MACRO LESSONS FROM MICROSTRUCTURE

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Abstract

This paper extracts four lessons from empirical FX microstructure for modeling short-run exchange-rate dynamics. These concern order flow as the proximate cause of most exchange-rate changes and, more importantly, the economic forces behind order flow. The paper notes that the workhorse models of international macroeconomics do not incorporate these lessons. This important shortcoming in their microfoundations may help explain those models' limited empirical success with short-run exchange-rate dynamics. Building on these four microstructure lessons, the paper constructs an optimizing model of currency flows that fits many of the puzzles associated with floating rates and predicts better than the random walk. [Keywords: Exchange rates, microstructure. *JEL* codes: F31, G12, G15.]

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It is now roughly ten years since the publication of Rich Lyons' seminal work, "Test of Microstructural Hypotheses in the Foreign Exchange Market" (1995), and of the NBER's compendium of distinguished papers, *The Microstructure of Foreign Exchange Markets* (1996). Though a few prescient researchers had previously turned their attention to the currency trading process (e.g., Goodhart 1988, Allen and Taylor 1990), it was around this time that "the new microeconomics of exchange rates" went from zero to sixty in the academic equivalent of a few seconds.

As with any individual market, the microeconomics of the currency market can be fascinating to study close up. The primary motivation for this line of inquiry, however, has been to enhance our understanding of the macroeconomics of exchange rates. Currency returns at short horizons, meaning those under a year or so, had not yielded their secrets to traditional macro-based exchange-rate models (Meese and Rogoff 1983; Flood and Taylor 1996). "There are, apparently, important influences, not on the list of standard macro fundamentals, which affect exchange rate behavior," observed Taylor (1995, p. 1). Meanwhile, those economists rash enough to visit a trading floor recognized that the macro-based models had little connection to the underlying microeconomics of exchange-rate determination. Goodhart, for example, remarked that, while working at the Bank of England as an academic advisor, "I could not help but observe that some of the features of the foreign exchange ... market did not seem to tally closely with current theory… [T]here appeared to be a number of discrepancies between economic theory in this field and the beliefs and views of practitioners" (1988, p. 437).

Together, these observations suggested that the traditional models' weakness might be their lack of well-specified microfoundations. As suggested by the editors of *The Microstructure of Foreign Exchange Markets*, "[i]t is only natural to ask whether [the] empirical problems of the standard exchange-rate models … might be solved if the structure of foreign exchange markets was to be specified in a more realistic fashion" (Frankel, Galli, and Giovannini 1996, p. 3).

In the decade since the publication of these major works, foreign exchange markets have been transformed from something peripheral and vaguely perceived to something fully in focus and understood in broad outline. Thus it is fitting on this anniversary to evaluate the evidence amassed in terms of its original goal. This paper focuses on four lessons from currency microstructure for the modeling of short-run exchange-rate dynamics.

Lessons one and two come from the statistical analysis of the trading process. Lesson one: Currency flows are among the principal determinants of exchange rates so models should represent these flows explicitly. This evidence also suggests that the appropriate exchange-rate equilibrium condition may be flow-supply-equals-flow-demand. Of course, it is critical to understand the economic forces driving order flow, and this is the subject of Lesson two: Models should distinguish the flows of "financial" traders, such as mutual fund and hedge fund managers, from those of "commercial" traders, who are essentially importing and exporting firms. Cumulative financial flows should have a positive relationship with exchange rates while cumulative commercial flows should have a negative relationship.

Lessons three through and four are based on the institutional knowledge acquired while studying currency markets closely. Though institutional information is often considered irrelevant, the implications of this information reach the very foundations of our exchange-rate models. Lesson three: Financial traders are motivated by profits, rather than consumption, and their risk-taking will be constrained. Furthermore, short-term currency speculators invest in deposits, which are in elastic supply, rather than bonds, which are in fixed supply. Lesson four: Commercial traders are motivated by exchange-rate levels and rationally choose not to speculate.

Sections I and II of the paper review the evidence behind these lessons. Section III finds that standard macro-based exchange-rate models incorporate few of these lessons, which indicates that their microfoundations are not well-specified. These important lacunae may explain the models' lack of success in capturing short-run exchange-rate dynamics. Section IV summarizes an optimizing model of currency flows that has microfoundations consistent with lessons one through four and an encouraging empirical record. Section V summarizes the findings.[1]

Before launching into the substance of the paper it may be helpful to put currency microstructure research into a philosophical context. Currency microstructure is founded on an explicit commitment to understanding microeconomic reality. This aligns it clearly with

[1] The paper focuses entirely on exchange rates among the currencies of developed, low-inflation economies, largely because the microstructure research has been limited to such currencies.

Akerlof's stance on the relative merits of positive economics (Friedman 1953) and pragmatic economics (Akerlof 2005). In Akerlof's words,

> [Friedman] says … that the exact realism of the model, the correspondence of the model to the details of economic transactions, should not matter. The test of the model, instead, is whether it is rejected (or not) by statistical testing… [S]uch positive methodology might be good for fields (such as physics, perhaps), where experiments are tolerably easy, [but] it cannot be good methodology in a field like economics where hypothesis testing is close to impossible. I can hardly imagine a worse prescription for how to do *economics*… [T]he formal positivist methodology wantonly throws away the best information available to us [which is] judgment,...anecdote and experience….I suggest that … economists should restrict their attention to models that are consistent with the detail of microeconomic behavior. Friedman may be correct that such methodology does not conform to the positivist ideal, but that does not make it 'unscientific.' On the contrary, I perceive most science as inferring macro behavior from micro structure (pp. 2-3, italics in the original).

I. FIRST LESSON FROM MICROSTRUCTURE: FLOWS ARE IMPORTANT

Chronologically, the first key lesson from currency market microstructure is that currency flows exert a huge influence, possibly the dominant influence, on short-run exchange-rate returns. This section first provides a brief overview of the structure of the currency market. It then reviews the evidence for the connection between currency flows and exchange rates and three explanations for that connection. Finally, it suggests that the appropriate equilibrium condition for exchange-rate models is flow-supply-equals-flow-demand. Additional observations that lend credence to the value of this equilibrium condition are presented in Section III.

A. The Structure of Currency Trading

Currencies are traded in a "two-tier" market.[2] In the first tier customers trade with dealers. In the second tier dealers trade with each other.[3] Customer trades, which represent a bit less than half the total, are arranged privately with dealers.[4] Interdealer trades are largely carried out through electronic brokers, though they may also be arranged privately.[5] Every exchange rate is always quoted according to convention and the denominator currency measures transaction

[2] Two-tier markets are aptly modeled in Naik et al. (1999).

[3] In the brokered interdealer market agents wanting immediate, certain execution place market orders, which indicate that the dealer wishes to buy a certain quantity immediately at the best available price. Agents with some flexibility on the timing or quantity of a trade post limit orders, which indicate that the agent is willing to trade up to a given quantity at a specified price or better. Whether and when a limit order gets executed depends on market dynamics. Those who trade via limit orders earn the spread ─ their buys are executed at the low price and vice versa. Those who trade via market orders pay the spread.

size. In dollar-yen, for example, the exchange rate is quoted as yen per dollar and transactions are measured in dollars. Order flow, which is important below, is defined as buy-initiated transactions minus sell-initiated transactions.[6] Customer order flow is simply customer buys (from dealers) minus customer sells (to dealers).

B. The Evidence

A number of studies show that interdealer order flow is positively associated with exchange rates (see Lyons 1995, Payne 2003, Evans 2002, Evans and Lyons 2002, Hau, Killeen and Moore 2002, *inter alia*). The positive association implies that a currency appreciates (depreciates) when buy-initiated (sell-initiated) trades dominate. Interdealer order flow can explain up to 63 percent of daily exchange-rate returns while standard fundamentals explain less than five percent (Evans and Lyons 2002). Order flow also accounts for around two thirds of the influence of news on exchange-rate levels (Love and Payne 2003) and a similar fraction of the influence of news on exchange-rate volatility (Evans and Lyons 2003). According to Cai et al. (2001), "order flow [was the] most important …source of volatility" in the dollar-yen exchange rate during the extremely unstable year of 1998, even after accounting for the influence of news and central bank intervention.

This evidence is usually interpreted as indicating a causal connection from order flow to prices. One could reasonably wonder, nonetheless, whether the contemporaneous correlations could reflect feedback trading, at least in part – that is, returns might be generating trades rather than vice versa. The empirical record on this issue is clear. Statistically, order flow can be considered weakly exogenous (Killeen et al. 2001). Nonetheless, high-frequency feedback trading is known to be active and sometimes important (Osler 2003, 2005), so further analysis is appropriate. Even after accounting for feedback trading, however, the influence of order flow on price survives intact in daily data (Evans and Lyons 2003) and is estimated to be even stronger in transactions data (Danielsson and Love 2005).[4]

To economists accustomed to the two current workhorse models of international macroeconomics – the monetary model and the intertemporal optimizing model of the New

[4] The influence of order flow doesn't necessarily mean that financial prices can be predicted by outsiders; indeed, since most outsiders don't know order flow they couldn't use this relationship to predict exchange rates. This is discussed at greater length in Sager and Taylor's contribution to this volume. However, the absence of information on order flow among non-dealers does not in any way undermine the argument that order flow does in fact drive rates.

Open Economy Macroeconomics (Obstfeld and Rogoff 1995) – the importance of order flow may seem surprising. But in fact the importance of order flow was foreshadowed by earlier research on exchange rates. Shortly after rates began to float in the 1970s economists learned "one very important and quite robust insight ... that the nominal exchange rate must be viewed as an asset price" (Obstfeld and Rogoff (1996, p. 529). In the late 1970s the inference from the finance connection was essentially this:

> [E]xchange rates should be viewed as prices of durable assets determined in organized markets (like stock and commodity exchanges) in which current prices reflect the market's expectations concerning present and future economic conditions relevant for determining the appropriate values of these durable assets, and in which price changes are largely unpredictable and reflect primarily new information that alters expectations concerning these present and future economic conditions (Frenkel and Mussa 1985 p. 726).

The implications of the finance connection are much broader than this, however. Most importantly, it also implies that order flow will matter for exchange rates, since it has long been known that equity prices are influenced by order flow (e.g., Shleifer 1986, Holthausen et al. 1990, Kaul et al. 2000), and evidence has emerged recently that bond prices are also influenced by order flow (Fleming 2003, Brandt and Kavajecz 2005, Pasquariello and Vega 2005).

The importance of currency flows for exchange rates is certainly no surprise to dealers. Cheung et al. (2004) find that among U.K. dealers "there is perfect and unanimous agreement that intraday changes in the exchange rate do not reflect fundamental value." Instead, the dealers have a shared understanding that currency flows drive rates. Among dealers, over 86 percent say they rely on analysis of flows in carrying out their responsibilities (Gehrig and Menkhoff 2004).

The idea that flows are the proximate cause of rate changes constitutes a consistent core for dealers' trading strategies. To provide just one example: Dealers are intensely concerned about large customer deals, meaning those in excess of around $50 million. Because they expect these deals to have a significant effect on price, dealers try to learn about them as they happen. They do this by dramatically narrowing the bid-ask spreads quoted for customers most likely to make large deals (Mende et al. 2006). Dealers also compete to manage large currency needs for their customers, which involves breaking the large amount into small individual transactions. Customers can usually get a better average price this way, since small transactions cause prices to move by less than large ones.[5] As one can readily see, the importance of large customer deals rests entirely on the idea that flow demand and supply drive exchange rates.[6]

The central role dealers assign order flow in short-run exchange-rate determination is more than a curiosity. On any given trading day over a thousand foreign exchange (FX) dealers undertake tens of thousands of transactions in aggregate. Each dealer makes his livelihood from trading currencies, so the accuracy of his interpretation of exchange-rate determination can make or break his career. As a community, dealers have now spent three decades trying to make money under floating exchange rates. If flows were not important they would know it by now – or so we should believe if we take seriously the hypothesis of individual rationality.

C. Why Do Flows Drive Exchange Rates?

Since the importance of order flow to exchange rates is not intuitively comfortable for many economists, it is important to have solid explanations. Once again the finance connection proves useful: by the time currency order flow evidence became available, financial economists had already developed three explanations of the parallel evidence for equities. All three explanations seem potentially relevant to currencies, though some modifications are necessary to reflect institutional differences across markets.

1. Inventories: The first explanation, chronologically, is that prices move to reflect inventory imbalances. If a customer comes into the market to sell, the dealer must buy, so the trade creates an inventory position ─ and inventory risk ─ for the dealer. As shown in the classic inventory paper of Stoll (1978), dealers will therefore charge a spread that, in itself, generates a positive relationship between order flow and price. This relationship can be intensified if dealers adjust their prices after the trade to restore inventories to desired levels. A customer sell transaction, which leaves the dealer with excess inventory, would be followed by lower prices as the dealer encourages other customers to buy his inventory. Similarly, a customer buy transaction would be followed by higher prices as the dealer attempts to buy back the missing inventory from other customers.

[5] The strategy of breaking up large deals is common throughout financial markets. Teams of FX dealers practice periodically so they can, when the need arises, work together effectively in splitting up big orders.

[6] Numerous other strategies could be listed that also rely on the view that flows drive rates, including: how to execute large stop-loss orders, how to adjust prices in response to observed interdealer trades, and how to manage inventories.

Hartmann (1999) finds that daily spreads in the dollar-yen exchange rate ("dollar-yen") increase with exchange-rate volatility, consistent with the first inventory effect noted above. However, currency dealers rarely shade prices to adjust their existing inventory (Yao 1997, Bjønnes and Rime 2005, Mende et al. 2006). Currency dealers prefer to exploit the fast, inexpensive, and anonymous interdealer market to lay off unwanted positions. Nonetheless, most interdealer transactions are announced to other dealers, who tend to raise (lower) prices after observing interdealer purchases (sales) (Goodhart et al. 1996). Thus, even though the process through which inventories affect exchange rates after a trade seems less direct than suggested by equity-inspired models, inventory effects both before and after a trade can generate a positive relationship between currency flows and exchange rates.

Inventory models, while successful at capturing the short-run relationship between order flow and price, can only explain a temporary price response. But the evidence suggests that much of the exchange-rate response is permanent. Since daily returns are well described as a random walk, Evans and Lyons' (2002) evidence that order flow has strong explanatory power for daily exchange-rate returns is tantamount to evidence that order flow has permanent effects. Payne (2003) uses a VAR analysis of transactions data to decompose returns into permanent and transitory components. He finds that "the permanent component accounts for … one quarter of all return variation" (p. 324). Killeen et al. (2006), Bjønnes et al. (2005), Bjønnes and Rime (2005), and Mende et al. (2006) show that order flow is cointegrated with exchange rates. So, what could explain a permanent effect of order flow on exchange rates?

2. Information: The finance literature's second hypothesis is that order flow moves prices because it conveys information about true asset values. Suppose a customer knows more than the dealer about the asset's true value. Then the dealer must protect himself by charging a bid-ask spread, since he can at best break even in trades with such customers (Copeland and Galai 1983).[7] In addition, the customer trades convey information that the dealer should reflect in his pricing: if the customer buys (sells), the dealer can infer that the true value is higher (lower) than the current price. Thus a rational dealer will charge higher prices to buyers than sellers (Glosten and Milgrom 1985, Easley and O'Hara 1987). Through this price-setting mechanism the

[7] If the customer knows the price should be higher (lower), the customer will only buy (sell), meaning the dealer will only sell (buy). When the price eventually does move higher (lower), the dealer loses.

customers' information about true value is ultimately embodied in prices. Since the information is fundamental, the price effect is permanent.

The adverse selection framework described above has proved quite successful for some equity markets, notably the NYSE. However, the hypothesis needs to be modified to fit the currency market, in part because the nature of fundamental information differs between these two markets. The fundamental determinants of exchange rates are generally understood to be macroeconomic variables such as economic activity, interest rates, and prices, all of which are typically considered public, not private, information once announced. Before they are announced, however, individual dealers can gather private information about such fundamentals from their private order flow (Lyons 2001). While any one customer may not consciously know anything about today's GDP or inflation, each customer may embody some of that fundamental in his own economic activity. If GDP growth accelerates, for example, so will demand for imports and demand for foreign currency. Likewise, any one mutual fund manager's opinion of inflation may have little signal value, while the average opinion of a group of such managers, as reflected in their aggregate currency trading, might have high signal value. Since each dealer's customer order flow is his own private information, the information it carries is thus the dealer's private signal about fundamentals prior to their announcement.

The FX version of the information hypothesis requires that order flow carry exchange-rate relevant information. Evidence for this is contributed by Covrig and Melvin (2002), which shows that informed order flow from Japan tends to lead dollar-yen. The importance of order flow in transmitting information is explicitly measured in Payne (2003), which finds that "around 40 percent of all information entering the [interdealer] quotation process does so through order flow, a figure which is comparable in magnitude to equivalent measures from equity market studies" (p. 310).

Evidence tying order flow more closely to macro fundamentals comes from a crucial paper by Evans and Lyons (2005). This paper shows that customer order flow at Citibank, one of the largest FX dealing banks, has substantial predictive power for U.S. and German announcements of GDP growth, inflation, and money growth at horizons ranging from one to six months. At the longer horizons, regressions using only order flow forecast between 21 percent and 58 percent of changes in the fundamental variables, while regressions using only the lagged dependent variable or the spot rate forecast less than 10 percent in most cases.

3. Downward-Sloping Demand and Liquidity Effects: Financial economists' third explanation for the effect of order flow on prices hypothesizes that the demand for financial assets is "downward sloping" (Shleifer 1986). With downward-sloping demand a permanent increase in an asset's supply requires a permanent decline in price. Over the years substantial evidence has accumulated to support this proposition in both equity markets (Holthausen et al. 1990) and bond markets (Simon 1991, 1994, Jovanovic and Rousseau 2001).

The version of this hypothesis applied in FX, referred to as a "liquidity effect," effectively postulates an upward-sloping supply curve. This involves no fundamental change, of course, since one currency's demand is the other currency's supply. It then suggests that a surge in demand pushes the exchange rate to a higher level that pulls in the required liquidity.[8]

The finance literature focuses on two sets of conditions under which demand for financial assets would be downward-sloping (Harris and Gurel 1986). In the first set, agents must be risk averse and the asset must have no perfect substitutes: if so, a higher risk premium (lower price) would be required to induce agents to hold more of the asset. This set of conditions seems plausible for currency markets, since risk-taking is definitely constrained in FX (as detailed in Section II) and the major exchange rates are well known to be poorly correlated with each other and with equities.

In the second set of conditions for downward sloping demand, arbitrage must be limited (Shleifer and Vishny 1997) and agents must be heterogeneous in terms of preferences, tax bases, or views of the future. This set of conditions is also plausible: the long and familiar list of limits to financial-market arbitrage includes many that are relevant to currency markets, such as wealth and credit constraints, position limits, and constraints on portfolio allocations. The heterogeneity of currency market participants is highlighted by research on currency forecasts (Ito 1990, Frankel and Froot 1987, Oberlechner 2001).

Currency demand curves should slope downward (or supply curves slope upward) for a third important reason unique to the FX market. Unlike demand for equities and bonds, currency demand stems in part from real-side commerce. A downward slope to commerce-driven currency demand is to be expected, given the effect of nominal exchange rates on the real exchange rate.[9]

[8] Note: There is no implication here that any agents are passive.

[9] Note: To maintain the intuitive flow, I abstract here from the Marshall-Lerner-Robinson elasticity condition. Even if this is not fulfilled, short-run commercial demand is likely to be downward-sloping for the second reason highlighted here.

A stronger foreign currency makes foreign goods more expensive relative to domestic goods, discouraging imports from abroad (and thus foreign currency demand) and encouraging domestic exports (and thus foreign currency supply). Recent research highlights that the strength of this relationship depends on the extent of pricing-to-market, which in turn depends on the type of goods and country sizes, among other factors (see, for example, Campa et al. 2005). Nonetheless, empirical studies show that the relationship between international trade and exchange rates is consistent with a downward-sloping demand curve at macroeconomic horizons (e.g., Artus and Knight 1984).

The negative relationship also applies at high frequencies. FX customers often instruct their dealers to buy (sell) a certain amount of currency if its value falls (rises) to a prespecified level. These instructions, called take-profit orders, can be rational if agents have liquidity needs that are not immediate and if market monitoring is not costless, conditions that characterize most commercial traders in FX.[10] Together, these orders comprise an instantaneous downward-sloping demand curve. To illustrate: Figure 1 shows a portion of this instantaneous demand curve at the (entirely arbitrary) moment of 20:53 G.M.T. on January 26, 2000. The underlying data comprise all outstanding dollar-yen take-profit orders at the Royal Bank of Scotland (formerly NatWest Markets), a large dealing bank. Of course, this is only a piece of the overall instantaneous demand curve at that moment. The rest of the demand curve comprised take-profit orders at other banks plus any other price-contingent negative-feedback demand in the market.

The evidence that order flow has a powerful effect on exchange rates implies that currency flows should be explicit in short-run exchange-rate models. How should flows be incorporated? The microstructure research shows that currency flows affect exchange rates in much the same way that supply and demand affect the prices of tomatoes, automobiles, and haircuts: If there are more buy-initiated trades the price rises, and vice versa. The standard representation of equilibrium in microeconomics is equality between flow supply and demand. The microstructure evidence suggests that this same equilibrium condition could be appropriate for currencies.

This equilibrium condition is entirely out of fashion, of course, but it is not obvious why. It is true that the structure of the currency market differs from the structure of the tomato market or the car market. But classic microeconomic analysis typically assumes that "supply equals

[10] Take-profit orders are discussed at length in Osler (2003) and Osler (2005).

demand" in equilibrium while abstracting from the process through which equilibrium is actually achieved. Macroeconomic exchange-rate models can do the same: an example of such a model is presented in Section IV.

It is also true that the motivation for buying currency differs from the motivations for buying tomatoes or cars. Currency is a long-lived commodity so its demand is determined in part by anticipated future returns. In this way information can be an important determinant of exchange rates while it won't be important for classic microeconomic goods like tomatoes. Nonetheless, even among commodities customers have different motivations for participating – the reasons for buying tomatoes are entirely different than those for buying cars – but "supply equals demand" is unquestioned as the appropriate equilibrium condition in all markets.

The relevance of the supply-equals-demand equilibrium condition for financial assets is entirely explicit in the "call markets" often used for the trading of equities and bonds. Every day's opening price on the NYSE, for example, is set in a call market, and call markets are used for equity trading in many emerging markets. In a typical call auction, there is a certain time interval during which agents place orders stating an amount they are willing to buy or sell at a specific price, At the end of the interval one price is set for all trades, chosen so that the market clears. In short, the price in call markets is explicitly set according to the condition that (flow) supply equals (flow) demand.

To build macroeconomic exchange-rate models that accurately reflect the central role of currency flows requires an explicit treatment of these flows. But flows are clearly just the proximate cause of returns, and are not in themselves interesting. To understand returns in an economically meaningful way we need know: Whose flows? And what motivates those agents to trade?

II. MORE LESSONS FROM MICROSTRUCTURE

The microeconomic evidence on currency markets identifies two groups whose flows are clearly important, financial and commercial traders, and tells us how those flows are related to each other.[11] The institutional knowledge gathered while studying these markets closely informs

[11] There is much interesting exchange-rate research that adopts Frankel and Froot's (1990) assumption that FX trading is carried out by two types of speculative agents (De Grauwe and Grimaldi 2005). "Chartists" extrapolate existing trends, while "fundamentalists" focus on the exchange rate's long-run equilibrium value. These groups

us that financial traders care about profits, rather than consumption, and are constrained in their risk-taking. Further they invest in deposits, rather than bonds, for short-term speculation. This knowledge also tells us that commercial traders care about exchange-rate levels and will rationally abstain from speculating.

A. Heterogeneity in Trading Motives Is Fundamental

To generate transactions volume it is critical to have heterogeneous agents. As financial economists have long noted, there can be a "no trade" equilibrium if supply and demand curves are common knowledge and all agents are rational speculators. In this case prices are immaculately conceived: new information is instantly and perfectly reflected in price with little or no trading (Milgrom and Stokey 1982, Morris 1982). This is not consistent with the reality of currency markets, however: as described above, order flow is central to the determination of exchange rates, even upon the arrival of news.

The importance of flows for exchange-rate determination could reflect the absence of common knowledge about FX demand and supply functions. Currency markets are notoriously "opaque." Individual customers have no way of knowing each other's information and trading behavior. Dealers have some information about their own customers' trades and orders, but that information covers only a fraction of the market and is at best a very noisy signal of prevailing demand and supply functions. This lack of transparency motivates the "information" explanation for the influence of order flow discussed in Section I.

The influence of order flow could also reflect heterogeneous motivations for trading. To generate trading volume in asset-pricing models, financial economists long ago developed a category of agents called "liquidity" or "noise" traders (Kyle 1985, Black 1986). These agents' sole purpose is to trade in a manner that is orthogonal, at least in part, to that of the rational speculators. Liquidity traders are identified informally as agents who need to rebalance portfolios for non-informational reasons. Noise traders could be liquidity traders or they could be individuals that "mistake noise for information" (Black 1986). Mathematically, these traders are typically not assigned an explicit objective function but are instead quite literally noise, in the sense of a random variable.

This solution is not completely satisfactory to everyone. As Ross (1989) notes,

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could well be important, but empirical microstructure research has not yet focused on this distinction so I do not comment on it here.

> It is difficult to imagine that the volume of trade in security markets has very much to do with the modest amount of trading required to accomplish the continual and gradual portfolio rebalancing inherent in our current intertemporal models. It seems clear that the only way to explain the volume of trade is with a model that is at one and the same time appealingly rational *and yet permits divergent and changing opinions in a fashion that is other than ad hoc* (italics added).

The FX microstructure research permits us to be less ad hoc about the sources of heterogeneity – and thus trading volume – in currency markets. It shows that trading volume at macro horizons is driven, at least in part, by two identifiable groups of agents: financial traders and commercial traders. Financial traders are essentially institutional asset managers who allocate wealth across currencies, including currency funds, some hedge funds, international mutual funds, etc. Commercial traders are essentially nonfinancial firms engaged in international trade.

Currency trades can occur between fully rational and equally-well-informed members of these groups because their motivations for trading are entirely different. Financial traders can be viewed as speculators whose currency demand is influenced by expected exchange-rate *changes*. In the language of monetary theory we can say that financial traders care about currencies as a store of value.[12] Commercial traders need currency as part of their primary business, international trade in goods and services, so they care about currencies as a medium of exchange. Commercial traders are influenced primarily by current exchange-rate *levels*, the influence of which operates primarily through the real exchange rate.

The financial-commercial distinction has long been central to the way dealers structure their operations.[13] Their practical definition of these categories may not correspond exactly to the distinction between store-of-value customers and medium-of-exchange customers. Real-world financial customers sometimes rebalance their portfolios for non-informational reasons, and sometimes speculate in equity or bond markets without regard to currency risk, in which case they are not considering currency as a store of value. Real-world commercial customers

[12] Technically speaking, financial traders only care about currency per se as a store of value when they trade intraday. Interbank trading, almost all of which is intraday, accounts for roughly half of all FX trading (B.I.S. 2004). Hedge funds, commodity trading arrangements (CTAs), and some quantitative groups at mutual funds also undertake substantial amounts of interday trading. When currency is held overnight or longer and invested in deposits or short-term securities, it is technically the investment vehicles that serve as a store of value. However, many investors treat "currencies as an asset class" of its own, in which case the best approximation to reality is that the currency itself serves as the store of value.

[13] The currency sales team at a substantial dealing bank will be divided into "corporate" and "institutional" sales.

sometimes buy or sell foreign companies. Nonetheless, the distinction is a reasonable first approximation.

Microstructural analyses of transaction records, with customers divided according to the dealers' own categories, show that these two groups have vastly different trading patterns. Most importantly, at short horizons cumulative financial order flow is positively cointegrated with exchange rates, while the reverse is true for cumulative commercial order flow. Confirming evidence for this pattern comes from so many studies that it can legitimately be considered a stylized fact. The pattern is found in Lyons (2001) study of monthly customer flows at Citibank; in Evans and Lyons' (2004) study of daily and weekly customer flows at the same bank; in Marsh and O'Rourke's (2005) analysis of daily data from the Royal Bank of Scotland, another large dealing bank; in Mende et al.'s (2005) analysis of transaction data for a small bank in Germany; and in Bjønnes et al.'s (2005) comprehensive study of overnight trading in Swedish kroner. There is no disconfirming evidence.

The evidence might appear to indicate that exchange rates react inversely to commercial trades, implying that commercial customers pay negative spreads. This would not be a correct inference, however. Mende et al. (2005) show that spreads for all customers are non-negative, and in fact spreads for commercial customers are larger, after controlling for deal size, than spreads for financial customers. Thus we must look deeper.

A major implication of these results is that financial flows and commercial flows are negatively related to each other, meaning that at horizons of a day or longer financial demand tends to be met by commercial supply. The microstructure evidence can explain this striking pattern in terms of liquidity. During trading hours dealers always stand ready to provide liquidity at a moment's notice. But the dealers themselves rely on liquidity coming from the customer community. Individual dealers generally prefer to end the day with zero inventory,[14] which means that the entire dealing community usually ends the trading day with roughly zero inventory. This means that if one customer opens a position and holds it overnight the dealing community must find some other customer(s) willing to take over the position within the same day. In essence, the other customer(s) provide a kind of "ultimate" liquidity while the dealers provide "immediate" liquidity.

[14] Indeed, they typically eliminate any newly-acquired inventory within a half hour (Bjønnes and Rime 2004, Mende et al. 2006).

The evidence to date indicates that the ultimate liquidity suppliers tend to be commercial agents. Since the relationship between financial order flow and exchange rates is positive, it seems as if financial agents are pushing the rate. A financial purchase, for example, would make currency more expensive. But who would supply the liquidity? Commercial agents are more likely to sell when a currency becomes expensive, so commercial liquidity is effectively pulled in by the new rate. Evidence for a crucial link in this chain of reasoning was recently provided by Bjønnes et al. (2005), which shows that commercial transactions tend to lag financial transactions, consistent with this liquidity hypothesis.

Some readers may be concerned that commercial trade is too small to be as important to exchange rates as financial trade. As noted by Pippenger, some "will argue that …exchanges of financial assets probably dominate the daily volume in foreign exchange markets. However gross volume is not what is relevant … What is relevant is the net volume" (2003, p.141). There is substantial heterogeneity in the way financial agents go about forecasting exchange rates: some focus on fundamental factors, others on technical factors, yet others focus on order flow (Gehrig and Menkhoff 2004). Thus there will doubtless be substantial trading within this group. The microstructure community has begun to analyze heterogeneity among financial traders (e.g., Fan and Lyons 2003), but the evidence is still scarce.

In short, the microeconomic evidence suggests that models of short-run exchange-rate dynamics should explicitly include flows from both financial traders and commercial traders, who are distinguished by the way exchange rates enter their objective functions. The cumulative order flow of financial (commercial) traders should be positively (negatively) cointegrated with exchange rates at short horizons.

B. Financial Traders

The third important lesson from microstructure concerns the nature and activity of financial traders. As participants in this field recognize, to do serious microstructure research one should be well-informed about the markets' institutional structure. At NBER microstructure conferences, for example, market participants are always invited to be luncheon speakers, for exactly this reason. The institutional knowledge gained in studying currency markets informs us that financial agents care about profits, rather than consumption, and will be constrained in taking risks.

Profits: Currencies of the developed, low-inflation economies are traded in a wholesale market where the average trade size exceeds $1 million. A potential customer cannot trade until a dealer has investigated its credit-worthiness and assigned it a credit limit. In consequence, the vast majority of currency trades are initiated by firms such as banks, corporations, and asset managers. Indeed, retail trade among major currencies is almost invisible statistically ─ and trading by individuals is just one piece of retail trading.[15] (Consumer demand may be a significant force in emerging market economies with substantial currency substitution.)

The centrality of institutions in the major FX markets suggests that the relevant microeconomic theory is the theory of the firm, which in turn suggests that profits are the relevant objective. Nonetheless, one can reasonably wonder whether a truly well-grounded theory would trace the motivations for trading back to deeper roots in the theory of the consumer. Institutional traders will behave like consumers when two conditions hold. First, the shareholders themselves must be motivated by consumption. Second, the incentives of shareholders and their trader-employees must be perfectly aligned with the shareholders' interest in consumption. In reality, however, neither of these conditions seems likely to hold.

The first condition is unlikely to hold because the "interest of shareholders" is, within the private sector, assumed to mean maximum share value. Even within microeconomics it is standard to assume that firms maximize profits, not shareholder utility. This vision of shareholders is reinforced by our own teaching. One of the core courses in any business or finance program is "Investments," at the center of which is Markowitz's Nobel prize-winning theory of portfolio choice. This interprets shareholders as caring about portfolio risk and return and includes no discussion of consumption.

The second condition may not hold because agency problems cause divergences between the interests of shareholders and of their employees. Take a large bank, for example. The line of responsibility begins with the Board of Directors and runs through the CEO, the Treasurer, the global head of trading, and the local chief dealer before finally reaching the people who actually do the trading. Incentive schemes must be carefully designed because asymmetric information plagues every link in this chain. The incentives facing traders at the bottom of the chain of

[15] Sources at the Bank for International Settlements estimate informally that retail trades account for less than one percent of total currency trading. Data on retail trade are not collected, so more exact estimates are unavailable.

command need not be perfectly aligned with those of shareholders at the top.[16] If shareholders actually care about consumption, then these incentives are in fact badly aligned, since in practice a large share of a financial trader's compensation, often more than three quarters, comes from an annual bonus heavily influenced by his profits, or from a share (sometimes hefty) of the returns to assets under management (Sager and Taylor 2005).

In short, shareholders might be motivated by consumption but it seems unlikely. Even if shareholders are motivated by consumption, the institutional reality is that financial traders are motivated by profits, not consumption, according to the conscious intent of their employers.

Constrained Risk Taking: Agency problems also lead institutions to impose formal constraints on risk-taking. At banks, for example, "[e]ach trader will be set prudential limits by his bank on his close-of-business open position, and a much larger intraday position" (Goodhart 1988, p. 456). Most speculative traders must comply with loss limits and position limits; indeed, such limits are considered an essential component of any sound internal control program. In addition, speculative traders at some institutions face the gambler's ruin problem (Carlson 1998): a long series of losses will put them out of a job. Under either explicit risk limits or the gambler's ruin problem the behavior of risk-neutral and risk-averse traders will be qualitatively similar.

Deposits: Euro-currency deposits of short maturity are the asset of choice for financial traders engaged in short-run speculation: the one-month maturity is particularly popular. Even the Bank of Japan tends to invest its currency reserves first in deposits and only later in bonds. To people in the market this is an uninteresting fact, as newsworthy as their morning coffee. From the perspective of modeling exchange rates, however, this bit of information is quite significant. It implies that the supply of investable assets is not fixed, since banks create and extinguish deposits on demand. And of course this implies a hugely influential role for monetary policy, since interest on short-term deposits is dominated by central bank intervention rates.

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[16] Agency problems in currency markets are not yet the subject of widespread research, but they seem likely to be an important influence on reality. Bensaid and DeBandt (2000) have already explained the use of stop-loss limits for currency traders using agency theory. Agency problems more generally have been a major theme in corporate finance research since Jensen and Meckling (1976), and the real-world importance of such issues was recently highlighted anew by a wave of major corporate scandals.

C. Commercial Traders

The last important lesson from microstructure concerns the nature of commercial traders. These agents are motivated by current exchange-rate levels and will in most cases rationally eschew speculation.

Exchange-Rate Levels: Commercial traders use currencies as a medium of exchange in carrying out their broader purpose of profiting from real-side commerce. Their trades respond to the current exchange-rate level, which matters in two ways. First, the exchange rate matters at macro frequencies because it affects the real exchange rate, as described earlier. Second, the exchange rate matters at high frequencies because of optionality embedded in their trading.

Suppose a customer needs currency but not instantly. For example, it may necessary to pay for last month's imported inputs from Japan sometime today. The customer could buy the foreign currency first thing in the morning or wait, hoping to get a better price later in the day. Given the volatility of exchange rates there is a high likelihood that waiting could yield at least a slightly better price. In effect, the customer owns an option to trade at a better price later. Since options are valuable as long as volatility is positive, trading immediately would be equivalent to throwing away the value of the option. To encourage their traders to capitalize on this option value and seek the best possible rates many firms instruct their Treasurer to ensure that the year's average traded rate is below a given target, typically set somewhat above the rate prevailing at the beginning of the (fiscal) year. In most cases it is too expensive for the firm to monitor the market continuously during the day; instead, corporations place take-profit orders with their dealers. These orders generate the instantaneous demand curve discussed in Section I.[17]

No Speculation: When exchange-rate models include explicit commercial traders, the following question is often posed: Shouldn't these agents speculate, if they are rational? By the same logic, of course, one could reasonably wonder whether rational speculative agents should engage in importing and exporting. Fortunately, microstructure has an answer to the original question, which is this: in reality, commercial agents rarely speculate. Insiders at one major dealing bank, for example, report that the commercial customers engaging in noticeable amounts of speculation could be counted on one hand (and the bank has hundreds of customers). Dealers at other banks concur. As one trader puts it, "Almost all of [the corporate customers] will tell you

[17] Additional costs and benefits of placing orders rather than dealing immediately are discussed in Handa and Schwartz (1996), Foucault (1999), and Hollifield *et al*. (2002), *inter alia*.

'we're not in the business of speculating'," (Clyde, quoted in Mende et al. 2005). Goodhart (1988) confirms this, noting "a feeling by corporate treasurers that they [a]re not in a position, with regard to comparative information and perceived role, where they should take up purely speculative positions" (p. 454). In fact, speculation is considered so inappropriate among commercial customers that many are forbidden by corporate resolution from engaging in it (e.g., Sony).

The microeconomic motivation for such seemingly draconian measures can be understood by turning once again to the economics of the firm. Corporations have learned through painful experience that their best strategy is (usually) to focus on "core competencies." This informal but influential conclusion is supported by empirical research documenting the lackluster performance of diversified firms relative to more focused firms (Lang and Stulz 1994, Berger and Ofek 1995). The benefits of focusing on core competencies are presumably related in part to the high costs of acquiring expertise – and it can certainly be expensive to hire currency traders.[18] Furthermore, the benefits from such expertise may not be substantial, "since academics view the exchange rate as a particularly difficult variable to forecast" (Cheung et al. 2004).

Permitting currency speculation in a nonfinancial corporate setting is also risky due to agency problems. Rogue trader risk, for example, is not only real but potentially deadly, as illustrated by the Barings fiasco. To control this and related risks, financial firms have elaborate systems of controls on trader behavior, including the limits mentioned earlier, and they maintain staff dedicated to enforcing those controls (a function known as "compliance"). When speculative trading is permitted, for example, financial firms know they must "separate the front office from the back office," meaning they must ensure that those responsible for trading are not also responsible for clearing and settlement. Nonfinancial firms usually cannot justify the expense of separate front-office and back-office staff, to say nothing of compliance staff, since they only trade sporadically. Thus nonfinancial firms seem entirely rational when they eschew currency speculation.

Flows versus stocks: Commercial foreign currency demand is determined entirely different from commercial demand for domestic currency. While commercial firms hold inventories of domestic currency, they typically avoid holding inventories of foreign currencies. Instead, they buy the foreign currency just before they need it to purchase an import, or sell

[18] Base pay for an experienced trader is easily $150,000, and the bonus will often exceed that by many multiples.

foreign currency just after receiving it in exchange for some export. Thus a "representative firm's" stock demand for foreign currency is zero at most times, and is non-zero only at moments that are intentionally brief.

A closer look at a commercial foreign-currency demand function shows that the first difference of this demand will not be the same as the associated currency market flows. Suppose a U.S. import firm buys Y yen in the FX market on day t and then uses it to pay for a machine imported from Japan on day t+1. Various aspects of this demand sequence are shown below:

	t -2	t -1	t	t+1	t +2
Stock Demand	0	0	***Y***	0	0
First Difference		0	***Y***	**-*Y***	0
FX Market Flows		0	***Y***	**0**	0

The stock demand is zero on every day except day t itself. The first difference of this stock demand is non-zero on two days, t and t+1. Our key comparison is between this first difference and the FX market flows generated by this firm. On day t the two are the same, since the firm buys the yen in that market. On day t+1, however, the first difference of demand is -Y but foreign-exchange-market flows are zero. Why? When the firm changes its foreign currency position from Y to 0 it simply pays the yen to the Japanese export firm; there is no need to transact in the FX market,. Since the yen are not foreign currency to the Japanese firm, but are instead domestic currency, there is no further need for either firm to transact in the FX market. (Note that first differences and FX market flows will be the same for financial firms.)

The assumption that first differences of stock demands capture currency market flows has long been provided a key piece of intellectual support for portfolio balance models. These models, however, typically ignored commercial flows through the foreign exchange market, or at best modeled them crudely. Yet, as documented earlier, the key determinant of short-run exchange rates is flow demand through the currency market *per se* (Lesson One), and the contribution of flow commercial demand is critical (Lesson Two). Thus an accurate model of short-run exchange-rate dynamics requires a conceptually correct model of commercial flows through the currency market. And since the first difference of commercial currency demand is fundamentally different from the FX market flows it generates, one cannot accurately represent commercial FX flows by modeling stock commercial demand and assuming that the first differences are isomorphic to the FX flows. In short, stock models of currency demand are unlikely to capture short-run exchange-rate dynamics because their flow commercial currency demands will be conceptually mis-specified.

III. MICROSTRUCTURE AND THE WORKHORSE EXCHANGE-RATE MODELS

As shown in Sections I and II, the microstructure evidence amassed to date provides four lessons for models of short-run exchange-rate dynamics: (1) Currency flows are immensely important and should be accounted for explicitly; (2) Exchange-rate returns are positively related to financial order flow and negatively related to commercial order flow; (3) Financial traders are motivated by profits, rather than consumption, behave as if they are risk averse, and invest short-term speculative funds in deposits rather than bonds; and (4) Commercial traders are motivated by exchange-rate levels and rationally choose not to speculate.

This section shows that the workhorse exchange-rate models fit few of these micro-structure lessons. This reflects, in part, the fact that they were developed before the microstructure evidence became available. These gaps between these theories and micro-economic reality could help explain the theories' limited empirical success with short-run data.

This analysis focuses exclusively on the workhorse models' relevance to exchange rates in the *short run*. The models' theoretical and empirical relevance to long-run exchange-rate dynamics has been amply demonstrated (e.g., Taylor 1995, Flood and Taylor 1996).

A. Flows in Exchange-Rate Models

This idea that exchange rates are determined in the short run by currency flows has a long history within international macroeconomics. Indeed, the earliest theories of exchange rates, which assumed that all currency demand and supply is prompted by commercial trade, imposed the standard microeconomic equilibrium condition, flow supply equals flow demand (see Krueger 1983). But these models excluded an important component of currency demand – the speculative component – so they were ultimately replaced.

The more comprehensive framework that came later, the Mundell-Fleming model, continued to assume that exchange rates are determined by flow supply and demand even as it broadened the determinants of flow to include speculative as well as commercial motives for trading (Fleming 1962, Mundell 1963). For practical purposes outside of academe this model offers powerful guidance to the forces at work among international macroeconomies. That is why most academics teach this model to their undergraduate and terminal masters' students, even while recognizing that it has serious conceptual shortcomings.

One such conceptual shortcoming is the Mundell-Fleming model's assumption that expected returns determine asset *flows* rather than asset *holdings*. The next generation of exchange-rate models, the closely-related monetary (Mussa 1976) and portfolio-balance models (Branson 1975), correctly assumed that asset holdings, rather than asset flows, are directly determined by expected returns. In the portfolio-balance model, for example, domestic and foreign demand for domestic bonds would be determined by the bonds' relative returns:

(1) $$B = B(r, r^*)W, \qquad B^* = B^*(r, r^*)W^*,$$

where B and B^* are domestic and foreign holdings of domestic bonds, r and r^* are domestic and foreign bond yields, W and W^* are domestic and foreign wealth, and $B_1(.)$, $B_1^*(.) \geq 0$, $B_2(.)$, $B_2^*(.) \leq 0$. The new models also correctly assumed that bond holdings around the world must aggregate to bond supplies, or $B + B^* = \overline{B}$ where $\overline{B}$ is the total stock of domestic bonds.

As a natural extension of this line of reasoning, the next-generation models also required continuous stock equilibrium in money markets at home and abroad:

(2) $$M = PL(r,Y), \qquad M^* = P^*L(r^*,Y^*).$$

Here, M is the domestic money stock, P is the domestic price level, and Y is domestic income; foreign variables are denoted with an asterisk. The models also assumed continuous PPP: $S = P/P^*$, where S is the domestic currency value of foreign currency. Together, the money-stock equilibrium conditions plus PPP imply that "the exchange rate [can be interpreted as] the relative price of two monies" (Krueger 1983, p. 62):

(3) $$S = \frac{M}{M^*}\frac{L(r^*,Y^*)}{L(r,Y)}.$$

The crucial role assigned to money stocks in these models is further highlighted in the exchange-rate solution to the more modern version of this model in which money demand is log-linearized: $m_t - p_t = -\eta i_t + \phi y_t$ and $m_t^* - p_t^* = -\eta i_t^* + \phi y_t^*$. Here, $i_t \equiv \log(1+r_t)$, $i^*_t \equiv \log(1+r^*_t)$, lower-case letters represent logs, and time subscripts are added for convenience. This version further assumes rational expectations and uncovered interest parity (UIP), $i_t \approx i_{t+1}^* + E_t\{s_{t+1}\} - s_t$. The implication is that the exchange rate must be the discounted sum of future expected fundamentals, where the fundamentals are money supplies and output:

(4) $$s_t = \frac{1}{1+\eta}\sum_{j=0}^{\infty}\left(\frac{\eta}{1+\eta}\right)^j E_t\left[(m_{t+j} - m^*_{t+j}) + \phi(y^*_t - y_t)\right].$$

In this way currency flows disappeared from standard exchange-rate models. Money markets were considered fundamental to the determination of exchange rates; indeed, a recent casual listing of exchange-rate fundamentals reads: “money supplies, money demand shocks, productivity shocks, and so forth” (Engel and West 2005, p. 492). Currency flows were invisible, and no one was bothered because such flows were considered unimportant. And yet, as is well known, the foreign exchange market is the largest in the world, with daily flows of almost $2 trillion (B.I.S. 2004). As pointed out by the editors of *The Microstructure of Foreign Exchange Markets*, there is “a prima facie contradiction between the models and reality. …[S]uch models imply the absence of trading in assets. By contrast, one of the most important empirical facts about the foreign exchange market is the high volume of transactions that occur daily” (Frankel, Galli, and Giovannini 1996, p. 2).

The most recent workhorse exchange-rate model (Obstfeld and Rogoff 1995) nonetheless adopts many of the same underlying assumptions as the monetary model, including continuous stock equilibrium in money markets and short-run PPP (in individual commodities). Unlike the monetary model, of course, the new approach embeds these assumptions in a dynamic general equilibrium framework in which all agents optimize intertemporally, output is endogenous, domestic and foreign bond holdings are chosen rationally, etc. Nonetheless, the core mechanism through which the exchange rate is determined, and the resulting expression for the equilibrium exchange rate, remain largely unchanged.

The theoretical unimportance of flows after the mid-1970s did not reflect empirical evidence suggesting that flows do not matter. To the contrary, the empirical record on this issue was essentially silent until the recent microstructure evidence. Nonetheless, the idea that currency flows matter for exchange rates became discredited within academe soon after the monetary model was introduced. As Phillips and Pippenger observed over a decade ago, “Stock models of … exchange rates have almost completely replaced flow models. But … there is no compelling body of empirical evidence supporting one approach over the other. Indeed, after years of work, stock models still have no better record for explaining exchange rates than the older flow approach associated with purchasing power parity” (1993, pp. 441-442). It was as if the idea that flows were central to exchange-rate determination was guilty by association. Since the flow models were incorrect in assuming that expected returns determine flows not stocks, the models were also assumed to be incorrect in assuming that flows matter at all.

Besides, there were good reasons to believe that the stock-flow issue was irrelevant. Stock equilibrium can be equivalent to flow equilibrium if all trading is carried out by agents with rational, well-defined demand for both domestic and foreign currency, and adjustment to desired portfolios is instantaneous. So there seemed no important reason to focus on currency flows rather than stocks in exchange-rate models.

Our newly enhanced understanding of the microeconomics of exchange rates shows that there are important reasons to focus on flows, after all. First, as discussed in Section I, currency flows are among the principal determinants of short-run exchange-rate dynamics. Second, as discussed in Section II, it is not possible to devise a stock-equilibrium model that accurately captures the impact of commercial agents.

In addition to these important reasons for modeling flows, there are good reasons to believe that money stocks are not themselves among the principal determinants of exchange rates at short horizons. As documented by Cai *et al.* (2001) and Anderson *et al.* (2003), currency market participants essentially ignore money supplies. News about exchange-rate fundamentals like GDP and the CPI generates an immediate and strong price response – in simple event studies these announcements explain up to thirty percent of post-announcement exchange-rate returns. However, the release of money stock figures generates almost no exchange-rate response. Cai et al. finds that dollar-yen did not respond at all to money supply announcements during 1998. Anderson et al., which examines more exchange rates and a longer time period, finds that the coefficient on standardized money surprises is only significant for some exchange rates. Further, when that coefficient is significant it is only about one tenth as large as the corresponding coefficients on GDP or the CPI, and the explanatory power of money supply surprises is similarly tiny. Economists at the Royal Bank of Scotland (RBS) do not include money supply announcements in their "Weekly Calendar" of upcoming statistical releases distributed to customers. As RBS's Neil Parker explains, "we do not include the money supply announcement for the reason that the financial markets have stopped watching them" (2005).

A close look at the microeconomics of money demand suggests a reason why money stocks generate so little interest in currency markets. When applied to the short run, the monetary theory of exchange rates suggests that when John Doe moves some cash into T-bills, dollar-yen responds immediately. Perhaps the reader is now sufficiently familiar with currency markets to find this implausible. One difficulty here is that the "demand for money" is an immense category, and there is no evidence linking most of its constituent pieces to short-run exchange rates. Instead, the evidence suggests that exchange rates are determined by changes in the narrow subset of money demand components that drive currency flows through dealers.

The monetary theory embodied in Equations (3) and (4) is further disadvantaged by its inconsistency with the macroeconomic models currently considered appropriate for monetary policy analysis. Standard macroeconomic models now focus on interest rates, either ignoring money altogether (Clarida *et al.*, 1999) or relegating it to an insignificant role (Romer, 2000). Realism is the most important reason for this modeling choice. "Most central banks, including the U.S. Federal Reserve, now pay little attention to monetary aggregates in conducting policy" (Romer 2000, p. 149). "Even in Germany, … policy from the 1970s through the 1990s was better described by an interest rate rule aimed at macroeconomic policy objectives than by monetary targeting. [Further,] the dominance of interest rates over monetary aggregates in the conduct of monetary policy is not a recent phenomenon. In the United States, for example, only in the 1979-1982 period did monetary aggregates play a significant role in policy" (Romer p. 155).

In light of this reality, the macro models used for monetary policy analysis now assume that central banks target interest rates. The models assume that central banks can control interest rates by adjusting high-powered money, but they leave the control process in the background. In these models, aggregate demand can be expressed as a function of expected future interest rates, rather than a function of expected future money supplies as in Equation (4) (Clarida *et al.*, 1999; Woodford, 2003).

While the empirical importance of money for exchange rates is apparently quite slight, as noted above, the empirical importance of interest rates can hardly be exaggerated. If exchange-rate models were to focus on interest rates as the target of central bank policy, rather than money, their realism would be enhanced in two ways: they would more accurately capture the true determinants of exchange rates and they would more accurately represent central bank policy.

B. Commercial and Financial Traders

The currency microstructure evidence indicates that commercial order flow and financial order flow are inversely related to each other and that financial order flow is positively related to exchange rates. The workhorse models do not conform to these lessons. In these models flows are intentionally not modeled, of course, but if asset holdings are modeled with sufficient care at least financial flows might be recoverable by taking first differences. However, the models essentially assume most flows entirely out of existence. Thus most flows cannot be identified and the models cannot not imply any particular relationship between commercial and financial trading. In addition, commercial and financial traders in these models do not have some of the properties determined by the FX market's institutional structure.

Absence of Flows: In the monetary model, both financial and commercial flows are non-existent. The model does not model financial traders explicitly, but instead assumes that they are sufficiently aggressively to maintain continuous uncovered interest parity. This implies, of course, an internal inconsistency: financial agents do not act but they nonetheless enforce continuous UIP. This type of inconsistency is entirely acceptable in certain circumstances. For example, it seems reasonable in the context of covered interest parity, where modelers regularly assume that parity holds without modeling the arbitrage activity that eliminates any deviation. With covered interest parity this modeling fudge is acceptable because parity truly does hold exactly – or at least very closely – all the time (Akram et al. 2005).

Unfortunately, the monetary model's internal inconsistency with respect to UIP cannot be justified on the same grounds. Indeed, interest-rate differentials in low-inflation countries tend to be negatively related to exchange-rate changes, rather than positively related as predicted by the joint hypothesis of UIP and rational expectations. The failure of UIP is so extreme that it has become known as the "forward premium puzzle" and hundreds of papers are devoted to explaining it. This puzzle, which seems to be consistent across the entire floating rate period (Chinn 2005), has been surveyed at least five times (Hodrick 1987, Froot and Thaler 1990, Lewis 1995, Engel 1996, Chinn 2005).[19]

The monetary model has no commercial traders though it assumes continuous PPP which requires arbitrage by commercial agents. This involves an internal inconsistency similar to the one discussed above with respect to UIP. Unfortunately, the assumption of short-run PPP has had no more empirical success than the assumption of short-run UIP. Indeed, the failure of PPP at short horizons was one of the first important lessons from floating rates. PPP usually does *not*

[19] Some have attributed the mystery to the transactions costs of arbitrage (Sarno et al. 2005), while others have attributed it to statistical difficulties associated with the standard estimation approach (Baillie and Bollerslev 2000). These answers are challenged to account for the many hedge funds, currency overlay firms, and others known to be profiting from forward bias. In any case, the fact remains that UIP is not a close approximation to short-run reality.

hold at short horizons, and deviations from parity are so often immense that influential studies are devoted to measuring the gap (e.g., Engel and Rogers 1996). Furthermore, convergence to PPP is quite slow: the half-life of PPP deviations is estimated to be anywhere from roughly one year (Obstfeld and Taylor 1997, Imbs et al. 2005) to three-to-five years (Rogoff 1996). For small deviations there may not no tendency towards convergence whatsoever (Obstfeld and Taylor 1997; Sarno et al. 2004).

The Obstfeld-Rogoff Redux model (1995) includes financial traders of a sort, but they are assumed to be consumer-producers. Thus one set of agents is assigned both of the critical trading motivations, speculation and commerce, and the flows associated with the two motivations cannot be distinguished. In effect, this model assumes away the heterogeneity that the microstructure evidence now suggests is critical to understanding exchange-rate dynamics.

The original Redux model also assumes PPP (in individual commodities), with the attendant deviations from reality described earlier. Important alternative versions of the model permit deviations from PPP (e.g., Betts and Devereux 1996), but exchange rates in these versions are still determined essentially as the relative price of two monies, and the exchange rate fulfills a modified version of equation (4).[20] Thus the fundamental difficulties of this workhorse model extend beyond the inaccuracy of assuming continuous PPP, and reflect instead the failure to model currency flows.

Properties of Financial Traders: The workhorse exchange-rate models typically incorporate only one of the institutionally-determined attributes of financial traders ─ a focus on profits, constrained risk-taking, and the use of deposits rather than bonds for short-term position-taking. Though the monetary model leaves financial traders implicit, the forces driving their behavior can be discerned through its uncovered interest parity condition. This condition is consistent with the financial traders having profits in their objective function but, since there is no risk premium, the condition requires that the traders be risk neutral. This prevents the model from providing a useful explanation for short-run currency risk premiums, though the evidence shows that such risk premiums are both substantial and variable (Hodrick 1987, Froot and Thaler 1990, Lewis 1995, Engel 1996, Chinn 2005).

While the speculative agents of the Redux model are risk averse, consistent with the lessons of microstructure, their objective function is defined over consumption rather than profits

[20] See for example equations (23) and (25) of Betts and Devereux (1996).

(Obstfeld and Rogoff 1995). When applied to short horizons, this implies an important role for consumption risk in currency risk premiums. While this may be theoretically satisfying, it doesn't fit the empirical evidence: as is widely recognized, consumption itself is not sufficiently volatile to account for observed volatility in currency risk premiums. The high volatility of currency risk premiums seems much more plausible when we recognize that speculative FX traders are actually motivated by profits.

The speculative agents of the Redux model are also assumed to invest in bonds which are, in turn, in fixed supply. This implies an important role for the bond supply in determining the exchange rate. This, too, has found little theoretical support despite its theoretical attractions.

The intent of the Redux model and subsequent modifications is to create a policy-relevant model "with well-specified microfoundations" (Lane 2001). The microstructure evidence shows that the microfoundations of the model are not well-specified with respect to exchange-rate determination. Economic models can never be fully realistic, of course. In designing models we are forced to hope that the inevitable abstractions will be sufficiently innocent to leave intact the models' empirical relevance. But the abstractions in the monetary model and the intertemporal optimizing model are not innocent. Because of these abstractions the models cannot replicate even the most basic feature of currency markets – the high trading volume. And yet the evidence shows that currency flows are the single strongest force driving exchange rates. Thus it should be no surprise that these models have not succeeded in teasing out the forces underlying short-run exchange-rate returns (Meese and Rogoff 1983, Flood and Taylor 1996).

The lack of well-specified microfoundations casts doubt on the workhorse models' relevance for the analysis of monetary policy, which has been their primary focus. Exchange rates are one of the most powerful links among economies. If the consequences of policy for exchange rates cannot be reliably replicated, then the policy analysis is critically incomplete. One solution could be to introduce well-specified exchange-rate microfoundations to these models and examine the consequences. Unfortunately, it is difficult to anticipate how this would affect the model's implications; as noted by Lane, "many welfare results [from this model] are highly sensitive to the precise denomination of price stickiness, the specification of preferences and financial market structure" (p. 262).

If understanding reality is our goal, then models connected tightly to reality, as we have come to understand it through the microstructure research, are most appropriate. A microstructure-consistent exchange-rate model is the paper's last topic.

IV. A MICROSTRUCTURE-CONSISTENT MODEL

Despite the newness of the microstructure evidence, a modeling structure has long existed that conforms to the important microstructure lessons highlighted in Sections I and II. The structure also fits important macro lessons from the floating-rate period: PPP holds only at long horizons, and UIP does not hold at all with respect to short-term returns.

The structure has been developed independently by numerous researchers who have published their findings in such distinguished journals as the *American Economic Review*, the *Journal of Political Economy*, the *Quarterly Journal of Economics*, the *Journal of International Economics*, and the *International Economic Review*. Papers using models with this underlying structure include Black (1973, 1985), Driskill (1981), Driskill and McCafferty (1980a, 1980b, 1982, 1987), Driskill, Mark, and Sheffrin (1992), Osler (1995, 1998), Carlson and Osler (2000), and Hau and Rey (2004). The model is consistent with flow exchange-rate models used in Phillips and Pippenger (1993) and Pippenger (2003). In addition, Sager and Taylor's (2005) "thumb-nail sketch" of an exchange-rate model also fits this underlying structure in many respects.

Those who developed this structure share the pragmatic perspective of Akerlof (2005) that assigns paramount importance to microeconomic reality in designing models. Stanley Black puts it concisely: "The basic rationale for using this theory is that empirical evidence appears to support its underlying assumptions, in contrast to monetary models based on assumptions of short-run purchasing power parity and/or perfect substitutability of assets denominated in different currencies" (1985, p. 73). Despite post-modern pessimism about the existence of objective reality, those who developed the models perceived reality the same way and so developed models with the same underlying structure. Their perceptions were based on observation and intuition, which Akerlof identifies as "the best information available to us" (2005 p. 2). The observation and intuition were based on close familiarity with the real world of currency trading, however. Since this familiarity is not equally available to all researchers, others may have been justified in requiring rigorous statistical evidence before accepting the structure's assumptions. Ample rigorous evidence certainly arrived later, with the currency microstructure research. But the delay could explain why this microeconomically accurate modeling structure has not become widely familiar.

This section reviews an optimizing model of currency flows based on this structure and reports evidence that it successfully captures key features of short-run exchange-rate dynamics that have eluded the standard macro-based models. The reader will see that the model is straightforward. It would not necessarily be difficult to incorporate its key elements into other models, or to create more elaborate versions appropriate to policy analysis and variety of other macroeconomic issues.

A. An Optimizing Model of Currency Flows

Consistent with the four lessons outlined in Sections I and II, the modeling structure under discussion explicitly describes the trading behavior of both financial and commercial agents, and its central equilibrium condition is that flow demand equals flow supply.[21] Financial agents are risk averse and care about anticipated exchange-rate changes; they invest in deposits which are supplied elastically rather than in bonds. Commercial agents care about current exchange-rate levels and do not speculate. These attributes can be, and have been, formalized in a variety of ways. In the streamlined version presented below all agents are rational and optimizing. Noncritical components, such as explicit money or labor markets, have been stripped away to enhance transparency, and the summary below is necessarily terse: further details on this interpretation are available in Carlson and Osler (2000, 2005).

The model's financial agents are taken straight from standard asset-pricing models: they maximize one-period-ahead CARA utility of profits, choosing between domestic and foreign assets. Since this is a short-run model the assets are taken to be deposits, consistent with Lesson Three. The short-run deposits are supplied elastically at an interest rate determined by the monetary authorities. A financial trader's profits, $\pi^F{}_t$, are proportional to his position, b_t, measured in units of foreign currency, and the excess return to foreign currency:

(5) $$\pi^F{}_{t+1} = b_t\,[s_{t+1} - s_t - (i_t - i_t^*)]\ .$$

[21] The model abstracts from the activity of dealers since it is intended to capture exchange rates at macro horizons.

Under standard normality assumptions the speculator's optimal position is proportional to expected profits and inversely proportional to risk aversion, θ, and the variance of the exchange rate, $Var(s)$:

(6) $$b_t = [E_t(s_{t+1}) - s_t - (i_t - i_t^*)]/\theta\, Var(s)\ ,$$

When the expected excess return to foreign currency is positive, speculators owe domestic currency and own foreign currency. When the expected excess return is negative, speculators do the reverse.

Net financial demand for currency in any period corresponds to the *change* in the financial traders' aggregate desired foreign-currency position. With N financial traders, aggregate net financial demand is: $N\,(b_t - b_{t-1})$.[22] Note that expected returns directly determine asset holdings, not flows, as is appropriate.

Commercial agents are taken to be the subset of firms at home and abroad that engage in international trade. There are K of these firms at home producing output Y using an imported input Z^* according to the production function: $Y = Z^{*1/2}$. The firm's profits are $\pi = PY - SP^*Z^*$, where S is the actual (not log) price of foreign currency in terms of domestic currency. Optimal imports of a profit-maximizing firm, $\tilde{Z}^*$, are: $\tilde{Z}^* = \left(P/2SP^*\right)^2$. We assume a similar foreign economy in which K^* firms produce output Y^* using imported input Z according to the same production function. Optimal imports (from the home country) of a profit-maximizing foreign firm, $\tilde{Z}$, are: $\tilde{Z} = \left(P^*S/2P\right)^2$.

Net foreign currency demand from these firms is:

(7) $$P^*\tilde{Z}^* - P\tilde{Z}/S = K\left(\frac{1}{2R}\right)^2 - K^*\left(\frac{R}{2}\right)^2,$$

where we define the real exchange rate as $R = SP^*/P$. Note that this model of commercial currency demand correctly focuses on commercial flows *through the currency market*. Equation (7) shows that influence of the nominal exchange rate on commercial demand works exclusively through the real exchange rate. Following Obstfeld and Rogoff (1995), we linearize this portion

[22] Note that we do not assume any lagged portfolio adjustment. As noted by Phillips and Pippenger (1993) and Pippenger (2003), this could be relevant for certain asset classes. It may not be very important for the short-term assets on which this model focuses.

of the model around a symmetric long-run equilibrium, which gives the following expression for net commercial foreign-currency demand, FX_t:

(8) $$FX_t = \ln(P_t / P_t{*})K - Ks_t \equiv C_t - Ks_t \ , K > 0 \ .$$

Here, the constant term in the middle equation has been labeled "C_t." Foreign-currency demand is proportional to economic activity (proxied by the number of firms). It is inversely related to the foreign relative price level ($P_t{*}/P_t$) and to the nominal exchange rate.[23]

In equilibrium, net flow demand from all agents sums to zero:

(9) $$N\,(b_t - b_{t-1}) \ + \ [C_t - K\,s_t\,] \ = \ 0\ .$$

This equilibrium condition gives currency flows the critical role in exchange-rate determination suggested by the new microstructure evidence. This equilibrium condition also implies that net commercial order flow must be negatively related to net financial order flow, consistent with the evidence.

Under the assumption of rational expectations the model's bubble-free solution is:

(10) $$s_t = \lambda\, s_{t-1} + (1\text{-}\lambda)\sum_{j=0}^{\infty}\lambda^j\,(E_t C_{t+j} - \lambda E_{t-1} C_{t+j})\,/\,S \ - \ \frac{\lambda}{1-\lambda}\sum_{j=0}^{\infty}\lambda^j\,(E_t\delta_{t+j} - \lambda E_{t-1}\delta_{t+j}) \ ,$$

where $\delta_t \equiv i_t - i_t{*} - (i_{t-1} - i_{t-1}{*})$ represents the change in the interest differential. The term λ is the smaller root of the associated characteristic equation; λ rises monotonically with speculative activity from a lower bound of zero to an upper bound of unity. Equation (10) states that the current exchange rate depends on expected future values of the fundamentals C_t and δ_t, a general property shared with the workhorse models.

To derive a closed-form solution, it is necessary to be more specific about the behavior of C_t and δ_t, the system's two exogenous variables. It is appropriate to assume that C_t is subject to both permanent and transitory shocks. The permanent shocks reflect the nonstationarity of price levels and aggregate demand, while the temporary shocks reflect the inevitable short-run lumpiness in currency flows. Both shocks are assumed i.i.d. normal with mean zero. Only a combined shock, ε_t, can be observed, so commercial demand can be re-expressed as $FX_t = C_t$ -

[23] Note that the agents in the model can be construed more broadly than this optimizing setting suggests. The agents that respond to exchange-rate levels, for example, can viewed as including firms engaging in foreign direct investment (the dependence of which on exchange-rate levels has been documented in Ray 1989 and Blonigen 1997, *inter alia*). Many market participants insist that some speculative traders are not perfectly rational; trading of such agents can be modeled like the "noise traders" of mainstream finance, as a contributor to the additive random shock to be described shortly.

$Ks_t = \overline{C}_t - Ks_t + \varepsilon_t$, where $\overline{C}_t$ is the current permanent component of commercial demand. The exchange rate's equilibrium in the absence of speculators is C_t/S, and we define its conditional central tendency as $\overline{s}_t \equiv \overline{C}_t/K$.

Interest differentials are assumed to be exogenous[24] and mean-reverting (McCallum 1994): $d_t = \rho\, d_{t\text{-}1} + \eta_t$, where $0 < \rho < 1$ and η_t represents a normally distributed, mean-zero, i.i.d. shock. Financial- and commercial-demand shocks are assumed uncorrelated.

The model can produce a positive correlation between exchange-rate returns and financial demand as required by the microstructure evidence. The conditions for this outcome can be inferred from analyzing two special cases.

Case 1: Suppose that only financial demand is subject to shocks (so $\varepsilon_t \equiv 0$). A rise in the foreign interest rate ($\eta_t < 0$) would bring higher financial purchases, appreciating the foreign currency. The appreciation would restore equilibrium by inducing less demand from commercial agents. In this way financial demand would be positively correlated with exchange-rate returns, as observed in reality.

Case 2: Suppose instead that only commercial demand is subject to shocks (so $\delta_t \equiv 0$). A rise in commercial demand ($\varepsilon_t > 0$) would bring a foreign currency appreciation. Recognizing that the price of foreign currency is likely to fall, financial agents would borrow foreign currency and invest in domestic currency. In this way financial demand would be negatively correlated with exchange-rate returns.

A comparison of Case 1 with Case 2 suggests that the observed positive correlation between financial demand and exchange-rate returns reflects the short-run dominance of financial shocks relative to commercial shocks. This condition seems plausible in light of the evidence that roughly one third of exchange-rate volatility can be attributed to news alone (Evans and Lyons 2003). Indeed, Taylor suggests "that real shocks cannot account for the major part of the short-run volatility of real exchange rates (since it seems incredible that shocks to real factors, such as tastes and technology, could be so volatile)" (2002 p. 83). In this sense the model provides a specific example of Sager and Taylor's (2005) "thumbnail sketch" of the major forces

[24] The assumption of exogenous interest rates is not necessary, as demonstrated in more elaborate versions of the model. However, the exogeneity of interest rates is also assumed elsewhere, e.g., Mark and Wu (1998). It seems like a reasonable representation of reality, given that a country's monetary policy is the main determinant of its short-run interest rates and that monetary policy is exogenous from a short-run perspective.

at work in the FX market in which market participants are divided into two groups. One group's trades "push" the exchange rate, while the other group's trades are "pulled" in by the exchange rate. Sager and Taylor's push agents correspond closely to the model's financial speculators. Their pull agents, who "effectively ... exercise an option to trade once the price crosses their implicit 'strike price'" (p. 19), correspond closely to the model's commercial agents.

With these assumptions, the solution for the exchange rate becomes:

$$(11) \qquad s_{t+1} = E_{t+1}\bar{s}_{t+2} + \lambda(s_t - E_t\bar{s}_{t+1}) + (1\text{-}\lambda)\,\varepsilon_{t+1} - \frac{\lambda}{1-\rho\lambda}\,\eta_{t+1} + \frac{\lambda\,(1-\rho)}{1-\rho\lambda}\,(i_t - i_t^*)\,.$$

The first term on the right-hand side of (11) is the expected long-run exchange rate in the absence of speculators, $E_t\bar{s}_{t+1} = E_tC_{t+1}/K$. Any change in the anticipated long-run exchange rate is immediately and fully reflected in the current exchange rate, consistent with standard depictions of efficient markets. The second term shows that the exchange rate converges to this long-run rate monotonically in expectation, eliminating the fraction 1-λ of any discrepancy between $E_t\bar{s}_{t+1}$ and s_t each period, since the remaining three exchange-rate determinants ($i_t - i_t^*$, ε_{t+1}, and η_{t+1}) all have a central tendency of zero.

The third term on the right-hand side of (11) shows that a positive shock to commercial foreign-currency demand, $\varepsilon_t > 0$, tends to appreciate the foreign currency, other things equal. The fourth and fifth terms show that the exchange rate is influenced by the level and the change in interest differentials: not surprisingly, a rise in domestic interest rates (a positive η_{t+1}) immediately depreciates the foreign currency. The coefficient on the current interest differential is positive because, with mean reversion, a high current interest-rate differential means declining differentials over the future. Thus speculators will be planning concurrent decreases in their holdings of foreign exchange.

The model converges to uncovered interest parity if financial agents are risk neutral or if there are infinitely many of them, neither of which seems likely. As discussed in Section II, risk-averse behavior is enforced by the institutions that employ financial traders. Infinite speculation is ruled out when participation is endogenous: with infinite speculation the activity becomes so unprofitable that some of the existing speculators shift into other markets (Carlson and Osler 2005).

This model is not intended to capture long-run exchange-rate dynamics. Nonetheless, the long-run neutrality of financial traders with respect to exchange rates is an attractive feature, since it leaves commercial trading as the sole determinant of long-run exchange rates. This, in turn, implies that the long-run nominal exchange rate is $\bar{s}_t \equiv \bar{C}_t/K = \ln(P_t/P_t^*)$ (assuming growth is roughly symmetric around the world). Thus the model's long-run equilibrium is consistent with the stylized fact that PPP holds at long horizons (Rogoff 1996). Given the long-run dominance of money over prices, the model's long-run equilibrium is also consistent with the monetary model. Since money only matters in this model through its influence on prices, the model is consistent with evidence that exchange rates react to price news but not to money-supply news (Anderson *et al.* 2003).

The long-run neutrality of financial traders can be understood by observing that speculators must ultimately unwind every position in order to reap their profits. Informally speaking, when a financial trader initially purchases foreign currency, it pushes up the price; when it ultimately liquidates the position by selling the foreign currency, it pushes down the price. This aspect of reality could not be explained in a model that ignores flows.

B. Lessons From the Model

Earlier models using the underlying structure analyzed here have been helpful in explaining the macro issues of each period. In Black (1985), for example, the model is used to support the "Harrod effect," the idea that the shift to floating rates might not have brought much stabilizing speculation because speculators were deterred by higher exchange-rate volatility. Driskill and McCafferty (1987) shows that the model "can … account for the 'stylized facts' of the open economy. …Our model gives rise to persistent deviations of relative prices from purchasing power parity, … [and] is consistent with higher variability of the exchange rate relative to the price level" (p. 260).

Osler (1998) shows that the model provides a straightforward explanation for the apparent "disconnect" between exchange rates and their macro fundamentals. Specifically, speculative trading dramatically alters the way fundamental factors affect exchange rates, making it difficult to identify the underlying connection econometrically. Carlson and Osler (2000) use the model to show that rational speculation can be destabilizing. Though speculators are stabilizing with respect to real-side shocks, as anticipated by Friedman (1953), they can introduce volatility because they respond to forces like interest rates and news that would not affect exchange rates in their absence.

The model is consistent with the volatility, persistence, and forward premium puzzles, as Carlson and Osler (2005) show using calibrated simulations. The volatility puzzle refers to the fact that exchange-rate volatility exceeds the estimated volatility of risk premiums and the volatility of interest differentials; the persistence puzzle refers to the fact that the autocorrelation of exchange-rate changes is close to zero while that of interest differentials is fairly high (Bekaert 1996).

Two studies have confronted this model with exchange-rate data and in each case the results are encouraging. Driskill, Mark, and Sheffrin (1992) estimate a relatively elaborate version of the model including output, prices, and money supplies. Their sample comprises quarterly observations from Switzerland and the U.S. from 1976:Q3 (the Rambouillet agreement) to 1987:Q4. They find that the model fits well: the residuals are serially uncorrelated, the cross-equation restrictions cannot be rejected, and the coefficient point estimates are reasonable.

Driskill, Mark, and Sheffrin (1992) also undertake the hardest test for an exchange-rate model – the forecasting horse-race: Can the model outperform the random walk in out-of-sample tests? It is well-known that our workhorse macro models do not outperform the random walk (Meese and Rogoff 1983). This model, however, does significantly better than the random walk. Out-of-sample forecasts from 1985:Q1 through the remainder of their sample period were created based on a series of rolling regressions. Following Meese and Rogoff (1983) the forecasts are based on realized values of the exogenous variables. The model outperforms the random walk at horizons of one, two, three, and four quarters. The root-mean square errors from model-based forecasts are, on average, about ten percent lower than those from the random walk forecast.

The model can also explain the behavior of short-run exchange-rate risk premiums, as shown in Carlson and Osler (2005). The model implies the following linear relationship between realized excess returns, $xr_{t+1} = s_{t+1} - s_t - (i_t - i^*_t)$, and interest-rate differentials:

(13) $$xr_{t+1} = [E_{t+1}\bar{s}_{t+2} - E_t\bar{s}_{t+1}] + (1-\lambda)(s_t - E_t\bar{s}_{t+1}) + (\beta - 1)(i_t - i^*_t) + \nu_t ,$$

where $\nu_t \equiv (1-\lambda)\,\varepsilon_{t+1} - \dfrac{\lambda}{1-\rho\lambda}\,\eta_{t+1}$. This means that in the following regression equation,

(14) $$xr_{t+1} = \alpha + \gamma[E_{t+1}\bar{s}_{t+2} - E_t\bar{s}_{t+1}] + (1-\lambda)(s_t - E_t\bar{s}_{t+1}) + (\beta - 1)(i_t - i^*_t) + \nu_t ,$$

the true value of α is zero, the true value of γ is unity, $0 < (1-\lambda) < 1$, and λ, which represents the speed of convergence to long-run equilibrium, should be of reasonable magnitude. Since the model is consistent with forward bias, it implies solely that β–1< 0. The long-run for the model is taken to be PPP.

The model was tested on quarterly exchange-rate and interest-rate data. PPP was assumed to govern long-run exchange rates. Data for the five most active currency pairs begin in the late 1970s (starting date varies by currency) and end in 2003. The results are encouraging. The model explains up to half the variation in realized risk premiums, far more than the standard UIP regressions (in which only the interest differential on the right-hand-side), for which the explanatory power is at most fifteen percent. In most cases the estimated coefficients for the model are statistically indistinguishable from their predicted values and the estimated convergence speeds are consistent with current best evidence (Imbs et al. 2005, Sarno and Taylor 2004). Note that this last set of evidence is based on a streamlined version of the model. More elaborate versions could potentially do better.

V. CONCLUSION

Ten years ago the editors of *The Microstructure of Foreign Exchange Markets* suggested that macro-based models are unable to replicate the properties of short-run exchange-rate dynamics because they do not accurately represent the process through which exchange rates are determined. Since then, research into the currency trading process has accelerated, motivated by the conviction that macro exchange-rate models must have well-specified microfoundations and that well-specified microfoundations should reflect reality to the extent possible. In this sense the study of currency markets embodies the philosophy behind Akerlof's (2005) pragmatic approach to economics.

Our job as economists is self-evidently to understand and explain reality, not to design utopian visions. To tease out the key economic forces we build models step by step, one upon the other, with each useful model capturing one or two new pieces of the overall structure. If the model's foundation is grossly inconsistent with reality the resulting superstructure will ultimately collapse, as with Ptolomy's vision of a geo-centric universe. Of course, the method we use to identify reality only matters to the extent that we are accurate. For some lessons it requires sophisticated econometric tools, for others it requires only observation. Akerlof's Nobel-prize winning lemon's model (1971) was based on nothing more than "extrapolat[ing] from the anecdote of [his] experience to the broader context [of] economic markets" (Akerlof 2005, p. 2). Currency microstructure attempts to identify reality using the entire set of available tools.

The currency microstructure evidence accumulated to date is sufficient to provide at least four substantive lessons for exchange-rate modeling. The first two lessons are based on state-of-the-art econometric analysis. Lesson one: Currency flows are among the primary determinants of exchange rates. This suggests that our models should explicitly include currency flows, and it raises the possibility that our models should be built on the equilibrium condition that flow demand equals flow supply. Lesson two: Exchange rates are determined through the interaction of financial agents with commercial agents, with the consequence that cumulative financial order flow is positively related to exchange-rate returns, while cumulative commercial order flow is negatively related to returns. The flow demand of commercial agents cannot be represented as the first difference of an associated stock demand function.

The third and fourth lessons are based on close observation of the institutional structure of currency markets. Lesson three: Financial traders are motivated by profits, rather than consumption, and their risk-taking is constrained. Lesson four: Commercial traders are motivated by exchange-rate levels and rationally choose not to speculate.

The paper briefly reviews standard macro-based exchange-rate models. Because the current workhorse models incorporate few of these microstructure lessons, there are significant gaps between the models' microfoundations and the microeconomic reality of currency markets. This implies that their microfoundations are not well-specified. Though these models may be appropriate for long-run analysis, they are probably inappropriate for short-run analysis in their current form. This may explain the models' general lack of success with short-run data.

The paper also reviews an optimizing model of currency flows independently developed by a number of authors. The model fits all four lessons from microstructure. It also fits many of the major lessons from macroeconomics, such as the failure of UIP with respect to short-term securities, the short-run failure of PPP, and the long-run relevance of PPP. Empirical tests of the model are encouraging. The model is consistent with the volatility, persistence, and forward premium puzzles, it fits the data well, and it forecasts noticeably better than the random walk.

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Figure 1: Take-Profit Orders Create an Instantaneous Currency Demand Curve

The figure plots open the cumulative value of all dollar-yen take-profit orders at Royal Bank of Scotland on January 26, 2000, at 20:53 GMT. The horizontal axis plots the exchange rate, with the contemporaneous market midrate, ¥105.77/$, shown by the vertical line. The vertical axis represents the cumulative dollar value of orders, in millions.