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Government Intervention in the Foreign Exchange Market

by Owen F. Humpage

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This article offers a survey of the literature on foreign exchange intervention, including sections on the theoretical channels through which intervention might affect exchange rates and a summary of the empirical findings. The survey emphasizes that intervention is intended to provide monetary authorities with an means of influencing their exchange rates independent from monetary policy, and tends to evaluate theoretical channels and empirical results from this perspective.

Key words: Foreign-exchange intervention, survey, empirical results.
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1. Introduction

Advanced economies with well-developed financial markets, credible monetary policies, and a broad nexus of commercial partners generally allowed market forces to determine their exchange rates.[1] Flexible exchange rates provide these economies with a higher degree of monetary-policy independence and with greater protection from idiosyncratic economic shocks than any system of fixed parities possibly could. The Bretton Woods system collapsed, after all, because of Europe's displeasure with a high, U.S.-determined inflation rate and because of the uneven impact of oil price shocks.

These same governments, however, have often refused markets free reign in determining the exchange value of their currencies. Although professing confidence in the overall competitive efficiency of foreign exchange markets, policy makers believe that information imperfections sometime make these markets excessively volatile or drive exchange rates away from values consistent with their underlying macroeconomic fundamentals. While similar information imperfections may affect other financial markets, government interventionists contend that the macroeconomic implications of even temporary exchange-market failures are great enough to warrant corrective actions. With fiscal policy too unresponsive and capital or trade controls too disruptive, such corrective actions naturally fall to monetary authorities.

Adding orderly exchange-market conditions to the list of central bank responsibilities, presents policy makers with the classic problem of more targets than independent instruments. When a central bank pursues an exchange-rate objective, it can sometimes lose control of its inflation target. The outcome depends on the nature of the

underlying exchange-market disturbance. To be sure some trade-off is feasible, but in general, a central bank that pursues two objectives with a single instrument can lose credibility with respect to both goals. How much inflation will a central bank tolerate to avoid a further appreciation of the exchange rate? How big an appreciation will it endure to avoid inflation?

This basic targets-versus-instruments problem underlies the controversy about foreign-exchange market intervention. The central question that both the theoretical and empirical investigations address is: Does intervention afford monetary authorities a means of influencing exchange rates *independent* of their domestic monetary policy objectives?

Overall, the existing research has failed to find reliable connections between official transactions and fundamental determinants of exchange rates that would allow monetary authorities to determine exchange rates independent of monetary policy. Instead, studies suggest the intervention can *sometimes* affect exchange rates in a manner that depends on such market conditions as the firmness and consistency of agents' expectations. Analysts increasing view intervention from an information perspective and ask: What operational conditions (e.g., transaction size; frequency, etc.) increase the chances that an intervention will have the desired effect on exchange rates? How long might the effect last? In what sense might intervention determine exchange rates?

These are not merely academic questions. Intervention remains an active policy tool. Although the frequency of intervention may have tapered off, notably in the United States and Europe, the size of an average transaction appears to have grown (Chiu 2003.

[1] Such economies include Australia, Canada, Japan, the Euro Area, Sweden, Switzerland, the United Kingdom, and the United States. On intervention and emerging market economies, see: Hutchinson

Neely 2001, Lecourt and Raymond, 2003). The Japanese Ministry of Finance has recently come under sharp criticism, primarily from U.S. manufacturers, for frequent and heavy interventions designed to stem a yen appreciation. Consequently, intervention remains a fruitful area for an active research agenda.

This article attempts to provide a fairly comprehensive introduction to the economics of foreign exchange intervention.[2] In section two, I define terms and draw an important distinction between official transactions that affect bank reserves and those that do not. Only the later type of transaction provides monetary policy makers with an independent mechanism for influencing exchange rates. In section three, I discuss possible theoretical channels through with intervention might alter exchange rates, focusing on the important role of expectations. Section four is a summary of the empirical evidence on the relationship between intervention and exchange rates. I do not provide a "he said – she said" type of review. Instead, I group previous studies according to the various topics mentioned in empirical section in the reference pages at the end of this paper. In section five, I discuss the connection between intervention and technical trading rule profits. Section six concludes with a short statement on the state of the art.

2. Intervention as Distinct from Monetary Policy

Intervention refers to official purchases or sales of foreign exchange undertaken to influence exchange rates. This definition describes intervention in terms of (1) a type of transaction and (2) a motive guiding such transactions.

The distinction among various types of transactions is important because countries have many policy levers through which to affect the exchange values of their

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(2003), Chiu (2003).

currencies. Central banks sometimes have altered overnight reserve-market interest rates through open-market operations or have adjusted interest rates on their official lending facilities with specific exchange-rate objectives in mind. Few economists doubt that monetary policy can manage nominal exchange rates, although researchers have raised important question about the costs and benefits of making an exchange rate the target of monetary policy.[3] Adjusting monetary-policy levers to achieve an exchange rate objective—while clearly feasible—does not constitute intervention by my definition, since it does not provide monetary authorities with an additional independent means for influencing exchange rates.

Other policy options similarly do not constitute intervention under my definition. Tobin (1980) suggested a tax on foreign-exchange transactions as a means of reducing exchange-rate volatility, and countries with pegged exchange rates often have resorted to various types of capital restraints in defense of their parities. In addition, some countries routinely try to jawbone exchange rates in one direction or another. These do not constitute intervention because they are not amenable to day-to-day exchange-rate management. I am concerned with the high-frequency foreign-exchange activities that do not alter a country's monetary base.

An understanding of the motive for buying or selling foreign exchange is also a necessary component of the definition of intervention because governments often transact in foreign exchange for purposes other than altering their exchange rates. Central banks sometimes buy or sell foreign exchange to manage the currency composition of their

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[2] Previous surveys include: Edison (1993), Almekinders (1995), Bailey, et al. (2000), and Sarno and Taylor (2001).

[3] On monetary policy, exchange rates, and economic shocks, see Turnovsky (1999) and Bordo and Schwartz (1989).

reserve portfolios, or undertake transactions for customers, such as their own fiscal authorities or other monetary authorities. In addition, some central banks have bought and sold foreign exchange solely for profit. While these transactions conceivably could affect exchange rates, that is not their purpose. This seemingly clear distinction, however, becomes somewhat muddied because central banks will occasionally time these transactions to maximize or minimize their influence on exchange rates. In such circumstances, these commercial or customer transaction constitute a type of "passive intervention," as in Adams and Henderson (1983)

Sterilized Intervention

The literature on foreign exchange intervention draws an important distinction between sterilized and non-sterilized intervention. Only the former provides monetary authorities an additional instrument with which to pursue an exchange rate objective independent of their monetary policy. Consequently, sterilized transactions are the key focus of the intervention literature.

When a central bank buys or sells foreign exchange it typically makes or accepts payment in domestic currency by crediting or debiting the reserve accounts of the appropriate commercial banks. Except for the instruments involved, the mechanics of the transactions are similar to those of an open-market operation, and like an open-market operation, foreign exchange interventions have the potential to drain or add bank reserves, customarily within two days.

Central banks typically offset, or sterilize, the impact of their foreign exchange interventions on their monetary base (see Lecourt and Raymond 2003 and Neely 2001). Any central bank that conducts its monetary policy through an over-night, reserve-market

interest rate—as nearly all large-country central banks do—will automatically offset all transactions, including intervention, that threaten its operating target rate.

The main reason central banks neutralize the monetary effects of their foreign exchange operations is that sterilization prevents foreign-exchange transactions from interfering with the domestic objectives of monetary policy. The potential for conflict between the two depends on the nature of the underlying disturbance to the exchange market. In general, only if the underlying disturbance is domestic in origin and monetary and nature, will pursing an exchange-rate objective through non-sterilized foreign exchange intervention not conflict with a central bank's inflation objective. If the underlying shock is either foreign, or domestic and non-monetary, intervention will inevitably interfere with a central bank's inflation objective (see Craig and Humpage, 2003 and Bordo and Schwartz, 1989).

Sterilization is also important in countries whose central banks are independent, but whose fiscal authorities maintain primary responsibility for intervention, because in the absence of sterilization, the fiscal authorities would maintain some direct control over monetary policy. In the Japan, for example, the Ministry of Finance maintains authority for foreign exchange intervention, and the, otherwise independent, Bank of Japan acts as its agent. A similar relationship exits in the United States between the U.S. Treasury and the Federal Reserve. If these central banks did not routinely sterilize foreign exchange operations, their independence and the credibility of their monetary policies might come under question, adversely skewing any short-term inflation-output tradeoff.

To be sure, central banks sometimes factor nominal exchange-rate objectives into their monetary-policy decisions. The Federal Reserve, for example, has occasionally

altered its federal-funds-rate target while undertaking compatible foreign-exchange operations. One might expect that implementing the appropriate monetary policy change through the purchase or sale of foreign currency could have a bigger impact on the exchange rate than implementing the move through open-market operations in government securities, and thereby justify official unsterilized foreign exchange operations. Bonser-Neal et al. (1998) and Humpage (1999) show that U.S. interventions undertaken in conjunction with changes in the federal funds rate have no apparent effect on exchange rates; both studies attribute observed exchange-rate responses solely to the federal funds rate. In contrast, Kim (2003) claims important effects from intervention in a VAR model that allows for the possible interactions between exchange-rate intervention and monetary policies. Kim's results are unusual and questionable, but they highlight the need for further research on this issue.[4]

As a general rule, central banks have little to gain from non-sterilized foreign exchange-market interventions. They can conflict with domestic monetary-policy objectives, and even when that is not the case, they are completely redundant to open-market operations in domestic securities. Sterilized intervention, on the other hand, holds open the prospect of providing central banks with the means of affecting exchange rates independent of their domestic monetary policy objectives. How might sterilized intervention actually do this?

[4] The discrete values and episodic nature of intervention data makes it inappropriate in a VAR model. Kim expresses it as a ratio to a trend in the monetary base, which must contaminate the intervention variable with movements in the base.

3. Theoretical Underpinnings

Exchange Rate Model

The asset market approach to exchange-rate determination provides a useful framework for conceptualizing the channels through which sterilized intervention might influence exchange rates. The asset market approach describes the exchange rate at time *t* (S_t) in terms of current fundamentals (Z_t) and a proportion (λ) of the expect future change in the exchange rate:

$$(1) \qquad S_t = Z_t + \lambda[E_t(S_{t+1}|\Omega_t) - S_t],$$

where $\lambda \in (0,1]$; E_t is the expectations operator and Ω_t is the information set. Z includes variables common to the asset market approach. Solving equation (1) forward yields

$$(2) \qquad S_t = \frac{1}{1+\lambda}\sum_{i=0}^{\infty}\left(\frac{\lambda^i}{(1+\lambda)^{i+1}}E(Z_{t+i})\right) + \left(\frac{\lambda}{1+\lambda}\right)^{t+i+1}E(S_{t+i+1}),$$

which emphasizes that current exchange rates depend on current fundamentals, and the expected future path of fundamentals. In addition to a *fundamental* solution, this equation also can have multiple, so-called, *bubble* solutions (see Aguilar and Nydahl, 2000).[5] The model suggests that sterilized intervention might affect the spot exchange rate either via some current fundamental (other than money), through expectations about future fundamentals, or expectations not based on fundamentals. These channels have starkly different policy implications.

Portfolio-Balance Channel

The process of sterilizing a foreign-exchange intervention through typical open-market operations will alter the currency composition of publicly held government

securities, which the asset-market-approach to exchange rate determination views as an important fundamental. If risk-averse asset holders view these securities as imperfect substitutes, they will hold them in their portfolio only if their expected rates of return compensate them for the perceived relative risk. Although economists lack a widely accepted theoretical model of the foreign exchange risk premium, most express it—among other things—as a positive function of relative assets supplies. The portfolio-balance mechanism directly links intervention and spot exchange rates through Z_t in equations 1 and 2, thereby providing monetary authorities an independent channel through which to influence exchange-rate movements. A sterilized purchase of foreign exchange, for example, increases the amount of publicly held domestic bonds relative to foreign bonds, inducing a depreciation of the domestic currency.

Unfortunately, with an unanimity rare in economics, most empirical studies find the relationship to be either statistically insignificant or quantitatively negligible. The reason offered for the lack of a portfolio effect is that the typical intervention transaction is miniscule relative to the stock of outstanding assets. Dominguez and Frankel (1993) is a notable, often cited, exception to the standard conclusion. In addition, a number of papers find some connection between intervention and uncovered interest parity, but the relationship is not very robust and, therefore, seems more consistent with an expectations effect. Galati, Melick, and Micu (forthcoming) suggest that a portfolio channel might still be relevant for emerging markets, if these countries have large reserve portfolios relative to the turnover in their local foreign exchange markets.

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[5] Baille and McMahon (1989) offer an excellent introduction to exchange-market economics. Lyons (2000) provides a good introduction to the microstructure approach to exchange markets.

Recently, proponents of the microstructure approach to exchange rate determination have renewed interest in the portfolio-balance approach (Evans and Lyons 2001, Lyons 2001). These models focus on the role of foreign-exchange dealers, who as market makers stand ready to buy and sell foreign exchange. These same dealers typically do not hold sizable open positions in a foreign currency, especially overnight (Cheung and Chinn 2001). They will try to distribute it among other dealers and eventually among their commercial customers. Since different currencies are not perfect substitutes in the dealers' portfolio, this inventory-adjustment process resembles a portfolio-balance-like mechanism at the micro level. Evans and Lyons (2001) claim evidence of both temporary—dealer to dealer inventory reshuffling—and permanent—dealer to customer—portfolio-balance effects. The permanent component of this model, however, is at odds with the macro literature. The microstructure model measures only currency flows in the foreign exchange market. It does not account for the fact that the sterilization process leaves the total amount of bank reserves for each currency unchanged, while changing the relative stock of interest bearing assets. Further work on this important issue is necessary.

Signaling or Expectations Channel

In a market characterized by information asymmetries, a monetary authority that had an information advantage with respect to current and prospective market fundaments could influence exchange rates if that authority conveyed private information to the market through its intervention. Most monetary authorities and many economists believe that intervention works through such a signaling or expectations channel.

The volume of foreign-exchange trading, estimated at approximately $1.2 trillion (equivalent) per day, seems large relative to the volume of cross-border commercial transactions. Approximately 80% of trades occur between dealers rather than between dealers and customers. Dealers acquire private information in part through their customer transactions. Much of this, seemingly excessive, dealer trading undoubtedly results from the heterogeneous information among market participants and is vital to price discovery.

Exchange markets are highly efficient processors of information, but not perfectly so. If information is costly, market participants either will not have all information or will not fully understand its implications, and market exchange rates cannot continuously reflect all available information about their future distributions. Exchange rates will instead reflect information up to the point were the marginal benefits from acquiring and trading on information equal the marginal costs.

Access to private information differentiates market participants. Survey evidence suggests that large foreign exchange players have better information derived from a broader customer base and market network, which gives them a better insight about order flow and the activities of other trading banks (Cheung and Chinn 2001). In such a market, exchange rates perform a dual role of describing the terms of trade and of transferring information. In such markets, however, non-fundamental forces like bandwagon effects, over-reaction to news, technical trading, and excessive speculation may affect short-term exchange rate dynamics. (Recall the bubble solutions to equation 2.) Any trader that others suspect of having superior information could affect price, if market participants observed his or her trades.

In extreme cases of information imperfections, when a substantial portion of market participants base trades on extrapolations of past exchange-rate movements, exchange rates might remain misalligned, even if more informed traders felt that the current exchange rate was inappropriate. In the presents of bandwagon effects or collective action problems, individually informed traders might not react to a misalignment, causing it to persist. Sterilized intervention—in addition to providing information about fundamentals—then might help market participants to coordinate on the "correct" equilibrium.

Research into foreign exchange market intervention then is largely predicated on the assumption that monetary authorities possess a significant informational advantage over other market participants. Is this a reasonable assumption for any player in a highly efficient market? If so, is this advantage routine or episodic?

Mussa (1981) suggested that central banks might signal future, unanticipated changes in monetary policy through their sterilized interventions, with sales or purchases of foreign exchange implying, respectively, monetary tightening or ease. This would have direct implications for future fundamentals, and forward-looking traders would immediately adjust spot exchange-rate quotations according equation 2. Mussa suggested that such signals could be particularly potent—more so than a mere announcement of monetary policy intentions—because the intervention gives monetary authorities open positions (i.e., exposures) in a foreign currencies that would result in losses if they failed to validate their signal. Reeves (1997) has formalized Mussa's approach and has demonstrated that if the signal is not fully credible, or if the market does not use all available information, then the response of the exchange rate to

intervention will be muted. In Reeve's model, the amount of intervention influences the market's response.

Central banks are not likely to actively employ intervention as a signal about future monetary policy. For one thing, when a central bank eventually validates its signals, the interventions are no longer sterilized. Consequently, such intervention does not ultimately provide central banks with an independent influence over exchange rates. Moreover, most large central banks do not intervene for profit, and although central banks do not like to sustain huge losses on their foreign exchange portfolios, the fear of losses does not strongly motivate their near-term actions. Typically these losses are unrealized. A large open position in foreign exchange—and the associated risk of substantial loss—is more likely to encourage large central banks to avoid intervention and to draw down their exposures than to alter their monetary policies. Central banks are more concerned with how the intervention might interact with monetary policy, than about profits and losses. Finally, as noted above, in countries like Japan and the United States where intervention falls under the purview of the fiscal authorities, central banks could lose their independence if they altered monetary policy in response the interventions of the fiscal authorities.

Intervention, of course, may offer a *passive* signal of future monetary policy; that is, purchases and sales of foreign exchange may simple be correlated with a future easing or tightening in monetary policy. In this case, one might find episodic evidence of signaling. Specifically, when the original shock to the exchange market results from an excessive easing or tightening in monetary policy, intervention might predict future policy corrections. One would then only find a consistent correlation between

intervention and future changes in monetary policy if the underlying shock to the exchange rate was persistently monetary in nature. When the underlying shock to the exchange market is not of that type, one might not find evidence of signaling.

As one might expect, if signaling depended on the nature of the causal shock, the empirical evidence for or against signaling should be mixed, and indeed it is, with no clear consensus emerging from this literature. Kaminsky and Lewis (1996), which is often cited as evidence for signaling, also finds that when intervention is supported by consistent movements in monetary policy, exchange rates tend to respond in the expected direction, but when intervention is followed by inconsistent monetary policy, exchange rates tend to move in the opposite direction.[6]

The connection between intervention and compatible monetary policy highlights the essential ambiguity in the monetary-policy signaling story: If intervention only works when it is consistent with immanent monetary policy changes, that implies that prior and current monetary policy created the exchange-rate disturbance in the first place. Why then intervene? Why not just alter monetary policy? Does intervention add important policy information that policy watcher do not already have? Carlson et. al. (1995) show that federal funds futures anticipate monetary policy changes fairly accurately within a two-month horizon, but Fatum and Hutchisen (1995) find that intervention adds noise to the federal-funds-futures market. It seems that when intervention accompanies a change in monetary policy, the former is entirely redundant.

Monetary authorities often claim to intervene when they view current exchange rates as being inconsistent with market fundamentals defined more broadly than

[6] Kaminsky and Lewis (1996) is often cited as evidence of signaling despite finding significant coefficients with signs opposite to that implied by the hypothesis.

monetary policy variables. They have large research staffs that gather and interpret statistics on current economic conditions. If central banks have useful private information about market fundamentals, providing that information to the market through intervention can alter market expectations. Battachary and Weller (1997) and Vitale (1999) present theoretical models in which central banks maintain an informational advantage and disseminate it to the market. Popper and Montgomery (2001) provide a particularly interesting model in which a central bank aggregates the private information of individual traders and disseminates this information through intervention. Central banks typically maintain an ongoing informational relationship with a select group of major banks (domestic and foreign) and use these banks as counterparties for their foreign exchange transactions. In exchange for their exclusivity, these dealers provide the central banks with interpretations of general market conditions, perceived reasons for market movements, and order flows. If monetary authorities routinely have better broad-based information than other market participants, as Popper and Montgomery (2001) argue, then their interventions should accurately predict future exchange-rate movements; that is, researchers should be able to uncover a statistically valid relationship between the two.

4. Empirical Evidence on Intervention

In recent years, as more and more central banks have released data on their official foreign exchange market operations, empirical research on the effectiveness of intervention has sharply grown. The results of this work have begun to converge towards consensus understanding on a number of important issues.

A Consensus View

Even though most empirical studies do not provide a fully articulated theoretical model of intervention, economists typically interpret their results as evidence of a broad signaling channel. These results clearly demonstrate a high-frequency—daily or intra-daily—connection between foreign exchange market intervention and exchange rates. The results, however, are not always robust across currencies, time periods and empirical techniques. Recent studies using intra-daily data suggest that exchange rates respond to intervention within minutes or hours, and some even suggest that exchange rates react in anticipation of an intervention or before the intervention is widely known in the market.

Unfortunately we do not know much about the duration of these effects. Given the near martingale nature of exchange-rate changes, however, it seems reasonable to interpret them as highly persistent, if not permanent. By affecting expectations, intervention sets the exchange rate off on an alternative random-walk path, but one that is consistent with the pre-existing, unaltered market fundamentals. Some intra-day studies suggest short-term persistence, but beyond one day, we really have little to say.

Many researchers also consider the second-moment of the exchange-rate process, finding that intervention typically *increases* exchange-rate volatility. They often interpret this finding has evidence of a perverse or destabilizing effect, but in a market characterized by information imperfections, volatility may be associated with the transmittal of new information. If so, one should expect an increase in exchange rate volatility around intervention periods. A higher volatility is not necessarily incompatible with intervention having the desired effect on the level of the exchange rate.

The empirical literature's lack of robustness suggests that if intervention does indeed operate through a general signaling channel, monetary authorities do not always

posses an information advantage over the market. Overall, intervention is a hit or miss venture, but some evidence indicates that how monetary authorities conduct their operations can influence the likelihood of success. Large interventions, undertaken with two or more central banks transacting in concert, seem more likely to affect exchange rates in the desire direction than small, unilateral operations. From a signaling perspective, large interventions may demonstrate a higher conviction on the part of a monetary authority, in the same manner that a speculator who is very certain about his or her expectations will take a larger position in the market. Similarly, coordinate interventions may have a bigger impact than unilateral operations because they suggest that more that one monetary authority shares a particular view about the market.[7]

Somewhat more controversial is the relative importance of secrecy to an intervention's success. Over the past decade, the monetary authorities of most large countries have routinely announced their interventions to markets. This, however, has not always been the case. During the 1970s and 1980s, central banks sometimes operated in secret, hoping to convince the market that the observed changes in market activity emanated from the private sector. During the first half of this year, moreover, the Japanese Ministry of Finance undertook a series of secret interventions. Given that intervention probably operates through a signaling or expectations channel, secrecy may seem counterproductive, but Battachary and Weller (1997) and Vitale (1999) present theoretical models in which secrecy contributes to an intervention's success. Dominguez and Frankel (1993), Hung (1997), and Chiu (2003) also discuss various reasons for

[7] Some times central banks participate in concerted intervention, even though they expect the operation has a low chance of success, simply to demonstrate a willingness to cooperate. From a game-theoretic perspective, a willingness to cooperate may have value in some broader future context.

maintaining secrecy. Research has not yet reached a consensus on the importance of secrecy.

Intervention often occurs over a string of days, with long intermittent periods of no action. If intervention works because monetary authorities provide private information to the market, then the first intervention in a series may have a greater impact on exchange rates—since it initially reveals new information—than subsequent interventions. In recent years, the monetary authorities of large countries have intervened fewer times, often only for a single day. Research offers some evidence consistent with this hypothesis, suggesting that persistent interventions are fairly useless. Further analysis should test the robustness of the finding.

Methodological Problems and the Evidence on Intervention

The myriad studies on foreign-exchange intervention are almost all empirical. They incorporate a broad range of experimental strategies and techniques. The various methodologies present researchers with different types of problems, about which anyone assessing their results needs to be mindful.

The overarching problem that confronts all empirical research on intervention is the simultaneous determination of official intervention and exchange-rate changes. Because researchers lack a sufficient amount of high frequency data, they generally have not applied standard statistical techniques to this problem. Instead, those using time-series analysis or regression-based event studies, typically manage the timing of their data so that intervention occurs before the exchange rate. Sometimes choosing an end-of-day exchange rate is sufficient to accomplish this; other times, lagging the intervention term one period is necessary. In this latter case, the higher the data frequently, the better.

Given that intervention often appears to affect exchange rate within minutes, estimating and interpreting a lag on an intervention term of even one day may be problematic. Studies that do not solve the timing issue tell us nothing about the efficacy of intervention.

Modeling the decision to intervene can provide a step toward addressing the simultaneity problem. Typical specifications of intervention reaction functions include terms for both the mean and volatility of exchange rates. Their dependent variable—intervention—contains many zeros and often a fairly limited range of values. The discrete nature of the intervention data presents problems in estimating the parameter values of reaction functions. For this reason, vector auto-regression (VAR) techniques are thus far inappropriate for the study of intervention.

An alternative strategy for minimizing simultaneity problems is to define various success criteria for intervention and then to evaluate the frequency of success over a specific period against a null hypothesis embodying randomness. This technique requires careful consideration of the appropriate probability distribution for the success counts. Individual successes need not be independent events and researchers often have little basis for exogenously assigning a probability to an individual success. Morevoer, determining whether a success count is random or not also requires that interventions be sterilized, much like the statistical analysis of coin flips assumes a fair coin. Specifying individual success criteria also permits researchers to estimate the probability of success conditional on various aspects of the intervention process—such as its size or whether it was coordinated—in a probit or logit model.

Defining success criteria is very much in the spirit of an event study. Some researchers are applying more traditional event study techniques to data at frequencies higher that a single day. These studies investigate the relationship between exchange-rate changes and various leads and lags on the intervention term, using regression techniques. Given the overarching simultaneity problem, interpreting causality as running strictly from intervention to exchange rates on the contemporaneous coefficient and on coefficients where intervention "leads" the exchange rate remains tricky, even when the signs on the appropriate terms have a reasonable interpretation. Some event studies widen the event window beyond a single day. As the event window opens, the chances grow that factors besides intervention (e.g., interest-rate changes) will confound any correlation between intervention and exchange rates.

Monetary authorities intervene out concern for both the level and the volatility of their exchange rates. GARCH models are particularly well suited to the study of intervention because they allow researchers to simultaneously estimate a conditional-mean equation and a conditional variance equation, with each containing intervention terms. One can interpret the appropriate coefficients in the conditional-mean equation and in the conditional-variance equation as, respectively, depicting the effects of intervention on the trend and on the volatility of the exchange-rate process. Although GARCH techniques seem to offer a better strategy for modeling exchange-rate processes than many other times-series methods, they do not avoid any of the statistical problems discussed above.

An alternative approach for investigating the effects on intervention on the second moment of the exchange-rate process measures the volatility of expected exchange-rate

changes as implied by prices of options on exchange-rate futures. Extracting exchange-rate volatility from option prices on futures contracts, instead calculating a variance term from actual exchange rates, lets researchers directly consider the impact on intervention on expectations. Consequently, this approach seems more compatible with the view that intervention operates through a broad signaling channel. The methodology still confronts many of the previously mentioned econometric problems, and results may be sensitive to the type of underlying option and to assumptions about risk neutrality.

A couple of recent studies have extended the use of option prices to study the impact of intervention on the entire expected distribution of future exchange rates—mean, variance, skewness, and kurtosis. Each of the higher moments potentially offers a specific insight about the nature of expectations. Holding the first two moments constant, skewness suggests that the market attaches greater probability to a specific direction of change, and kurtosis suggests that the market attaches a great deal of probability to very large changes.

Similarly, only a couple of papers have considered the effect of official intervention on the behavior of bid-ask spreads for foreign exchange. This seems a particularly fruitful area of investigation because one interpretation (adverse selection costs) views bid-ask spread as, in part, providing protection to market makers against transactions with better informed traders. The latter might include central banks.

5. Central Bank Profits and Technical Trading Rules

Monetary authorities that intervene usually acquire and hold portfolios of very liquid, interest earning, foreign-currency-denominated assets. Generally, these positions

are uncovered—exposed to valuation gains and losses. The analysis of central bank profits from intervention is interesting on number of dimensions.

Friedman (1953) argued that destabilizing foreign-exchange speculators necessarily incur losses that quickly drive them from the market.[8] Only stabilizing speculators remain in the market. He warned, however, that central banks do not face hard budget constraints and, therefore, could undertake more persistent unprofitable and destabilizing transactions. Subsequent work, however, indicated that Friedman's correspondence between profitable and stabilizing speculation does not always hold, particularly if the underlying equilibrium exchange rate is not constant. Consequently, one cannot infer much about the ability of central banks to stabilized exchange rates from the profitability of the foreign-exchange operations.

Perhaps the most interesting way to think about central bank profits, however, is in terms of a possible connection to profits generated through technical trading rules. A substantial number of studies have found that fairly simple technical trading rules—including *ex ante* rules, as in Neely, Weller, and Ditmar (1997)—generate profits that are difficult to explain in terms of standard risk measures.[9] (Osler 1996 suggests that more elaborate trading rules, specifically head-and-shoulders rules, largely mimic much simpler rules.) Recent surveys suggest that technical trading rules seem to account for a large and growing segment of foreign-exchange trading.

[8] Note that Friedman's criterion considers only valuation gains and losses; it abstracts from interest earnings and from the opportunity cost associated with investing in alternative (e.g., domestic) assets.
[9] Neely and Weller (2003), however, find no evidence that technical trading rules result in excess returns when they are applied to intra-day trading. These results seem particularly interesting given that traders typically do not carry open positions for long periods of time, especially over night.

Quite a few studies have shown that technical trading rules generate excess returns during periods of central bank intervention. This seems especially likely if central banks adopt a "leaning against the wind" intervention strategy. If central banks slow, but do not reverse, exchange rate movements, they will inevitably sustain valuation losses, at least in the short-run. By taking a position opposite that of the central bank, technical traders apparently stand to profit. In contrast to these findings, however, many other studies conclude that central banks have earned small profits from their intervention operations since the collapse of Bretton Woods.

Neeley (1998) reconciles the technical trading results with the apparent overall profitability of intervention by showing that intervention profits occur over a longer time horizon than technical trading profits. In the short-run, intervention often generates losses, a point that Goodhart and Hesse (1993) also illustrate. Hence, it is possible that technical traders profit against the central bank in the short-run while central banks profit in the long-term. Further work on these seemingly anomalous results is warranted.

6. The State of the Art

Sterilized intervention affords monetary policy makers a means of occasionally pushing an exchange rate in a desired direction. The alternative level then serves as a new starting point for a random walk process compatible with existing fundamentals. The empirical support for this conclusions seems consistent with the idea that monetary authorities periodically possess better information than other market participants and, in these instances, can sometimes can affect market expectations through intervention. This description does not preclude intervention as a signal of future monetary policy, but interpreting intervention as solely or even primarily such a signal is probably wrong. The

likelihood that a given intervention will have the desired effect increases if the transaction is large and coordinated with the foreign monetary authority whose currency is involved.

Nevertheless, because sterilized intervention does not affect market fundaments, it does not afford monetary authorities a means of routinely guiding their exchange rates along a path that they determine independent of their monetary policies. While monetary authorities in large developed countries certainly can affect nominal exchange rates through non-sterilized foreign exchange intervention, doing so either will conflict with their domestic policy objectives or it will be entirely redundant to open market operation in domestic securities. The outcome depends on the nature of the underlying economic shock to their exchange market.

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