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THE PROFITABILITY OF U.S. INTERVENTION

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ABSTRACT

In this paper I address some of the issues associated with measuring the profits and losses from intervention and show that U.S. intervention since the beginning of generalized floating in 1973 has earned positive economic profits for the U.S. monetary authorities. Profitability has been largest during episodes of intervention that have generated large foreign-exchange exposures. Fundamental explanations for the profitability of intervention are difficult to isolate, but I discuss possibilities that are consistent with the data. Finally I consider the effects profitable intervention may have on macroeconomic activity through its effect on the government budget constraint.

The Profitability of U.S. Intervention

Michael P. Leahy[1]

I. Introduction

What are the economic costs of official intervention in foreign-exchange markets? Because some believe government intervention is largely ineffective, they perceive that the resources used to conduct that intervention to be wasted; others, including Milton Friedman,[2] claim that, although intervention can affect the exchange rate, in practice a government's purchases to support its currency merely generate profitable sales for speculators at taxpayers' expense. Other commentary on the costs of intervention have pointed out that official purchases of large quantities of dollars in 1987 must have generated big losses for central banks, since the dollar fell more than 15 percent against the mark and more than 20 percent against the yen over that year.

A full evaluation of the costs and benefits of official intervention should include not only a measure of the profits and losses associated with the government's foreign-exchange portfolio but also some measure of the benefits or costs arising from the effect of intervention

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1. The author is a staff economist in the Division of International Finance. This paper represents the views of the author and should not be interpreted as reflecting those of the Board of Governors of the Federal Reserve System or other members of its staff. I am grateful to Hali Edison, Neil Ericsson, Richard Freeman, David Howard, Laurence Jacobsen, Dianne Pauls, Larry Promisel, Ralph Smith, Charles Thomas, Edwin M. Truman, and Paul Wood for helpful discussions and suggestions. Virginia Carper provided valuable research assistance.

2. "Both the rise and subsequent decline in the dollar have probably been overdone, a not unusual phenomenon, but one that was exacerbated in this instance by unwise intervention by central banks in the exchange market--intervention that is proving costly to Japanese, German, U.S., and other countries' taxpayers." Friedman [1988], p. A18.

on exchange rates and interest rates as well. To the extent that intervention is sometimes effective in smoothing or stabilizing exchange rates, considerations of profit and loss need not be dominant. However, regardless of the effectiveness of intervention, any evaluation of it should include some measure of profit and loss.

The measurement of profits and losses in intervention requires careful analysis, and different approaches may produce different results. In this paper I address some of the issues associated with measuring the profits and losses from intervention and show that, by the approach adopted, U.S. intervention since 1973, when generalized floating began, has, for the most part, earned positive economic profits for the U.S. monetary authorities. Profitability has been largest during episodes of intervention that have generated large foreign-exchange exposures. Fundamental explanations for the profitability of intervention are difficult to isolate, but I discuss possibilities that are consistent with the data. Finally I consider the effects profitable intervention may have on macroeconomic activity through its effects on the government budget constraint.

This work draws heavily on Laurence Jacobson's 1983 Federal Reserve Staff Study, "Calculations of Profitability for U.S. Dollar-Deutsche Mark Intervention." At the same time it offers some formal innovations. The profit measure used here is a generalization of Jacobson's and recognizes the interplay of exchange rates and interest rates. These interactions can be large in periods in which exchange rates are volatile and interest rates are high. Also, the calculations are extended through January 1988 and cover U.S. dollar-yen intervention as well as dollar-mark intervention.

In the first parts of this paper I describe a general formula for computing the profits associated with intervention, discuss the conditions under which intervention would be profitable, and analyze the sensitivity of profit calculations to the choice of period. Next, I present estimates of the profits associated with U.S. intervention since 1973 and speculate as to why it shows profits so consistently. Finally, I consider the significance of profitable intervention for the government budget constraint. There are also four appendices. The first relates the profit calculation I use to those used by Jacobson and others. The second examines in more detail the implicit assumption of a zero initial position and its implications for the additivity of profit calculations. The third briefly presents some formulas that could be used to calculate profits from intervention in the forward market. The fourth documents the data sources and transformations.

I. Methodology

Several issues arise in the construction of a measure of the profitability of intervention. One concerns the proper measurement of the opportunity costs associated with intervention. A spot purchase of dollars against marks, for example, requires that the marks be sold from reserves or borrowed. In either case, interest on the DM assets will be foregone. Similarly, the dollars purchased earn interest. To estimate economic profits, which are net of opportunity costs, the interest cost of funds used to make intervention purchases should be deducted from the interest earnings on the assets acquired. These issues are addressed in section A on the general formula.

Section B presents an interpretation of the formula and discusses the conditions under which this formula would show intervention to be profitable.

A second issue in the construction of a measure of the profitability of intervention concerns the distinction between profits and losses arising from intervention operations and profits and losses arising from other official transactions involving foreign currencies. This issue is addressed in section C on reserves.

A third issue concerns the proper valuation of large positions in foreign currencies. Because the current value of a foreign-currency position is sensitive to changes in the relevant exchange rate, profit calculations based on end-of-period exchange rates are quite sensitive to the choice of period when foreign-currency positions are large. This issue is discussed in section D on choice of period.

A. General Formula

The formula presented below is based on the construction of a notional portfolio of domestic-currency and foreign-currency assets. It can be used to estimate the difference between the portfolio's net worth after a period of intervention and its net worth had no intervention occurred at all. In the ideal calculation, to compute the counterfactual net worth, one would reverse any effects intervention may have had on exchange rates and interest rates during the period and compute net worth under the assumption of no intervention with the alternative rates. This approach, which would require a model of the effects of the intervention on exchange rates and interest rates and which would be necessary for a fuller evaluation of the costs and benefits of intervention, is not taken here. Rather, for the limited purpose of calculating the intervention portfolio's net worth, it is assumed that intervention has no effect on exchange rates and interest rates and that the same data on rates can be used to evaluate net worth with intervention and without.

It is necessary to make some assumption about the initial portfolio of domestic-currency assets and foreign-exchange reserves so that one can compare the change in the value of that initial portfolio to the difference between the value of the initial portfolio and the value of the portfolio that results after a sequence of intervention transactions. For simplicity I assume the initial portfolio is empty (i.e., it contains no assets and no liabilities, of either currency of denomination). Its initial value is, by construction, zero. Under these conditions, one can then simply determine the terminal value of the portfolio that results from the sequence of intervention transactions to compute the contribution of intervention to the final value of the portfolio. As shown in Appendix B, any other initial portfolio can be incorporated into the analysis. The contribution of the intervention transactions to the final value of the portfolio will be the same, however, regardless of the initial portfolio assumption.

I begin the construction of this formula by computing the future (day t) value of the currency purchased on a given day (day i) less the future value foregone of the currency sold on that day. Given the assumption that the initial portfolio is empty, it will be necessary to borrow assets to begin intervening. I assume the interest paid on an asset borrowed is the same as the interest that would be foregone if the same asset were sold from the portfolio. Thus, it makes no difference for this calculation that the asset sold is not already owned.

Let x_i represent government purchases (or sales, if $x_i < 0$) of dollars against a foreign currency on day i, S_i represent the price of dollars in terms of the foreign currency on day i, r_i represent the daily interest rate on dollar assets held as reserves, and r_i^* represent the daily interest rate on foreign-currency assets. When the x_i dollars are purchased on day i, it is assumed that these dollars are used to purchase an asset that earns interest r_i, and that principal and interest are reinvested at the interest rates available on the subsequent days until day t, the date at which we wish to evaluate the profits associated with the intervention. Thus, the dollar value on day t of intervention on day i is given by:

$$(1)\quad VI_i = x_i(1+r_i)(1+r_{i+1})(1+r_{i+2})\cdots(1+r_{t-1})$$

$$= x_i \prod_{j=0}^{t-1-i} (1+r_{i+j}).$$

For notational simplicity, define $\tilde{r}_i$ as:

$$(2)\quad \tilde{r}_i = \prod_{j=0}^{t-1-i} (1+r_{i+j}) - 1.$$

The compound interest rate $\tilde{r}_i$ represents the rate of return associated with an investment on day i in which principal and interest are reinvested until day t. In a world of perfect foresight and no risks, it might also be interpreted as the rate of return on a single asset that matures on day t. Using $\tilde{r}_i$, one can express VI_i as:

$$(3) \quad VI_i = x_i(1+\tilde{r}_i).$$

To calculate the value on day t of a sequence of intervention purchases of dollars that began on day k and ended on day t, take the sum:

$$(4) \quad \sum_{i=k}^{t-1} VI_i + x_t = \sum_{i=k}^{t-1} x_i \prod_{j=0}^{t-1-i} (1+r_{i+j}) + x_t$$

$$= \sum_{i=k}^{t-1} x_i(1+\tilde{r}_i) + x_t$$

$$= TDP(k,t).$$

The expression TDP(k,t) is the terminal dollar position resulting from intervention beginning on day k and ending on day t. It is the sum of the day-t values of dollars purchased (or sold) between days k and t, including the value of dollars purchased on day t itself. TDP(k,t) will be positive when the terminal dollar position is long and negative when the terminal dollar position is short.

To compute the opportunity cost of these intervention purchases of dollars (OCI), consider the foreign-currency value on day t of the investment of $S_i x_i$ foreign currency units on day i:

$$(5) \quad OCI_i = S_i x_i (1+r_i^*)(1+r_{i+1}^*)(1+r_{i+2}^*)\cdots(1+r_{t-1}^*)$$

$$= S_i x_i \prod_{j=0}^{t-1-i} (1+r_{i+j}^*) = S_i x_i (1+\tilde{r}_i^*),$$

where $\tilde{r}_i^*$ is defined as

$$(6) \quad \tilde{r}_i^* = \prod_{j=0}^{t-1-i} (1+r_{i+j}^*) - 1.$$

The opportunity cost in terms of day-t dollars of the sequence of intervention purchases between days k and t is:

$$(7) \quad (1/S_t)\left[\sum_{i=k}^{t-1} OCI_i + S_t x_t\right] = \sum_{i=k}^{t-1} (S_i x_i/S_t) \prod_{j=0}^{t-1-i} (1+r_{i+j}^*) + x_t$$

$$= \sum_{i=k}^{t-1} (S_i x_i/S_t)(1+\tilde{r}_i^*) + x_t$$

$$= -(1/S_t)TFCP(k,t),$$

where TFCP(k,t) is the terminal foreign-currency position from intervention beginning on day k and ending on day t. As with TDP(k,t), TFCP(k,t) is defined to be negative when the terminal foreign-currency position is short and positive when the terminal foreign-currency position is long.

Subtracting from the values of the sequence of interventions their associated opportunity costs, one can compute the economic profits (P) arising from intervention between day k and day t:

$$(8)\quad P(k,t) = \sum_{i=k}^{t-1} VI_i - (1/S_t)\sum_{i=k}^{t-1} OCI_i$$

$$= \sum_{i=k}^{t-1}\left[x_i\left\{\prod_{j=0}^{t-1-i}(1+r_{i+j}) - (S_i/S_t)\prod_{j=0}^{t-1-i}(1+r^*_{i+j})\right\}\right]$$

$$= \sum_{i=k}^{t-1}\left[x_i\left\{(1+\tilde{r}_i) - (S_i/S_t)(1+\tilde{r}^*_i)\right\}\right]$$

$$= TDP(k,t) + (1/S_t)TFCP(k,t)$$

From the derivation shown above, one can see that this opportunity-cost measure of economic profits is equivalent to the sum of the terminal dollar position plus the dollar value on day t of the terminal foreign-currency position. Note, however, that the sum of currency positions will yield the proper measure only if accumulated interest flows are included in the computation of the position values.

One can also decompose the expression for P(k,t) into profits from foreign-exchange transactions alone and profits from net interest flows.

$$(9) \quad P(k,t) = \sum_{i=k}^{t-1} x_i(1 - S_i/S_t) + \sum_{i=k}^{t-1} x_i(\tilde{r}_i - (S_i/S_t)\tilde{r}_i^*).$$

The first term on the right-hand side of the equation above represents profits measured at the day-t exchange rate from intervention if both dollar and foreign-currency interest rates were zero. The second term captures the interest earnings from purchases of dollar-denominated assets and the foregone interest earnings from sales of foreign-currency-denominated assets. Because the interest flows associated with the foreign-currency asset are denominated in foreign currency units, it is necessary to include the exchange-rate factors to obtain a dollar value on day t. While the interaction, in an accounting sense, between exchange-rate changes and foreign-currency interest rates is second-order for small changes, large swings in exchange rates can produce large effects on the net interest component of profits, as shown in Appendix A.

The profit calculations reported below are computed using the formula P(k,t). Appendix A contains a comparison of this formula with those used by Jacobson and others and shows that this formula can be considered a generalization of those methods.

B. Conditions under which Intervention is Profitable

Rewriting the profit formula once more, we can isolate the factors that determine whether a particular day's intervention contributes positively or negatively to profits.

$$(10)\quad P(k,t) = \sum_{i=k}^{t-1} \left[(1/S_t)(1+\tilde{r}_i)x_i\left\{S_t - S_i(1+\tilde{r}_i^*)/(1+\tilde{r}_i)\right\}\right]$$

$$= \sum_{i=k}^{t-1} \left[(1/S_t)(1+\tilde{r}_i)x_i(S_t - \tilde{F}_i)\right],$$

where $\tilde{F}_i = S_i(1+\tilde{r}_i^*)/(1+\tilde{r}_i)$. $\tilde{F}_i$ is a forecast of sorts. It is a constructed forward exchange rate, where the interest rates used to construct the forward rate reflect the future pattern of interest rates with perfect accuracy.

Given this representation, it is clear that any term of the profit summation will be positive if and only if the sign of intervention, x_i, is the same as the sign of $(S_t - \tilde{F}_i)$. If the dollars are purchased when the constructed forward rate underpredicts the day-t value of the dollar and sells dollars when the constructed forward rate overpredicts the day-t value of the dollar, then intervention, evaluated on day t, will be profitable. If the constructed forward rate predicts S_t perfectly, the sign of the intervention doesn't matter: profits will be zero in either case. An examination of this formula in the context of some specific assumptions about market and central-bank behavior will demonstrate some of its characteristics.

If the interest-earning assets are perfect substitutes in all respects except for currency of denomination, if markets are efficient and market participants are risk-neutral, and if the central bank has no better idea than the market what the future value of the exchange rate will be, then, ex ante, expected intervention profits should be zero. Ex post profits will, of course, be nonzero, but there is no reason to believe that profits will be systematically biased toward the positive or the negative in the long run, and there is no reason to believe dollar purchases as opposed to dollar sales should be more profitable.

Profits and losses will accrue systematically, however, if the interest-earning assets are not perfect substitutes. For example, if the dollar-denominated asset is more liquid than the foreign-currency asset and the yields reflect the existence of this liquidity premium, the constructed forward rate will tend to overpredict the day-t spot rate and a short dollar position will be more likely than a long dollar position to be profitable.

Another case in which systematic ex post profits can arise occurs if the authorities have information not available to the market about future market conditions. They could know, for example, that monetary policy would tighten if intervention purchases of the dollar fail to stop its decline. If the market is not expecting a change in monetary policy, then the intervention will be profitable if monetary policy does change and the dollar responds. Presumably, this would be only a short-term effect. Over a longer period, as the market came to recognize that intervention was done with knowledge of inside information, the threat of intervention would be sufficient to alter market rates and very little actual intervention would need to be done.

A third case in which systematic ex post profits can arise occurs when markets fail to use available information efficiently. This situation could reflect a better understanding by officials of how markets work or of the implications of current policies and data. If the authorities believe the current market assessment of the long-run exchange rate is, for example, too low, they may try to guide the market with intervention purchases of dollars so as to smooth the adjustment over time. As long as they are correct, the intervention will be profitable, even if they are not able to affect market rates significantly with their intervention. One should also include in this category those episodes described by the term "disorderly markets." In this situation officials have an assessment different from the market's of the risks involved in taking one side of a foreign-exchange transaction or the other. The market may have overreacted to some piece of new information, and the central bank can earn profits, as long as its view is correct that the market is overreacting, from taking the temporarily unwanted side of a transaction.

Consider next the more mechanical policy of leaning against the wind. If the value of the dollar depreciates continuously during the period, S_t will be below S_i. Clearly, a sequence of dollar purchases need not be profitable, since the authorities would be filling their portfolios with a currency whose value is declining. However, it is possible that the interest-rate differential could more than compensate for the currency loss, making leaning against the wind profitable after all. Thus, buying a declining currency does not rule out profits. If the constructed forward rate underpredicts the value of the currency (i.e., overpredicts its decline), then buying the declining currency will be profitable.

One condition that has no bearing on whether a given sequence of intervention purchases is profitable is the identity of the intervening country. A sequence of interventions that is profitable for the domestic government is also profitable for a foreign government. To convert P(k,t) to foreign-currency profits, one need only multiply P(k,t) by the appropriate day-t exchange rate. No sign changes can result. Thus, to the extent that one country's intervention is positively correlated with others' official intervention, through concerted actions or even looser policy coordination, the governments will profit or lose together.

C. Reserves

Reported profits and losses will differ by the identity of the intervening country, however, when the change in the local currency value of a country's initial foreign-exchange reserves is included with the profits from a sequence of intervention purchases. A decline in the value of the dollar will lead to an increase in the dollar value of U.S. foreign-currency reserves (an unrealized profit) and a decrease in the foreign-currency value of a foreigner's dollar reserves (an unrealized loss). Since countries evaluate changes in net worth in terms of their own currencies, these valuation effects on initial reserve holdings can alter the sign of reported profits. Thus, in a period in which two countries make identical intervention transactions, a negative profit report for one country and a positive report for the other means only that the local currency values of their initial stocks of foreign-exchange reserves moved differently, not that the particular sequence of intervention transactions during the period was profitable for one country and unprofitable for the other.

Profit and loss calculations that use changes in the value of foreign-exchange reserves fail to distinguish between intervention operations and other official transactions involving foreign currencies. Those calculations measure the profitability of all the foreign-currency operations conducted by a government, including not only intervention during a period, but also asset exchanges with foreign monetary authorities, foreign central bank swap drawings, intervention purchases of foreign currencies made prior to the period under consideration, and interest earnings on those prior purchases.

In this study, only intervention transactions, and subsequent net interest earnings and exchange-rate changes on the dollar values of positions generated by those intervention transactions, affect the value of the portfolio. Other transactions that might affect reserves are not used in the calculations. Furthermore, by assuming that intervention portfolios contain no assets and no liabilities of either currency at the beginning of the period, the effects of exchange-rate changes and cumulative interest flows on stocks of foreign exchange acquired in previous periods are excluded from the calculations.

D. Choice of Period

An important property of this profit formula is its sensitivity to the choice of period. As a result of this sensitivity, it is possible that two adjacent periods of unprofitable intervention can be profitable when considered as a whole. Consider the following example. Suppose that between days k and q the dollar depreciates and the constructed forward rates consistently overpredict the value of the dollar on day q. If a government follows a policy of leaning against the wind, it purchases dollars during the period and on day q shows a loss. Suppose next that between days q+1 and t the dollar appreciates and the constructed forward rates consistently underpredict the value of the dollar. If the government sells dollars during this second subperiod, it again registers a loss, according to the profit formula. However, it is possible that the long-dollar position (and the short-foreign-currency position) attained on day q rose in value between days q+1 and t by enough to offset the total of the losses recorded in both subperiods.

This anomaly stems in part from the fact that in one calculation the terminal portfolio in the first subperiod is evaluated at the exchange rate occurring at the end of the first subperiod, while in the other it is evaluated at the exchange rate occurring at the end of the second subperiod. Also, in the second calculation the terminal positions at the end of the first subperiod continue to earn or pay interest. Applying the profit formula individually to each subperiod does not take into account changes in the value of the terminal position in both currencies between the end of the first subperiod and the end of the second. As a consequence, measures of profits for adjacent subperiods are not likely to sum to a single profit measure for the whole period. A corollary to this proposition is that losses registered during some time period can be turned to profits at later times even if no further intervention is undertaken. When terminal positions are large, the estimate of profitability is quite sensitive to the choice of period and, in particular, to the end-of-period exchange rate. Only if the position in both currencies at the end of a period is zero will the profit calculation be unchanged by future changes in exchange rates and interest rates. These features are presented in more detail in Appendix B.

The sensitivity of profit measures to choice of period has led some analysts (e.g., Argy) to restrict profit measurements to periods in which terminal foreign-currency positions are close to zero. As the analysis in Appendix B shows, zero foreign-currency positions will eliminate the effect on calculated profits of future changes in foreign-currency interest rates and in the exchange rate. However, it is also necessary to have a zero terminal dollar position as well to avoid sensitivity to future dollar interest rate changes. Unfortunately, it is unlikely that after any period of intervention the terminal position in both currencies will be zero. Restricting profit measures to periods in which the terminal foreign currency position is close to zero reduces the effects of at least two of the three potential sources of change--the foreign-currency interest rate and the exchange rate.

Another reason for limiting profit measures to periods in which foreign currency positions are near zero stems from the potential difficulty of measuring the dollar value of large stocks of foreign exchange. If one assumes that intervention can affect exchange rates, then the value in terms of dollars of a large long position in foreign exchange is unlikely to be equal to the product of the size of the position and the current exchange rate, since the value of the foreign currency may decline as the reserves are sold. Thus, estimates of the value of long positions are possibly overstated. Similarly, estimates of the value of short positions are possibly overstated also.[3] In either case, it is not clear how much these positions are worth in terms of dollars, and the larger the positions are the more likely it is that their calculated values could not be realized in the market.

While the problems associated with valuing the terminal foreign-currency position are reduced for subperiods in which those positions are small, restricting profit calculations to subperiods with zero terminal foreign-currency positions introduces the possibility of sample-selection bias, as discussed by Corrado and Taylor [1986]. With a model of a central bank that mechanically leans against the wind and in which the exchange rate follows a random walk, they show that the conditional expectation of profits given that cumulative intervention is zero is greater than the unconditional expectation of profits. Thus, one should be wary of making inferences about the profitability of intervention from observing only subsamples of the data.

Because, in general, profit estimates will be sensitive to end-of-period exchange rates, especially when terminal foreign-currency

3. For example, the dollar value of a negative foreign-currency position may become more negative if the value of the dollar falls as dollars are sold against the foreign currency to liquidate the short position. An estimate which fails to take the adverse exchange-rate movement into account would overstate the value of the short position.

positions are large, it is useful to have some gauge with which to calibrate the uncertainty of the estimates. By separating profits into terminal positions in each currency, it is easy to determine the sensitivity of the profit estimate to changes in the exchange rate. For example, assume dollars are sold for marks on day one and that on the next day the value of the dollar falls and the same quantity of dollars is repurchased for marks. By recognizing that the terminal dollar position is zero and the terminal mark position is positive, one can evaluate the terminal mark position at a variety of exchange rates to calibrate the sensitivity of the profit estimate to possible future changes in the exchange rate.

The separation of profits into the terminal currency positions, as shown in equation (8), is an alternative to the decomposition of total profits into realized and unrealized profits that is often presented. The precise breakdown into realized and unrealized profits depends on the accounting convention that profits are "realized" only when purchases or sales have been reversed and a decision about the accounting method to use to calculate the acquisition "cost" of foreign currencies resold to the market--LIFO, FIFO, or an average cost method. While these practices are based on standard accounting procedures, which may have arisen from the need to distinguish realized and unrealized profits for tax purposes, their relationship to the calculation of economic profits from official intervention is not transparent. Certainly, the issue of determining taxable income is not relevant. Still, the practice persists, probably because by splitting total profits into realized and unrealized, it conveys some measure of the confidence with which one should regard the profit estimate. Under any of these accounting methods, some portion of the total profits from the simple example mentioned above would be recorded as realized and some unrealized, but one is left wondering how uncertain the unrealized portion of profits is. Splitting the total profit estimate into the sum of the terminal currency positions, however, allows one to conduct a more precise sensitivity analysis.

III. Calculations

It should be stressed that the following calculations are estimates. They are approximate in that no attempt was made to determine the exact exchange rates at which each day's intervention was done or the exact rates of return associated with the particular instruments used in each transaction. I assume all intervention for a particular day was done at exchange rates observed at noon in the New York market and that the relevant interest rates are those on the U.S. three-month Treasury bill, the German interbank rate less 25 basis points, and the three-month gensaki rate in Japan.[4] These rates are comparable to the actual rates at which U.S. authorities borrow and lend dollars, marks, and yen.

Table 1 shows estimates of profits from dollar-mark intervention by the U.S. Treasury and the Federal Reserve System combined for selected periods. It also provides information used to compute the dollar value of the notional dollar-mark portfolio for these periods. As shown at the top of column (1), cumulative net sales of dollars against marks between

4. For dates before March 1979, the gensaki rate was not available, so I used the interest rates quoted on "over-two-month-end" loans in the Japanese commercial bill market.

Table 1

Estimates of Profits from Dollar-Mark Intervention
(rounded to millions of U.S. dollars or equivalent, unless otherwise indicated)

	September 1985-December 1985 (1)	September 1985-December 1986 (2)	October 1977-February 1981 (3)	September 1985-January 1988 (4)	March 1973-January 1988 (5)
(1) Cumulative net dollars purchased	-1,861	-1,861	-915	1,093	-1,171
(2) Gross dollar purchases and sales	1,861	1,861	49,304	6,138	63,283
(3) Terminal dollar position	-1,892	-2,012	869	849	417
(4) Terminal mark position*	2,052	2,728	168	360	3,867
(millions of DM)	(5,022)	(5,247)	(362)	(609)	(6,543)
(5) Profits	161	716	1,037	1,209	4,284
Memo:					
(6) Profits without net interest earnings	170	723	265	1,185	2,859
(7) Net interest earnings	-10	-7	772	24	1,425
(8) end-of-period exchange rate (DM/$)	2.4470	1.9235	2.1520	1.6920	1.6920
Profits based on valuing terminal mark position at:					
(9) 20% stronger dollar	-181	262	1,009	1,149	3,640
(10) 20% weaker dollar	674	1,398	1,079	1,299	5,251

* Terminal mark positions are elements of the notional intervention portfolios described in the text and are not equal to U.S. official reserve balances, since the terminal positions exclude reserves acquired through means other than intervention. Terminal foreign-currency positions differ from official reserve balances when reserves are augmented by asset exchanges with foreign monetary authorities and foreign central bank swap drawings, as well as by intervention purchases of foreign currency made prior to the period under consideration or by the interest earnings on those prior purchases.

the time of the Plaza Accord in September 1985 and the end of that year amounted to almost $1.9 billion. Since there were no offsetting dollar purchases against marks during that period, gross dollar purchases and sales, line (2), are of the same magnitude as the net.

Line (3) shows the short-dollar position that had accumulated in the notional portfolio by the end of the period. The magnitude of the terminal dollar position is slightly larger in absolute value than the cumulative net dollar purchases because the terminal dollar position includes an estimate of the accumulated interest cost of the dollars sold during the period.

Line (4) contains the corresponding mark position in the notional portfolio at the end of the period and includes an estimate of the accumulated interest earnings on the marks purchased.

The profit estimate shown on line (5) is the sum of the terminal dollar position and the terminal mark position, where the latter is converted into dollars using the end-of-period exchange rate. If the dollar-mark intervention immediately following the Plaza Accord is evaluated as of the end of 1985, profits are estimated to have been $161 million. Lines (6) and (7) show an alternative decomposition of line (5) into profits from net interest flows and profits from exchange-rate changes alone. This decomposition is done as described by equation (9) in the text.

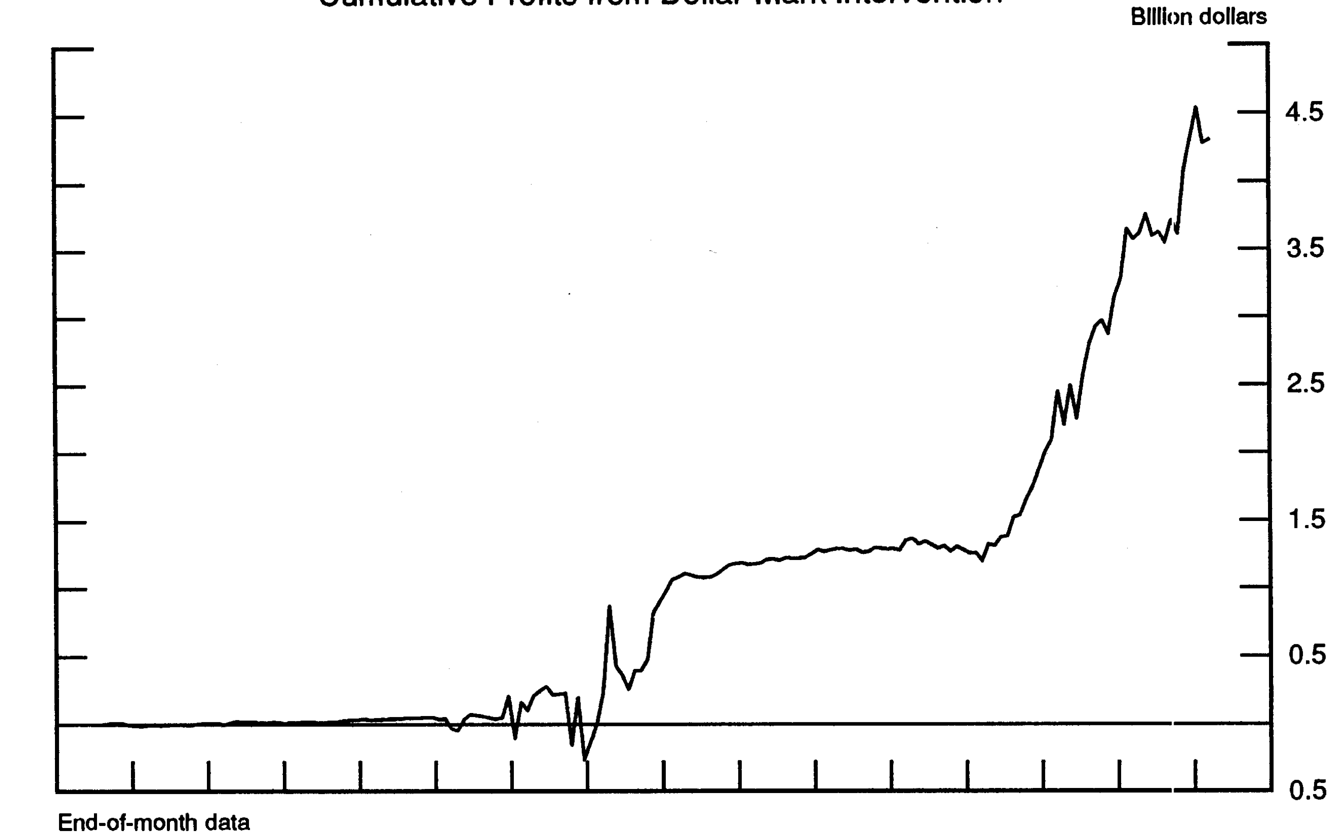
The sensitivity of the profit estimates to end-of-period exchange rates can be seen by comparing the profits shown in columns (1) and (2). Extending the calculation period to the end of the next year--as in column (2)--when no additional intervention was done, yields a much larger estimated profit of $716 million. Profits increased because the dollar continued to decline in 1986, by more than the depreciation implicit in the dollar-mark interest-rate differential, raising the dollar value of the long-mark position that had accumulated by the end of 1985 more than enough to offset the deterioration of the short dollar position. To calibrate the sensitivity of the profit estimates to end-of-period exchange rates, lines (9) and (10) provide alternative estimates based on hypothetical values of the dollar that are 20 percent stronger and 20 percent weaker than the actual end-of-period value.

The remaining columns of table 1 summarize the profitability of dollar-mark intervention from late 1977 to early 1981 and from 1985 to the end of January 1988--two periods of large foreign-exchange exposures for U.S. authorities--and, in the last column, during the entire period of generalized floating since March 1973 with a cutoff date of January 1988. As shown in line (5), U.S. operations in DM in those periods are estimated to have been profitable.

Chart 1 displays cumulative profits and the cumulated dollar and mark positions, evaluated at month-end exchange rates, for dollar-mark intervention beginning in March 1973 and ending each subsequent month until January 1988. The chart highlights the two subperiods during which dollar-mark intervention generated relatively large exposures, from late 1977 to early 1981 and from 1985 to sample-end, and shows that they correspond to marked changes in the volatility and level of the profitability of the constructed portfolio. In the earlier subperiod, intervention purchases of dollars against marks in 1978 and 1979 generated large long-dollar and short-mark positions. Because of the

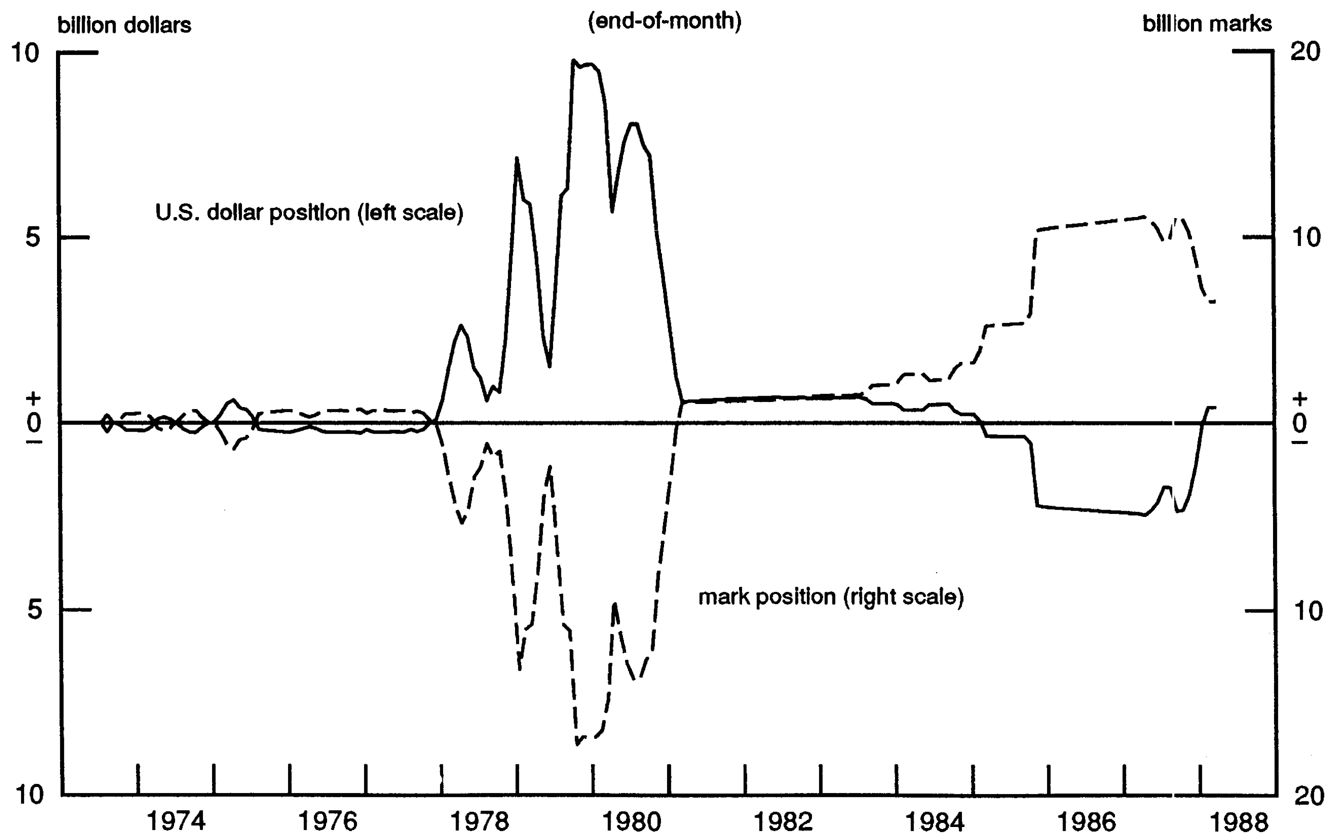
CHART 1

Cumulative Profits from Dollar-Mark Intervention



Positions in the Dollar-Mark Portfolio

(end-of-month)



size of the positions and a favorable interest-rate differential, especially after the dollar began appreciating in the second half of 1980, interest earnings contributed significantly to profits. When measured at the end-of-period exchange rate, profits from dollar-mark intervention during that period alone totaled about $1 billion, three-quarters of which was net interest earnings. (See column (3) of table 1.)

Following this subperiod, the dollar-mark portfolio was slightly long in both currencies until early 1985. Intervention in the four years between 1980 and 1985 was light, amounting to net sales of about $2-3/4 billion against marks. (See table 3B, column (8).) Since the dollar appreciated during this period and interest-rate differentials favored dollar-denominated assets, this small amount of intervention was quite unprofitable. Assuming an initial portfolio in January 1981 of no assets of either currency, dollar-mark intervention until February 1985, when the dollar began to decline, produced losses of nearly $1-1/2 billion.[5] The upper panel of chart 1 does not show cumulative profits dropping off during this period because these losses were offset by the interest earnings on the long dollar and mark positions that had been attained by the end of 1980. The interest rates in both the United States and Germany in the early 1980s and the long positions in both currencies produced just enough in interest earnings to offset the losses associated with intervention during that period.

5. Evaluated near the dollar's peak in early 1985, this short-dollar, long-mark position is clearly unprofitable. However, at any exchange value for the dollar below DM 2.0000, that position becomes profitable. Thus, by the end of 1986, the intervention done between 1981 and 1984 began to contribute positively to overall intervention profits.

In early 1985, when the dollar position became short and the foreign-exchange value of the dollar began to fall, the profitability of the dollar-mark portfolio began rising again. As the dollar continued to fall and the intervention immediately following the Plaza agreement increased still more the long-mark, short-dollar positions, the value of the portfolio increased sharply. Later, after the Louvre accord in 1987, the United States began to sell marks and reduce its long-mark position somewhat. Intervention from the time of the Plaza Accord until the end of January 1988 contributed about $1.2 billion to U.S. government net worth. (See column (4) of table 1.)

Table 2 and chart 2 provide similar information about dollar-yen intervention. They show that dollar-yen intervention during the first 15 years of the floating rate period has been profitable, on balance, although because positions were smaller, profits were of a substantially smaller magnitude than for dollar-mark intervention. Between 1978 and 1985, the dollar-yen portfolio was predominantly long yen and short dollars, although, as shown in the bottom panel of chart 2, foreign-exchange exposure in the dollar-yen portfolio was relatively small. These long-yen and short-dollar positions generated losses, on balance, during the early 1980s when the dollar appreciated against the yen. The value of the dollar-yen portfolio began to increase, however, after the dollar's value against the yen started falling in February 1985. Furthermore, following the Plaza Accord in September of that year, the profitability of the dollar-yen portfolio increased sharply, as the United States increased its long yen position and decreased its short dollar position while the dollar's exchange value continued to fall. The

Table 2

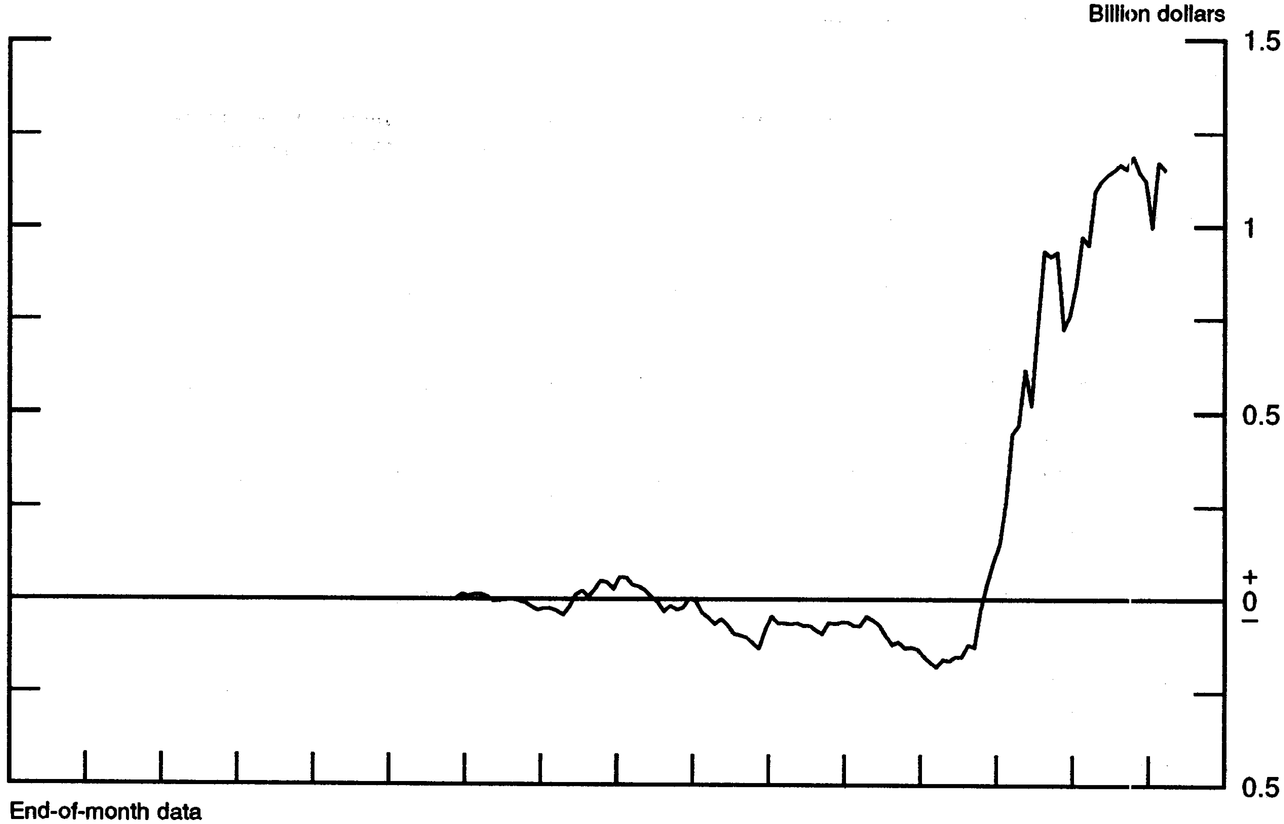
Estimates of Profits from Dollar-Yen Intervention
(rounded to millions of U.S. dollars or equivalent, unless otherwise indicated)

	September 1985- December 1985 (1)	September 1985- December 1986 (2)	September 1985- January 1988 (3)	March 1973- January 1988 (4)
(1) Cumulative net dollars purchased	-1,440	-1,440	5,730	5,163
(2) Gross dollar purchases and sales	1,440	1,440	8,759	9,914
(3) Terminal dollar position	-1,463	-1,556	5,750	4,658
(4) Terminal yen position (billions of yen)	1,585 (317)	2,107 (333)	-5,165 (-668)	-3,487 (-451)
(5) Profits	122	551	585	1,172
Memo:				
(6) Profits without net interest earnings	200.25	158.30	460	967
(7) Net interest earnings			125	205
(8) end-of-period exchange rate (yen/$)	200.25	158.30	129.38	129.38
Profits based on valuing terminal yen position at:				
(9) 20% stronger dollar	-142	200	1,427	1,753
(10) 20% weaker dollar	518	1,078	-706	300

* Terminal yen positions are elements of the notional intervention portfolios described in the text and are not equal to U.S. official reserve balances, since the terminal positions exclude reserves acquired through means other than intervention. Terminal foreign-currency positions differ from official reserve balances when reserves are augmented by asset exchanges with foreign monetary authorities and foreign central bank swap drawings, as well as by intervention purchases of foreign currency made prior to the period under consideration or by the interest earnings on those prior purchases.

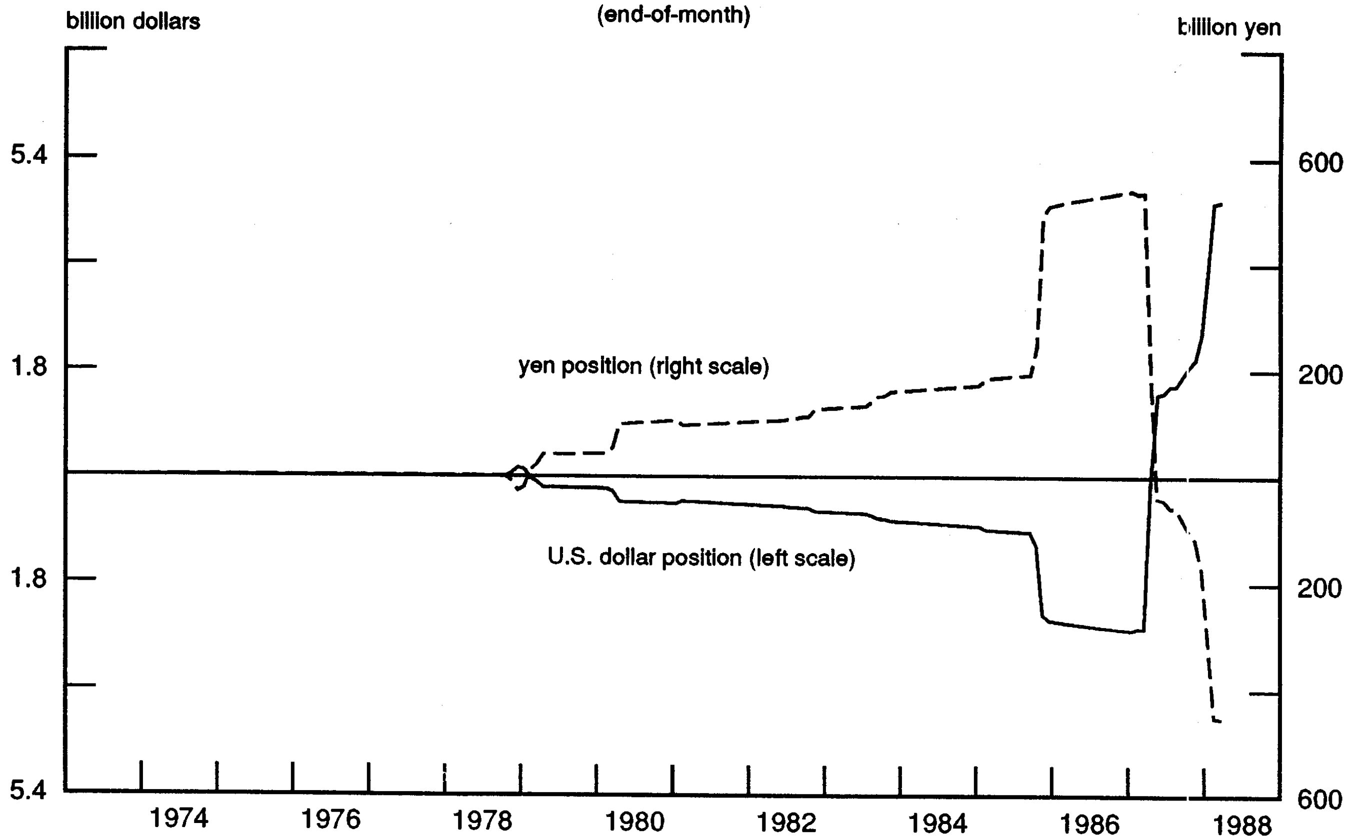
CHART 2

Cumulative Profits from Dollar-Yen Intervention



Positions in the Dollar-Yen Portfolio

(end-of-month)



large long-yen, short-dollar positions attained following the Plaza Accord were quickly reversed in 1987 after the Louvre agreement in April. Consequently, the profitability of the dollar-yen portfolio turned down in the later part of 1987.

The remaining tables (3A, 3B, and 4) show profit calculations for a variety of other subperiods. Many of these were chosen to contain at least one cycle of purchases and sales and to end with relatively small terminal foreign-currency positions. Some, however, end with relatively large positions. In either case, one should consider these subperiod estimates mindful of the caveats mentioned above. As in tables 1 and 2, alternative estimates based on hypothetical values of the dollar that are 20 percent stronger and 20 percent weaker than the actual end-of-period values are presented to show the sensitivity of these estimates to possible deviations from the end-of-period exchange-rates. The subperiods for dollar-mark intervention before December 1981 correspond quite closely to the subperiods Jacobson studied.[6] There are fewer subperiods for dollar-yen intervention because U.S. intervention in yen was minimal until November 1978.

6. These are the subperiods shown in column (3) of table 1 and columns (1) through (6) in tables 3A and 3B. There are some slight differences in three of these subperiods, since it appears that Jacobson may have chosen his subperiods to coincide with cycles of foreign-currency borrowings and repayments through central bank swap arrangements and that these cycles differ in three subperiods at least from the terminal foreign-currency calculation I have made.

Table 3A

Estimates of Profits from Dollar-Mark Intervention
(rounded to millions of U.S. dollars or equivalent, unless otherwise indicated)

	July 1973-August 1973 (1)	February 1974-September 1974 (2)	October 1974-December 1975 (3)	January 1976-August 1976 (4)	October 1978-May 1979 (5)
(1) Cumulative net dollars purchased	8	-51	10	1	405
(2) Gross dollar purchases and sales	550	1,064	2,598	573	14,425
(3) Terminal dollar position	9	-41	35	3	623
(4) Terminal mark position* (millions of DM)	-2 (-5)	39 (104)	-20 (-53)	-2 (-4)	-404 (-775)
(5) Profits	7	-1	14	1	218
Memo:					
(6) Profits without net interest earnings	8	0	11	1,185	87
(7) Net interest earnings	-1	-1	3	24	131
(8) end-of-period exchange rate (DM/$)	2.4612	2.6455	2.6185	2.5227	1.9173
Profits based on valuing terminal mark position at:					
(9) 20% stronger dollar	8	-8	18	2	286
(10) 20% weaker dollar	7	8	9	1	117

* Terminal mark positions are elements of the notional intervention portfolios described in the text and are not equal to U.S. official reserve balances, since the terminal positions exclude reserves acquired through means other than intervention. Terminal foreign-currency positions differ from official reserve balances when reserves are augmented by asset exchanges with foreign monetary authorities and foreign central bank swap drawings, as well as by intervention purchases of foreign currency made prior to the period under consideration or by the interest earnings on those prior purchases.

Table 3B

Estimates of Profits from Dollar-Mark Intervention
(rounded to millions of U.S. dollars or equivalent, unless otherwise indicated)

	June 1979-December 1980 (6)	May 1984-September 1984 (7)	January 1981-January 1985 (8)	February 1985-January 1988 (9)
(1) Cumulative net dollars purchased	-250	-50	-2,726	593
(2) Gross dollar purchases and sales	26,155	320	3,252	6,638
(3) Terminal dollar position	735	-45	-3,928	243
(4) Terminal mark position*	-200	61	2,503	1,467
(millions of DM)	(-394)	(186)	(7,960)	(2,483)
(5) Profits	535	16	-1,426	1,711
Memo:				
(6) Profits without net interest earnings	235	13	-761	1,659
(7) Net interest earnings	300	2	-665	52
(8) end-of-period exchange rate (DM/$)	1.9735	3.0615	3.1800	1.6920
Profits based on valuing terminal mark position at:				
(9) 20% stronger dollar	568	5	-1,843	1,466
(10) 20% weaker dollar	485	31	-800	2,078

* Terminal mark positions are elements of the notional intervention portfolios described in the text and are not equal to U.S. official reserve balances, since the terminal positions exclude reserves acquired through means other than intervention. Terminal foreign-currency positions differ from official reserve balances when reserves are augmented by asset exchanges with foreign monetary authorities and foreign central bank swap drawings, as well as by intervention purchases of foreign currency made prior to the period under consideration or by the interest earnings on those prior purchases.

Table 4

Estimates of Profits from Dollar-Yen Intervention
(rounded to millions of U.S. dollars or equivalent, unless otherwise indicated)

	November 1978-January 1979 (1)	December 1978-August 1987 (2)	February 1985-March 1987 (3)	September 1985-March 1987 (4)	February 1985-January 1988 (5)
(1) Cumulative net dollars purchased	-43	2,003	1,047	1,096	5,682
(2) Gross dollar purchases and sales	444	6,674	4,024	3,975	8,808
(3) Terminal dollar position	-40	1,216	903	960	5,691
(4) Terminal yen position*	52	-65	-163	-259	-5,052
(billions of yen)	(11)	(-9)	(-24)	(-38)	(-654)
(5) Profits	12	1,151	740	701	638
Memo:					
(6) Profits without net interest earnings	11	1,104	708	672	509
(7) Net interest earnings	2	47	32	29	130
(8) end-of-period exchange rate (yen/$)	202.75	141.75	146.82	146.82	129.38
Profits based on valuing terminal yen position at:					
(9) 20% stronger dollar	4	1,162	768	744	1,480
(10) 20% weaker dollar	25	1,134	700	636	-625

* Terminal yen positions are elements of the notional intervention portfolios described in the text and are not equal to U.S. official reserve balances, since the terminal positions exclude reserves acquired through means other than intervention. Terminal foreign-currency positions differ from official reserve balances when reserves are augmented by asset exchanges with foreign monetary authorities and foreign central bank swap drawings, as well as by intervention purchases of foreign currency made prior to the period under consideration or by the interest earnings on those prior purchases.

IV. Explanations of the Profitability of U.S. Intervention

Why has U.S. intervention in the floating rate period been profitable? It is difficult to single out any one answer to this question. As shown in charts 1 and 2, the bulk of U.S. intervention profits were generated during two periods--the two episodes of large foreign-exchange exposure from late 1977 to early 1981 and from 1985 to sample-end. If the first 15 years of the floating rate period are characterized as containing only two episodes during which the United States intervened to any significant extent, then our experience with intervention is quite limited. With a sample size of two, it is difficult to rule out pure chance as an explanation for the profitability of U.S. intervention during these periods. But given the large contributions intervention during those periods has made to overall profitability, it is interesting to consider the list of other candidate explanations provided in section II.B. to see which might apply in these two specific episodes of intervention.

A liquidity premium argument could be applicable in part but only in the later episode. This argument relies on the hypothesis that U.S. Treasury assets normally command a liquidity premium over foreign-currency assets. If the United States is on average short dollars and long marks, for example, it could be that the liquidity premium makes the cost of borrowing in dollars smaller than the exchange-rate-adjusted return from holding mark-denominated assets and that profits arise because the United States has been able to take advantage of that spread. In this case, the calculated profits may be considered a return to foregoing the liquidity of holding Treasury securities. This argument might apply to dollar-mark intervention in the later period and to dollar-yen intervention in the later period before April 1987, since during those times the United States was on average short dollars. However, it appears that the premium would have to have been very large, much more than a percentage point, to have been the sole factor generating profits of those magnitudes.

A second possible explanation for the profitability of U.S. intervention involves information asymmetries. The most likely type of inside information concerns the future course of policy, particularly monetary policy. In the earlier period, the rate of dollar depreciation implicit in the dollar-mark interest-rate differential was too large, *ex post*. At the same time, there was a dramatic change in U.S. monetary policy. In the later period, the market appeared to be surprised by the Plaza agreement in September 1985, since the G-5 nations agreed to lean *with* the wind by selling dollars after the dollar had already been falling for six months. Thus, one might explain the large profits associated with U.S. intervention by claiming that U.S. officials had better information about the future course of the dollar and intervened heavily with that in mind.

Elements of market inefficiency, a third possibility, may also have played a part, especially in the later period. Even after U.S. policy became clear in late 1985, interest-rate differentials seriously underpredicted the *ex post* rate of dollar depreciation in 1986. Here and in other periods it could be the case that the market is not setting exchange rates and interest rates efficiently and that U.S. officials do better at judging the future. While this conjecture is consistent with evidence on profitability, it is not very satisfying, since it transforms the issue into why the market is inefficient and why the authorities have keener insight. On the other hand, this conjecture is consistent with the many empirical tests that reject the joint hypothesis of market efficiency and perfect substitutes and with market commentary that refers to investors who trade on the basis of "technical analysis," "chart points," and other non-fundamental factors.

One particular type of market inefficiency is currently under research. If private traders are unwilling or unable to hold long-term positions and central banks are willing to wait "a long time" for exchange rates to return to long-run equilibrium levels, then intervention done when market rates appear to have deviated from levels consistent with a long-run equilibrium, even if the intervention is not effective in moving rates toward that long-run, can be profitable. Without a binding liquidity or solvency constraint, central banks can take on a large foreign-exchange exposure, wait until exchange rates have reversed themselves, and then reduce their exposure. For this outcome to occur, of course, exchange rates and interest rates must move toward some long-run equilibrium, and the intervening officials must be able to recognize what the long-run equilibrium should look like. Recent work on mean reversion in asset market prices and the successful estimation of error-correction models for exchange rates (see Edison [1988]) suggest that long-run forces may indeed be operating in asset markets, albeit slowly. In addition, everyone in the market may know where the dollar has to go in the long run, but not everyone may be willing or able to tie up current resources for a period long enough to profit from that knowledge. If the authorities are not constrained to operate under the same short horizons, then intervention can be profitable in the long run.

One argument I have not considered is whether intervention has been profitable because it has been effective at stabilizing exchange rates. I avoid this explanation for two reasons. First, the empirical results suggest that sterilized intervention does not appear to have had more than a short-term effect on exchange rates. (See Danker, et. al. [1984], Frankel [1982], Loopesko [1984], Rogoff [1984], and Tryon [1983]. Obstfeld [1988] contains a recent survey.) Second, theoretical research exploring the link between profitable speculation and price stability suggests that such a link is problematic. The presumption that profitable speculation is equivalent to stabilizing speculation is based on the reasoning that to earn profits a speculator must buy a commodity when it is cheap and sell it when it is expensive. Numerous studies have shown, however, that the connection is not so straightforward. Salant [1974] presents examples in which profitable speculation increases price variability, and Mayer and Taguchi [1983] show how stabilizing intervention can be unprofitable. Thus, profitable intervention neither implies nor is implied by increased exchange-rate stability. One can see some of the complications by considering two simple examples. If a government purchases foreign exchange when the dollar is strong and sells foreign exchange when the dollar is weak, then, abstracting from interest-rate considerations, intervention will be profitable even if these purchases and sales have no significant effect on exchange rates. Alternatively, if the government successfully stabilizes the exchange value of the dollar so that the exchange rate remains unchanged (and if interest-rate differentials are zero), then intervention profits will be zero.

V. Intervention Profits and the Government Budget Constraint

While it is difficult to infer from the profitability of U.S. intervention that intervention acted as a stabilizing factor in foreign-exchange markets, ex post positive profits do imply an increase in the net worth of the United States government and, consequently, have an impact on the government's budget constraint.[7] Like tax revenue or lottery proceeds, these profits represent an increase in the resources available to the government and a decrease in the resources available to the private sector. The government can use profits to reduce borrowing in domestic or foreign currencies, to increase spending, or to reduce taxes--any of which would be stimulative. On the other hand, however, any stimulative effects of the increase in the government's net worth must be weighed against the depressing effects associated with extraction of the profits. To the extent that the government's gains are losses for the private sector, intervention profits are merely a transfer and need not result in a net stimulus. (Even if the losses were borne entirely by foreign residents, the decrease in foreign net worth would likely have a depressing effect on domestic economic activity.) For example, if private-sector losses induce a reduction in aggregate consumption to

7. Obstfeld [1988] contains a discussion of the links between intervention and government budget constraints in the context of policy credibility.

restore savings, the stimulative effects associated with the government's use of these profits could be offset.

It is conceivable that a tax could be designed that would duplicate the effects on the private sector of the transfer of resources to the government associated with profitable intervention. In that case, the making of intervention profits would be identical to the receipt of a particular kind of tax revenue. And the overall effect on aggregate demand associated with the making of intervention profits then hinges on the question of whether one method of financing a given level of government spending is more or less stimulative than another. If the making and using of intervention profits are characterized as an increase in taxes and a decrease in government borrowing, then the question can be cast as the familiar one of Ricardian equivalence. More generally, profitable intervention is equivalent to a type of transfer, and without more assumptions about the spending propensities of the agents involved, there is no reason to presume that making intervention profits is on net stimulative.

Even if in the U.S. case the net effect on aggregate demand of intervention profits is not zero, the magnitude of the increase in U.S. government net worth over the 15 years of these calculations is quite small. Intervention profits, according to these calculations, have added about $350 million per year to the government's net worth. Compared to the average fiscal deficit during those years of about $100 billion per year, the aggregate demand effect associated with intervention profits is marginal at best.

The preceding discussion applies to the effects on aggregate demand of ex post intervention profits. Ex ante, however, the government's gains may not be identical with private sector's losses. Since no one is forced to deal with the government, one might presume that there are ex ante gains for private agents from taking the other side of the central bank's intervention transaction. Perhaps the long-term perspective of the government, its power to tax, or its different attitudes toward the riskiness of large positions enables it to engage in welfare-enhancing transactions. This issue deserves further investigation.

VI. Summary and Conclusion

U.S. intervention since the onset of generalized floating in 1973 has earned positive economic profits for the U.S. monetary authorities, according to the measurement of the profitability of that intervention presented in this paper. Taken together, it is estimated that U.S. intervention in marks and yen since March 1973 increased the net worth of the Federal Reserve System and the Treasury combined nearly \$5-1/2 billion by January 1988. Overall profitability increased most significantly during those periods when U.S. authorities took on relatively large foreign-exchange exposures--between late 1977 and early 1981 and since the Plaza agreement in September 1985. However, the books are not closed. The terminal foreign-currency positions in the notional intervention portfolios as of the end of January 1988 were large, and thus, cumulated profit estimates through January are subject to change to the extent that exchange rates and interest rates change before these foreign-currency positions are closed out. For example, those positions at exchange rates current during the second week of January 1989 would yield profits about $400 million lower than the profits computed above.

It is difficult to pinpoint the specific reasons for the profitability of U.S. intervention, but explanations that ultimately resort to information asymmetries are consistent with the results and at the same time do not require the abandonment of the efficient markets hypothesis. On the other hand, if one is willing to stray from the assumption of efficient markets, it appears that a possible explanation for intervention profits is the unwillingness or inability of private traders to hold long-term positions. In either case, the fact that intervention profits are positive implies that the government has increased its net worth and that it has avoided turning over profits to "speculators." Profitable intervention does not necessarily imply, however, that intervention has reduced exchange-rate variability nor does it imply that the government's exchange-rate policy has been stimulative in a macroeconomic sense.

Appendix A: Comparison with Earlier Profit Formulas

In this appendix, I analyze the relationships between the profit formula derived in the text and formulas used by others, especially that used by Laurence Jacobson in "Calculations of Profitability for U.S. Dollar-Deutsche Mark Intervention," Federal Reserve Staff Study #131. Jacobson provides a useful study of methods for calculating the profitability of intervention. His analysis incorporates and extends the work of Taylor [1982], Argy [1982], and others to U.S. purchases of dollars against marks between 1973 and 1981. I show that under two assumptions, (i) that interest rates for both currencies are close to zero and (ii) that the values of the exchange rate taken during the period are close to the value at the end of the period, Jacobson's calculation can be considered a first-order approximation to the general formula I present.

Jacobson's Study

Let z be a vector whose elements z_ℓ are the elements of the array $(S_k, S_{k+1}, S_{k+2}, \ldots, S_{t-1}, r_k, r_{k+1}, r_{k+2}, \ldots, r_{t-1}, r_k^*, r_{k+1}^*, r_{k+2}^*, \ldots, r_{t-1}^*)$, and define the function p(z) to be equal to P(k,t):

$$\text{A1)} \quad p(z) = \sum_{i=k}^{t-1} \left[x_i \left\{ \prod_{j=0}^{t-1-i} (1+r_{i+j}) - (S_i/S_t) \prod_{j=0}^{t-1-i} (1+r_{i+j}^*) \right\} \right].$$

Define $\bar{z}$ as the value of z when $S_i = S_t$ for all i and $r_i = r_i^* = 0$ for all i. Then consider a first-order expansion of p(z) around $\bar{z}$:

$$\text{A2)} \quad PJ(z) = p(\bar{z}) + \sum_{\ell} (\partial p(\bar{z})/\partial z_\ell)(z_\ell - \bar{z}_\ell).$$

For z_ℓ equal to S_n, $k \le n \le t-1$, the partial derivative of p(z) with respect to z_ℓ is:

$$\text{A3)} \quad \partial p(z)/\partial S_n = -(x_n/S_t) \prod_{j=0}^{t-1-n} (1+r^*_{n+j}).$$

For z_ℓ equal to r_n, the partial derivative of p(z) with respect to z_ℓ is:

$$\text{A4)} \quad \partial p(z)/\partial r_n = (1/(1+r_n)) \sum_{i=k}^{n} \left[x_i \left\{ \prod_{j=0}^{t-1-i} (1+r_{i+j}) \right\}\right].$$

For z_ℓ equal to r_n^*, the partial derivative of p(z) with respect to z_ℓ is:

$$\text{A5)} \quad \partial p(z)/\partial r_n^* = -(1/(1+r_n^*)) \sum_{i=k}^{n} \left[(S_i x_i/S_t) \left\{ \prod_{j=0}^{t-1-i} (1+r^*_{i+j}) \right\}\right].$$

Using the fact that $p(\bar{z}) = 0$ and evaluating the first derivatives of p(z) at $\bar{z}$, one can show that PJ(z) can be rewritten as:

$$\text{A6)} \quad PJ(z) = \sum_{n=k}^{t-1} \left[x_n(1 - (S_n/S_t)) + (r_n - r_n^*) \sum_{i=k}^{n} x_i \right].$$

This expression for PJ(z) represents the method used by Jacobson to calculate the profitability of intervention and is a first-order approximation to p(z)=P(k,t) at $\bar{z}$. For values of S_i close to S_t and for values of r_i and r_i^* close to zero, PJ(z) and P(k,t) should yield similar profit measures. However, the more volatile are exchange-rate movements (i.e., the further the values of S_i diverge from S_t) and the higher are U.S. and foreign interest rates (i.e., the further r_i and r_i^* diverge from zero), the poorer the approximation will be.

Comparing PJ(z) and P(k,t), one can see that any discrepancies between the two formulas arise from differences in the computation of net interest receipts. To get a sense of the size of the approximation error, I have computed the net interest earnings for dollar-mark intervention for selected periods using both methods. These calculations are presented below.

Table A.1

Net Interest Earnings Comparison
for
Selected Episodes of Dollar-Deutsche Mark Intervention, 1973--1988
(millions of dollars)

Period	$\sum_{n=k}^{t-1}(r_n - r_n^*)\sum_{i=k}^{n} x_i$ (1)	$\sum_{n=k}^{t-1} x_n(\tilde{r}_n - (S_n/S_t)\tilde{r}_n^*)$ (2)	Difference (1) - (2) (3)
1) July 1973 -- August 1973	-0.8	-0.6	-0.1
2) February 1974 -- September 1974	-1.3	-1.2	-0.1
3) October 1974 -- July 1975	0.8	2.0	-1.2
4) January 1976 -- May 1976	0.5	0.6	0.0
5) October 1977 -- January 1981	468.4	745.1	-276.6
6) October 1978 -- May 1979	122.5	131.3	-8.8
7) June 1979 -- December 1980	197.0	300.0	-103.0
8) March 1973 -- December 1981	418.1	919.1	-501.0
9) February 1985- January 1988	-103.9	51.9	-155.8
10) March 1973 -- January 1988	67.6	1,425.2	-1,357.6

Note: Values displayed in column (3) may not equal those displayed in column (1) minus those displayed in column (2) due to rounding.

The table above shows the first-order approximation to net interest earnings in column (1) and the value it approximates in column (2). One can see that the largest discrepancies are in periods 5, 7, 8, 9, and 10--the longest periods considered and the periods for which the dollar-mark exchange rate took its widest range of values. The importance of the large fluctuations in the exchange rate can be seen particularly in period (9), where the column (1) approximation shows a negative contribution to profits while the column (2) value shows a positive contribution. This reversal in sign arises because the value, in terms of 1988 dollars, of the DM interest receipts early in the period, when the United States was buying marks, was nearly double the DM value of the interest receipts, since the value of the mark nearly doubled over that period. Thus, the day-t dollar value of interest flows on day n can be of a different sign than the day-n interest-rate differential. A second element contributing to approximation error may be the neglect of compounding, especially in longer periods that extend into the high interest-rate days of the early 1980s as do periods (7) and (8).

<u>Other Studies</u>

The first part of the summation in the expression for PJ(z), involving only exchange rates and the intervention quantities, reproduces the calculation made by Taylor [1982]. Taylor's calculation would be given by:

$$\text{A7)}\quad PT(z) = \sum_{n=k}^{t-1} x_n(1 - (S_n/S_t)).$$

This expression could also be derived directly from P(k,t) under the assumption that interest rates in the United States and in the foreign country are zero throughout the period.[8]

As Jacobson points out, Argy [1982] restricts his calculations to periods in which net intervention in the foreign asset is zero (i.e., $\sum_{n=k}^{t-1} S_n x_n = 0$). Imposing Argy's constraint on Jacobson's profit measure yields:

$$\text{A8)}\quad PA(z) = \sum_{n=k}^{t-1} x_n + (r_n - r_n^*) \sum_{i=k}^{n} x_i.$$

It is not clear how Argy would impose his constraint on the more general profit measure P(k,t). If one interprets the constraint to mean, as in PA(z), that net intervention in the foreign currency is zero, then the general formula under the Argy constraint is:

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8. PT(z) is a close approximation to the calculations of net profits and losses on foreign currency operations in the report of the Manager of Foreign Operations of the System Open Market Account on Treasury and Federal Reserve Foreign Exchange Operations. That calculation does not measure the economic profits associated with foreign-exchange operations because it ignores some interest flows. Interest earnings that would arise from purchases of dollar-denominated securities as well as the interest foregone on dollar and foreign-currency sales are excluded. Interest earnings on holdings of foreign-currency assets are included, however, and are valued at an exchange rate occurring the date interest is paid.

$$\text{A9)}\quad P_{A1}(k,t) = \sum_{n=k}^{t-1} x_n + \sum_{n=k}^{t-1} x_n(\tilde{r}_n - (S_n/S_t)\tilde{r}_n^*).$$

This interpretation is consistent with Argy's description of his calculation of profits but does not completely eliminate the problem of valuing a terminal foreign-currency reserve position. On the other hand, if one interprets the constraint to mean that the change in the foreign asset position is zero (i.e., $\sum_{n=k}^{t-1} S_n x_n(1+\tilde{r}_n^*) = 0$), then the general formula becomes:

$$\text{A10)}\quad P_{A2}(k,t) = \sum_{n=k}^{t-1} x_n(1 + \tilde{r}_n).$$

The benefit of using P_{A2} is that one need not be concerned with valuing the terminal stock position, since through the proper choice of k and t, that position is zero. In actuality, however, it is probably impossible to find dates in the recent history of U.S. intervention for which the foreign-currency position is exactly zero. This can only be approximated. Appendix B considers the problem of valuing the terminal foreign currency position in more detail.

Appendix B: Terminal Currency Positions and the Initial Position Assumption

In this appendix I first present a simple example that shows how losses in adjacent subperiods do not imply losses for the overall period. Then I show in general terms that the difference between the profit calculation for a given period and the sum of the profit calculations for two, adjacent subperiods is the change in the value of the currency position at the end of the first subperiod. This analysis yields a simple updating formula one could use to extend a profit calculation to include a subsequent period without recalculating profits over the initial period.

Example

Assume that a government wants to stabilize the exchange rate at 1.5 foreign currency units per domestic currency unit and, for simplicity, that interest rates on both assets are zero. Consider the scenario presented in the following table:

Table B.1
Period of Domestic Currency Appreciation

Time	Foreign Currency Price	Intervention Sales of Domestic Currency	Cumulative Domestic Currency Sales	Cumulative Foreign Currency Purchases
1	1.5	0	0	0
2	2	-10	-10	20
3	3	-10	-20	50
4	4	-10	-30	90
5	5	-10	-40	140
6	6	-10	-50	200

At the end of time 6, the calculated loss would be $200/6 - 50 = -16\frac{2}{3}$.

Assume the value of the domestic currency declines subsequently.

Table B.2
Period of Domestic Currency Depreciation

Time	Foreign Currency Price	Intervention Purchases of Domestic Currency	Cumulative Domestic Currency Purchases	Cumulative Foreign Currency Sales
7	5	0	0	0
8	4	0	0	0
9	3	0	0	0
10	2	0	0	0
11	1.5	0	0	0
12	1	10	10	-10
13	0.5	10	20	-15

If we begin with the domestic- and foreign-currency positions at time 7 set to zero, then at time 13 the calculated loss would be -15/0.5 + 20 = -10. However, if we evaluate profits from time 1, profits are (200 - 15)/0.5 + (-50 + 20) = 340. In fact, evaluating intervention from the first subperiod alone at any time after time 8 will show positive profits.

This example points out the difficulties of interpreting profit measures for periods in which there are large accumulations of foreign currency balances. Exchange rate changes can turn what in the first instance appears to be unprofitable intervention into profitable intervention.

A More General Analysis

In general, interest-rate changes and exchange-rate changes alter the subsequent values of currency positions so that profits calculated at one time may be positive and at another, negative. Let TDP(k,q) be the terminal domestic currency position for the first subperiod:

$$\text{B1)} \quad TDP(k,q) = \sum_{i=k}^{q-1} x_i(1+\tilde{r}_i)/(1+\tilde{r}_q).$$

Expression B1) is the sum of domestic currency purchased plus interest earnings between days k and q. The interest rate is adjusted so that compounding ends on day q instead of day t, which is assumed to occur later. The terminal foreign-currency position for the first subperiod is given by:

$$\text{B2)} \quad TFCP(k,q) = \sum_{i=k}^{q-1} (-S_i x_i)(1+\tilde{r}_i^*)/(1+\tilde{r}_q^*).$$

Expression B2) is the sum of foreign currency purchased plus adjusted interest earnings. Combining these two expressions in domestic currency terms gives the domestic currency value of the portfolio on day q as well as the value of profits obtained from applying the profit formula described in the text to intervention between days k and q:

$$B3)\quad VP(k,q,q) = TDP(k,q) + (1/S_q)TFCP(k,q) = P(k,q).$$

The value on day t of the day-q portfolio is:

$$B4)\quad VP(k,q,t) = TDP(k,q)(1+\tilde{r}_q) + (1/S_t)(1+\tilde{r}_q^*)TFCP(k,q).$$

Define E(k,q,t) as the difference between the value of the portfolio at the end of the first subperiod and the value on day t:

$$B5)\quad E(k,q,t) = VP(k,q,t) - VP(k,q,q)$$

$$= (\tilde{r}_q)TDP(k,q) + (1/S_t)(\tilde{r}_q^*)TFCP(k,q)$$

$$+ \left\{(1/S_t) - (1/S_q)\right\}TFCP(k,q).$$

One can see that E depends on both the domestic- and foreign-currency interest rates as well as on the change in the exchange rate. When terminal currency positions are large, the profits associated with a given sequence of intervention between days k and q will be subject to potentially large revisions if they are reevaluated later at different exchange rates and if interest earnings are large.

It is now straightforward to show that E is the difference of the sum of the two subperiod profit calculations and the profit calculation for the whole period, i.e.,

$$B6)\quad P(k,t) = P(k,q) + P(q,t) + E(k,q,t).$$

Thus, if $E > 0$, it is possible for $P(k,t)$ to be positive even when $P(k,q) < 0$ and $P(q,t) < 0$.

Furthermore, from this analysis one can see how it is possible to extend a profit calculation to a longer time period without resurrecting data on intervention, interest rates, and exchange rates prior to day q. If one knows the terminal currency positions at time q, no data prior to day q is needed to calculate $P(k,t)$. The updating formula is given below.

$$B7)\quad P(k,t) = VP(k,q,t) + P(q,t)$$

$$= TDP(k,q)(1+\tilde{r}_q) + (1/S_t)(1+\tilde{r}^*_q)TFCP(k,q) + P(q,t).$$

Appendix C: Profit Formulas for Intervention in the Forward Market

Simple Forward Market Intervention

Let y_i represent purchases on day i of domestic currency τ days forward against a foreign currency and F_i represent the forward price on day i of domestic currency to be traded against the foreign currency on day $i+\tau$. When the government purchases y_i domestic currency forward on day i, it is assumed that nothing of value is exchanged until day $i+\tau$. On day $i+\tau$ the domestic currency purchased are invested at interest rate $r_{i+\tau}$, and on subsequent days the principal and interest are reinvested until day t. Thus, the value on day t of forward intervention on day i is given by:

$$VFI_i = y_i(1+r_{i+\tau})(1+r_{i+\tau+1})(1+r_{i+\tau+2})\cdots(1+r_{t-1})$$

$$= y_i \prod_{j=0}^{t-1-i-\tau} (1+r_{i+\tau+j}) = y_i(1+\tilde{r}_{i+\tau}),$$

where it is assumed that $i < t-\tau$. Forward intervention between days $t-\tau$ and t is assumed to have no effect on the day-t value of the government's portfolio.

A sequence of forward purchases that began on day k and ended on day $t-\tau$ would yield the terminal domestic currency position on day t:

$$TDP(k,t) = \sum_{i=k}^{t-\tau-1} VFI_i + y_{t-\tau} = \sum_{i=k}^{t-\tau-1} y_i(1+\tilde{r}_{i+\tau}) + y_{t-\tau}.$$

The opportunity cost of this sequence of forward purchases is:

$$\sum_{i=k}^{t-\tau-1} OCFI_i + y_{t-\tau} = \sum_{i=k}^{t-\tau-1} (F_i y_i/S_t)(1+\tilde{r}^*_{i+\tau}) + y_{t-\tau}.$$

$$= -(1/S_t)TFCP(k,t)$$

Thus, the profits associated with this sequence of forward purchases are given by:

$$PF(k,t) = \sum_{i=k}^{t-\tau-1} VFI_i - \sum_{i=k}^{t-\tau-1} OCFI_i$$

$$= \sum_{i=k}^{t-\tau-1} y_i\left\{(1+\tilde{r}_{i+\tau}) - (F_i/S_t)(1+\tilde{r}^*_{i+\tau})\right\}$$

<u>Forward Intervention with Swaps</u>

Case A: Rollover of Domestic Position Position

In this section I describe a formula that can be used to calculate the profits associated with intervention in the forward market and subsequent rollovers of the forward domestic currency position through swaps.

Define J(i) as the greatest integer less than or equal to

$(t-i)/\tau$. The value of $J(i)$ represents the number of forward contracts made between day i and day t when the forward position is rolled over with swaps. It is assumed that the maturity of these forward contracts remains fixed at τ days. Thus, after a forward purchase on day i, there will be $J(i)-1$ swaps made before day t. If doing one more swap would extend the maturity of the forward position beyond day t, it is assumed resulting currency position is held until day t.

The profit from forward intervention when the domestic currency position is rolled over is given by PFRD(k,t):

$$\text{PFRD}(k,t) = \sum_{i=k}^{t-\tau-1} \Big[y_i \Big\{ (1+\tilde{r}_{i+\tau*J(i)}) - (F_{i+\tau(J(i)-1)}/S_t)(1+\tilde{r}^*_{i+\tau*J(i)}) \Big\}$$

$$+ y_i \Big\{ (1/S_t) \sum_{j=1}^{J(i)-1} (S_{i+\tau*j} - F_{i+\tau(j-1)})(1+\tilde{r}^*_{i+\tau*j}) \Big\} \Big]$$

The first term on the right-hand side above corresponds to a simple forward intervention $J(i)*\tau$ days forward and represents the forward purchase rolled into the future every τ days with the $J(i)-1$ swap transactions. One can see that if $J(i)=1$ that this term is identical with the expression for the profit from a simple forward transaction. The remaining term corresponds to the profits associated with the swap transactions. Because in this case it is assumed that the domestic currency position is rolled over, profits and losses are held in foreign currency and only the foreign-currency interest rate is needed to calculate the associated interest flows.

Case B: Rollover of Foreign-Currency Position

The profit from forward intervention when the foreign-currency position is rolled over is given by PFRFC(k,t):

$$PFRFC(k,t) = \sum_{i=k}^{t-\tau-1} \Big[(F_i y_i / F_{i+\tau(J(i)-1)}) \Big\{ (1+\tilde{r}_{i+\tau*J(i)}) - (F_{i+\tau(J(i)-1)}/S_t)(1+\tilde{r}^*_{i+\tau*J(i)}) \Big\}$$

$$+ F_i y_i \Big\{ \sum_{j=1}^{J(i)-1} [(1/F_{i+\tau(j-1)}) - (1/S_{i+\tau*j})](1+\tilde{r}_{i+\tau*j}) \Big\} \Big]$$

Appendix D: Data

Interest Rates

United States -- daily observations[9] on U.S. three-month Treasury bill rate, quoted on a discount basis at an annual rate using a 360-day year, from January 1, 1973 to February 1, 1988. Source: Federal Reserve Bank of New York.

-- these discount rates were converted to daily yields using the following formula:

$$\frac{\text{(discount rate)}/100}{360 - (91)\text{(discount rate)}/100},$$

where 91 days is assumed to be the maturity of the bill quoted each day.

Germany -- daily observations on domestic German three-month interbank interest rates, assumed to be quoted on a simple-interest basis at an annual rate using a 360-day year, from January 1, 1973 to February 1, 1988. The annual rate was decreased by 25 basis points to obtain a better approximation to the actual rate of return on U.S. holdings of DM reserves at the Bundesbank. Source: International Finance Division database, Federal Reserve Board.

Japan -- Two interest-rate series were spliced to obtain Japanese interest rates covering the whole period. From January

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9. Interest rates on Saturdays, Sundays, and holidays are assumed to be the same as on the previous business day in the country. Exchange rates on Saturdays, Sundays, and holidays are assumed to be the same as on the previous business day in the New York market.

1, 1973 to March 1, 1979, I used daily observations on interest rates quoted for "over-two-month-end" loans in Japan. From March 2, 1979 to February 1, 1988, I used daily observations on three-month gensaki rates. Both of these were assumed to be quoted on a simple-interest basis at an annual rate using a 365-day year. Source: International Finance Division database, Federal Reserve Board.

Intervention Data

Class II FOMC - Strictly Confidential (FR) data on U.S. official purchases of dollars against yen and dollars against marks, daily observations. Sources: from January 1, 1973 to December 31, 1976, Federal Reserve Bank of New York; from January 3, 1977 to February 1, 1988, International Finance Division database, Federal Reserve Board.

Exchange Rates

Dollar/mark and dollar/yen exchange rates are daily observations of noon spot rates in New York City from January 1, 1973 to February 1, 1988. Source: International Finance Division database, Federal Reserve Board.

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