonstrate that similar results apply to U.K. stocks that are cross-listed on London and New York exchanges and that consequently trade simultaneously in a similar fashion to the foreign exchange trading that we document here. It appears that we must turn to explanations other than current information models if we are to account for the behavior of prices and volumes in both stock and foreign exchange markets.

We suggest two possible explanations for the empirical results documented in section 2.1. First, we place importance at the open of trade on learning by traders about the structure of the market, particularly concerning the identity and behavior of other traders. This can be linked both to behavioral experimental results and to the results in recent literature that examines the implications for information aggregation of a lack of common knowledge among traders concerning the preferences and beliefs of market participants. During the period when traders pursue various mechanisms to learn the feel of the market, spreads may be set sufficiently wide to avoid trading at an informational disadvantage.

Second, at the close of trade, much of the activity in the closing market documented in section 2.1 may be due to the inventory-related activities of traders at market close, especially for the large group of day traders who must close their positions by the end of trading.

While these explanations seem plausible—and indeed are confirmed by foreign currency traders—further investigation is warranted.

References

- Admati, A. R. 1991. The informational role of prices: A review essay. *Journal of Monetary Economics* 28:347–61.
- Admati, A. R., and P. Pfleiderer. 1988. A theory of intraday patterns: Volume and price variability. *Review of Financial Studies* 1:3–40.
- Amihud, Y., and H. Mendelson. 1980. Dealership market: Market-making with inventory. *Journal of Financial Economics* 8:31–53.
- Bagehot, W. (pseud.). 1971. The only game in town. *Financial Analysts Journal* 27:12–14, 22.
- Barclay, M. J., R. H. Litzenberger, and J. B. Warner. 1990. Private information, trading volume, and stock-return variances. *Review of Financial Studies* 3:233–53.
- Bollerslev, T., and I. Domowitz. 1993. Trading patterns and prices in the interbank foreign exchange market. *Journal of Finance* 48:1421–43.
- Brock, W. A., and A. W. Kleidon. 1992. Periodic market closure and trading volume: A model of intraday bids and asks. *Journal of Economic Dynamics and Control* 16:451–89.

- Burnham, J. B. 1989. Marketmakers, speculators and customers: The U.S. foreign exchange market. Working Paper no. 130. St. Louis: Center for the Study of American Business, Washington University.
- Chan, K. C., W. G. Christie, and P. H. Schultz. 1995. Market structure and the intraday pattern of bid-ask spreads for Nasdaq securities. *Journal of Business* 68:35–60.
- Crnja, Z. 1993. Environmental uncertainty in the foreign exchange market. Honors thesis, Department of Economics, Stanford University.
- Foster, F. D., and S. Viswanathan. 1989. Variations in volumes, spreads and variances. Research Paper no. 88-108. Fuqua School of Business, Duke University.
- . 1990. A theory of the interday variations in volume, variance, and trading costs in securities markets. *Review of Financial Studies* 3:593–624.
- Frankel, J. A., and K. A. Froot. 1990. The rationality of the foreign exchange rate: Chartists, fundamentalists, and trading in the foreign exchange market. *American Economic Review* 80:181–85.
- Frankel, J. A., and A. K. Rose. 1994. An empirical characterization of nominal exchange rates. In *The handbook of international economics*, ed. G. Grossman and K. Rogoff. Amsterdam: North-Holland.
- Freeman, R. 1989. A theory of the impact of international cross-listing. Graduate School of Business, Stanford University. Typescript.
- Garman, M. B. 1976. Market microstructure. *Journal of Financial Economics* 3:257–75.
- Genotte, G., and H. Leland. 1990. Market liquidity, hedging and crashes. *American Economic Review* 80:999–1021.
- Goodhart, C. 1990. "News" and the foreign exchange market. Discussion Paper no. 71. Financial Markets Group, London School of Economics.
- Goodhart, C., and L. Figliuoli. 1991. Every minute counts in financial markets. *Journal of International Money and Finance* 10:23–52.
- Grossman, S. J., and M. H. Miller. 1988. Liquidity and market structure. *Journal of Finance* 43:614–33.
- Hansch, O., N. Naik, and S. Viswanathan. 1993. Trading profits, inventory control and market share in a competitive dealership market. Fuqua School of Business, Duke University. Typescript.
- Ho, T., and H. R. Stoll. 1981. Optimal dealer pricing under transactions and return uncertainty. *Journal of Financial Economics* 9:47–73.
- . 1983. The dynamics of dealer markets under competition. *Journal of Finance* 38:1053–74.
- Jacklin, C., A. W. Kleidon, and P. Pfleiderer. 1992. Underestimation of portfolio insurance and the crash of October 1987. *Review of Financial Studies* 5:35–63.
- Kleidon, A. W. 1992. Market and environmental uncertainty. In *The new Palgrave dictionary of money and finance*, vol. 2, ed. P. Newman, M. Milgate, and J. Eatwell. London: Macmillan.
- . 1995. Stock market crashes. In *Finance handbook*, ed. K. Jarrow, V. Maksimovic, and W. T. Ziemba. Amsterdam: North-Holland.
- Kleidon, A. W., and I. W. Werner. In press. U.K. and U.S. trading of British cross-listed stocks: An intraday analysis of market integration. *Review of Financial Studies*.
- Kyle, A. S. 1984. Market structure, information, futures markets, and price formation. In *International agricultural trade: Advanced readings in price formation, market structure, and price instability*, ed. G. G. Storey, A. Schmitz, and A. H. Sarris. Boulder, Colo.: Westview.
- Lewis, K. K. 1989a. Can learning affect exchange-rate behavior? The case of the dollar in the early 1980s. *Journal of Monetary Economics* 23:79–100.
- . 1989b. Changing beliefs and systematic rational forecast errors with evidence from foreign exchange. *American Economic Review* 79:621–36.

- Lyons, R. K. 1992. Private beliefs and information externalities in the foreign exchange market. Columbia University, March. Typescript.
- . 1993. Optimal transparency in a dealership market with an application to foreign exchange. University of California, Berkeley, September. Typescript.
- . 1995. Tests of microstructural hypotheses in the foreign exchange market. *Journal of Financial Economics* 39:321–51.
- O'Hara, M., and G. S. Oldfield. 1986. The microeconomics of market making. *Journal of Financial and Quantitative Analysis* 21:361–76.
- Romer, D. 1993. Rational asset-price movements without news. *American Economic Review* 83:1112–30.
- Son, G. 1991. Dealer inventory position and intraday patterns of price volatility, bid/ask spreads and trading volume. Department of Finance, University of Washington. Typescript.
- Subrahmanyam, A. 1989. Risk aversion, market liquidity, and price efficiency. Anderson Graduate School of Management, University of California, Los Angeles. Typescript.
- . 1991. Risk aversion, market liquidity, and price efficiency. *Review of Financial Studies* 4:417–41.

Comment Zhaohui Chen

In this paper, Hsieh and Kleidon begin with a precise description of the state of the “market microstructure literature.” They remind the readers of the original definition of *market microstructure* by Mark Garman (1976) and summarize the current dominating paradigm in the literature—the asymmetric information models in the line of Admati (1991), Admati and Pfleiderer (1988), and others. This introduction is useful to exchange rate researchers attempting to exploit microstructure models. It serves as a warning that, given its narrow focus, we should not expect this literature to give us answers to all the macroeconomic puzzles related to foreign exchange rates. On the bright side, this paper has made a welcome attempt to expand the current literature with alternative paradigms. A broader intellectual base may well be what we need to understand the behavior of the foreign exchange market.

The empirical evidence amassed in the paper clearly indicates that the opening and closing of New York and London markets seem to be local events. The associated trading activity and volatility do not transmit from one location to the other, even though the two markets are open to trade at the same time. This evidence could be interpreted in two different ways. First, the asymmetric information model may be wrong, in the sense that private information associated with high volatility in one market is not picked up by the other market. Given the simultaneity of information processing on the Reuters screen in the two markets, and given that currencies are the most standardized vehicle of trade, this interpretation does not stand well. This leads to the second interpre-

tation: the unusual market activities around the opening and closing of the markets are not driven by private information. Under this interpretation, the evidence should not be seen as a rejection of the asymmetric information model since the events used are not information driven and therefore cannot be used to test the information transmission story behind the Admati and Pfleiderer-type models. However, the evidence and the institutional analysis in the paper unambiguously show that the conventional asymmetric model is not applicable to the problems of this paper. This is an important message since it proves, by counterexamples, that the currently dominating paradigm in the microstructure literature is inadequate to cover a possibly broad array of issues in the foreign exchange market.

The second half of the paper explores different paradigms, including the traditional inventory models and the new models of learning. At this stage, most of the learning models are based on experimental results. Nevertheless, it would be extremely interesting if the authors, or future researchers, could apply their econometric tools to test the applicability of such theories and to provide evidence that can help validate different assumptions behind the new theories.

Following the discussion of the learning models in the paper, I would like to raise two questions. One is what the traders try to learn in the process; the other is whether there is a welfare gain from learning. Regarding the first question, the paper mentioned specific parameters such as preferences and beliefs and the ambiguous notion of the "feel" of the market. One possible explanation is that traders need to learn each other's trading rule, or asset valuation scheme, and even the theories behind them, as they do not want to be the outliers in the market. They can do that by testing each other's reaction to various quotes, hence the large number of quotes and high volatility from the screen data around the opening of the market. Regarding the second question, my hypothesis is that a pricing rule formed through consultation with other market participants is more likely to be correct (in absolute terms) than a simple average of other people's quotes (the whole is larger than the sum of the parts). This point is illustrated plainly (or mysteriously) in the popular management experimental game known as "Desert Survival Game," where a group of people are asked to form a survival strategy after an imaginary plane crash in a desert. The group decision following a full consultation among the group members is almost always better than the simple average of individual opinions before the consultation.

Finally, the use of the Reuters quote data in this paper is open to question in light of the recent study by Goodhart, Ito, and Payne (chap. 4 in this volume), in which they find no linkage between these quotes and real trading activities as captured by a more up-to-date data screen. Given the dismissal of the private information story, the problem is less damaging to this paper because, as the later part of the paper suggests, there may be different reasons leading to the

use of quotes, such as learning and testing (“feeling”) the market, that are not necessarily linked to actual trading activities.

References

- Admati, A. R. 1991. The information role of prices: A review essay. *Journal of Monetary Economics* 28:347–61.
- Admati, A. R., and P. Pfleiderer. 1988. A theory of intraday patterns: Volumes and price volatility. *Review of Financial Studies* 1:3–40.
- Garman, M. B. 1976. Market microstructure. *Journal of Financial Economics* 3:257–75.

Comment Antti Suvanto

The authors make the empirical observation that volatility of the deutsche mark/dollar exchange rate and the spread are high at both the open and the close of the trading day. This U-shaped pattern is evident for both New York and London. Because of time-zone differences, London opens when New York is still closed. When New York opens, London still has a few hours to go.

The second observation made in the paper is that the higher volatility and wider spread in New York at the time of opening are in no way reflected in the volatility and spread in the London market. Similarly, the higher volatility and wider spread at the time London closes do not affect midday volatility and spread in New York.

These observations seem to contradict predictions of recent microstructure theory based on asymmetric information between informed insiders and liquidity traders. This theory has been used to explain the similar U-shaped intraday pattern of the volatility and the spread in organized securities markets, such as the New York Stock Exchange.

The authors argue that, because the foreign exchange market is globally integrated and the object of trade the most homogeneous of all, the participation of informed traders at the beginning of the trading day in New York should be visible in London as well. Therefore, the spread should widen and the volatility increase at the same time in both markets. The same should be true if informed trading in London is concentrated toward the end of the trading day. Because this is not the case, the asymmetric information argument is not applicable to the foreign exchange market.

The authors suggest two types of explanations for these observations. The first is based on the heterogeneity of information across marketmakers. The

second is based on the inventory (position) adjustment behavior of "day traders." I find these suggestive explanations plausible, and I agree with the authors' final conclusion that further investigation along these lines is warranted.

Position Constraint

Let us take the inventory argument first. The authors point out that a large proportion of foreign exchange trading is "day trading," by which they mean that the banks open and close the day with closed positions. I am not sure whether it is accurate to refer to smaller regional banks alone in this context because all banks, including branches of the big international banks, are "day traders." They stop trading at some point in the day, whether their overnight position is open or not. Otherwise, there would not be distinct but overlapping trading days in London and New York.

The point made by the authors is, however, relevant. The fact that important news may be disclosed during the time when the bank is not trading and the fact that trading continues in other time zones imply that the dealers must pay attention to overnight positions. As the trading day winds down, dealers must either close a position or aim at a desired fixed open position. Whatever the position target for the end of the day, the problem of achieving this target becomes increasingly acute toward the end of the trading day, as the authors correctly point out.

I have shown elsewhere that this is true in a partial equilibrium model of the pricing behavior of an isolated profit-maximizing marketmaker facing stochastic but price-sensitive order flow from uninformed customers and aiming at a closed position or at any other fixed position target for the end of the day (Suvanto 1993, chap. 2).

Applying dynamic programming techniques, the resulting sequential pricing rule implies weak efficiency of the mid-rate and low-volatility of prices (relative to the volatility of order flow) during the most of the day, with volatility increasing toward the end of the day. The spread is chosen so as to maximize the expected trading income at each short trading period given the price sensitivity of customer orders.

The reluctance of the dealer to make frequent and drastic changes in the quoted two-way price in the absence of new information derives from the fact that such changes are generally revenue reducing, that is, selling at a low price a currency just purchased at a high price. Note that in this model the binding two-way price is set before the direction and size of the trade are known. The counterpart to small price adjustments is the dealer's willingness to accept comparatively large open intraday positions. In fact, the *ex ante* position variance increases at the beginning of the day and starts to decline toward the end of the day.

Although the environmental assumptions of this (monopolist) model are far from those of the highly competitive and closely integrated foreign exchange

market of today, the results can be generalized to a more realistic setting. Opening the model to competition and interdealer transactions makes the quotation of an individual dealer dependent on the price quotes of others and narrows the spread. From the position-adjustment point of view, the life of an individual dealer is easier because he can undo an unwanted position by calling another marketmaker or he can stay on the "right side of the market" and attract orders from other dealers by making a very small price adjustment.

This is true for the most of the day, but the mechanism does not work in the same way just before the close. Dealers who are already satisfied with their positions do not want new orders. Widening the spread decreases the likelihood of new orders. There may be unwanted open positions that do not find buyers until the spread is sufficiently large to make the price attractive to somebody, or sufficiently unattractive to the seller, until either of them is willing to carry an open overnight position.

Allowing for overlapping time zones eliminates this problem because dealers in a closing time zone can sell unwanted open positions to buyers in open time zones. Dealers in the latter are happy to buy these positions because they are on the "right side of the market" and have plenty of time to undo the position during the remainder of the day.

Heterogeneous Information

Let us now turn to the heterogeneity of information. Information may be heterogeneous even if all participants have the same information but interpret its significance for the exchange rate somewhat differently. Economists very often have the same information. Yet they may permanently disagree on the interpretation. Could one reasonably expect dealers always to have a uniform interpretation of the remainder of the day?

The authors point out correctly that dealers need to get the "feel" of the market before engaging in active trading. What does this *feel* mean?

Assume that at the time of the London opening all dealers have the same information on the macroeconomic and political news that has been reported since the previous close and that they have the same expectations about news that is forthcoming during the day. Assume further that each dealer knows with probability one that all nonbank customers that may appear during the day are price-sensitive liquidity traders. These rather extreme assumptions should eliminate all information asymmetries at the beginning of the day, but this is not the case.

Depending on the situation, each dealer acts in two different roles in relation to his interbank counterparties. Sometimes he is on the "right side" of the market and acts as a marketmaker in relation to another dealer who is requesting a quote. On other occasions, he is on the "wrong side" of the market, requesting a quote from someone else.

Each time dealer A quotes a two-way price to another dealer, B, he does not know exactly what prices are quoted by his rivals. In particular, he does not

know whether at the very same moment his dealer-customer B is receiving from dealer C a price that is inconsistent with his own quote in the sense that his ask price is below the bid price quoted by dealer C (or vice versa). If this is the case, there is an arbitrage opportunity for dealer B, who would never leave such an opportunity unexploited.

I have argued elsewhere that the possibility of inconsistent quotes cannot be eliminated entirely as long as two-way prices are quoted independently without full knowledge of all other quotes at the same moment (Suvanto 1993, chap. 3). This brings potential insiders into the picture because some participants may have observed a pair of inconsistent prices. This explains the positive bid-ask spread in the same way as the possibility of informed traders explains the positive spread in the stock market. Fundamental valuation efficiency plays no role in this context.

A dealer who has a given interpretation of the significance of publicly available information on the exchange rate during the remainder of the day may take a position based on this view by asking a price from another dealer and transacting accordingly, but he does not make a large adjustment to his own price immediately if he is not absolutely sure that all other marketmakers have already made a similar price adjustment. If he did, he might receive unwanted orders because his quote might be inconsistent with prices quoted by others. Rather, he is likely to widen the spread in order to reduce the likelihood of such an occurrence.

It is plausible to assume that dealers opening their screens in the morning have different outlooks for the remainder of the day even in the absence of any private inside information. Dealers are cautious not to start the day with a price far out of line with other quotes, which explains the wide spread. But with a wide spread there is little or no trading and hence little or no trading profit. Therefore, the dealers are eager to start trading as soon as possible, which explains the rapid convergence of the spreads to the level that makes active trading possible. Once established, the "feel" of the market is maintained because the prices and the spreads can be constantly tested in active trading.

The short period during which the "feel" of the market is established in an opening time zone need not affect prices quoted in a time zone where the markets are soon to close, provided there is sufficient overlapping. Dealers in the opening zone may get attractive quotes from the soon-to-close zone, where some dealers may get rid of their remaining positions at an attractive price. In addition, sufficient overlapping provides dealers in the soon-to-close zone sufficient time to wait until the "feel" is established in the opening zone.

Additional Remarks

The paper marks an opening to a new area of research, that is, the intermarket connections across overlapping time zones. It would be interesting to have comparable data on the overlapping Asian and European markets. Data on the

spread and volatility at closing time in Continental Europe might also be illuminating.

The data are based on indicative quotations from the Reuters' screen (FXFX), which do not give the actual transaction prices or trade volume. As the authors point out, it would be useful to check the results using alternative and more accurate sources of information.

As the data reveal, the changeover from the opening phase, when dealers are getting the "feel" of the market, to active trading takes place in a relatively short span of time. It is more or less over by the time corporate treasurers and other nondealer customers step in and begin to request prices. Similarly, most of the nonbank customers have probably already disappeared when, shortly before closing, the spread widens and the volatility increases.

This raises the question of the role of nonbank customers in the foreign exchange market. Despite the high proportion of interdealer trade, nondealer customers may be needed after all to maintain the depth of the market. Otherwise, how would dealers in the aggregate earn their trading income over the long run?

Reference

Suvanto, A. 1993. *Foreign exchange dealing: Essays on the microstructure of the foreign exchange market*. Helsinki: Research Institute of the Finnish Economy (ETLA).

