

SPECIAL PAPERS IN INTERNATIONAL ECONOMICS

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THE EFFECTIVENESS OF CENTRAL-BANK
INTERVENTION: A SURVEY OF THE
LITERATURE AFTER 1982

HALI J. EDISON

INTERNATIONAL FINANCE SECTION

DEPARTMENT OF ECONOMICS
PRINCETON UNIVERSITY
PRINCETON, NEW JERSEY

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International Finance Section

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1 INTRODUCTION

Over the years, there have been radical changes in the conduct of foreign-exchange intervention and in the way it is viewed by economists. In the 1960s, under the Bretton Woods System of fixed exchange rates, intervention was used to help maintain the exchange rate within prescribed margins and was considered to be an essential part of a central bank's tool kit. With the collapse of the Bretton Woods System in the early 1970s and the move to managed floating, the scale of intervention initially increased. In late October and early November of 1978, for example, the central banks of Japan, Germany, Switzerland, and the United States intervened together to support the dollar; the Federal Reserve alone sold over \$2 billion worth of foreign currencies, a substantial amount at the time. The intervention was successful in supporting the dollar, but only temporarily, and the Federal Reserve intervened again in December. Episodes such as this suggest that intervention can affect the exchange rate but that its effects will be short-lived at best if macroeconomic policies are left unchanged.¹

In the early 1980s, government officials and economists began to question the effectiveness of intervention as an independent policy tool. The first Reagan administration viewed it as both costly and ineffectual and adopted an explicitly *laissez-faire* policy toward foreign-exchange markets. Except for a few minor episodes, the United States did not intervene again until 1985. The view of most U.S. economists during those years was that intervention has only a limited effect. This view was probably influenced by research in the late 1970s showing that exchange markets are efficient, requiring no risk premium to engage in cross-

I would like to thank Kathryn Dominguez, Ellen Dykes, Jeffrey Frankel, William Helkie, Dale Henderson, David Howard, Karen Johnson, Graciela Kaminsky, Michael Leahy, Theodore Sims, Ralph Smith, Edwin Truman, Ralph Tryon, and Ignaccio Visco for helpful comments. I am also grateful to the many authors of the studies surveyed who commented on an earlier draft.

The views expressed in this paper are solely the responsibility of the author and should not be interpreted as reflecting those of the Board of Governors of the Federal Reserve System or of other members of its staff. The paper draws heavily on an earlier annotated bibliography by Edison (1990a).

¹ For more about the U.S. experience during this period, see Greene (1983b).

currency arbitrage, and that the exchange rate can and should be viewed as the relative price of domestic to foreign currency. It may also have been influenced by the large number of studies rejecting the empirical significance of intervention. Some of these studies will be discussed in detail in Chapter 3.

Outside the United States, central banks continued to intervene on behalf of their currencies.² The Europeans used both intervention and interest-rate policies to keep their exchange rates within the bands prescribed by the Exchange Rate Mechanism (ERM) of the European Monetary System (EMS).³ The Japanese, and the Canadians, who had long used intervention to “lean against the wind,” also intervened at various times during this period.

The dollar rose through most of the first four years of the Reagan administration, peaking in February and March of 1985. In response to political pressures from Congress, which threatened to adopt severe protectionist measures, the United States began again to intervene.⁴ Actual operations resumed after a Group of Five (G-5)⁵ meeting in January 1985, but the obvious switch in policy occurred after the Plaza Agreement in September 1985, when the G-5 finance ministers and central-bank governors agreed to engineer a depreciation of the dollar. The United States intervened then on a large scale, mainly in cooperation with the other major countries, and it has since undertaken several other large-scale operations. In 1989-90, it undertook the largest intervention operation in its history.

With the renewed participation of the United States in the foreign-exchange market and the apparent success of intervention episodes following the September 1985 Plaza Agreement and the February 1987

² In most countries, the central bank implements intervention policy, but, in many countries, it does not determine the extent of intervention. In the United States, for example, the Treasury has primary responsibility for intervention. The Treasury determines the timing and the amount of intervention in consultation with the Federal Reserve, and the Federal Reserve Bank of New York undertakes the actual intervention.

³ This survey does not review the extensive literature on the EMS and the role of intervention by member countries to maintain their exchange rates in the ERM. On this, see, for example, Giavazzi and Giovannini (1989), Ungerer et al. (1990), and Dominguez and Kenen (1992).

⁴ About this same time, research results using longer data sets and more sophisticated statistical techniques than those used in the 1970s overturned the earlier conclusion that the risk premium was negligible or constant. Researchers in the mid-1980s focused instead on finding an explanation for time-varying risk premiums.

⁵ The G-5 countries are the United States, Japan, Germany, France, and the United Kingdom.

Louvre Accord, economists have begun to reassess the effectiveness of intervention. The present survey contributes to this reassessment by examining the recent literature on exchange-market intervention. It includes studies undertaken for the Group of Seven (G-7) Working Group on Exchange Market Intervention in 1982-83, as well as subsequent empirical work.⁶

Most of the studies covered here consider sterilized intervention and ask whether it has a quantitatively significant effect on the exchange rate, that is, an effect that is predictable, sizeable, and lasting. The papers do not focus on nonsterilized intervention, which, because it affects the monetary base, is generally assumed to have significant effects on exchange rates. Other important questions addressed by these studies are (1) whether coordinated intervention has a different effect than noncoordinated intervention,⁷ (2) whether the G-7 countries have operated within a target zone since the Louvre Accord, (3) to what extent intervention has been sterilized, (4) what factors have prompted intervention, and (5) whether intervention has been profitable.

The literature on the effectiveness of intervention adopts the general view that exchange rates are determined in asset markets and that they adjust to equilibrate global demands for stocks of national assets rather than demands for flows of national goods. In the class of asset-market models using the portfolio-balance approach, domestic and foreign assets are deemed to be imperfect substitutes. In these models, asset holders allocate their portfolios to balance exchange-rate risk against expected rates of return, which are affected by relative supplies of assets. In the

⁶ The G-7 includes the G-5 countries plus Italy and Canada. The G-7 Working Group completed its report (commonly called the "Jurgensen Report") in January 1983 and released it in April. The report draws no explicit conclusions. The official press release of the G-7 finance ministers and central-bank governors reviewing the report states that its analysis seems to suggest that sterilized intervention (1) has a much smaller impact than nonsterilized intervention has on exchange rates, (2) may have some short-run impact on exchange rates and may therefore be effective in achieving some short-run exchange-market objectives, (3) does not appear to have much long-run impact, and its effects are often swamped by those of other macroeconomic policies, and (4) is more effective when coordinated than when initiated by a single country, although the conditions for successful coordination are exacting. Henderson and Sampson (1983) summarize the ten staff studies written for the G-7 Working Group by the Federal Reserve System and the U.S. Treasury Department.

⁷ Coordinated intervention occurs when two central banks intervene in the same direction. At times, we shall refer to coordinated intervention as "international cooperation." Noncoordinated intervention occurs when only one central bank intervenes. It has sometimes been called "unilateral intervention."

class of asset-market models using the monetary approach, domestic and foreign assets are deemed to be perfect substitutes. This approach makes portfolio shares infinitely sensitive to changes in expected rates of return. In contrast to portfolio-balance models, monetary models typically focus on the demand for and supply of money, bond supplies being irrelevant when all bonds are perfect substitutes.

The portfolio-balance approach has commonly been used to assess the effectiveness of intervention because it identifies a direct channel through which intervention can influence the exchange rate. It predicts that sterilized intervention will affect the exchange rate by altering the supplies of domestic and foreign assets. The monetary approach, by contrast, predicts that sterilized intervention will have no direct effect. Both approaches permit intervention to affect the exchange rate indirectly, however, by providing information about the views and intentions of the monetary authorities and thus influencing the expectations of exchange-market participants. This indirect influence is described as the signaling effect, or signaling channel.

Three problems arise in surveying studies of intervention. The first is that the literature is somewhat fragmented. Although there are often several articles on a particular topic, they may refer to each other only cursorily if at all. They tend not to build on one another or to broaden previous research. This self-imposed isolation makes it difficult to explain why results differ from study to study, a problem that is particularly acute in the recent literature on the signaling effect and on the probability of intervention. A case in point is the paper by Dominguez and Frankel (1992), which investigates both the signaling and portfolio-balance channels. It uses the same mean-variance optimization restrictions employed by many other portfolio-balance studies but differs from those studies in finding that intervention works through both channels. It fails to explain, however, precisely why it contradicts other research on the same subject.

The second problem, rarely addressed explicitly, derives from the great difficulty economists have had modeling exchange-rate behavior. In fact, as Meese (1990) has recently reemphasized, most of the profession has concluded that structural exchange-rate models explain only a small part of the movements in dollar exchange rates.⁸ Some examiners

⁸ This view originates in the seminal work by Meese and Rogoff (1983). Levich (1985) and Isard (1987) survey empirical studies of exchange-rate behavior that tend to support it.

have used this conclusion to argue that very little should be expected from research focusing specifically on the effectiveness of intervention. Failing to find a statistically reliable relation between exchange rates and intervention is no different from failing to find a statistically and quantitatively significant relation between exchange rates and other economic variables such as interest rates.⁹ We shall return to this theme from time to time.

The third problem plaguing the literature is the lack of data on actual amounts of intervention. Central banks are reluctant to release these figures, and most researchers have had to rely on imperfect proxies.¹⁰ Some of the portfolio-balance studies have tried to extract information from the balance sheets of the monetary authorities (for example, Danker et al., 1987), but these ledgers are not usually available on a daily or weekly basis. More recent studies, especially those concerned with the signaling channel, have used reports in the financial press to identify the days on which intervention has occurred.¹¹ Other studies, particularly those examining the motivation for central-bank intervention, have used changes in foreign reserves. Reserves may change for reasons other than intervention, however, so reserve statistics tell us little. The particular problem of using reserves is illustrated by Mastropasqua, Micossi, and Rinaldi (1988), who compare changes in reserves with actual amounts of intervention for France, Germany, and Italy. The authors show that intervention by France over the 1983-85 period was \$2.7 billion, whereas the corresponding change in reserves was \$9.6 billion. Such disparities occur for Germany and Italy as well.

We shall remind the reader of these problems when reviewing specific studies, but we should state at the outset that existing empirical methods and the data available are not yet sophisticated enough to enable researchers to resolve completely questions about the effectiveness of intervention.

⁹ Edison and Melick (1992) and Edison and Pauls (1993) test the statistical relation between nominal or real interest rates and exchange rates.

¹⁰ The Federal Reserve Board is a notable exception; it now releases U.S. intervention data on a daily basis. These data are available from 1973, with a one-year lag. The Bundesbank has made daily data available informally to researchers within the central banks.

¹¹ Klein (1992) finds with regard to U.S. intervention, however, that the newspapers often mention intervention that did not occur or fail to note intervention that did occur. In addition, he finds that the interventions reported by the newspaper are larger on average than those not reported.

The next chapter discusses sterilized and nonsterilized intervention. Subsequent chapters examine papers grouped into eight areas of enquiry. Chapters 3 and 4 review empirical studies asking if sterilized intervention has a quantitatively significant effect on exchange rates. Studies of the portfolio-balance channel are discussed in Chapter 3. All of these papers test and reject the joint hypothesis that assets are perfect substitutes and that expectations are rational. Because it is a joint hypothesis, however, we cannot conclude that assets are imperfect substitutes, which is the basic supposition of the portfolio-balance approach.

Chapter 4 reviews studies examining the signaling channel. These studies do not use a common model and are therefore difficult to summarize. Most of them, however, find that the signaling channel gives sterilized intervention some statistically significant effect on the exchange rate.

Chapter 5 surveys studies asking what factors have prompted intervention and the extent to which intervention has been sterilized. These studies estimate policy reaction functions for intervention operations and for conventional open-market operations. They find that intervention has been undertaken to smooth nominal and real exchange rates and to achieve a target level of the nominal exchange rate. Most of the studies analyzing sterilization find that a large part of intervention has, indeed, been sterilized.

Chapter 6 discusses studies asking whether intervention has been profitable. The majority of the papers find that it has been profitable in most of the time intervals considered.

Chapter 7 reviews descriptive studies examining particular episodes of intervention. These studies were largely undertaken for the G-7 Working Group. They conclude for the most part that sterilized intervention has had a temporary impact on the exchange rate and has been useful as a short-term tool to stabilize trading conditions and buy time for policy adjustments.

Chapter 8 reviews the most recent intervention literature, which assesses the post-Plaza intervention policies of the G-7 countries, especially the G-3 (the United States, Japan, and Germany), and attempts to estimate the probabilities of intervention by them. These recent studies are focused, not on testing the effectiveness of intervention per se, but on assessing recent G-7 or G-3 intervention policy. Their common premise is that the effects of intervention in the post-Plaza or post-Louvre period may have been quite different from those of earlier periods. Exchange-rate policy has figured prominently in the

news since the Plaza Agreement, and much of the foreign-exchange intervention has been coordinated among the G-7 countries.

Chapter 9 summarizes and concludes the survey.

2 THE MECHANICS OF INTERVENTION¹²

Sterilized and Nonsterilized Intervention

Studies of intervention often distinguish between sterilized intervention, which does not affect the money supply, and nonsterilized intervention, which does. There is virtually unanimous agreement among economists that nonsterilized intervention can affect the exchange rate, just as conventional changes in monetary policy, typically through central-bank purchases or sales of domestic securities, can affect the exchange rate. It does so by changing the stock of base money and thus changing broader monetary aggregates, interest rates, real demands for goods and assets, and market expectations. The effect of sterilized intervention, however, is much more controversial. Because sterilized intervention leaves the monetary base unchanged, it cannot affect the exchange rate through the “monetary” channel. In theory, sterilized intervention might directly affect the exchange rate by changing the relative supplies of domestic and foreign bonds and by changing market expectations.¹³ It is not certain, however, that sterilized intervention influences the exchange rate through either of these channels. Because its effects are controversial, and because interest in its effects is, in essence, interest in its utility as a policy instrument independent of monetary policy, sterilized intervention will be the focus of this survey.¹⁴

The balance sheet of the monetary authorities may be used to illustrate the important distinction between sterilized and nonsterilized intervention. Like any other balance sheet, it is organized according to the principles of double-entry bookkeeping. The acquisition of an asset by the monetary authorities appears on the asset side of the ledger. Similarly, any addition to the authorities’ obligations appears on the liability side.

Table 1(A) shows the initial balance sheet of the monetary authorities. On the asset side are foreign assets, consisting mainly of foreign-currency bonds and gold, and domestic assets, usually domestic government bonds

¹² Adams and Henderson (1983) provide background materials on the measurement of intervention.

¹³ Nonsterilized intervention may also influence the exchange rate through these channels.

¹⁴ In subsequent chapters, “intervention” will always refer to sterilized intervention.

and loans to commercial banks. When the monetary authorities intervene in the foreign-exchange market, their holdings of foreign assets will change. Similarly, when they engage in open-market operations, their holdings of domestic assets will change.

On the liability side of the ledger are commercial-bank deposits and domestic currency in circulation. The two sides of the ledger are equal, that is, the sum of foreign and domestic assets equals the sum of monetary liabilities.¹⁵ When the monetary authorities buy (sell) a domestic or foreign asset from the public, both their assets and liabilities increase (decrease). Thus, a change in the level of asset holdings by the monetary authorities will be accompanied by a change in the money supply.

When the monetary authorities intervene in the foreign-exchange market, foreign assets are exchanged for a liability of the monetary authorities. If, for example, the monetary authorities buy foreign assets, both sides of the balance sheet will increase. This sort of intervention is similar to a domestic open-market purchase in its impact on monetary liabilities. The only difference is that the monetary authorities alter the monetary base through a change in their foreign (rather than domestic) asset holdings. The impact of intervention on the domestic money supply can be neutralized by an offsetting transaction in domestic assets having the same magnitude as the transaction in foreign assets. If, for

TABLE 1
THE MONETARY AUTHORITIES' BALANCE SHEET

A. Initial Situation			
<i>Assets</i>		<i>Liabilities</i>	
Foreign		Deposits held by commercial banks	
Domestic		Currency in circulation	
B. Foreign-Asset Sale: Without Sterilization			
<i>Assets</i>		<i>Liabilities</i>	
Foreign	-	Deposits held by commercial banks	-
Domestic	0	Currency in circulation	0
C. Foreign-Asset Sale: With Sterilization			
<i>Assets</i>		<i>Liabilities</i>	
Foreign	-	Deposits held by commercial banks	0
Domestic	+	Currency in circulation	0

¹⁵ For simplicity, it is assumed that the net worth of the monetary authorities is zero.

example, the monetary authorities make an open-market sale of domestic assets, they will reduce both their assets and liabilities, completely offsetting the money-supply effect of the original purchase of foreign assets. The net result of this second transaction will be to leave the public with unchanged holdings of monetary assets (liabilities of the monetary authorities), but with a larger stock of domestic assets.

When exchange-market intervention is combined in this way with an open-market operation, it is said to be “sterilized.” Sterilized intervention is a “pure” change in the relative stocks of domestic and foreign assets held by the public, unaccompanied by any change in the monetary base. It changes currency composition of the assets held by the public by changing the composition of the monetary authorities’ portfolio. All major central banks tend to use open-market operations to sterilize intervention.

A simple example can illustrate the difference between the two types of intervention. Suppose the dollar has weakened against the deutsche mark, and the U.S. monetary authorities want to see the trend halted. They decide to intervene in the foreign-exchange market to support the value of the dollar. Initially, the U.S. monetary authorities will sell some of their holdings of deutsche mark assets. This will in turn lower their domestic monetary liabilities. If the monetary authorities stop at that point, the intervention is said to be nonsterilized. Table 1(B) highlights the impact of nonsterilized intervention on the balance sheet. On the asset side of the ledger, the monetary authorities’ holding of foreign assets declines; on the liability side, the amount of deposits held by commercial banks falls by an equal amount. The change in the balance sheet implies a decline in the money supply. Table 1(C) shows how this exchange-market intervention might be sterilized. The monetary authorities can buy domestic assets to offset the initial effect on the money supply. This additional transaction will return domestic monetary liabilities to their original level, leaving the monetary base unchanged but increasing the monetary authorities’ holdings of domestic assets. The currency composition of the securities portfolios of both the monetary authorities and the public will change, but the transactions in foreign and domestic assets offset each other, altering only the composition of assets, not the total amounts of assets and liabilities.

How does this change in the composition of assets influence the exchange rate? As sterilized intervention changes the outstanding stocks of internationally traded assets denominated in various currencies, it tends to cause changes in the expected rates of return on these assets, which should in turn change the exchange rate. It is widely accepted

that sterilized intervention changes the relative stocks of assets; it has been difficult to establish, however, that it leads to changes in the exchange rate.

The Scale of Intervention

One argument for the claim that intervention has only small effects is that the size of intervention is small relative to the total stocks or flows in the foreign-exchange market. Even though the scale of central-bank intervention has been larger since 1985 than it was in the early 1980s, it still remains small compared to the overall market size. For April 1992, for example, foreign-exchange trading was estimated at \$192 billion per business day (after adjusting for double counting) in the U.S. foreign-exchange market and at nearly \$900 billion per business day in the global foreign-exchange market (BIS 1993).¹⁶ Typically, individual episodes of central-bank intervention amount to less than \$200 million per day. When intervention is coordinated with other central banks, the amount is larger but is usually still small relative to total market volume.

Another argument is that intervention should not be expected to have much influence when it is compared to the existing stock of internationally traded assets. The stocks of traded assets denominated in U.S. dollars and other major currencies are obviously in the trillions. The argument is not absolutely correct, however, because small changes in quantities may produce large changes in prices, particularly when price elasticities are small. In such cases, central-bank transactions, although small relative to the market, would nevertheless induce large changes in exchange rates. Because we do not observe these large changes in exchange rates, we have not considered this low-elasticity case.

*U.S. Intervention*¹⁷

Figure 1 depicts U.S. intervention from 1973 to 1990. Clearly, it has been episodic and highly variable in size. The first major episode of U.S. intervention began in late 1974, after the 1973-74 oil-price shock. The substantial depreciation of the dollar in 1977 and 1978 triggered a

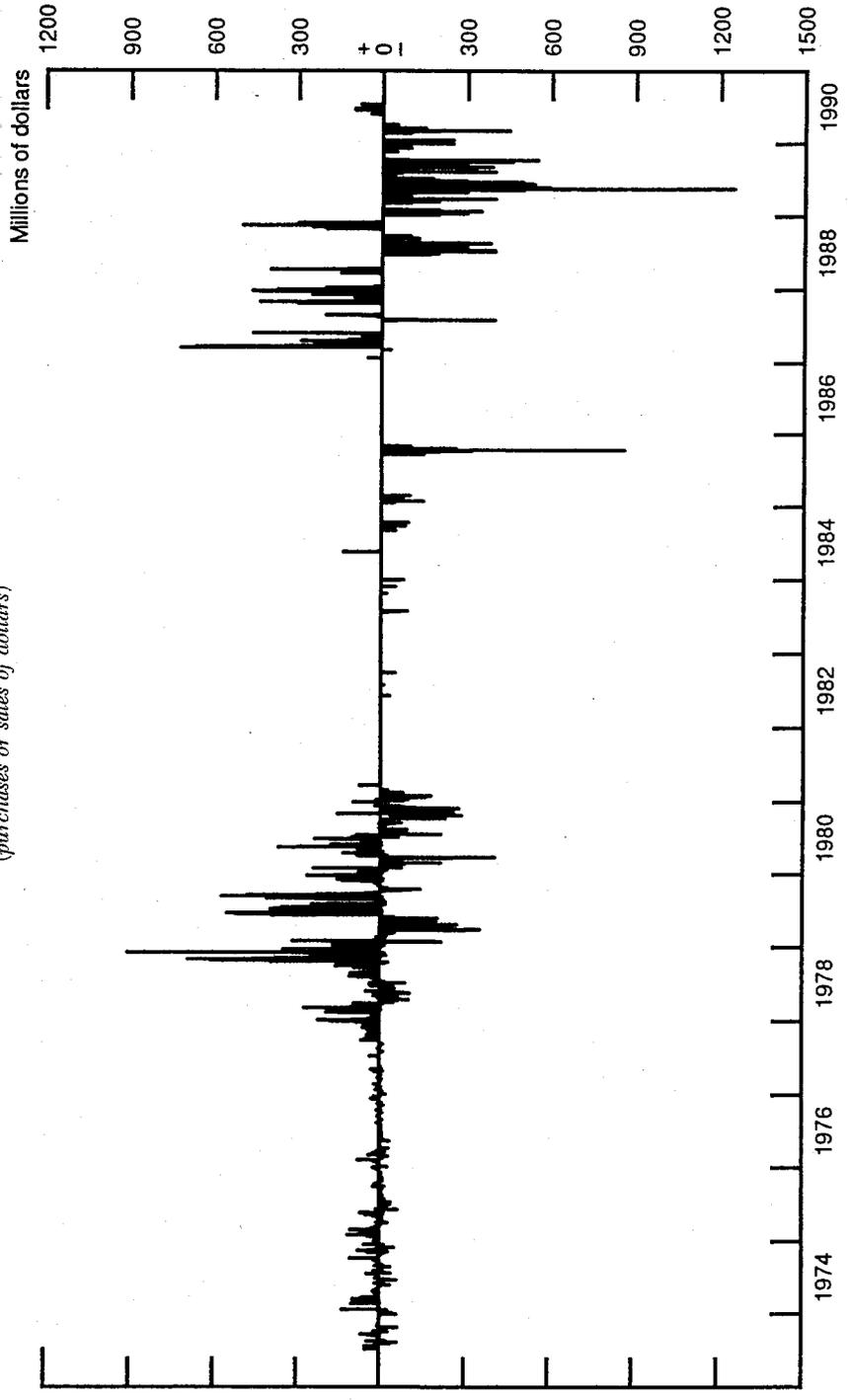
¹⁶ The comparable estimate of global turnover in April 1989 was \$620 billion per business day. The growth in turnover from 1989 to 1992 is estimated to have been 42 percent, which represents a marked slowdown as compared with the growth in the previous three-year period.

¹⁷ Chapter 7 reviews several articles that describe various episodes of U.S. intervention. A thorough survey of U.S. exchange-rate policy since the collapse of the Bretton Woods System is contained in Pauls (1990).

second wave of intervention. From early 1981 to early 1985, the U.S. monetary authorities limited intervention to a few instances in which there was a clear perception of market disorder requiring corrective action. By early 1985, however, U.S. officials had become concerned that the dollar had risen to levels that were out of line with underlying economic fundamentals. Consequently, after the January 1985 G-5 meeting, the United States entered the market, selling a moderate amount of dollars to encourage a decline in dollar exchange rates. This policy was coordinated with other central banks. The dollar gradually declined throughout the spring and summer, but the decline had ceased by September. The United States, together with the other G-5 countries, therefore announced in the Plaza Agreement that “some further orderly appreciation of the non-dollar currencies is desirable” and that the G-5 countries stood “ready to cooperate more closely to encourage this when to do so would be helpful.”¹⁸ The U.S. authorities then intervened during the next six weeks to help achieve this goal. The foreign-currency value of the dollar, measured on a trade-weighted basis, declined about 8 percent. In 1986, the United States did not intervene; in 1987, it intervened only once (Figure 1). Following the Louvre Accord in February, the G-7 shifted its objective from encouraging dollar depreciation to fostering greater exchange-rate stability. The U.S. monetary authorities have intervened several times since that shift, with the largest U.S. intervention occurring in May 1989, when the dollar strengthened.

¹⁸ As Dominguez and Frankel (1993) note, the language in this communiqué constitutes, in retrospect, strong support for concerted intervention, even though the word “intervention” is not specifically used.

FIGURE 1
DAILY U.S. INTERVENTION
(purchases or sales of dollars)



3 THE PORTFOLIO-BALANCE CHANNEL

Studies using the portfolio-balance model fall into three groups, all of which assume that assets are imperfect substitutes. The groups are distinguished by their auxiliary assumptions and by whether or not they imbed the portfolio-balance model in a small, but more comprehensive, macroeconomic model. The studies discussed are therefore divided into those using (1) traditional portfolio-balance models, (2) portfolio-balance models featuring mean-variance optimization, and (3) small macroeconomic models containing portfolio-balance equations.¹⁹

Some of the studies use bilateral exchange rates; others, especially those based on mean-variance optimization, use several exchange rates simultaneously. The frequency, definition, and quality of the data vary across studies. When actual asset supplies are employed, the data used are weekly, monthly, or quarterly. When actual or reported data on intervention are used, the frequency tends to be daily. Information on actual intervention comes from official sources, whereas information on reported intervention comes from the financial press.

A common feature of the portfolio-balance literature is that it tests and rejects the joint hypothesis that assets are perfect substitutes and that expectations are rational. As earlier noted, because it is a joint hypothesis, we cannot conclude that assets are imperfect substitutes, which is the basic supposition of the portfolio-balance approach. In most of the studies reviewed, the researchers do not find a statistically, and/or quantitatively, significant role for sterilized intervention.

The General Framework

When a central bank uses sterilized intervention, the relative supplies of domestic and foreign assets are changed. Under certain circumstances, such changes in relative asset stocks will affect exchange rates. This section presents the general framework used to obtain that result.

¹⁹ For historical background on portfolio-balance models and intervention, see Tryon (1983) and Boothe et al. (1985). These authors review earlier empirical studies on the effectiveness of intervention. For a more recent review of this literature, see Humpage (1991). The nonstructural time-series techniques used to examine the short-run impact of intervention are reviewed by Rogoff (1983).

One strategic assumption, that asset holders are risk averse, creates a role for sterilized intervention in the portfolio-balance model. Under this assumption, investors will not be indifferent to the currency composition of their portfolios, and assets denominated in different currencies will not be perfect substitutes. Investors will allocate their portfolios to balance exchange-rate risk against expected rates of return. The general portfolio-balance model consists of demand equations for domestic and foreign assets, which are functions of expected returns, wealth, and a variable representing transactions demand.

A brief review of the model will illustrate the potential value of sterilized intervention as a policy tool and will serve as background for the subsequent survey of empirical applications.²⁰ The portfolio-balance model assumes that domestic residents hold wealth in the form of domestic currency and in interest-bearing assets denominated in domestic and foreign currencies. Similarly, it assumes that foreigners hold foreign money and domestic and foreign interest-bearing assets. The assumptions that domestic and foreign residents do not hold each other's currencies is a useful simplification aimed at focusing attention on the portfolio-balance channel.²¹ These demand equations are written as

$$M_H = m_H(r, r^*, \Delta s_{t+1}^e, Y, W) , \quad (1)$$

$$B_H = b_H(r, r^*, \Delta s_{t+1}^e, Y, W) , \quad (2)$$

$$(1/S)B_H^* = b_H^*(r, r^*, \Delta s_{t+1}^e, Y, W) , \quad (3)$$

$$M_F^* = m_F(r, r^*, \Delta s_{t+1}^e, Y^*, W^*) , \quad (4)$$

$$SB_F = b_F(r, r^*, \Delta s_{t+1}^e, Y^*, W^*) , \quad (5)$$

$$B_F^* = b_F(r, r^*, \Delta s_{t+1}^e, Y^*, W^*) , \quad (6)$$

where S is the spot exchange rate (foreign currency per domestic-currency unit), r and r^* are the domestic and foreign interest rates,

²⁰ The model given below is similar to that used by Kouri and Porter (1974) and by Tryon (1983).

²¹ A more general specification of asset-demand models would assume that the residents of both countries hold four assets: home money, foreign money, home (currency)

Δs_{t+1}^e is the expected change in the exchange rate, M_H and M_F^* are the demands for domestic and foreign money, B_H and $(1/S)B_H^*$ are the domestic demands for the domestic and foreign bonds, both measured in domestic currency, and SB_F and B_F^* are the foreign demands for the domestic and foreign bonds, both measured in foreign currency. Nominal income and wealth are denoted by Y and W , with asterisks used to identify foreign values.

Wealth in each country is defined as the sum of domestic bond holdings, foreign bond holdings, and money holdings:

$$M_H + B_H + B_H^* = W , \quad (7)$$

$$M_F + B_F + B_F^* = W^* . \quad (8)$$

It should be noted that the inclusion of equations (7) and (8) renders the previous demand equations redundant.

The supplies of money and bonds are assumed to be predetermined, and equilibrium in the relevant markets occurs when the demand for each asset is equal to its predetermined supply:

$$M_H = \bar{M} , \quad (9)$$

$$M_F^* = \bar{M}^* , \quad (10)$$

$$B_H + B_F = \bar{B} , \quad (11)$$

$$B_H^* + B_F^* = \bar{B}^* . \quad (12)$$

Equation (11), which states that the sum of domestic and foreign demands for domestic-currency bonds equals the supply of those bonds, is rewritten as

$$\bar{B} = b_H(r, r^*, \Delta s_{t+1}^e, Y, W) + (1/s)b_F(r, r^*, \Delta s_{t+1}^e, Y^*, W^*) , \quad (13)$$

securities, and foreign (currency) securities. Many of the studies described in this survey have used models that make several simplifying assumptions, such as (1) residents do not hold foreign currency, ruling out currency substitution; (2) each country's demand for money is independent of the return on the security denominated in the foreign currency; (3) all changes in residents' demand for money resulting from changes in nominal income and prices are matched by changes in their demand for securities denominated in domestic currency; and (4) the demand for money is independent of nominal wealth in each country. For more on the specification of asset-demand functions, see Branson and Henderson (1985).

which contains the mechanism by which supplies of bonds affect the exchange rate. A rise in the supply of domestic-currency bonds requires a rise in the quantity demanded. The rise in demand can be achieved by a rise in domestic interest rates, by a depreciation of the domestic currency, or by a fall in foreign interest rates. (This assumes that wealth, income, and exchange-rate expectations are fixed in the short run.) If interest rates are determined in the money markets, then it is the exchange rate that must change.²² The strength of this effect will depend on the degree of asset substitutability.

The empirical implementation of the portfolio-balance model varies among the different studies surveyed. Some studies estimate the structural asset-demand equations directly (*the direct approach*).²³ Others invert the asset-demand functions (*the inverted asset-demand approach*), estimating the risk premium, which is defined as the expected deviation from uncovered interest-rate parity, as a function of asset supplies.²⁴ A typical risk-premium equation²⁵ takes the form of

$$\rho = r - r^* + E(s_{t+1}) - s = f(B/B^*) , \quad (14)$$

which, as is often the case in an inverted model, excludes the income and wealth variable and yields a simple linear regression of the risk premium on relative bond supplies.²⁶ An increase in the supply of domestic assets requires that asset holders be compensated by a higher

²² See Kenen (1982); see also Branson and Henderson (1985) for general results using this model.

²³ In estimating an equation such as (13), the focus is on the coefficient of the risk-premium variable, because it reflects the degree of asset substitutability. A small coefficient implies that assets are imperfect substitutes; a large coefficient implies that they are close substitutes. If the coefficient on the risk premium approaches infinity, assets are deemed to be perfect substitutes. Any change in the supply of bonds can be offset by an infinitesimal change in interest rates.

²⁴ Uncovered interest-rate parity states that the expected rate of return on the domestic asset equals the expected rate of return on the foreign asset when expressed in domestic currency.

²⁵ Dooley and Isard (1982, 1983) and Frankel (1982a) were the first to derive equations for the risk premium from a portfolio-balance framework.

²⁶ Under the null hypothesis of perfect substitutability, the coefficients on the right-hand side are all zero. Under the alternative hypothesis of imperfect substitutability, the coefficients are finite but not zero. To reject the joint hypothesis of perfect substitutability and rational expectations, the coefficients on the right-hand side—including the autoregressive coefficient if one is estimated—should be jointly significant. In particular, if the portfolio-balance channel exists, the coefficients on the asset supplies should be significantly different from zero.

expected return so that they will be encouraged to hold the increased supply. Sterilized intervention creates an excess demand for the asset purchased by the authorities and an excess supply of the asset sold. This imbalance necessitates a movement in the exchange rate, the interest rates, or both, to restore equilibrium.

In the monetary approach, assets are assumed to be perfect substitutes. There can thus be no portfolio-balance channel through which changes in relative supplies of bonds can affect the exchange rate. In the monetary approach, there is no need to offer asset holders a risk premium ($\rho = 0$), and uncovered interest-rate parity must hold:

$$r = r^* - E(s_{t+1}) + s . \quad (15)$$

The above discussion has not specified how expectations are formed. The early literature on the risk premium commonly assumed that expectations are stationary. Over time, and especially in the empirical literature, it has become more usual to assume that expectations are formed rationally. Modern empirical work consequently recognizes that any test concerning the behavior of the risk premium is necessarily a test of the joint hypothesis on the degree of asset substitutability and on expectations formation. The weight of the evidence leads one to reject forcefully the joint hypothesis that assets are perfect substitutes and expectations are rational. But which of its two components is flawed?

Recent research efforts have been devoted to showing that the failure of the joint hypothesis lies in its insistence on rational expectations. This research supposes that survey data on exchange-rate expectations provide an unbiased measure of those expectations, a supposition that leads to a new joint hypothesis: that assets are perfect substitutes and that the survey data are valid.²⁷ This joint hypothesis is usually rejected. But here, as before, it is not possible to disentangle the cause for rejection. Some studies also attempt to use survey data when studying the portfolio-balance model and the effects of intervention (for example, Dominguez and Frankel, 1992); this work is discussed below.

The portfolio-balance model represents only one strand of the literature modeling the risk premium. A great number of studies testing the same joint hypothesis focus on the question of market efficiency, rather than the role of intervention. These studies attempt to explain the

²⁷ The survey data show that there are substantial extrapolative and adaptive components to expectations (Frankel and Froot, 1987) and that there are systematic differences in the expectations of groups of investors with different net-asset positions (Ito, 1990).

risk premium using microfinance fundamentals, which typically concentrate on the interaction of exchange rates and asset prices. In general, they do not ask explicitly whether sterilized intervention is effective. Instead, they use a finance perspective to test alternative explanations of why the joint hypothesis fails (Hodrick, 1987; Baillie and McMahon, 1989).

Before turning to the survey of empirical work, we must further qualify the accepted condition that intervention will affect the exchange rate only if securities denominated in different currencies are imperfect substitutes. When a government exchanges foreign for domestic assets with domestic residents, there may be no exchange-rate effect, because private agents take account fully of all future net taxes levied by the government. In this extreme case of Ricardian equivalence, the government cannot systematically affect the *relevant* bond supplies—the supplies of net claims on governments that the public must hold. In a Ricardian world, therefore, imperfect substitutability is not a sufficient condition for sterilized intervention to affect exchange rates. Stockman (1979) and Obstfeld (1982) discuss the relation between Ricardian equivalence and intervention effects. Their papers and, more recently, a paper by Backus and Kehoe (1989) note that intervention cannot be analyzed independently of its effects on the government’s intertemporal budget constraint.²⁸ The studies reviewed hereafter in this survey assume explicitly or implicitly that intervention affects asset supplies.

Traditional Portfolio-Balance Models

General Econometric Problems. Several econometric problems arise in the estimation of asset-demand functions in either direct or inverted form. One problem relates to simultaneity. The analytical specification requires estimating an equation with several endogenous variables on the right-hand side. This biases ordinary least-squares estimates. Another problem, already mentioned, involves the treatment of exchange-rate expectations. Early studies commonly assumed that expectations are static. The studies we survey commonly assume that expectations are rational. Under rational expectations, the *ex post* rate of return can be used as a proxy for the expected rate of return; the difference between

²⁸ As Maurice Obstfeld has pointed out to me, Backus and Kehoe go further than Stockman and Obstfeld. If sterilized intervention does have effects, they argue, these will alter the government’s net assets and thus necessitate fiscal changes that maintain intertemporal budget balance. The fiscal changes may, in turn, swamp the portfolio effects of the intervention. Hence, it makes no sense to examine the effects of sterilized intervention without asking how the accompanying budgetary effects are financed.

the two is a forecast error. Thus, the overall equation error depends both on this forecast error and on an ordinary equation error. The presence of the forecast error can impart unusual properties to the overall equation error, including both an autoregressive and a moving-average component. The problems posed by having both endogenous explanatory variables and this complicated error term have been handled by using some form of instrumental-variable estimation. See Hodrick (1987) for a description of these techniques.

Another problem, more difficult to resolve, is the limited availability of official intervention data. Researchers have typically to construct measures for the stock of outstanding assets using methodologies that give rise to measurement error. Most researchers discuss this problem, but few account for it in their empirical work. Some very recent research has benefited from the release of official U.S. intervention data.

Empirical Evidence. In a contribution to the 1983 G-7 Working Group study, Danker et al. (1987) estimate portfolio-balance models using both actual and inverted bond-demand equations.²⁹ They evaluate separate bilateral equations for U.S. dollar exchange rates with the deutsche mark, yen, and Canadian dollar, using carefully constructed monthly data on stocks of German and Japanese bonds and quarterly data on Canadian bonds. In all the equations, the U.S. dollar is treated as the foreign currency, and foreign wealth is defined as the cumulated sum of the budget deficits of the governments of the other G-10 countries minus the net foreign assets of the private sector in the home country.³⁰ The authors use two ways of modeling exchange-rate expectations—static expectations and rational expectations. To take account of the econometric problems posed by endogeneity and a complicated error process, Danker et al. use the Hayashi-Sims two-step two-stage least-squares method. In general, they reject the joint hypothesis that assets are perfect substitutes and expectations are rational. Yet, their risk-premium equations provide little evidence to support the portfolio-balance model. Although the portfolio-balance variables are jointly significant in the dollar-deutsche mark equations, many of the individual coefficients are of the wrong sign. The authors are unable to reject the joint hypothesis for the Japanese case, and, although they can reject it

²⁹ They defend the use of inverted demand equations to test the portfolio-balance hypothesis by noting that the econometric estimates of bond-demand equations are interpretable only if the hypothesis of imperfect substitutability is maintained.

³⁰ The G-10 includes Belgium, the Netherlands, and Sweden in addition to the G-7 countries.

for Canada, they cannot adduce support for the portfolio-balance model. For thoroughness, the authors also estimate bond holdings as left-hand-side variables. Once again, the results for Germany conform more to the portfolio-balance model than do results for Japan and Canada. The coefficients on the risk-premium term are often of the correct sign, although not always significant. In general, the results of the G-7 study are inconclusive with respect to the effectiveness of sterilized intervention.

In two later studies, Rogoff (1984) and Lewis (1988a) reexamine the issues examined by Danker et al. (1987). Rogoff uses an inverted demand equation and tests for the existence of the portfolio-balance effect. In particular, he uses an uncovered interest-rate parity equation for the Canadian and U.S. dollars that resembles equation (15), in which deviations from parity depend on relative supplies of outside assets. Rogoff uses weekly data for the period from March 1973 to December 1980, and, because he assumes that expectations are rational, he estimates the equation using ordinary least squares and two-step two-stage least squares. Relative asset supplies are constructed in two ways, using interest-bearing assets only, and using interest-bearing assets plus the monetary base. The coefficients on these measures of relative asset supplies are found to be insignificant and of the wrong sign. These results are invariant to a number of alternative specifications and estimation procedures. Rogoff concludes that it is difficult to demonstrate that *ex post* returns respond as predicted by theory to changes in relative supplies of outside assets denominated in different currencies.

Lewis estimates asset-demand functions directly using multilateral asset-demand equations for the currencies of the United States, Germany, Japan, the United Kingdom, and Canada. The data for German, Japanese, and Canadian assets and wealth are essentially those from Danker et al., with some modification in timing. The data for the United States and United Kingdom are constructed by the author in a similar manner. As in most such studies, Lewis assumes rational expectations and therefore uses a two-step two-stage least-squares estimator. With this multilateral setup, Lewis also exploits some of the cross-equation restrictions on the covariance matrix.

Despite her attempts to use improved and more efficient empirical techniques, Lewis' estimates of the coefficients on the relative rates of return are for the most part insignificant. The only exception is the positive relation between the relative return on yen-denominated assets and the supply of Canadian bonds. The effect of wealth on asset demands provides some evidence for the portfolio-balance model, but

this result does not go to the central issue—whether asset supplies affect rates of return.

Loopesko (1984) obtains somewhat different results using a measure of cumulated daily central-bank intervention rather than outstanding asset stocks to evaluate the portfolio-balance channel. Her study analyzes the effect of sterilized intervention using daily data on U.S. dollar exchange rates vis-à-vis the currencies of the other G-7 countries. The data are carefully compiled and constructed, taking into consideration the institutional structures of the various markets. To test the usual joint hypothesis, Loopesko estimates an equation for the risk premium using lagged values of the risk premium, lagged exchange rates, and cumulated intervention as a proxy for the stock of domestic assets. Under the joint hypothesis, none of these variables should enter significantly into the regression. For the great majority of the currencies and subsample periods, however, Loopesko rejects the joint hypothesis. To identify the reasons, she determines which variables enter significantly into the regression equations. In about half the cases, she finds that lagged cumulated intervention is significant, which leads her to conclude that sterilized intervention may have an impact on the exchange rate through a portfolio-balance channel.³¹ Although Loopesko states that this impact will be short-lived, it is not self-evident from her results that one can easily determine the duration of the effects.

Ghosh (1992) follows a different strategy. He uses monthly data for the dollar-deutsche mark exchange rate for the 1980-88 period and estimates both a monetary model and a portfolio-balance model. His portfolio-balance model, using the supply of assets denominated in dollars and deutsche marks, explains deviations of the exchange rate from the value implied by the monetary model. Ghosh concludes that there is a statistically significant portfolio-balance effect on the exchange rate but that it is weak.

Portfolio-Balance Models with Mean-Variance Optimization

Derivation of the Estimated Equations. Another approach that is closely aligned to the standard portfolio model incorporates mean-variance optimization. This strategy, pioneered by Frankel (1982b), attempts to link expected rates of return with bond supplies by requiring

³¹ Following Loopesko's work, Micossi and Rebecchini (1984) use data for Italy to estimate the effect of intervention on the *ex post* rate of return. Their results indicate that current and lagged intervention do not have statistically significant effects on rates of return.

that the coefficients of an inverted asset-demand function be closely related to the variance-covariance matrix. Frankel's own model is based on asset demands derived from the solution to a two-period mean-variance maximization problem. The parameters of the asset-demand equations become explicit functions of the means and variances of rates of return and of investors' attitudes toward risk. This approach provides more structure than merely testing for nonzero coefficients. It is distinguished from the general finance literature, from which it comes, by the assumption that relative asset supplies influence rates of return.

The mean-variance optimization model posits that an investor maximizes a function of the mean and variance of end-of-period real wealth, W_{t+1} , which depends on the portfolio allocation and on real returns:

$$W_{t+1} = W_t + W_t x_t' r_{t+1} + W_t (1 - x_t' \tau) r_{t+1}^{\$}, \quad (16)$$

where W_t is initial real wealth, x_t is the vector of portfolio shares, $(1 - x_t')$ is the U.S. share, r is the vector of real returns corresponding to x , $r^{\$}$ is the U.S. real return, and τ is the column identity vector.

The vector of returns relative to the dollar is simply

$$r_{t+1} - \tau r_{t+1}^{\$} \approx i_t - \tau i_t^{\$} - \Delta s_{t+1}, \quad (17)$$

where Δs_{t+1} is the rate of depreciation and i is the vector of nominal returns. Equation (16) can thus be rewritten as

$$W_{t+1} = W_t [x_t' (i_t - \tau i_t^{\$} - \Delta s_{t+1}) + 1 + i_t^{\$} - \Pi_{t+1}^{\$}]. \quad (18)$$

where $\Pi_{t+1}^{\$}$ is the rate of inflation during the period for the appropriate basket of goods. It is assumed that the goods prices are nonstochastic when expressed in the domestic currency. Only the exchange rate is uncertain. The expected value and variance of end-of-period wealth are written as follows:

$$\begin{aligned} E(W_{t+1}) &= W_t [x_t' (i_t - \tau i_t^{\$} - E\Delta s_{t+1}) + 1 + i_t^{\$} \\ &\quad - \alpha' (\Pi_{t+1}^{\$} - E\Delta s_{t+1}) - (1 - \alpha' \tau) \Pi_{t+1}^{\$}], \\ V(W_{t+1}) &= W_t^2 [V(-x_t' \Delta s_{t+1} + \alpha' \Delta s_{t+1})] \\ &= W_t^2 [(-x_t' + \alpha') \Omega (-x_t + \alpha)], \end{aligned} \quad (19)$$

where α is the vector of consumption shares, $(1 - \alpha)$ is the consumption share allocated to U.S. goods, and Ω is the conditional covariance matrix of relative rates of currency depreciation (defined as $E[\Delta s_{t+1} - E\Delta s_{t+1}] [\Delta s_{t+1} - E\Delta s_{t+1}]'$).

It is then assumed that investors maximize a function of the expected value and variance:

$$\text{Max } F[E(W_{t+1}), V(W_{t+1})] . \quad (20)$$

Differentiating with respect to x_t and setting the derivative equal to zero,

$$i_t - \tau_t^s - E(\Delta s_{t+1}) = \rho \Omega (x_t - \alpha) . \quad (21)$$

Equation (21) represents the basic model investigated empirically by Frankel. It expresses the risk premium as a function of the optimal portfolio choices of individual investors. The estimation of equation (21) generally proceeds under the assumption of rational expectations. It can be shown to be a restricted version of the more general inverted portfolio-balance model. If, for example, we write the general model as

$$i_t - \tau_t^s - E(\Delta s_{t+1}) = \beta_0 + \beta_1 x_t , \quad (22)$$

then equation (22) encompasses equation (21). More specifically, equation (21) requires the matrix of coefficients in the N equations to be proportional to the covariance matrix of forecast errors, instead of allowing them to be estimated freely, as in equation (22).

Empirical Evidence. Frankel (1982b) was the first to estimate the mean-variance model. He used carefully defined measures of asset supplies and assumed rational expectations. The innovation introduced by his paper is that the term Ω is simply the variance-covariance matrix of the error term, and the system of equations is estimated subject to this constraint. The estimated results reject the joint null hypothesis of rational expectations and perfect asset substitutability. Nevertheless, the study is unable to establish a link between asset supplies and the risk premium.

The paper by Frankel and Engel (1984) uses the same data and country coverage as Frankel (1982b) but differs from the earlier study by relaxing the assumption that inflation rates are predetermined variables. The first half of the Frankel and Engel paper reports estimates of a standard inverted portfolio-balance model and, like most other studies, rejects the joint hypothesis. Frankel and Engel use this result to justify the estimation of a model containing the mean-variance constraints, and the second half of their paper estimates this constrained model. The likelihood-ratio test rejects the constraints imposed by the mean-variance hypothesis. Like most of the previous studies, this one fails to link asset supplies with the risk premium.

Lewis (1988b) extends the work of Frankel (1982b) and Frankel and Engel (1984) by explicitly introducing inflation risk and asset-market disturbances. To allow for these additional sources of uncertainty, an alternative estimation method is derived to identify the covariance constraints. The results are similar to those of earlier studies despite the innovations in the method of estimation.

Engel and Rodrigues (1989) attempt to explain why the models described and tested in Frankel (1982b) and Frankel and Engel (1984) are not supported by the data. They do so by relaxing some of the previous studies' stringent assumptions, in particular by examining different ways of modeling the variance. Like the previous authors, they test a six-country model using *ex post* rates of return, first by relating the variances to macroeconomic data (the U.S. money supply and oil prices), and then by modeling the variances as autoregressive conditional heteroscedastic (ARCH) processes. In addition, they generalize the "Frankel-type" model, as Lewis does, by introducing the possibility that the asset-demand equations do not hold exactly. Their paper extends the frontiers of estimation to consider some of the more important explanations offered for the failure of previous mean-variance models; nevertheless, their own model is not supported by the data. As in the earlier studies, the authors find no evidence to suggest that intervention can be effective.

Each of the papers discussed above estimates a system of demand equations for five or six currencies and assumes that expectations are rational. Another study using the mean-variance approach, but for a single bilateral exchange rate and without invoking rational expectations, is provided by Dominguez and Frankel (1992). They represent expected future exchange rates by survey data and use a two-equation, simultaneous system to find statistical evidence of portfolio-balance, as well as signaling, effects.³² Their study will be discussed at length in the next chapter, which deals with the signaling channel and international cooperation.

Small Macroeconomic Models

Description of the Models. Studies by Obstfeld (1983), Kearney and MacDonald (1986), and Blundell-Wignall and Masson (1985) not only

³² Black (1992) also measures the risk premium with survey data rather than with *ex post* exchange-rate changes. In addition, he uses the concept of net foreign assets rather than the concept of outside assets, and he finds that central-bank intervention may have a short-run effect on exchange rates.

estimate portfolio-balance equations, they also simulate different forms of intervention using small macroeconomic models. The efficacy of the different types of intervention is judged by the extent to which they influence the exchange rate. Obstfeld and Blundell-Wignall and Masson report results consistent with those in much of the rest of the literature—that intervention may be statistically, but not quantitatively, significant. Kearney and MacDonald, however, find strong evidence that intervention is both statistically and quantitatively significant.

Obstfeld's study of Germany investigates two issues: (1) whether the German central bank (the Bundesbank) engaged in sterilized intervention and (2) whether sterilized intervention was effective in the German case. He addresses the first question by estimating a domestic-credit reaction function, which tests whether domestic-credit creation by the Bundesbank responded positively to cyclical shortfalls in output but negatively to increases in foreign-exchange reserves. To assess the efficacy of sterilized intervention, Obstfeld estimates and simulates a small macroeconomic model of the German economy that contains structural equations for money demand, money supply, the domestic demand for bonds denominated in deutsche marks, and the foreign demand for those bonds.

Blundell-Wignall and Masson follow a slightly different strategy. They extend the Dornbusch overshooting model by including a role for asset supplies through a risk-premium variable and an intervention rule whereby the authorities attempt to resist movements in the real exchange rate. They estimate a small macroeconomic model for Germany, using full-information methods under the assumption of rational expectations.

Empirical Evidence. The econometric evidence reported in Obstfeld supports the hypothesis that the Bundesbank used domestic-credit policy to attain domestic-policy objectives while engaging in sterilized intervention. In estimating his small macroeconomic model, he finds that the coefficient on interest rates is significant in the equation for the foreign demand for bonds, but that this is the only equation in which the risk-premium variable has a significant effect. Furthermore, the explanatory power of the demand equation for bonds is almost entirely due to the wealth term and lagged dependent variable. These conclusions offer only slight support for the portfolio-balance model.

To evaluate the effectiveness of sterilized intervention, Obstfeld undertakes three simulations. The first is a benchmark simulation, in which the model assumes perfect foresight for the exchange rate, so that

the forward rate in one period is equal to the spot rate in the next.³³ The second simulation considers the effect of a temporary decline of 10 percent in the monetary base. The third considers the effect of a sterilized sale of deutsche marks. The general conclusion implied by these simulations is that the Bundesbank's ability to influence the exchange rate through sterilized intervention is very limited.

Kearney and MacDonald base their study of the United Kingdom on Obstfeld's study of Germany. They estimate the Bank of England's reaction function and show that the bank has tended to lean against the wind when intervening in the foreign-exchange market. They also confirm that the Bank of England has usually sterilized its intervention.

To assess the efficacy of sterilized intervention, Kearney and MacDonald estimate and simulate a small macroeconomic model of the U.K. economy, with equations for money demand and supply and for the domestic and foreign demand for bonds denominated in domestic currency. The estimated coefficients of the demands for U.K. bonds by U.K. and U.S. residents are correctly signed, but few are statistically significant. To evaluate the effectiveness of sterilized intervention, the authors conduct two policy simulations. They first consider a nonsterilized intervention, in which the authorities sell foreign-exchange reserves and allow the monetary base to contract by 10 percent. They next consider a sterilized intervention, in which the same sale of foreign exchange is offset by a purchase of domestic assets. Both policies are unanticipated and transitory. The effect of the nonsterilized intervention is an immediate appreciation of the pound by almost 8 percent. The effect of sterilized intervention is smaller but is also substantial.

Blundell-Wignall and Masson (1985) consider the effect of sterilized intervention in a model in which price stickiness causes monetary policy to produce deviations of the real exchange rate from its long-run equilibrium value. The risk-premium parameter is estimated to be small but statistically significant. It suggests that a 1 percent change in the cumulated current account (a proxy for a change in the stock of outside assets) will lead to a very small change (0.05 percent) in the spot exchange rate if other factors remain unaltered. To examine the full effects of intervention, the model is simulated with and without inter-

³³ As Tryon (1983) has pointed out, using the forward premium as the measure of expected appreciation implies the absence of an exchange-rate risk premium. This implies, in turn, that assets are perfect substitutes, which means that intervention cannot operate through the portfolio-balance channel. Obstfeld recognizes this problem and appeals to political risk, instead, to explain portfolio diversification.

vention and assumes that expectations are rational and that future values of the exogenous variables are known with certainty. The authors find that the effect of intervention is small, especially over the first few periods. They also find that intervention complicates the dynamics of the model, introducing cycles into the outcomes.

4 THE SIGNALING CHANNEL

The bulk of the evidence reviewed in Chapter 3 indicates that sterilized intervention has no direct effect on exchange rates through the portfolio-balance channel. It may still have an important indirect effect, however, that may at least temporarily alter the exchange rate. Sterilized intervention may affect exchange rates through a signaling, or expectations, channel, whether or not domestic and foreign bonds are imperfect substitutes.³⁴

Sterilized intervention may operate through the signaling channel if it causes private agents to alter their exchange-rate expectations. For example, agents may be induced to change their views about the likely future actions of the monetary or fiscal authorities or of other private agents, or, even if agents do not change their views about likely future actions, they may change their views about the likely implications of those actions for the future exchange rate.

More explicitly, sterilized intervention can affect the spot exchange rate through a signaling channel if a change in relative bond supplies conveys any information that causes agents to change their estimates of the expected future exchange rate. This is true even if domestic and foreign bonds are perfect substitutes. A change in the expected future exchange rate alters the expected return on foreign bonds. When domestic and foreign bonds are perfect substitutes, however, both types of bonds will be held simultaneously only if the domestic interest rate equals the expected return on foreign bonds. If sterilized intervention leaves interest rates unchanged, the spot exchange rate must change by the same amount as the expected future exchange rate to reestablish equality between the domestic interest rate and the expected return on foreign bonds.

Two questions have been raised about the use of the signaling channel. The first asks why the monetary authorities would convey information by intervening unannounced in the foreign-exchange market. Clearly, intervention will affect expectations only if agents know about it. Although studies of the signaling channel do not address this question directly, some researchers recognize that it must be taken seriously.

³⁴ Mussa (1981) contains one of the first discussions of the signaling role of intervention.

The second question asks why the monetary authorities would use intervention instead of, or in addition to, simple announcements to affect exchange-rate expectations. Mussa (1981), answers this question by arguing that intervention provides credible information about future policy intentions, because the monetary authorities stake their capital in support of those policies. If the monetary authorities are concerned about their profits and losses, they have an incentive to adopt a monetary policy consistent with the balance-sheet effects of their intervention. If they sell foreign bonds, for example, and the domestic currency depreciates because monetary policy is not changed, their balance sheet will be adversely affected.

Unlike studies examining the portfolio-balance channel, no common model exists among studies examining the signaling channel. Dominguez and Frankel (1992) assume that sterilized intervention can have effects through both the portfolio-balance and signaling channels, whereas Humpage (1989) and Dominguez (1990) emphasize the signaling channel. Most of the studies considered in this survey find that sterilized intervention has had some statistically significant impact through the signaling channel. Except for Dominguez and Frankel, however, the researchers do not assess the quantitative significance of the signaling effect.

The latter part of this chapter will discuss studies focusing on the differential effects of coordinated and noncoordinated intervention. Loopesko (1984) and Dominguez (1990) find that there is a statistically significant difference, but Humpage (1989) and Humpage and Osterberg (1992) do not.

*Studies of the Signaling Hypothesis*³⁵

Although tests of the signaling channel vary across studies, there appear to be two general approaches. The first group of studies examines the impact of intervention on exchange-rate expectations in the context of a portfolio-balance model. The second group assumes that an anticipated change in future monetary policy will alter exchange-rate expectations and asks whether or not intervention actually signals a change in monetary policy. Various techniques are used to model this question.

The Impact of Intervention on Exchange-Rate Expectations. In one of the early studies of the signaling channel, Humpage (1989) assumes that intervention works only through that channel. He examines the

³⁵ Most of the studies of the signaling channel have used daily intervention data.

relation between day-to-day official intervention and day-to-day exchange-rate movements by regressing the spot exchange rate on the two-day lag of the spot rate, on lagged intervention, and on lagged interest-rate differentials. The lagged spot rate is a proxy for the expected exchange rate, absent any change in actual monetary policy or some signal of a change in future monetary policy. The interest-rate differential is included to capture actual changes in monetary policy. Humpage suggests that the coefficient on the lagged exchange rate should be equal to one and that the coefficient on intervention should be greater than zero for the results to show that intervention works through the signaling channel. He estimates an equation for the dollar-yen and the dollar-deutsche mark rates from August 1984 through October 1987, dividing the sample into five subperiods. The overall results show that intervention is generally not statistically related to future exchange-rate movements.³⁶

Dominguez (1990) examines the signaling channel by adopting an approach that differs slightly from that of Humpage. Rather than use changes in the spot exchange rate, she uses the risk premium as the dependent variable and invokes rational expectations to estimate a portfolio-balance equation. Dominguez argues that the coefficients on intervention will provide information about the portfolio-balance channel as well as the signaling channel, and, recognizing that she cannot separate the two effects, she emphasizes the signaling channel. Dominguez bases her argument on her use of actual intervention as an explanatory variable, rather than cumulated intervention, which is often employed when testing the portfolio-balance channel.

Like Humpage, Dominguez tests the signaling channel by examining the dollar-deutsche mark and dollar-yen exchange rates. She regresses the risk premium on a constant and on the previous day's intervention,³⁷

³⁶ Eijffinger and Grujters (1992) study the effectiveness of Bundesbank and Federal Reserve intervention in the dollar-deutsche mark market using actual daily intervention and intradaily exchange-rate data from February 1985 until September 1988, following closely the Humpage methodology. They conclude that the effectiveness of intervention in the foreign-exchange market is limited and depends on the specific circumstances at the time intervention occurs. In another related study, Humpage and Osterberg (1992), using a generalized autoregressive conditional heteroscedastic (GARCH) model, find results that are similar to those of the original Humpage study.

³⁷ The quality of her intervention data vary between countries. For Germany, she uses actual daily intervention data. For the United States, she constructs an intervention series from Federal Reserve publications. For Japan, she creates a dummy variable obtained from reports in the financial press.

which she splits into coordinated and noncoordinated intervention. She runs the regressions over the entire three-year period from January 1985 to December 1987 and over five subperiods covering separate episodes of intervention. In the first two episodes, the coefficients on both coordinated and noncoordinated intervention are generally statistically significant and of the correct sign. In the remaining three episodes, however, the coefficients are either insignificant or of the wrong sign, with the exception of the short episode immediately following the 1987 stock market crash, when intervention appears to have had a statistically significant effect.

Neither the Dominguez nor the Humpage study can isolate and test the signaling hypothesis precisely. A more rigorous procedure is proposed in Dominguez and Frankel (1992), which tests both the signaling and the portfolio-balance channels without invoking rational expectations. Dominguez and Frankel use survey data on market forecasts of exchange rates to represent the expected future exchange rate. They then estimate both a portfolio-balance equation and an equation for the formation of exchange-rate expectations. This framework is more appropriate for testing the signaling channel, because the expectations equation includes all the variables that may enter the reduced-form equation for the exchange rate—not just intervention, as in Dominguez (1990), or intervention, the lagged exchange rate, and the interest-rate differential, as in Humpage (1989). The data used in Dominguez and Frankel are weekly or biweekly, depending on availability. Another innovation of their 1992 study is the use of actual intervention data for the 1982-88 period.

The portfolio-balance equation, the first in the paper's two-equation system, is an inverted asset-demand equation imposing the mean-variance optimization constraint described in Chapter 3. Changes in asset supplies are represented by intervention, or by intervention as a percentage of total wealth (with wealth defined as the outstanding stock of government debt). In each case, intervention is measured in three different ways: (1) intervention occurring during the day before the survey, (2) intervention accumulated between survey forecasts, and (3) intervention accumulated from the beginning of the sample period.

The second equation models the formation of expectations. The dependent variable is the investor's forecast of the change in the expected future spot rate, as measured by survey data. The regressors include the difference between the lagged and contemporaneous spot rate and the difference between the lagged expectation and contempo-

aneous spot rate. These terms allow the authors to test for extrapolative, static, and adaptive expectations. The equation also includes three dummy variables that capture information about Federal Reserve and Bundesbank exchange-rate policy. These are (1) official exchange-rate policy announcements (excluding interventions), (2) reported interventions, and (3) secret (not reported) interventions.

The authors find that intervention has statistically significant effects through both the portfolio-balance and signaling channels and that the effects can be quantitatively significant, depending upon the particular scenario investigated.

The Dominguez and Frankel paper is unique insofar as it is the only study that finds a portfolio-balance effect while imposing the mean-variance optimization restrictions. It is difficult to say just what contributes to the study's singular finding, because the study differs in several ways from other mean-variance studies. Three of the more obvious differences are that Dominguez and Frankel (1) use survey data for exchange-rate expectations, rather than invoke rational expectations; (2) examine simple bilateral relations between currencies, rather than use several currencies simultaneously; and (3) use data for the 1980s only. This list is not exhaustive. For example, an explanation might also be found in the way the authors impose the mean-variance constraint.

Intervention as a Signal of Future Monetary Policy. Dominguez (1992a) adopts a framework that differs from those discussed above in that it studies the ability of intervention to signal monetary-policy intentions. Dominguez performs two sets of empirical tests, using daily data on official intervention from February 1977 to February 1981.³⁸ First, she regresses intervention on weekly money surprises, defined by comparing the actual money supply with publicly available forecasts. Her results indicate that intervention conveys information about the implications of the expected future money supply. Next, she regresses the risk premium on intervention. She finds that intervention has significant effects in many subperiods and thus tends to influence market expectations.

A number of recent studies have followed the approach used by Dominguez (1992a). Klein and Rosengren (1991a) use daily intervention data (constructed from newspaper reports) and discount-rate changes to ask whether intervention signaled changes in monetary policy between the 1985 Plaza Agreement and the 1987 stock market crash. They find

³⁸ The intervention data are from the Federal Reserve for the United States and from the Bundesbank for Germany.

that intervention did not precede changes in monetary policy.³⁹ They show, however, that intervention had a significant effect on the exchange rate immediately after the Plaza Agreement, although not subsequently. They attribute this subsequent decline to the market's having learned that intervention does not serve as a signal of future monetary policy.

In a second paper, Klein and Rosengren (1991b) investigate whether intervention is used to clarify imprecise monetary-policy announcements. To test this hypothesis, they regress changes in exchange rates on intervention but allow the regression coefficients to vary over time. The results suggest that intervention may have a significant effect on the exchange rate, but that the effect of intervention declines with an increase in the amount of time between the intervention and the last major monetary-policy announcement.

Lewis (1992) continues this line of research by examining the relation between intervention and U.S. monetary-policy variables for the 1985-90 period. Using Granger-causality tests of intervention on monetary-policy variables (and vice versa), she finds a significant relation between intervention and U.S. monetary variables.⁴⁰ When Lewis lags intervention one period to reduce the likelihood that sterilization is not yet complete, intervention continues to explain movements in the Federal funds rate but not in any of the monetary aggregates. In contrast to most other researchers, Lewis also examines whether monetary variables are related to exchange rates in the manner predicted by theoretical models. She finds evidence that monetary variables do affect exchange rates in the direction implied by these models. She hints, but does not explicitly conclude, that intervention may signal monetary policy.

In a similar vein, Kaminsky and Lewis (1992) use data on market observations of U.S. intervention from 1985 to 1990 to test whether market participants view intervention as a signal of future changes in monetary policy. Kaminsky and Lewis estimate a regime-switching model, which allows them to identify changes in monetary policy and to ask whether intervention signals these changes in monetary policy. On average, however, the signals of future monetary policy are opposite in direction to those implied by the interventions. The authors also examine

³⁹ By contrast, Watanabe (1992) reports that changes in Japanese monetary policy are consistently preceded by intervention. He argues that the Bank of Japan adopts a monetary policy that is more consistent with its intervention policy because it assigns a higher weight to the stability of the exchange rate than does the Federal Reserve.

⁴⁰ Lewis uses four measures of monetary policy: M1, the monetary base, nonborrowed reserves, and the Federal funds rates.

the response of dollar-deutsche mark and dollar-yen exchange rates to news of intervention, dividing the sample between episodes of “correct” and “incorrect” signaling identified by their monetary-policy model. They find some evidence that exchange rates and intervention are correlated with the appropriate sign, depending on the information set and the sample period. The novelty of the Kaminsky-Lewis paper is that it attempts to test both the way intervention interacts with future shifts in the money supply and the way intervention affects the exchange rate.

The Effects of International Cooperation

Various studies ask whether coordinated and noncoordinated intervention affect exchange rates differently. Since the Plaza Agreement, the amount of central-bank intervention by the G-7 countries has increased and the countries have frequently coordinated their intervention operations. It has been suggested that coordinated intervention is more effective than noncoordinated intervention because the central banks are seen as supporting each other’s operations.

To ascertain whether coordinated intervention is, in fact, more effective, the literature compares the coefficients obtained by econometric methods that distinguish between the two regimes. The results are mixed. About half of the studies find that coordinated intervention is more effective than noncoordinated intervention; the other half find no special significance to the difference between regimes. Once again, the authors do not, for the most part, explain why the results of their respective studies differ from one another.

Loopesko (1984), in addition to testing the portfolio-balance model for the United States and Germany, also tests the proposition that coordinated intervention has a different effect than noncoordinated intervention. She defines coordinated intervention as intervention by two or more countries occurring on the same day and in the same direction, and noncoordinated intervention as intervention undertaken by one country alone or taken in opposite directions by two or more countries. Loopesko’s results depend on her measurement of intervention. When using a broad measure, Loopesko finds that coordinated and noncoordinated intervention have the same effect. When using a narrower measure, she finds that coordinated intervention has a significantly greater effect than noncoordinated intervention.

Humpage (1989) and Humpage and Osterberg (1992) also distinguish between episodes of coordinated and noncoordinated intervention and find the distinction to be unimportant. Dominguez (1990), by contrast, shows that, for various subperiods, coordinated and noncoordinated

intervention yield different effects, a finding more consistent with that of Loopesko. Moreover, the differentiated effects of coordinated intervention tend more often to be significant and of the correct sign. This result is echoed by Eijffinger and Gruijters (1992).

5 CENTRAL-BANK POLICY REACTION FUNCTIONS

The preceding two chapters reviewed studies asking whether sterilized intervention influences the exchange rate. This chapter considers research asking what prompts the monetary authorities to intervene in the first place and whether intervention is fully sterilized.⁴¹

These questions are as important as those about the effectiveness of intervention. Answering the first helps us understand the monetary authorities' motives for intervening. Answering the second tells us something about the extent to which intervention has a direct effect on domestic money supply. A change in the money supply should have a direct effect on the exchange rate. Sterilized intervention, however, involves a pure swap of foreign for domestic assets and thus leaves the money supply unaltered. It is therefore useful to ascertain whether intervention is indeed sterilized.

We begin with studies that use policy reaction functions to examine the motives for intervention. Monetary authorities give various reasons for intervening in the foreign-exchange market: to calm disorderly markets, influence exchange-rate movements, target exchange rates, or simply to support other central banks' exchange-rate operations. It is difficult to capture all of these reasons empirically, but many studies attempt to assess the importance of several competing explanations. In general, researchers find that intervention is undertaken to smooth nominal exchange rates and occasionally to target levels of exchange rates.

With regard to sterilization, we review studies that ask whether monetary authorities pursue an identifiable sterilization policy. Most G-7 countries claim that they completely sterilize their intervention. Yet Dudler (1988), studying Germany, and Masunaga (1988), studying Japan, note that intervention by these countries has not been completely sterilized in certain instances, notably during periods of pressure. Most other researchers find that, with the exception of Germany, intervention by the G-7 countries has been fully sterilized.

A problem common to most studies of sterilization policy is the choice of data. Changes in foreign reserves were used instead of actual intervention data, which were not available to the authors. As noted above,

⁴¹ For a comprehensive survey of empirical studies on the objectives of intervention, see Almekinders and Eijffinger (1991).

changes in reserves may be a poor proxy for intervention, so the results may well be flawed.

Motives for Intervention

Most studies ascribe an *ad hoc* reaction function to the monetary authorities. It is usually a single equation and has as the left-hand-side variable either actual intervention or changes in reserves as a proxy for intervention. The right-hand-side variables vary between studies, but most studies include changes in the exchange rate and deviations of the rate from a target level. A typical estimated equation takes the form

$$I_t = \alpha_0 + \alpha_1(s - s^*) + \alpha_2\Delta s + \beta X + u_t, \quad (23)$$

where I is intervention (with $I > 0$ for a purchase of dollars), s is the logarithm of the exchange rate (foreign currency per dollar), s^* is the logarithm of the target exchange rate, X is a vector of other economic variables, such as the trade balance or lagged intervention, and Δ is the first-difference operator. The X vector indicates that other macroeconomic variables may influence intervention decisions. Most researchers report not only ordinary least-squares estimates of this equation but also an instrumental-variables estimate that enables them to allow for possible simultaneity between exchange rates and intervention.

In equation (23), α_1 attempts to capture the possibility that the authorities target the level of the exchange rate, while α_2 attempts to capture the possibility that they lean against the wind. The expected sign of the coefficient α_1 is negative, because it is hypothesized that the monetary authorities will sell dollars if the actual exchange rate exceeds the target rate. The expected sign of the coefficient α_2 is negative, because, to lean against the wind, the monetary authorities must sell foreign currency (dollars) when their currency is depreciating.⁴²

Many of the studies focus on Germany and Japan. Gaiotti, Giucca, and Micossi (1989) consider both German and Japanese policies from 1973 through 1987. They find that both countries have tended to use intervention to lean against the wind and that Japan has done so to a greater extent than Germany. Furthermore, they find that both Germany and Japan have reacted asymmetrically to appreciations and depreciations. The Bank of Japan has exhibited a comparatively stronger

⁴² If the coefficient on α_2 is positive, the monetary authorities lean with the wind, which amplifies exchange-rate volatility. Such a reaction is expected to be exceptional, rather than the rule.

resistance to appreciations of the yen; the Bundesbank has demonstrated a comparatively stronger resistance to depreciations of the deutsche mark. The authors also find evidence that the central banks of both countries tend to react to deviations of the exchange rate from its implicit target levels.

Takagi (1991) studies the Bank of Japan's reasons for intervening over the period from 1973 to 1989 by estimating a simple reaction function that includes only lagged changes in reserves and changes in the exchange rate. Like Gaiotti, Giucca, and Micossi, he finds that the Bank of Japan tends to intervene to prevent large movements in the exchange rate and that its reactions are asymmetric. His study indicates, however, that, at least for the period after 1985, the Bank of Japan tended to intervene more decisively when the yen was depreciating than when it was appreciating.⁴³

There have been several other studies of central-bank reaction functions. Eijffinger and Gruijters (1991) examine the short-term objectives of the Federal Reserve and Bundesbank from February 1985 through September 1988 using actual daily intervention data. They conclude that both central banks have typically leaned against the wind to smooth exchange-rate fluctuations. Almekinders and Eijffinger (1992) extend the Eijffinger-Gruijters study to cover the period from October 1988 to October 1990. They add the conditional variance in dollar-deutsche mark returns, derived from a GARCH model, as a proxy for anticipated exchange-market uncertainty. They find that an increase in uncertainty led both the Bundesbank and the Federal Reserve to increase the volume of intervention.

Neumann (1984), investigates other possible motives for German intervention and concludes that the Bundesbank used intervention to try to reduce movements of the real exchange rate. Blundell-Wignall and Masson (1985) follow Neumann, estimating a reaction function for the Bundesbank that uses movements in the real exchange rate and a target level of reserves as explanatory variables. They find this intervention function introduces cycles into their model of the German economy. Kearney and MacDonald (1986), studying the U.K. intervention, find that the Bank of England seeks to smooth fluctuations in the exchange rate rather than to target a particular exchange rate. In studying Swiss intervention policy, Gartner (1987) reports that the Swiss National Bank

⁴³ Watanabe (1992) and Glick and Hutchison (1992) also find evidence of an asymmetric pattern to Japanese intervention. Hutchison (1984) finds that, during the 1970s, the Bank of Japan's intervention policy was characterized by leaning against the wind.

leans against the wind by purchasing foreign currency when the Swiss franc is appreciating and is above the bank's exchange-rate target, and by selling foreign currency when the reverse is true. In a follow-up paper, Gartner (1991) finds the same selective leaning against the wind for Japan and Germany, but pure leaning against the wind for Canada, and inconclusive results for the United Kingdom.

As one can see from this summary of the various case studies, the motives for intervention tend to vary across countries. Nevertheless, the most persistent explanation is that the monetary authorities intervene to smooth fluctuations in the exchange rate.

The Degree of Sterilization

To investigate the extent of sterilization, most studies examine a domestic-credit policy reaction function. Typically, domestic credit, the left-hand-side variable, is assumed to respond to increases in reserves, the current output gap, and the inflation rate. The reaction function takes the form

$$\Delta DC = \alpha_1 \Delta NFA + \alpha_2 GAP + \alpha_3 \Pi + u \quad , \quad (24)$$

where DC is the level of domestic credit, NFA is the level of net foreign reserves, GAP is the output gap, and Π is the inflation rate. The extent of sterilization is indicated by the coefficient α_1 , often called the "sterilization coefficient." It should be negative with sterilization, and, if it is not statistically significantly different from -1 , intervention is said to be fully sterilized. (If α_1 lies between -1 and 0 , intervention is said to be partly sterilized.)

An alternative formulation of this equation uses changes in the monetary base as the left-hand-side variable. To test the degree of sterilization using this formulation, researchers examine, as before, the coefficient on the changes in net foreign assets. The hypothesis of complete sterilization, however, is consistent with a zero coefficient.

The empirical results vary across countries and studies. Several studies involving Germany find that the Bundesbank has sterilized its foreign-exchange intervention and used domestic-credit policy to attain domestic objectives. Obstfeld (1983), for example, estimates an equation similar to equation (2) for the 1975-81 period and finds that the Bundesbank fully sterilized its intervention. Mastropasqua, Micossi, and Rinaldi

(1988) confirm this result for the more recent 1979-86 period.⁴⁴ In contrast, Neumann (1984), Gaiotti, Giucca, and Micossi (1989), von Hagen (1989), and Neumann and von Hagen (1992) find that the Bundesbank did not fully sterilize its intervention.⁴⁵ The period studied by Neumann overlaps the one reviewed by Obstfeld, whereas Gaiotti, Giucca, and Micossi include data from 1973 to 1987. Gaiotti, Giucca, and Micossi find evidence that the degree of German sterilization fluctuated over their sample period. Von Hagen distinguishes between short-run and long-run sterilization and finds that the Bundesbank has fully sterilized intervention in the short run, but not in the long run. Neumann and von Hagen likewise report that the Bundesbank does not permanently sterilize its intervention, and they argue that it fails to do so when the deutsche mark is strong against both the dollar and EMS currencies.

For Japan, the studies by Takagi and by Gaiotti, Giucca, and Micossi find that the Bank of Japan completely sterilized its reserve movements over the entire sample periods examined. Takagi, however, finds some evidence suggesting that the Bank of Japan became more accommodative over time, in that it allowed an increasing fraction of the change in the foreign-asset component of the monetary base to affect the overall monetary base. These results are echoed in the recent paper by Click and Hutchinson (1992).

Kearney and MacDonald find that the Bank of England tended to sterilize its intervention completely over the 1973-81 period. By contrast, Mastropasqua, Micossi, and Rinaldi report that several of the smaller European countries—Belgium, France, and Italy—have not fully sterilized their interventions. The authors note, however, that this result may be due to difficulties in estimating the equation because of significant institutional changes in these countries during the sample period.

⁴⁴ Their estimates of the coefficient on net foreign assets, using ordinary least squares, is around -0.8 , but it is not statistically significantly different from -1.0 . Their two-stage least-squares estimate is -0.6 , which is statistically, although marginally, different from -1.0 .

⁴⁵ Neumann estimates a reaction function imposing the restriction $\alpha_1 = -1.0$ and finds that it increases the sum of squared errors of his nonlinear reaction function.

6 THE PROFITABILITY OF INTERVENTION⁴⁶

The Conceptual Issue

The use of profitability to measure the success of intervention can be traced to Friedman (1953). Although he favors freely floating exchange rates and is opposed to official intervention, Friedman suggests that, if governments are going to intervene, they should measure the success of their intervention by its profitability, as a private speculator would. Thus, a central bank is “successful” in its intervention if it stabilizes the foreign-exchange market and makes a profit; it is unsuccessful if it suffers a loss. Friedman’s notion is based on the principle that intervention should promote economic efficiency, rather than slow or smooth exchange-rate fluctuations.

Since Friedman first advanced his argument, many researchers have used profitability to measure the success of intervention. Profitability may well be a meaningful indicator of the fiduciary impact of intervention. It may not be a meaningful indicator of the success of intervention, however, because it says nothing about the extent to which intervention influences exchange-rate movements.

More specifically, the profitability argument raises two issues: whether intervention aimed at stabilizing the exchange rate is always profitable and whether profitable intervention is always stabilizing. Some researchers have observed that, if the monetary authorities are successful in pegging the exchange rate, intervention should yield zero profits (Jacobson, 1983).⁴⁷ Alternatively, if the monetary authorities buy foreign currency when its price is low and sell it when its price is high, their intervention will be profitable even though it may have no significant impact on the exchange rate (Leahy, 1989). These arguments suggest that profitability may be a questionable criterion for evaluating the success of intervention. Nevertheless, there has been a limited research effort devoted to determining the profitability of central-bank intervention.

⁴⁶ This chapter has benefited from discussion with, and work done by, Michael Leahy.

⁴⁷ This proposition and those immediately below abstract from the effects of interest-rate differentials on the earnings of the central bank.

There are substantial practical problems in trying to calculate the profits from intervening in the foreign-exchange market, and most of the papers reviewed in this chapter address one or more of them. Each paper adopts a different method for choosing the period in which to make its profit calculations and for selecting the interest rates by which to measure interest income. Although dramatically different results arise from altering various assumptions, most of the studies find that central banks usually make profits from their interventions. Only one study reports persistent losses.

Measuring the Profitability of Intervention

The method of calculating profits from central-bank intervention can be quite complicated, and several issues arise in constructing a measure. Equation (25) presents a simplified formula containing only two elements, the profits and losses from foreign-exchange trading and the net interest income earned on reserves obtained through that trading:⁴⁸

$$\pi_t = \sum_{i=1}^t [n_i (e_t - e_i) + e_i (r_i^* - r_i) \sum_{i=1}^i n_i] , \quad (25)$$

where π is profits, n_i is the purchase (sale) of dollars by the foreign (e.g., German) monetary authorities, e_t is the end-of-period exchange rate in deutsche marks per dollar, e_i is the period i exchange rate, and r^* and r are the U.S. and German interest rates. The first part of equation (25) says that profits equal the difference between the value of the intervention (dollar purchase) measured at the end-of-period exchange rate and its value at the exchange rate prevailing when the intervention was undertaken. The second part of the equation measures the additional interest income earned from holding dollars rather than deutsche marks. Interest-rate differentials have sometimes been excluded from profit calculations, an error that can substantially affect the results when the differentials are large.

In Table 2, we use equation (25) to illustrate the method of calculating the profits of the monetary authorities and the sensitivity of the results to the exchange rates and time period used in the calculation.⁴⁹ To simplify matters, we abstract from interest-income effects and

⁴⁸ Leahy (1989) describes a more general method of calculating total profits. Following Leahy, we assume that the value of the initial portfolio is zero.

⁴⁹ This example draws heavily on Leahy (1989) and on Mayer and Taguchi (1983).

assume that the German monetary authorities intervene to smooth exchange-rate fluctuations. Initially, on day 1, the exchange rate is DM 2.0 per dollar. As the dollar depreciates to DM 1.5 per dollar, the German monetary authorities are assumed to intervene in the market, purchasing \$10 million dollars on day 2. If the profit calculation is done on day 3, when the exchange rate depreciates further to DM 1.0 per dollar, it will show that the German monetary authorities have suffered a loss of DM 5 million, assuming they purchased dollars at the DM 1.5 per dollar exchange rate. Suppose, instead, we begin calculating profits on day 3. As the dollar appreciates to DM 2.0 per dollar between days 3 and 5, the German monetary authorities sell \$10 million dollars at DM 1.5 per dollar. If the profit calculation is done on day 5 and covers only the period from day 3 to day 5, it will again show that the German monetary authorities have suffered a loss of DM 5 million. But, if the calculation covers the whole period, from day 1 to day 5, there will be no recorded profit or loss. Therefore, the sum of the profits calculated in the two subperiods does not yield the profitability over the whole period. Because, by day 5, the mark value of the dollar moved back up from its low level on day 3, the day-3 loss associated with the intervention in the first subperiod has been reversed.

The Evidence of Profitability

Prior to 1982, very little empirical work was done on the profitability of intervention. One of the first, and probably best known, papers on profitability in the post-Bretton Woods period is by Taylor (1982). He examines nine major industrial countries—Canada, France, Germany, Italy, Japan, Spain, Switzerland, the United Kingdom, and the United States—using monthly reserve data from the beginning of 1973 to the end of 1979. He defines profits as the sum of dollars purchased *less* the sum of the dollar value of domestic currency sold, and he excludes valuation changes in the assets initially held as well as net interest income. In general, the results do not compliment the monetary

TABLE 2
CALCULATING THE PROFITABILITY OF INTERVENTION

Day	Exchange Rate in DM/\$	Intervention	Profit (+) in DM
1	2.0	-	-
2	1.5	Buy \$10 million	-
3	1.0	-	-\$5 million
4	1.5	Sell \$10 million	-
5	2.0	-	0

authorities' role in the foreign-exchange market. His estimates show that the central banks together lost between \$11 and \$12 billion over the entire period. The profits and losses of individual countries varied substantially, depending on the beginning and ending dates.

Jacobson (1983) overturns Taylor's results for the United States. He calculates profits for the United States using a different formula and daily data from 1973 through 1981. He first calculates profits as the dollar value of foreign currency purchased since the start of the initial period, valuing it at the end-of-period exchange rates *less* the actual dollar cost. Net profits for the entire period are found to be \$289 million, a result that contradicts Taylor's. For the 1973-79 subperiod, however, Jacobson reports a loss of \$504 million. That loss is a consequence of the revaluation of large net dollar purchases at the dollar's historic low. The differences between Taylor's and Jacobson's results illustrate the sensitivity of profit calculations to the choice of period. Jacobson also calculates profits for periods in which net intervention is close to zero, including in his calculations approximations for net interest earnings. Profits are shown to be positive for all but one subperiod.⁵⁰ The inclusion of net interest earnings raises measured profits significantly.

Leahy (1989) also uses daily data to evaluate the profitability of U.S. intervention but computes net interest earnings using a more general formula than Jacobson's. In general, Leahy's calculations show that the U.S. monetary authorities have earned profits since 1973. His results also show that the calculations are extremely sensitive to changes in sample periods and end-of-period exchange rates. For example, U.S. dollar-deutsche mark intervention from September to December 1985 yielded profits of \$161 million. Extending the period to the end of the next year, during which no intervention occurred, yields much larger profits of \$716 million. The increase occurred because the dollar continued to depreciate in 1986—by more than the depreciation implicit in the dollar-deutsche mark interest-rate differential—thereby raising the dollar value of the long position in marks that the U.S. authorities had accumulated by the end of 1985.

Murray, Zelmer, and Williamson (1989) give empirical evidence of the profitability of Canadian intervention from 1975 to 1988, using many of Leahy's refinements. Their results suggest that Canadian intervention

⁵⁰ Corrado and Taylor (1986) show theoretically that, when net intervention is zero and the monetary authorities lean against the wind, the monetary authorities will always report a profit. They argue that studies evaluating profits when cumulated intervention sums to zero will obtain biased results.

has been very profitable over the post-Bretton Woods period as a whole, although substantial trading losses were realized through most of the 1980s.

Mayer and Taguchi (1983) attempt to circumvent some of the problems inherent in the profit criterion by proposing a number of alternative criteria to evaluate intervention. All of their alternatives involve the calculation of an equilibrium exchange rate for use as the reference rate.⁵¹ Using monthly data, they find that German, Japanese, and British intervention was primarily stabilizing from January 1974 to June 1982.

⁵¹ This methodology has not been adopted by other researchers, probably because of the difficulty associated with calculating the equilibrium exchange rate.

7 DESCRIPTIVE STUDIES OF INTERVENTION

The studies considered in this chapter describe particular episodes of intervention rather than pose questions about effectiveness or motivation. They are included in this survey for the reader who wishes to learn more about intervention policy and who may be frustrated by the inconclusiveness of the statistical evidence regarding effectiveness.

Greene wrote three studies for the G-7 Working Group on the objectives and effects of several episodes of U.S. intervention during the period of floating rates before 1982. She reviews these interventions from the perspective of the U.S. monetary authorities at both the time they occurred, as well as later, when the G-7 Working Group was convened. In Greene (1983a), she covers the first major episode of intervention in late 1974 and early 1975. This included the first instance of concerted intervention, in February 1975, when an attempt was made to break a pattern of exchange-rate changes in which the dollar was declining day by day. According to Greene, although the intervention appears to have achieved the U.S. goal, the overall downward trend of the dollar was reversed only after the market became convinced that U.S. economic performance was improving relative to that of other countries.

In Greene (1983b), she examines several episodes of U.S. intervention between September 1977 and December 1979. She concludes that the evolving U.S. efforts to provide more effective and forceful support for the dollar during those two years helped at first to demonstrate to the market and the world that the U.S. government was concerned about, and willing to address, the large and rapid decline in the U.S. market. When the intervention was not followed by consistent and effective measures to strengthen the dollar, however, the short-term positive impact faded.

In Greene (1983c), she covers the year between October 1980 and September 1981, focusing on two subperiods, October 1980 to February 1981, and April 1981 to mid-August 1981. During each subperiod, the dollar appreciated by about 20 percent against the deutsche mark. During the first subperiod, the U.S. authorities sought to take advantage of the move by acquiring foreign currencies with which to repay outstanding foreign-currency commitments (but used techniques not usually applied when intervening to affect market conditions, so as to avoid slowing the appreciation of the dollar). During the second run-up

of the dollar, there was no U.S. intervention, and Greene asks whether the exchange markets were less orderly during that subperiod than during the first. An analysis of exchange rates suggests the evidence is ambiguous.

Pauls (1990) describes the U.S. exchange-rate policy from December 1958 to early 1990. She includes descriptions of the major episodes and the U.S. responses to them, including several instances of large-scale intervention.

Dominguez and Frankel (1993) give a general overview of U.S. intervention policy.⁵² They describe the radical changes that have occurred in that policy since the collapse of the Bretton Woods System. They discuss the intervention episodes of the early 1970s, the noninterventionist policy of the first Reagan administration, and experience with managing the dollar after the 1985 Plaza Agreement.

In a more general study of exchange-rate cooperation, Marston (1988) compares and contrasts two episodes of intervention, the U.S. dollar-defense package of 1978 and G-5 intervention after the Plaza Agreement. He concludes that sterilized intervention tends to have minimal effects on the exchange rate, although announcements of intervention may lead to an occasional rally in the foreign-exchange market, especially when the market believes that the intervention is signaling a broader change in monetary policy.

Obstfeld (1990) examines U.S. intervention policies and general macroeconomic policies in order to explain movements of the dollar during the 1980s. He concludes that events in the foreign-exchange market from 1985 to 1988 do not support the idea that sterilized intervention has been an important determinant of exchange rates. Some of the anecdotal evidence leads Obstfeld to suggest that intervention is a useful device for signaling official views to foreign-exchange markets, but that these signals are effective only when backed up by actual adjustments in other macroeconomic policies.⁵³

Yoichi Funabashi (1988) gives a behind-the-scenes account of the period from the Plaza Agreement through the Louvre Accord. He

⁵² As noted earlier, Dominguez and Frankel (1993) not only put U.S. intervention policy in perspective, but also analyze the intervention data in an attempt to evaluate the effectiveness of intervention.

⁵³ Bordo and Schwartz (1991) review the conduct and scale of intervention by the monetary authorities in the United States, Japan, and Germany since the Plaza Agreement. Kenen (1988) explores the rationale for managing exchange rates and reviews intervention policy by the United States.

examines the policy coordination involved in the G-5 Plaza strategy, focusing primarily on the United States, Germany, and Japan. Using interviews with, and reports by, the leading participants, he explains the events in the context of domestic and international politics, and he discusses the implications of the Plaza Agreement for international economic-policy coordination.

8 RECENT LITERATURE

In the last two years, there has been a surge of papers about intervention. With the recent release of actual U.S. intervention data, this work is likely to continue for some time. This chapter reviews recent papers not discussed earlier in this survey.

Some recent studies examine the post-Plaza period to determine the possibility of predicting central-bank intervention in the foreign-exchange market. These studies are closely related to the papers discussed in Chapter 5 and model the intervention behavior of the monetary authorities by focusing on the deviation of the actual exchange rate from its target level. They are thus closely linked to recent work on target zones.⁵⁴ This small but growing body of research indicates that intervention tends to increase as the exchange rate deviates from its target level.

A few recent papers ask whether intervention has affected exchange-rate volatility. They differ from the studies surveyed in Chapters 3 and 4 in that they do not focus on the channel through which intervention affects the exchange rate. Some of them find that intervention reduces exchange-rate volatility and may have contributed to the stabilization of exchange rates in the latter part of the 1980s.

Lewis (1991) develops and implements a target-zone model in which intervention is used to keep exchange rates near their target levels, rather than strictly within the limits of a band. Her framework differs from the one implied by the standard target-zone model in that intervention occurs within the band, rather than at the limits of the band. She employs a multinomial logit model to estimate the probability of intervention by the G-3 central banks. Using daily newspaper reports on intervention during the post-Plaza period, she finds that the probability of intervention increases as exchange rates deviate from their targets, especially during the period in early 1987 immediately following the Louvre Accord.

⁵⁴ The rapidly growing literature on exchange-rate behavior in target zones originated with Krugman (1987) and has been formalized and refined by Froot and Obstfeld (1991), Flood and Garber (1991), and Krugman (1991). Much of the limited empirical work in this area has focused on the experience of the EMS; see, for example, Flood, Rose, and Mathieson (1991), Edison and Kaminsky (1990), and Dominguez and Kenen (1992). A comprehensive survey of the literature is contained in Svensson (1992).

In a closely related paper, Klein and Lewis (1991) allow the market to learn about the authorities' intervention policies. They study the period between the Louvre Accord and the October 1987 stock market crash, a period they believe to have been characterized by close cooperation and tight, consistent exchange-rate management. Like Lewis (1991), they estimate a logit model to assess the probability of intervention. They update this probability using a learning process, which allows them to capture the evolution of the implicit target zones. The market's perceptions concerning the location of the target zones are found to have shifted significantly during the period in question.

In a related paper, Goodhart and Hesse (1991) use continuous-time data (gathered from Reuter's screens) for the period from April through June 1989. They try to determine the odds that intervention will occur in the next half hour and in longer periods of up to one day and, using the profitability criterion, whether or not intervention is successful.⁵⁵ They find that the mean of the exchange rate in the previous half hour is important in influencing the probability of future intervention. In addition, they find that, immediately following intervention, central banks tend to experience losses, but that, over time, these become profits.

Baillie and Humpage (1992) also estimate a target-zone model for the period after the Louvre Accord. They differ from Lewis and from Klein and Lewis in that they use a number of variables to explain the probability of intervention, including a measure of exchange-rate volatility. Using a GARCH model, the authors jointly estimate an exchange-rate equation and an intervention equation. They find no evidence that intervention influences the conditional variance of the exchange rate. They do find, however, that Germany and the United States have reacted to exchange-rate movements in a manner consistent with an attempt to maintain a target-zone mechanism. Baillie and Osterberg (1991) examine the impact of intervention on the conditional mean and variance of the daily forward-rate forecast error, and they find that U.S. purchases of foreign currency influence the conditional mean.

Examining the Norwegian experience, Mundaca (1990), like Baillie and Humpage, treats both the exchange rate and intervention as endogenous. She models the exchange rate as a stochastic process, includes intervention as an explanatory variable in a standard GARCH model, and uses a logit model to examine the probability of intervention in a target-zone framework. Unlike Baillie and Humpage, Mundaca finds that intervention is significant and a key explanatory variable in her

⁵⁵ More was said about the profitability criterion in Chapter 6.

exchange-rate equation. She also finds that the Bank of Norway intervenes differently when the kroner is weak than when it is strong.

Dominguez (1992b) explicitly investigates whether intervention by the U.S. and German authorities has influenced the variance of the exchange rate, using GARCH models similar to those used by Baillie and Humpage, Baillie and Osterberg, and Mundaca. She finds that intervention since the Plaza Agreement has tended to decrease exchange-rate volatility, the exception being U.S. intervention from 1985 to 1987, which increased volatility.

Juann Hung's (1991) study of U.S. intervention differs from all of the papers discussed above by proposing that intervention might be effective through an alternative channel, the noise-trading channel. For intervention to be effective through this channel, many market participants must be noise traders (or nonfundamentalists), and the adjustment toward stock equilibrium cannot be instantaneous. These assumptions allow for the possibility that intervention will alter market conditions and hence influence noise traders, an effect that would perpetuate, at least temporarily, the effects of intervention. Hung tries, with partial success, to capture this effect empirically.

Bossaerts and Hillion (1991) also view intervention as operating through a market microstructure characterized by the presence of heterogeneous traders. Their paper presents evidence that tests of forward-market efficiency are biased, at least for currencies in the EMS, because the tests ignore variations in the bid-ask spread. They find that spreads are wider on Fridays, and they suggest that this may result from anticipation of central-bank intervention, but they never test this supposition. Although intervention does not occur on weekends, realignments do. Bossaerts and Hillion attempt to account for realignments by using interest differentials, but it is not clear that their findings with respect to intervention are supported. Osterberg (1992) uses G-3 intervention data to see if intervention influences bid-ask spreads for the currencies of the G-3 countries. He finds little evidence to support the view that spreads widen in anticipation of intervention.

Catte, Galli, and Rebecchini (1992) evaluate the effectiveness of coordinated intervention using daily intervention data to examine nineteen efforts to influence the dollar-deutsche mark and dollar-yen exchange rates over the past seven and a half years. They rely on descriptive statistics rather than formal econometric testing and consider intervention to be successful if the trend of the exchange rate is reversed in the weeks following intervention. The authors conclude that intervention was successful in all nineteen episodes. Half were successful

in temporarily halting the course of the dollar; the other half were “definitely” successful in reversing the course of the dollar. In a comment on the paper, Truman (1992) argues that the authors should be “more modest about the effectiveness of intervention.” He suggests that intervention was partly successful in only about five of the episodes cited. Truman argues that the authors’ method of selectively isolating short episodes may create an illusion that intervention is indeed successful in influencing the exchange rate, when there may merely be a spurious association between intervention and the eventual change in the paths of the exchange rates.

9 SUMMARY AND CONCLUSION

The conventional wisdom of the early 1980s held that intervention does not offer the monetary authorities an independent policy tool for influencing the foreign-exchange market. With renewed intervention by the United States in 1985 and the apparent success of several episodes, a reassessment of the literature seemed appropriate. Furthermore, some of the anecdotal evidence described in Chapter 7 suggests that market participants and central bankers believe this recent intervention has had at times an important effect on the foreign-exchange market.

The post-1982 literature on intervention examines a number of issues. It considers the effectiveness of sterilized intervention through the portfolio-balance and signaling channels, the differences between coordinated and noncoordinated intervention, the motives for central-bank intervention, and the profitability of intervention. All of these issues are important in current policy discussions.

Like earlier work on the effectiveness of intervention through the portfolio-balance channel, recent empirical work generally finds no quantitatively significant relation between intervention and the risk premium. This finding suggests that sterilized intervention cannot permanently alter the exchange rate.

In contrast, most of the empirical evidence summarized in this survey suggests that intervention can affect the exchange rate through the signaling channel, a channel that was not widely studied by earlier empirical work. It is not clear from the studies surveyed, however, whether the statistically significant effect reflects the impact of intervention on expectations about future monetary policy or expectations about other policy decisions. In either case, moreover, the implication is that the signaling effects of intervention can have only a temporary influence on the exchange rate.

The amount of G-7 intervention has increased since the Plaza Agreement, and it has often been coordinated. Attempts to ascertain whether coordinated intervention is more effective than noncoordinated intervention have led to mixed results. Some papers show that the effects differ for various short subperiods, suggesting that other factors may play a role.

In examining the motives for intervention, researchers identify as key incentives the desire to smooth movements in nominal or real exchange

rates or the wish to achieve a target level for the nominal rate. The most recent literature, which focuses on the post-Louvre experience, suggests that intervention during this period may be quite different in its effects from intervention in earlier periods, because the authorities have tried to keep exchange rates within narrow bands.

Most of the studies concerned with the profitability of intervention find that it has usually been profitable. It is generally believed, however, that profitability is not a relevant criterion for assessing the effectiveness of intervention. It can be shown that stabilizing intervention may be unprofitable and that profitable intervention may not be stabilizing.

What conclusion should we draw from this survey of the literature? The results overwhelmingly suggest that, although we may be able to explain why a central bank intervenes in the foreign-exchange market, it remains difficult to find empirical evidence showing that intervention has a long-lasting, quantitatively significant effect. This conclusion needs to be qualified, however, because, as with any empirical work, existing models and the quality of the available data may not be sophisticated enough to resolve properly the questions asked. These qualifications seem consistent with the observation that exchange-market participants appear to believe that central-bank intervention is important and that they therefore react to news of intervention. Nevertheless, the empirical evidence, although allowing for the possibility of short-lived effects, does not ascribe to intervention a long-lasting effect on the foreign-exchange market.

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