Exchange Rate Policy and Shocks to Asset Markets: The Case of Taiwan in the 1980s

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This paper uses a simple theoretical model to show how the credibility of unsterilized intervention policy may affect the pattern of adjustment in the exchange rate, velocity, and asset prices. When the outcome of unsterilized intervention is credible, any degree of exchange rate stability can be achieved at the cost of a sufficiently large, one-time change in the money supply. When the outcome of intervention is not credible, intervention can lead to persistent, and possibly accelerating, changes in exchange rates, the money supply, velocity, and asset prices. Under certain conditions, intervention may even amplify the cumulative change in the exchange rate, rather than reduce it. The model is used to interpret Taiwan's experience with unsterilized exchange rate intervention in the second half of the 1980s.

Over the past decade, international capital mobility in many Pacific Basin economies has increased considerably. This trend has made it more difficult for policymakers to stabilize the foreign value of their currencies. The greater ability of speculators to buy and sell domestic currency in foreign exchange markets has in some cases resulted in unwelcome fluctuations in currency values, in spite of government efforts to limit such fluctuations.

Some progress has been made in understanding the problems of stabilizing the exchange rate in economies with mobile international capital. Research in open economy macroeconomics since the 1960s describes how disturbances to foreign exchange markets and government policies affect exchange rate behavior given certain institutional features of the economy, such as the degree of capital mobility or asset substitutability.

More recently, research has clarified how credibility affects the ability of the government to enforce an exchange rate target. For example, Krugman (1979) shows how government attempts to peg the exchange rate with limited foreign exchange reserves may lead to speculative attack and an abandonment of the peg. Another literature (see Lessard and Williamson 1987) analyzes capital flight in economies that are forced to deal with serious macroeconomic imbalances or that are saddled with large external debt burdens. Such capital flight may impair the government's ability to stabilize the exchange rate. However, these approaches do not necessarily highlight the difficulties that may arise when a well-managed economy (one that faces no foreign exchange reserve constraints, maintains a largely balanced government budget, and has no external debt burden) attempts to stabilize its currency.

This paper draws on the experience of Taiwan in the 1980s to shed some light on these potential difficulties. Due to certain asymmetries in foreign exchange controls, Taiwan had a relatively high degree of capital mobility up to 1987, while it maintained a policy of limiting movements in the exchange rate. Taiwan's relative openness exposed it to disturbances to its foreign exchange markets in the second half of the 1980s that illustrate the difficulties that may arise when a country attempts to stabilize its exchange rate.

Two features of Taiwan's experience in the 1980s are of particular interest. First, following a period of tranquility in foreign exchange markets in the first half of 1980s, the New Taiwan (NT) dollar appreciated at an accelerating rate against the U.S. dollar from late 1985 through 1987, in spite of increasing intervention in exchange markets designed to limit such appreciation.[1] Second, in spite of the steep acceleration in money growth associated with intervention after 1985, there was relatively little inflation in the goods market. Rapid money growth was associated instead with a persistent decline in the income velocity of money and a boom in asset prices. Neither the persistent acceleration in exchange rate appreciation, nor the relationship between money growth and domestic goods and asset prices have been fully explained.[2]

This paper suggests that the persistent and accelerating appreciation of the NT dollar may have been related to government efforts to limit such appreciation. Some simple examples are offered to illustrate how such a situation may arise if the government's exchange rate policy loses credibility. Using a conventional small open economy model, it is also shown that intervention in response to disturbances in Taiwan's foreign exchange markets may have contributed to persistent declines in the income velocity of money and to the boom in Taiwan's asset prices. It is suggested that weak international arbitrage links, which are at least partly attributable to Taiwan's relatively undeveloped domestic financial markets, facilitated the sharp changes in asset prices. While the paper uses conventional analytical tools, it offers a new way of thinking about the interaction between exchange market intervention and exchange rate expectations and about the potential effects of such interaction.

The paper is organized as follows. Section I provides some background on Taiwan's exchange rate policy, capital mobility, and the domestic financial sector. Section II describes a simple theoretical model that can be used to examine the likely effects of Taiwan's exchange rate policy on the persistence of shocks to exchange rate expectations and the behavior of money, velocity, and asset prices. Section III interprets Taiwan's experience using the framework developed earlier. Section IV sums up some of the lessons of Taiwan's experience.

I. Exchange Rate Policy, Capital Controls and the Domestic Financial Sector[3]

To set the context for the theoretical analysis that follows, we review the characteristics of Taiwan's exchange rate policy, capital controls, and financial markets. Table 1 summarizes the evolution of Taiwan's external and domestic financial sector policies in the 1980s.

Exchange Rate Policy

The government's exchange rate policy in the 1980s reflected two basic criteria. Beginning in September 1982, daily fluctuations in the currency were limited by a policy rule requiring that the daily adjustment (upward or downward) of the spot rate not exceed 2.25 percent of the central rate on the previous business day. This rule was in effect until April 1989, when the currency was floated. Policymakers also sought to prevent currency movements from excessively impairing the competitiveness of Taiwan's export sector by limiting the rate of appreciation of the currency.

Controls on Capital Outflows, Not Inflows

The implementation of exchange rate policy also was influenced by the nature of capital controls. Until 1987 capital controls in Taiwan focused on preventing capital outflows. For example, the government required that all foreign exchange be sold to the central bank in exchange for local currency. (Authorized foreign currency deposits in local banks were exempt.) In contrast to the stringent controls on outflows, Taiwan historically had no effective controls on capital inflows. In particular, foreign asset holders could easily acquire NT dollar assets through the banking sector.

The asymmetry in Taiwan's capital controls was reduced in 1987 when the government significantly tightened restrictions on capital inflows while liberalizing capital outflows. (These measures were in response to a surge in short-term capital inflows discussed later.) In May 1987, the government froze the outstanding amount of commercial banks' foreign liabilities at US$13.8 billion (the level of May 31, 1987) and in July 1987 restricted inward remittances for each person to US$50,000 per year. Restrictions on capital inflows were liberalized in 1989 when the limit on individual remittances was raised to US$200,000 in July, to US$500,000 in September, and to US$1 million in November 1989.

At about the same time as restrictions on capital inflows were being imposed, restrictions on capital outflows were liberalized. Current account transactions were completely liberalized on July 15, 1987, and individuals or companies were allowed to purchase and remit outward up to an annual limit of US$5 million.

Thin and Underdeveloped Markets

As is the case in many developing economies, Taiwan's domestic financial markets are relatively underdeveloped.

Table 1

Financial Sector Policies

	pre-1979
External	New Taiwan (NT) dollar pegged to the U.S. dollar.
	All foreign exchange transactions require government approval. Current account transactions and capital outflows restricted. Exporters required to surrender their foreign currency earnings to the government.
	Moderate restrictions on foreign borrowing by financial institutions, and on certain capital inflows.
Domestic	Government determines interest rates set by banks and in money and capital markets.
	1979
External	***February*** The foreign exchange market is established and a managed float is adopted.
	The spot central rate of the U.S. dollar against the NT dollar henceforth to be set daily by 5 major authorized banks on the basis of the weighted average of interbank transaction rates on the previous business day.
	The buying and selling rates for the U.S. dollar between the bank and the customer are set within the limit of NT$0.05 above or below the central rate for transactions up to US$30,000. For larger transactions, the corresponding limit is NT$0.10.
	1980
External	***January*** Privately held foreign currency deposits in authorized banks permitted.
	March Daily exchange rate ceiling abandoned by Central Bank.
Domestic	***November*** Banks allowed to set their own interest rates on NCDs and debentures, as well as on bill discounts.
	A committee of the Bankers' Association is authorized to set, on a monthly basis, actual deposit and loan rates within ceilings determined by the Central Bank. The Central Bank sets maximum deposit rates and maximum and minimum loan rates.
	Interest rates on commercial paper, bankers' acceptances and Treasury bills are fully liberalized.
	1982
External	***September*** Central rate trading system established in the foreign exchange market with the exchange rate to be based on the daily weighted average exchange rate of interbank trading.
	1983
External	***December*** Offshore Banking Statutes established allowing local banks to engage in offshore banking business.
	1984
External	***August*** Bank restrictions on the holding of long positions in foreign currencies removed.
Domestic	***November*** Range of maximum and minimum loan rates widened by the Central Bank. The base loan rate lowered ½ percentage point.

(continued)

Table 1 - Financial Sector Policies *(continued)*

	1985
Domestic	***March*** Banks allowed to set prime rate according to market conditions.
	August Banks allowed to set own rates on foreign currency deposits.
	Banker's association to set the range of maximum and minimum lending rates while the individual banks allowed to charge customer rates based on credit rating and loan maturity date.
	1986
External	***October*** Allowed foreign banks to set up second branches in Taiwan.
Domestic	***March*** Limitation on the holding position and underwriting of short-term bills issued by any single firm removed.
	Upper limit on commercial paper underwriting for the branches of foreign banks raised.
	1987
External	***May*** The Central Bank freezes the outstanding amount of commercial banks' foreign liabilities at US$ 13.8 billion, the level of May 31, 1987.
	June Foreign banks permitted to join the local inter-bank remittance system and the interbank ATM sharing system.
	July Current account transactions are completely liberalized on July 15. Requirements to surrender export proceeds, advanced import deposits and restrictions on payments for invisibles are lifted.
	An individual or a company is allowed to purchase and remit outward up to an annual limit of US$5 million.
	A ceiling on inward remittances for each person set at US$50,000 per year.
	October The Central Bank lifts the freeze on banks' foreign liabilities on October 1, 1987. Following capital inflow of $3 billion, the Central Bank reimposes a freeze at $16.2 billion on October 2.
	Borrowing of foreign exchange by nonbanks is not subject to the freeze.
	1989
External	***April*** A new system of foreign exchange trading is established, based on bid-ask quotations. The new system applies to interbank trading and retail trading over US$10,000. The previous limits on daily fluctuations of the interbank rate are rescinded.
	July The ceiling for banks' foreign liability is raised to 30% of the average daily balance during the 45-day period ended July 15, 1989.
	The ceiling for inward remittances for each person is raised to US$200,000 on July 20.
	August Foreign exchange interbank call loan market established.
	September Annual capital inflow increased from US$200,000 to US$500,000 per person.
	November Capital inflow limitation increased to US$1 million per individual.
Domestic	***July*** All remaining regulations controlling maximum deposit rates and maximum and minimum loan rates are eliminated.

Although interest rate restrictions were gradually liberalized in the 1980s and a 1989 banking law significantly liberalized entry by allowing foreign banks to offer a full range of banking services, restrictions on the financial sector had an important effect on financial market behavior for much of the decade. Financial policies have traditionally guaranteed a dominant role for government-owned domestic banks. These policies included entry restrictions (particularly branching and operational restrictions that have limited the activities of foreign banks) and restrictions on deposit and loan interest rates that tended to limit competitive pressures.[4]

Financial sector restrictions tended to segment financial markets and reduced the allocation of funds outside the regulated financial sector. Flow of funds data reported by the Central Bank of China (1989) indicate that up to the mid-1980s, more than 50 percent of the financial uses of funds of households and non-profit institutions were channeled to regulated financial market intermediaries, notably banks.

Outside of regulated financial intermediaries, the bulk of household funds was channeled to two sectors. First, households placed funds in the unregulated "curb" market. On average, this sector accounted for less than 8 percent of household uses of funds, and its share tended to decline in the 1980s. Second, households invested between 1/5 and 1/3 of their funds in capital markets. The bulk of such investment was in the direct acquisition of shares in enterprises or in the stock market.

Stock market shares were the only tradable securities readily available to household investors. By all accounts, this market was quite thin, and a relatively limited amount of capital was raised in this market. In the period 1980-85, companies listed in the stock market accounted for only about 16 percent of the total capital of Taiwan enterprises, so that households may have allocated as little as 3 percent (the 20 percent total flow allocated to capital markets times the 16 percent share of listed firms in the capital of registered enterprises) of their funds to the stock market in the 1980s.

The allocation of household funds to long-term bonds, or to money markets was negligible. The holding of long-term bonds (mainly central bank securities) and money market instruments (negotiable certificates of deposit, bankers acceptances, and commercial paper) was dominated by financial intermediaries.

To sum up, three features characterize the macroeconomic and financial environment in the 1980s. First, exchange rate policy was influenced by the desire of policymakers to preserve the competitiveness of the export sector and by a policy rule that limited fluctuations in the exchange rate. Second, until 1987, capital controls curbed capital outflows but did not effectively restrict capital inflows. Subsequently, capital outflows were liberalized, while inflows were restricted. Third, Taiwan's secondary financial markets were thin and underdeveloped.

II. A Small Open Economy Model

To assess the implications of the institutional characteristics of Taiwan's economy, consider a static, small open economy model with flexible prices. There are three assets: domestic money (m), a domestic financial asset earning nonzero returns (h) which will be called a bond, and a foreign asset (f) denominated in foreign currency.

For convenience, the return on the foreign asset is fixed at zero. Real money demand is then a function of the nominal return on the domestic asset (i), the expected rate of appreciation of the domestic currency (x), real wealth (w), and real income (y). In what follows variables in lower case, except for i and x, are in logs. To simplify the discussion, which is mainly concerned with the effects of shocks to exchange rate expectations, we assume inflationary expectations are exogenous and set them to zero.

In equilibrium real money supply equals real money demand:

$$(1) \qquad m_t^s - p_t = m_i i_t + m_x x_t + m_y y_t + m_w w_t$$

where p is the domestic price and $m_i<0$; m_x, m_y, $m_w>0$. In equation (1), i reflects the opportunity cost of holding money rather than the domestic bond, while x is the cost of holding the foreign asset.

The equilibrium in the market for the foreign asset may be expressed as follows:

$$(2) \qquad f_t^s - (s_t + p_t) = f_i i_t + f_x x_t + f_y y_t + f_w w_t$$

where s_t denotes the nominal exchange rate (foreign currency/NT$). It is assumed that $f_i, f_x<0, f_x, f_w>0$. Since real money and foreign asset and domestic bond holdings comprise total wealth, equilibrium in the domestic bond (h) market follows from the wealth constraint and equations (1) and (2).

The economy produces a single internationally traded good. Domestic demand (a_t) depends on wealth, while net exports (b_t) are determined by wealth and the real exchange rate $r_t = s_t + p_t - p_t^*$, where p_t^* denotes the (exogenous) foreign price. Equilibrium in the goods market requires that the sum of domestic and net export demand equal an exogenously determined national income:[5]

(3) $y_t = a_t + b_t = a_w w_t + b_w w_t + b_r r_t,$

where a_w, $b_w > 0$; $b_r < 0$. In the model, s, p, and r are endogenous and can be solved using equations (1), (2), and (3). As shown in Appendix A, the model yields the following reduced form responses to shocks to the exogenous variables:[6]

(4) $\Delta s_t = s_x \Delta x_t + s_m \Delta m_t^s + s_f \Delta f_t^s,$

$s_x > 0,\ s_m < 0,\ s_f > 0$

(5) $\Delta p_t = p_x \Delta x_t + p_m \Delta m_t^s + p_f \Delta f_t^s,$

$p_x < 0,\ p_M > 0,\ p_f < 0$

(6) $\Delta i_t = i_x \Delta x_t + i_m \Delta m_t^s + i_f \Delta f_t^s,$

$i_x < 0,\ i_m < 0,\ i_f < 0,$

where Δ is the first difference operator, so $\Delta s_t = s_t - s_{t-1}$. We focus on the effects of disturbances to exchange rate expectations, the money supply, and foreign assets because they are particularly relevant for Taiwan's case over the time period being discussed.

Under plausible assumptions, an expected appreciation (a rise in x) increases the demand for domestic assets, resulting in currency appreciation, a lower price level, and a decline in the domestic interest rate. An increase in the money supply creates an excess supply of money, resulting in the depreciation of the domestic currency, an increase in the domestic price level, and a lower domestic interest rate. An increase in the supply of the foreign asset creates an excess demand for domestic assets, resulting in currency appreciation, a lower price level and a decline in the domestic interest rate (qualitatively the same as an expected appreciation). These effects conform to what might be expected from intuition.

Implications of Institutional Characteristics

The institutional characteristics of Taiwan's economy described in Section I affect the specification of the model or the model's parameters in a number of ways. In Taiwan, the absence of restrictions on capital inflows allowed speculators to arbitrage between domestic and foreign assets (it is assumed that speculators who use foreign assets to acquire domestic assets can reverse such transactions with relative ease, as seems to have been the case in Taiwan). This is reflected in the assumption that exchange rate expectations affect the demand for domestic assets. If capital controls were effective, speculators would be unable to exchange their foreign assets for domestic assets in response to changes in exchange rate expectations, and the terms s_x, p_x, i_x in equations (4) to (6) would equal zero.

In small open economy models that assume perfect substitutability between domestic and foreign assets, the domestic interest rate is determined by the interest parity condition $i = x$. However, the thin and relatively less developed financial markets of Taiwan suggest that domestic and foreign assets are imperfect substitutes. As a result, the domestic interest rate i, and exchange rate expectations x enter separately in the model rather than being directly linked by an arbitrage condition.[7] Thin and undeveloped financial markets also reduce the interest sensitivity of the demand for money and foreign assets (m_i and f_i). Inspection of Appendix A shows that this increases the response of interest rates (or asset prices) to shocks to exchange rate expectations or to changes in the supply of domestic money or foreign assets (i_x, i_m, i_f increase in equation (6)). Relatively weak arbitrage links may partly explain why certain asset prices in Taiwan—notably the stock price—changed much more sharply than did comparable asset prices in the U.S. and Japan in the later part of the 1980s.

Implications of Exchange Rate Policy

Adjustment when the intervention outcome is credible. To highlight the consequences of central bank intervention more fully, it is useful to recall that the central bank can change the money supply in two ways. First, it can intervene in the foreign exchange market, which will be reflected in changes in the net foreign assets held by the central bank, labeled f_t^{cb}. Second, it can undertake open market purchases or sales of domestic bonds that change the supply of domestic credit, d_t. These implications of the central bank balance sheet are approximated by:

(7) $\Delta m_t = \omega \Delta f_t^{cb} + (1 - \omega) \Delta d_t,$

where ω, $1 - \omega$ are respectively the average weights of net foreign and domestic assets in the central bank balance sheet.[8] We assume for now that the government changes the money supply only by intervening in foreign exchange markets and that there are no domestic open market operations, so $\Delta d_t = 0$. This is known as "unsterilized" intervention.

Suppose a shock raises the expected rate of appreciation in the currency from 0 in period 0 to x_1 in period 1. The net change in the exchange rate in response to this shock is the sum of the changes in the exchange rate attributable to the private sector and the government,

(8) $\Delta s_1 = \Delta s_1^p + \Delta s_1^g$,

where the numeral subscripts refer to the time period. The change in the exchange rate attributable to the private sector follows from equation (4):

(9) $\Delta s_1^p = s_x \Delta x_1$.

The change in the exchange rate attributable to the government depends on the government's exchange rate policy. Suppose that the government has a policy of reducing the rate of change in the exchange rate that would otherwise result from private sector actions by a proportion $0 \leq \alpha < 1$. This policy can be described by the following equation:

(10) $\Delta s_1^g = -\alpha \Delta s_1^p = -\alpha s_x \Delta x_1$.

The first equality in equation (10) is the government's exchange rate rule. The second equality follows from equation (9). Equations (8), (9), and (10) then imply that the one-period change in the exchange rate in response to a shock to exchange rate expectations is:

(11) $\Delta s_1 = (1 - \alpha) s_x \Delta x_1$.

The central bank can implement the exchange rate rule (10) by increasing the money supply in order to purchase foreign bonds in the foreign exchange market. In the absence of offsetting domestic open market operations, this will be reflected in an increase in the money supply and a matching reduction in the supply of foreign assets held by domestic residents ($\Delta m_1^s = -\Delta f_1^s$). Equations (4) and (9) imply that in order to meet the central bank's foreign exchange target, the money supply must adjust to a shock to exchange rate expectations according to the following:[9]

(12) $\Delta m_1^s = \dfrac{-\alpha s_x \Delta x_1}{s_{nfa}}$,

where we define the coefficient $s_{nfa} \equiv s_m - s_f < 0$. In the absence of domestic open market operations, the central bank balance sheet relationship (7) implies that $\Delta m_1^s = \omega \Delta f_1^{cb}$. (The reader may recall that ω, the average share of foreign assets held by the central bank, appears in this expression because we are using a log approximation to the central bank balance sheet.) Using this last equality to substitute for Δm_1^s in equation (12), we find the increase in the foreign assets held by the central bank that is consistent with the exchange rate target, given an initial shock to exchange rate expectations:

(13) $\omega \Delta f_1^{cb} = \dfrac{-\alpha s_x \Delta x_1}{s_{nfa}}$.

We can use the preceding framework to assess the implications of policy and behavioral parameters. Equation (11) implies that the government can limit exchange rate changes to any degree desired by increasing the intervention parameter α. However, greater exchange rate stability will be associated with a larger change in the money supply and in the net foreign assets held by the central bank (equations (12) and (13)). This is a familiar tradeoff.

Equations (12) and (13) also indicate that the volume of intervention required to satisfy the exchange rate objective (10) is a function of institutional and behavioral parameters. The required intervention is larger, the larger the impact of expectations on the exchange rate s_x. As discussed in Section I, if capital were not mobile, $s_x = 0$ and no intervention would be required for the government to achieve its exchange rate target. The required intervention is smaller, the larger the impact of such intervention on the exchange rate (s_{nfa}).

Adjustment when the intervention outcome is not credible. The discussion up to this point has focused on the one-period response to a shock to exchange rate expectations. The total change in the exchange rate in the long run will depend on how expectations, so far treated as exogenous, are affected by intervention. Suppose that the outcome of intervention is credible, in the sense that speculators believe that there will be no further change in the exchange rate. Then agents will make no further effort to acquire domestic assets. Equation (11) then describes the total change in the exchange rate that will occur in response to the initial shock to exchange rate expectations.

To see how the pattern of adjustment differs when the outcome of intervention is not credible, assume that speculators believe that the exchange rate must ultimately adjust to some target exchange rate s^*, regardless of the short-run attempts of policymakers to prevent such adjustment. We can think of s^* as the level of the exchange rate that will satisfy some long-run equilibrium condition (for example, the value of the exchange rate that will guarantee that the net present value of an economy's external liabilities is zero). Alternatively, we can think of s^* as the level of the exchange rate that is seen as acceptable by a country's major trading partners or a country's creditors.

Consider now a shock to exchange rate expectations in period 1, caused by a one-time increase in s^* above the spot exchange rate, or $(s^* - s_0) > 0$. Speculators acquire domestic assets on the expectation that the gap between the target exchange rate s^* and the spot rate s_0 will be eliminated.

When markets reopen in the next period, the government has prevented full adjustment in the spot rate to s^* by the proportion $(1-\alpha)$ (as in equation (11)), and speculators again acquire domestic assets on the expectation that the remaining gap between s^* and the spot rate will be eliminated. This process of repeated domestic asset acquisition and intervention will continue in subsequent periods, producing further changes in the exchange rate. In effect, we can say that intervention spreads the initial shock to exchange rate expectations over several periods. In each period, the shock to expectations is measured by the gap between the target rate and the spot rate:

$$(14)\quad \Delta x_t = s^* - s_{t-1};\ t = 1,2,3,\ldots,$$

where Δx_t is now the shock to exchange rate expectations that occurs in each period as a result of the initial increase in s^* above s_0.

In equation (14), the path of Δx_t depends on the path of s_t. We can solve for the path of s_t by using equations (4) and (14), which yield the following difference equation:

$$(15)\quad \Delta s_t = s_x(1-\alpha)\Delta x_t = s_x(1-\alpha)(s^* - s_{t-1});\ t = 1,2,\ldots,$$

where the coefficient s_x is implied by equation (4).[10]

As discussed in Appendix B, the solution to equation (15) is:

$$(16)\quad \Delta s_t = s_x(1-\alpha)\beta^{t-1}(s^* - s_0);\ t = 1,2,3,\ldots,$$

where $0 \leq \beta = 1 - s_x(1-\alpha) \leq 1$. Equation (16) shows that the rate of change in the exchange rate in each period after the initial shock depends on the rate of intervention α and the magnitude of the initial shock to exchange rate expectations. The term β^{t-1} implies that the rate of change in the exchange rate declines asymptotically towards zero. In the absence of intervention ($\alpha = 0$), the full impact of the shock to expectations is felt in the first period, and according to equation (4) the exchange rate changes by $\Delta s_1 = s_x(s^* - s_0)$.

From equation (16), the cumulative change in the exchange rate over T periods that is associated with the initial shock is:

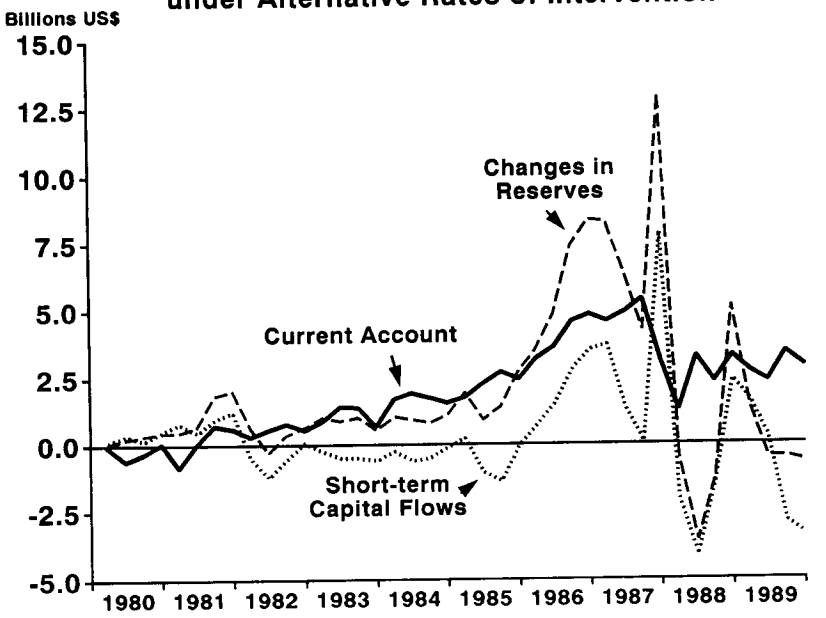
$$(17)\quad \sum_{t=1}^{T} \Delta s_t = (1-\alpha)s_x \sum_{t=1}^{T} \beta^{t-1}(s^* - s_0).$$

Chart 1 illustrates the path of exchange rate changes implied by equation (16). The area under the curve is measured by equation (17). The chart assumes a 100 percent appreciation in the target exchange rate s^*, and $s_x = 1$. The paths of exchange rate changes are illustrated for the cases in which the rate of appreciation in each period is limited to 2.5 percent ($\alpha = 0.975$) and 10 percent ($\alpha = 0.9$).

Inspection of the chart and the equations suggests that

Chart 1

Response to Appreciation in Target Exchange Rate under Alternative Rates of Intervention



the expectation that the spot exchange rate in any given period will tend to some target s^* affects the pattern of exchange rate adjustment in a number of ways.

First, *intervention can distribute the impact of a one-time shock to expectations over time under certain assumptions about the adjustment of expectations.* The reason is that speculators seek to acquire domestic currency—and create upward pressure on the currency—in every period so long as the exchange rate is below s^*. In contrast, when the outcome of intervention is credible (as in equation (11)), the exchange rate change lasts only one period.

Second, *intervention is effective in the short run, but not in the long run.* In the absence of intervention ($\alpha = 0$), the spot exchange rate would appreciate 100 percent in one period, and there would be no further changes in the exchange rate. In contrast, in Chart 1, for the case $\alpha = 0.9$, the cumulative change in the exchange rate is limited to 10 percent in the first period and 65 percent after 10 periods. While intervention does stabilize the exchange rate in the short run, in the very long run the spot rate converges to s^*.[11]

Third, *the cumulative intervention is larger when the outcome of intervention is not credible.* Equation (13) is now the starting point for a sequence of intervention actions, rather than representing the total intervention. Cumulative intervention over T periods is now given by:

$$(18) \qquad \omega \Delta f_t^{cb} = -\alpha \frac{S_x}{S_{nfa}} \sum_{t=1}^{T} \Delta x_t = -\alpha \frac{S_x}{S_{nfa}} \sum_{t=1}^{T} \beta^{t-1}(s^* - s_0),$$

where the second equality follows because, from equations (15) and (16), $\Delta x_t = \beta^{t-1}(s^* - s_0)$. Over an infinite horizon, cumulative intervention is:

$$(18') \qquad \lim_{T\to\infty} \omega \sum_{t=1}^{T} \Delta f_t^{cb} = \frac{-\alpha s_x (s^* - s_0)}{S_{nfa}} \lim_{T\to\infty} \left[\sum_{t=1}^{T} \beta^{t-1} \right]$$
$$= -\frac{\alpha (s^* - s_0)}{(1-\alpha) S_{nfa}},$$

which exceeds intervention in equation (13) by

$$\frac{\alpha\beta (s^* - s_0)}{(1-\alpha) S_{nfa}}.$$

Fourth, *the rate of intervention influences the pattern of exchange rate adjustment over time, as well as the total cumulative intervention.* As can be seen in Chart 1, if the rate of intervention is very large ($\alpha = .975$), the first-period change in the exchange rate will be small, but subsequent exchange rate changes will decline very gradually. If the rate of intervention is smaller ($\alpha = 0.90$) the first period change in the exchange rate will be quite large, but subsequent exchange rate changes will drop off more steeply. The reader can verify that cumulative intervention in equation (18′) increases with the rate of intervention α.

Instability

The preceding analysis predicts a gradually declining rate of change in the exchange rate. At times, however, changes in the exchange rate *accelerate* rather than die down gradually. There is no easy way of modeling such a process. One way to proceed is to assume that speculators believe that the adjustment to the target exchange rate will need to be larger the longer the gap between the spot and the target exchange rate persists.

To motivate this last assumption, consider a country whose large trade surpluses provoke threats of protectionist retaliation by its trading partners. Agents set the target exchange rate s_t^*, which now may vary from period to period, at a level they think will reduce trade surpluses by enough to avert retaliation. They revise their estimate of s_t^* upward if the news this period indicates no reduction in the trade surplus or complaints by trading partners. Otherwise, the target s_t^* remains unchanged or is lowered. We can think of a situation where intervention prevents equilibrium exchange rate adjustment, resulting in a sequence of increasing trade surpluses. This in turn prompts a sequence of upward revisions in s_t^* that are associated with accelerating appreciation over several periods. In this manner, *the interaction between intervention and expectations may be destabilizing.*[12]

To illustrate this argument in a simple way, assume that the target or equilibrium exchange rate grows at the constant rate $(1+\phi)$ when the exchange rate is below target, where $\phi > 0$. Suppose also that in period 1 there is a shock that raises the target exchange rate by a factor $(1-\phi)$, so that $(s_1^* = (1+\phi)s_0^*)$. Then, so long as the positive gap between the target and actual exchange rate remains, in subsequent periods,

$$(19) \qquad s_t^* = (1+\phi)s_{t-1}^*; \quad t = 2,3,4,\ldots.$$

By suitably modifying equation (14), we have the following sequence of shocks to expectations:

$$(20) \qquad \Delta x_t = (1+\phi)s_{t-1}^* - s_{t-1}; \quad t = 1,2,3,\ldots.$$

By modifying equation (15), we find that the change in the exchange rate in each period is now governed by

$$(21) \quad \Delta s_t=(1-\alpha)s_x\Delta x_t=(1-\alpha)s_x((1+\phi)^t s_0^* - s_{t-1}); \; t=1,2,\ldots.$$

The solution to this difference equation, derived in Appendix B, implies that:

$$(22) \quad \Delta s_t=(1-\alpha)s_x\left(s_0^*(1+\phi)^t z_t-\beta^{t-1}s_0\right),$$

where z_t is defined in Appendix B. In equation (22), the path of the exchange rate is unstable, and the rate of change in the exchange rate increases over time. This instability is associated with the shocks to exchange rate expectations, which are increasing in each period. Equating Δs_t in equations (21) (first equality) and (22), we can express the shocks to expectations in terms of the starting values of the target and spot rates:

$$(23) \quad \Delta x_t=(s_0^*(1+\phi)^t z_t-\beta^{t-1}s_0); \; t=1,2,\ldots.$$

Cumulative changes in the exchange rate and cumulative intervention now grow without bound and are respectively described by:

$$(24) \quad \sum_{t=1}^{T}\Delta s_t=(1-\alpha)s_x\sum_{t=1}^{T}\left(s_0^*(1+\phi)^t z_t-\beta^{t-1}s_0\right)$$

and

$$(25) \quad \omega\sum_{t=1}^{T}\Delta f_t^{cb}=-\frac{\alpha s_x}{s_{nfa}}\sum_{t=1}^{T}(s_0^*(1+\phi)^t z_t-\beta^{t-1}s_0),$$

where we use equation (23) to obtain equations (24) and (25).

In the preceding we have assumed that speculators act as if ϕ is fixed, so that s_t^* increases forever. This assumption allows us to solve a difference equation. In reality, however, the value of ϕ and the continued accumulation of positive changes to the exchange rate in equation (24) will depend on news about the external balance or the reactions of trading partners or other pertinent events. Once agents receive the news that trade surpluses have fallen or that trading partners are satisfied with the current level of the exchange rate, exchange rate appreciation will cease, and may even sharply reverse direction if s^* falls below s_t.

Effects on Velocity and Asset Prices

In the unstable case just described, the target rate is growing each period, producing increases in the expected rate of appreciation in each period. According to equations (4) to (6), these period-to-period changes in exchange rate expectations will affect the price level and domestic interest rates as well as the exchange rate. Furthermore, the government's intervention rule implies that these shocks to expectations will be associated with increases in the money supply and matching increases in the net foreign asset holdings of the central bank. To determine the combined effects of shocks to exchange rate expectations and money creation on the cumulative change in the price level, note that equation (5) implies that:

$$(26) \quad \sum_{t=1}^{T}\Delta p_t=p_x\sum_{t=1}^{T}\Delta x_t+p_{nfa}\omega\sum_{t=1}^{T}\Delta f_t^{cb},$$

where, from equation (5), $p_x<0$; $p_{nfa}=p_m-p_f>0$. Applying (23) and (25) to (26) we obtain:

$$(26') \quad \sum_{t=1}^{T}\Delta p_t=\left[p_x-\frac{\alpha s_x p_{nfa}}{s_{nfa}}\right]\sum_{t=1}^{T}(s_0^*(1+\phi)^t z_t-\beta^{t-1}s_0)\gtreqless 0$$

Equation (26) shows that the inflationary effects of the sequence of increases in the money supply due to intervention ($p_{nfa}\omega\Sigma_{t=1}^{T}\Delta f_t^{cb}>0$) are offset by the deflationary effects of the sequence of positive shocks to exchange rate expectations ($p_x\Sigma_{t=1}^{T}\Delta x_t<0$). As a result, less than proportional increases in the price level may be associated with money growth. Given a constant level of real GNP, this may result in persistent declines in velocity (the ratio of nominal GNP to money).

Equation (26′) shows how the path of the price level depends on the underlying behavioral and intervention parameters. It is apparent from (26′) that velocity may decline at an accelerating rate influenced by the magnitude of ϕ. Also, the deflationary effects of shocks to exchange rate expectations will tend to be larger, the larger is the impact of expectations on the price level (p_x). If these deflationary effects are sufficiently large, the money growth resulting from intervention could be associated with a declining rather than increasing price level. Thus, *an increase in the money supply resulting from intervention will be associated with a less than proportional increase in inflation (and possibly deflation) and with persistent and accelerating declines in velocity.*

To determine the impact of shocks to exchange rate expectations and associated intervention on asset prices, we use equations (6), (23), and (25) to obtain:

$$(27)\quad \sum_{t=1}^{T}\Delta i_t = i_x\sum_{t=1}^{T}\Delta x_t + i_{nfa}\omega\sum_{t=1}^{T}\Delta f_t^{cb} = \left(i_x - \frac{\alpha s_x i_{nfa}}{s_{nfa}}\right)\sum_{t=1}^{T}(s_0^{*}(1+\phi)^t z_t - \beta^{t-1}s_0) < 0,$$

where, from equation (6), $i_x<0$; $i_m<0$; $i_f<0$, and we assume that $i_{nfa}\equiv i_m - i_f<0$. Equation (27) says that both the sequence of increases in expected appreciation and the expansion in net foreign assets and money will contribute to persistent and accelerating declines in the domestic interest rate, or, equivalently, to persistent and accelerating increases in the domestic bond price. As noted in our earlier discussion of the implications of institutional characteristics, the magnitude of the changes in the domestic interest rate (or domestic asset price) will be larger if the domestic bond is a poor substitute for domestic money or the foreign asset (in such a case the results in Appendix A imply that i_x and i_{nfa} will tend to rise in absolute value).

To sum up, the preceding discussion illustrates how the credibility of intervention policy may affect the pattern of exchange rate adjustment. When the outcome of intervention is credible, any degree of exchange rate stability can be achieved at the cost of a sufficiently large, one-time change in the money supply. When the outcome of intervention is not credible, however, intervention can lead to persistent and possibly accelerating changes in exchange rates, the money supply, velocity, and asset prices. Under certain conditions, intervention may even *amplify* the cumulative change in the exchange rate rather than reduce it. The increased exposure to external shocks that may be associated with unsterilized intervention is typically of great concern to policymakers.

Reducing the Exposure to External Shocks

The government may attempt to reduce the economy's exposure to external shocks in three ways. First, the monetary effects of exchange rate intervention may be offset by adjusting domestic credit. Such a policy is known as "sterilized intervention," and can be described by the rule:

$$(28)\quad (1-\omega)\Delta d_t = -\gamma\,\omega\Delta f_t^{cb};\ \gamma > 0,$$

where γ is the degree of sterilization. The central bank balance sheet equation (7) then implies that the change in the money supply associated with intervention is $\Delta m_t^s = (1-\gamma)\omega\Delta f_t^{cb}$. It is apparent that the change in the money supply associated with intervention falls as the rate of sterilization γ rises. Nevertheless, there is a limit to how much policymakers can sterilize. One difficulty is that sterilization may be incompatible with the government's exchange rate policy, as it reduces the impact of intervention on the exchange rate. With sterilization, the change in the exchange rate associated with government intervention is:

$$(29)\quad \Delta s_t^{cb} = s_m\Delta m_t^s - s_f\,\Delta f_t^s = (s_m(1-\gamma) - s_f)\omega\Delta f_t^{cb} = s'_{nfa}\omega\Delta f_t^{cb},$$

where $s'_{nfa} - s_{nfa}<0$ and the gap between the two expressions increases with the rate of sterilization γ. The effect of sterilized intervention on the exchange rate falls as the rate of sterilization γ rises. If sterilization is complete ($\gamma=1$), so that there is no change in the money supply, the impact of intervention on the exchange rate is entirely the result of the exchange of foreign for domestic bonds, as reflected in the term $-s_f\omega\Delta f_t^{cb}$. Because s_f declines as the degree of substitutability increases, the impact of sterilized intervention also declines. Intuitively, sterilized intervention provides the speculator with a domestic bond rather than with money in exchange for the foreign asset. The greater the substitutability of the domestic bond for the foreign asset relinquished by the speculator, the smaller the impact on the exchange rate.

Aside from being potentially less effective, sterilized intervention may require the government to issue debt instruments in order to bring about sufficiently large adjustments in domestic credit, if central bank holdings of marketable securities are insufficient. In the absence of changes in fiscal policy, the intertemporal government budget constraint implies that government debt instruments issued today must be redeemed by printing money at some time in the future. Thus sterilization may reduce the change in the money supply today at the cost of a larger change in the money supply in the future.

Second, the government can impose capital controls. Such controls tend to insulate the economy from the impact of exchange rate expectations by making it difficult for speculators to transact in foreign exchange markets. Capital controls reduce s_x, p_x, i_x in equations (24), (25), (26′), and (27). Inspection of these equations shows that over any finite horizon, cumulative changes in the exchange rate, intervention, and any related disturbances to the domestic price level and the domestic interest rate associated with a shock to exchange rate expectations decline as these coefficients decline. If the controls are so extensive that they are

interpreted as a major regime shift, they may also drive the target exchange rate s_t^* below the spot rate and cause a reversal in the path of the exchange rate. While this possibility is not explicitly modeled here, it was probably important in Taiwan's case.

Third, the government can reduce the rate of intervention, thus allowing the exchange rate to float more freely in each period. As suggested by our discussion of Chart 1, reducing the rate of intervention tends to reduce the persistence of changes in the exchange rate attributable to a one-time shock to exchange rate expectations.

III. Taiwan's Experience

To analyze Taiwan's experience in the 1980s, we examine the path of the exchange rate and some of the factors

Chart 2
Taiwan
Current Account and Exchange Rates

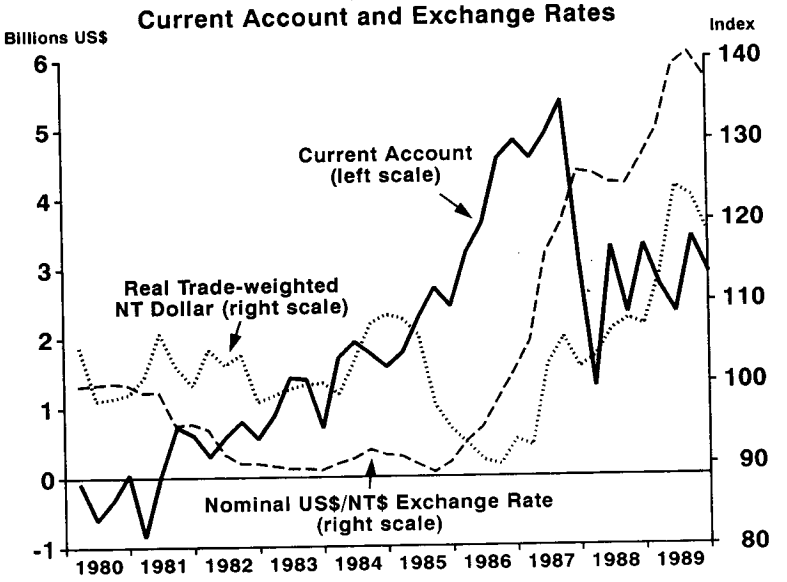
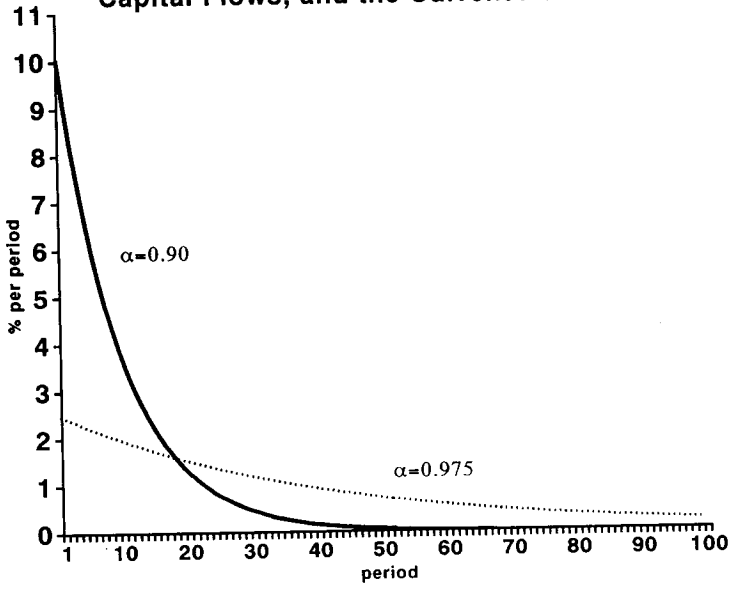


Chart 3
Taiwan
Changes in Reserves, Short-term Capital Flows, and the Current Account



that may have influenced exchange rate behavior. For this purpose, Chart 2 shows the nominal US$/NT$ exchange rate, the real trade-weighted NT dollar, and the current account in the 1980s. We also examine the pattern of intervention of the central bank by reviewing changes in foreign exchange reserves by the central bank, and its two major determinants—short-term capital flows and the current account, illustrated in Chart 3.[13]

In Chart 3, changes in the foreign exchange reserves of the central bank are a proxy for intervention. To ascertain the suitability of this proxy, we need to do two things. First, we need to determine the extent to which changes in reserves result from shocks to exchange rate expectations, as only such changes can be said to correspond to intervention in foreign exchange markets. To deal with this question, we note that when there are positive shocks to exchange rate expectations speculators attempt to acquire domestic assets, and the central bank intervenes to dampen the resulting upward pressure on the exchange rate. These actions will simultaneously be reflected in the balance of payments accounts as an increase in short-term capital inflows and in the foreign exchange reserves held by the central bank. The converse holds when there are negative shocks to expectations. Thus, a high correlation between short-term capital flows and changes in foreign exchange reserves indicates whether such changes largely reflect intervention.

Second, we need to assess the likely effects of systematic changes in foreign exchange reserve holdings that are unrelated to intervention. In the case of Taiwan, the main source of such systematic changes was the requirement, in effect until July 1987, that exporters surrender their foreign exchange earnings (see Section I). The path of the current account balance thus provides an indicator of the influence of the trade sector on foreign exchange reserves.

As illustrated in Chart 3, changes in reserves are highly correlated with short-term capital flows, in spite of a widening gap between the level of changes in foreign exchange reserves and short-term capital flows in the course of the 1980s. This widening gap is attributable to the rising current account surpluses that are also shown in the chart. Thus, changes in foreign exchange reserves appear to be a reasonably good proxy for intervention in Taiwan in the 1980s.

Patterns in the Exchange Rate, Capital Flows, and Intervention

Inspection of Charts 2 and 3 suggests that the 1980s may be divided into three periods. In the first period, 1980:1-1985:3, there was a downward trend in the US$/NT$ exchange rate up to 1982, followed by a period of stability. In this period, the exchange rate against the U.S. dollar on average depreciated at a compound annual rate of just under 2 percent, in spite of growing current account surpluses. The real trade-weighted exchange rate also exhibited a slight downward trend. Short-term capital flows and the associated intervention were relatively small (capital outflows averaged $128 million per quarter), and showed no systematic trend. The relative tranquility in foreign exchange markets suggests that speculators did not doubt the government's ability to limit movements in the NT dollar over this period. In terms of the model developed in Section II, it appears that adjustments in the exchange rate in response to shocks could be described by equation (11).

Doubts about the government's ability to prevent the NT dollar from appreciating against the U.S. dollar appear to have arisen in the mid-1980s. One reason is that the NT dollar's relative stability against a falling U.S. dollar in 1985 was associated with a sharp real trade-weighted depreciation that was incompatible with Taiwan's growing external surpluses (Chart 2). In this context, the statement by the G-5 industrial countries, following their September 1985 Plaza meeting, that the U.S. dollar should depreciate further apparently created expectations that the Taiwan government would have to allow the NT dollar to appreciate against the U.S. dollar. This perception was reinforced in the course of the second half of the 1980s, as Taiwan's trading partners, notably the U.S., openly expressed concern about Taiwan's trade surplus and government exchange rate policy.

These developments provide the context for the behavior of the exchange rate and short-term capital flows in the second period, 1985:4 to about 1987:4. In this period, the rate of appreciation in the NT dollar accelerated every quarter for nearly two years, from a compound annual rate of 2.2 percent in 1985:4 to a peak of nearly 31 percent in 1987:3. On average, the NT dollar appreciated against the U.S. dollar at a compound annual rate of 14 percent in 1985:4-1987:4, compared to an average depreciation of 1.8 percent in the first period. There was a concomitant increase in short-term capital inflows, which averaged nearly US$2.4 billion per quarter, compared to average outflows of US$128 million in the first period. Largely as a result of stepped-up intervention, the accumulation of foreign exchange reserves rose to an average of US$6.5 billion a quarter, from an average of under $1 billion in the first period. By comparison to other economies, or to Taiwan's own historical experience, the amount of intervention was unprecedented. Taiwan's foreign exchange reserves rose to a peak of US$77 billion in 1987, third after Japan and Germany in that year. (In domestic currency terms, foreign assets held by the Central Bank of China

(CBC) increased from NT$504 billion in 1983, to a peak of NT$2.26 trillion in 1987, about 30 times its level ten years earlier.)

The discussion in Section II suggests that the apparent instability of the NT dollar and of capital inflows over this period may have been partly the result of government intervention in foreign exchange markets, in a situation where the exchange rate outcome of such intervention was not credible because of rising current account surpluses and expressions of concern by Taiwan's major trading partners. In particular, the behavior of the exchange rate over this period appears to be roughly consistent with the unstable case described by equation (24), while the sharp acceleration in intervention appears to conform to equation (25).[14]

The government sought to limit the impact of shocks from the external sector in a number of ways (see discussion in Section I). First, it sought to curb short-term capital inflows by freezing the external liabilities of the banking sector at the end of May 1987 and then again in October 1987. Second, it attempted to reduce the link between current account surpluses and changes in foreign exchange reserves by lifting all restrictions on current account transactions in July 1987, including the requirement that foreign currency export revenues be exchanged for domestic currency. Third, it shifted to floating exchange rates in April 1989.

These policy measures were followed by marked changes in the pattern of external disturbances and their impact on foreign exchange reserves, which characterized the third period, 1988-1989. Restrictions on capital inflows prevented speculators from freely acquiring NT dollar assets, contributing to a slowdown in the rate of appreciation of the NT dollar to 8.3 percent (the NT dollar actually fell sharply late in the period, a decline that continued in 1990). There was also a reversal in short-term capital inflows to average outflows of US$1.2 billion per quarter.[15] Thus, in the later part of the 1980s, short-term capital flows had a contractionary influence on foreign exchange reserves and on the domestic monetary base.

The liberalization of current account transactions and the shift to floating had strong effects on the accumulation of foreign exchange reserves of the central bank. As is apparent in Chart 3, the gap between changes in foreign exchange reserves and short-term capital flows was largely eliminated after 1987, when the requirement that exporters surrender their foreign exchange reserves was suspended. Changes in foreign exchange reserves diverged sharply from short-term capital flows after the shift to floating in the second half of 1989, suggesting that the government had stopped intervening.

Effects on the Domestic Money Supply, Velocity, and Asset Prices

The effects of intervention on the money supply were influenced by the government's sterilization policy. To describe this policy, we examine the patterns of changes in net foreign assets and in domestic credit (the two components of the monetary base in equation (7)), reported in Table 2. The table suggests that in the first two periods, net foreign asset expansion was associated with large reductions in domestic credit. The contraction in domestic credit was largely accomplished through the issuance of interest-bearing short-term central bank certificates of deposits and savings bonds, as the supply of Treasury securities is limited by Taiwan's conservative fiscal policy. Table 2 also shows that domestic credit expanded very strongly in the third period. This appears to have been related to earlier sterilization policy, as the Central Bank created money to redeem its maturing short-term liabilities in that period.[16]

In spite of the high rate of sterilization, Table 3 shows that the rate of base money growth accelerated from an average annual rate of 16 percent in the period 1980:1-1985:3 to 35 percent after 1988. The acceleration in money

Table 2

Growth in components of monetary base
(billions of NT dollars)

	Change in foreign assets	Change in domestic credit	Total change
80:2-85:3	35	-26	11
85:4-87:4	158	-128	30
88:1-89:4	-24	79	55

Table 3

Growth in money and velocity
(compound annual rates in percent)

	Money base	M1	M1 velocity
80:1-85:3	16.4	16.0	-2.6
85:4-87:4	28.3	44.5	-20.2
88:1-89:4	34.8	16.7	-2.5

growth initially reflected the direct expansionary effects of intervention policy. However, base money growth continued to accelerate even after the reversal of capital inflows in 1988. One reason is that the government shifted to floating exchange rates in April 1989, which limited the contractionary influence of capital outflows on the monetary base.

Another reason for the acceleration in base money growth in the later part of the 1980s is that the redemption of short-term CBC paper had a strong expansionary impact on domestic credit. Thus, efforts to limit monetary growth through sterilization in the mid-1980s contributed to more rapid money growth later in the decade.[17]

The growth of M1 accelerated from 16 percent in the first period to about 44 percent in the second period, even faster than the rate of growth in the monetary base. In the third period, however, M1 growth slowed to about half the rate of growth in the monetary base. One possible explanation is that the efforts by speculators to exchange their NT dollar deposits for foreign assets offset the expansionary impact of the rapid growth in the monetary base.

The acceleration in money growth did not result in correspondingly large increases in inflation. In fact, inflation *declined* (from a compound annual rate of 6 percent in the first period to 2.3 percent in the second period) as money growth accelerated, suggesting that increases in the demand for M1 exceeded the growth in the money supply. Speculators were apparently not interested in purchasing goods with the NT dollars they acquired in the foreign exchange market, but held them on the expectation of earning large gains from currency appreciation. In line with this, M1 velocity declined at a 20 percent annual rate in the period 1985:4-1987:4, compared to 2 percent in the first period. Inflation picked up and the decline in velocity slowed sharply in the last two years of the 1980s, as the curbs on capital inflows took effect and the speculative demand for NT dollar assets ceased. The sharp fluctuations in velocity are consistent with the predictions of the model discussed earlier.[18]

Effects on Asset Prices

While the expansion of liquidity did not result in an increase in inflation in the short run, our earlier discussion suggests that it should have resulted in an increase in asset prices or (equivalently) declines in interest rates. Furthermore, the effects on asset prices should have been smaller in those domestic asset markets that are more tightly linked by arbitrage to foreign asset markets, or where domestic assets are closer substitutes for foreign assets. The results of Tables 4 and 5 are roughly in line with these expectations. As shown in Table 4, Taiwan's domestic money market rate fell in comparison to foreign short-term rates (the 3-month eurodollar rate) as the 1980s progressed, but the relative decline in domestic interest rates was quite limited. The reason is that Taiwan's domestic money market interacted quite extensively with international financial markets.

In stark contrast, the prices of assets that were not so closely linked by arbitrage to external markets increased sharply. Land prices rose as much as 250 percent between 1987 and 1989. Increases in stock prices were even steeper. As shown in Table 5, the compound annual rate of growth of stock prices in Taiwan accelerated from 2 percent in the first half of the 1980s to 70 to 80 percent in the second half. Table 5 also shows that the increases in Taiwan's stock price were several orders of magnitude larger than stock price increases in Japan and the U.S., which also experienced stock market booms in the second half of the 1980s. Taiwan's stock price index rose from 162 at the end of 1986 to 1557 by the end of 1989, raising price/earnings ratios of listed companies to over 55 by the end of 1989 (compared to 13 in the U.S., and 62 in Japan).[19]

Table 4

Changes in interest rates
(annual rates in percent)

	Money market interest rate	3-month Eurodollar rate
80:1-85:3	-0.3	-0.4
85:4-87:4	-0.2	-0.05
88:1-89:4	-0.1	0.05

Table 5

Changes in stock prices
(compound annual rates in percent)

	Taiwan	Japan	U.S.
80:1-85:3	2	15	10
85:4-87:4	81	29	7
88:1-89:4	72	16	14

IV. Conclusions

In this paper we have attempted to explain certain puzzling features of the behavior of exchange rates, money velocity, and asset prices in Taiwan in the 1980s by suggesting a different way of looking at the interaction between exchange market intervention and exchange rate expectations. Using a simple theoretical framework, we have discussed how the credibility of intervention policy may affect the pattern of adjustment in the exchange rate, velocity, and asset prices. When the outcome of intervention is credible, any degree of exchange rate stability can be achieved at the cost of a sufficiently large, one-time change in the money supply. When the outcome of intervention is not credible, however, intervention can lead to persistent, and possibly accelerating, changes in exchange rates, the money supply, velocity, and asset prices. Under certain conditions, intervention may even amplify the cumulative change in the exchange rate rather than reduce it. An informal examination of the data suggests that the model developed in the paper can be used as a framework for explaining Taiwan's experience.

Two implications of Taiwan's experience are worth highlighting. First, disturbances to foreign exchange and domestic asset markets in a developing economy need not arise from unsustainable fiscal and monetary policies and macroeconomic instability. Foreign exchange rate intervention may be associated with large disturbances to asset markets even in a stable and well-managed economy. Second, there is a little recognized potential tradeoff between the desire to protect tradable goods production by limiting exchange rate movements and the desire to stabilize in foreign exchange and domestic asset markets. In economies with a high degree of capital mobility, and where intervention policy is not credible, efforts to protect the tradable goods sector through such intervention may contribute to instability in asset markets. This effect may be more pronounced when domestic and foreign assets are not good substitutes.

Endnotes

1. The upward pressure on the NT dollar appears to have been related to Taiwan's current account surpluses, which on an annual basis averaged close to 14 percent of GNP between 1983 and 1988, and reached a peak (on an annual basis) of over 20 percent in 1986. These surpluses appear to be the largest ever recorded in the world. By comparison, at their respective peaks in the 1980s, current account surpluses reached 1.1 to 1.2 percent of GNP in Japan and Germany, and 7.7 percent in Korea.

2. A similar pattern of rapid money growth, low inflation and declining velocity, and asset price inflation was observed in Japan in the second half of the 1980s.

3. For more details on the institutional characteristics of Taiwan's financial sector see Cheng (1986), Kuo (1989), Liang (1988), Shea (1990), Yang (1990), and Wang and Kim (1990).

4. In particular, the interest-setting arrangements prevailing in Taiwan in the 1980s apparently introduced a certain amount of rigidity in deposit rates. Yang (1990) notes that the variation in bank rates in Taiwan tends to be smaller than the variation in market rates. She also refers to a study she has carried out using vector ARIMA techniques which finds that the bank rate in the 1980s adjusted about a month after the freely-determined money-market rate. (The latter rate is the rate set in the short-term bills exchange market established in 1976.) Some interest rate policies were also designed to subsidize credit to certain priority sectors, specifically the export sector up to the 1980s, and later the high-tech sector.

5. Strictly speaking, equation (3) also applies *ex post* to the national income accounting identity in levels rather than in logs. The present approach can be seen as an approximation that simplifies the exposition without changing the qualitative results.

6. For a full description of this type of model, see Branson and Henderson (1985).

7. One way to think about this is to argue that lack of domestic financial market development raises the transactions cost associated with investing in domestic marketable securities. Under these conditions, the influence of the external sector in affecting domestic interest rate determination is reduced. For a demonstration of these effects, see Niehans (1991). A similar argument appears to underlie the specification adopted by Edwards and Khan (1985).

8. The assumption that the weight ω is constant is an approximation that has no effect on the qualitative results of the model. Such an approximation would not be needed if the variables were expressed in levels rather than in logs. For a similar log-linear approximation of the central bank balance sheet, see Flood and Hodrick (1985).

9. To derive (12), note that the effect of unsterilized intervention on the exchange rate is given by $s_m\Delta m_1 - s_f\Delta f_1 = (s_m - s_f)\Delta m_1^s = \Delta s_1^g$, where we use $|\Delta m_1| = |\Delta f_1^s|$. Applying equation (10), we have $\Delta s_1^g = -\alpha\Delta x_1$, which yields equation (12).

10. The agents in the model use information about the target exchange rate in forming their expectations. This is part of the information set we would expect rational agents to use. A fully developed rational expectations model would require us to assume that (i) exchange rate expectations depend on the rate of intervention and on the structure of the economy and (ii) the government takes into account how intervention affects expectations when formulating exchange rate policy. The equilibrium under these conditions is more difficult to derive and is a topic for future research.

11. The long-run ineffectiveness of intervention can also be seen in the more general case of equation (17). Note that

$$\lim_{T\to\infty}\sum_{t=1}^{T}\Delta s_t=(1-\alpha)s_x\lim_{T\to\infty}\sum_{t=1}^{T}\beta^{t-1}(s^*-s_0)=(s^*-s_0)$$

where we use $\lim_{T\to\infty}\sum_{t=1}^{T}\beta^{t-1}=\frac{1}{1-\beta}=\frac{1}{s_x(1-\alpha)}$.

12. An alternative way of modeling instability in the path of the exchange rate is to use a monetary approach to the exchange rate with rational expectations and pick the unstable solution of the difference equation for the exchange rate. The disadvantage of this approach is that no intuition is offered for the underlying process that generates the explosion. Certain arguments have also been offered to rule out such explosive processes. Still another approach is to analyze what happens when an expected change in monetary policy is not realized over the sample period (the "peso problem"). Obstfeld (1989) shows that such a situation can lead to an exchange rate process that is indistinguishable from an explosive speculative bubble. In Obstfeld's framework, persistent appreciation may arise if speculators expect that the government will have to reverse its monetary policy (or its unsterilized intervention in exchange markets, in the case considered in the text) at some time in the future. In the text we suggest the alternative possibility that intervention itself may contribute to the apparent instability.

13. The underlying data used in Charts 2 and 3 and the Tables in this section were obtained from various issues of the Central Bank of China's *Financial Statistics, Taiwan District* or the International Monetary Fund's *International Financial Statistics*. The real trade-weighted NT dollar illustrated in Chart 2 was constructed by taking the geometric weighted average of the exchange value of the NT dollar with respect to the currencies of eight of its trading partners, including the U.S. dollar, the yen, and the deutschemark. The weights were based on Taiwan's total bilateral trade with these trading partners in 1980.

14. An alternative explanation is that a sequence of shocks to exchange rate expectations in 1985-1987 (absent in 1980-85) that resulted in persistent and accelerating appreciation. However, it is not obvious what these shocks could be. As we shall see, on the domestic side, money growth accelerated in the second period, so that the persistent and accelerating appreciation in the NT dollar cannot be explained by progressively tighter monetary policy. There were no dramatic changes in Taiwan's fiscal policy that could explain real appreciation either. On the external side, current account surpluses had been increasing since the early 1980s, so in this respect the period 1985-87 was not very different from 1980-85. The main shocks that may have affected exchange rate expectations differently in 1985-87 were the real trade-weighted depreciation of the NT dollar in 1985, which predates the persistent appreciation of the NT$ against the U.S. dollar, and the one-time decline in oil prices late in 1986. As these were one-time shocks, something else must explain why the appreciation persisted and accelerated in 1985-87. We suggest that the effects of intervention on expectations played an important role.

15. The effects of the freeze in external liabilities were already apparent in 1987. As can be seen in Chart 3, short-term capital flows drop from a peak of around $ 3.7 billion to nearly zero between the first and third quarters of 1987, with a concomitant dip in the accumulation of foreign exchange reserves by the central bank. There was an even larger drop between the fourth quarter of 1987 and the first quarter of 1988.

16. Sterilization policies produced sharp fluctuations in the amount of interest-bearing liabilities of the CBC. The outstanding value of these liabilities increased from NT$ 14 billion in 1983 to a peak of nearly NT$ 1.2 trillion in 1987. They subsequently fell to NT$ 415 billion at the end of 1989, as the CBC retired short-term liabilities as they came due.

17. This point is made in Yin (1990). The episode can be thought of as an illustration of Sargent and Wallace's unpleasant monetarist arithmetic, where—absent changes in fiscal policy—the issuance of government bonds to reduce money growth today leads to more rapid money growth in the future. For a discussion of unpleasant monetarist arithmetic see Sargent (1987b).

18. In contrast to the sharp fluctuations in narrow money aggregates, there was no acceleration in M2 growth between the first and second periods. It appears that speculators acquiring NT dollar assets preferred to hold readily convertible or liquid assets, like M1, rather than the less liquid components of M2. This appears to have offset significantly any tendency for the demand for M2 to rise as a result of the overall increase in the demand for NT dollar assets. In line with this view, there was a smaller (rather than larger) rate of decline in M2 velocity as the decade progressed.

19. Other factors also appear to have contributed to the very steep increases in Taiwan's stock prices. First, stock prices may have been undervalued, as the rate of increase in stock prices in Taiwan up to 1985 was low given Taiwan's exceptional economic performance. Second, the expansion in liquidity in the mid-1980s appears to have triggered a speculative bubble in Taiwan's stock markets that lasted until the end of the decade (the existence of a bubble is suggested by the fact that Taiwan's stock market subsequently lost as much as 80 percent of its value in 1990).

Appendix A

Responses to Shocks in a Static, Small Open Economy Model

Differencing the system (1) to (3) yields:

$$\text{A1} \quad \begin{bmatrix} -1 & -m_i & 0 \\ -1 & -f_i & -1 \\ (a+b_w) & 0 & -b_R \end{bmatrix} \begin{bmatrix} \Delta p_t \\ \Delta i_t \\ \Delta s_t \end{bmatrix}$$

$$= \begin{bmatrix} m_x \\ f_x \\ 0 \end{bmatrix} \Delta x_t + \begin{bmatrix} -1 \\ 0 \\ 0 \end{bmatrix} \Delta m_t + \begin{bmatrix} 0 \\ -1 \\ 0 \end{bmatrix} \Delta f_t,$$

where the structural coefficients are discussed in the text. The inverse of the matrix on the left-hand side is:

$$\text{A2} \quad \frac{1}{DET} \begin{bmatrix} f_i b_r & -m_i b_r & m_i \\ -b_r-(a+b_w) & b_r & -1 \\ f_i(a+b_w) & -m_i(a+b_w) & f_i-m_i \end{bmatrix},$$

where $DET=-f_i b_r+m_i[b_r+a+b_w]<0$;

it is assumed that $a_w+b_w+b_r>0$. From the preceding, we can derive the reduced form responses of the exchange rate, the domestic interest rate and the price level to a variety of shocks.

Exchange rate expectations:

$$\text{A3} \quad \frac{\Delta p_t}{\Delta x_t} \equiv p_x = \frac{b_r}{DET}(f_i m_x - m_i f_x) < 0$$

$$\text{A4} \quad \frac{\Delta i_t}{\Delta x_t} \equiv i_x = \frac{1}{DET}[-(b_r+(a+b_w))m_x + b_r f_x] < 0$$

$$\text{A5} \quad \frac{\Delta s_t}{\Delta x_t} \equiv s_x = \frac{(a+b_w)}{DET}(f_i m_x - m_i f_x) > 0.$$

The sign of equation A4 is actually ambiguous, because the decline in the demand for the foreign asset tends to lower the domestic interest rate, while the concomitant increase in the demand for money tends to raise the domestic interest rate. The intuitively plausible case $i_x<0$ is selected here.

Money supply

$$\text{A6} \quad \frac{\Delta p_t}{\Delta m_t} \equiv p_m = -\frac{f_i b_r}{DET} > 0$$

$$\text{A7} \quad \frac{\Delta i_t}{\Delta m_t} \equiv i_m = \frac{b_r+(a+b_w)}{DET} < 0$$

$$\text{A8} \quad \frac{\Delta s_t}{\Delta m_t} \equiv s_m = -\frac{f_i(a+b_w)}{DET} < 0$$

Foreign assets

$$\text{A9} \quad \frac{\Delta p_t}{\Delta f_t} \equiv p_f = \frac{m_i b_r}{DET} < 0$$

$$\text{A10} \quad \frac{\Delta i_t}{\Delta f_t} \equiv i_f = -\frac{b_r}{DET} < 0$$

$$\text{A11} \quad \frac{\Delta s_t}{\Delta f_t} \equiv s_f = \frac{m_i(a+b_w)}{DET} > 0$$

Summing equations A5, A8, and A11 yields equation (4) in the text. Summing A3, A6, and A9 yields equation (5), while summing A4, A7, and A10 yields equation (6).

Appendix B

The Path of the Spot Exchange Rate under Alternative Expectations Assumptions

To illustrate how the solutions to difference equations in the text are derived, consider the most general case:

$$\text{B1} \qquad \Delta s_t = (1-\alpha)s_x \Delta x_t = (1-\alpha)s_x(s_t^* - s_{t-1})$$

The first equality in equation B1 says that the change in the exchange rate in this period depends on the rate of intervention α, the reduced form response of the exchange rate to a shock to exchange rate expectations s_x (from equation (4) in the text), and the magnitude of the shock to exchange rate expectations this period Δx_t. The second equality shows that the shock to exchange rate expectations depends on the gap between the target exchange rate this period s_t*and last period's exchange rate s_{t-1}.

Rewriting B1 yields

$$\text{B1}' \qquad s_t = \beta s_{t-1} + (1-\alpha)s_x s_t^* ,$$

where $\beta = 1 - s_x(1-\alpha)$. We assume $0 \leq \beta \leq 1$.

Recursive substitution into B1′ yields the following solution (alternatively, see Sargent (1987a) Chapter 9):

$$\text{B2} \qquad s_t = \beta^t s_0 + (1-\alpha)s_x \sum_{i=0}^{t-1} \beta^i s_{t-i}^* ,$$

where s_0 is the initial value of the spot exchange rate. The change in the spot rate in each period is given by:

$$\text{B3} \qquad \begin{aligned} \Delta s_t &= (1-\alpha)s_x \left[\sum_{i=0}^{t-1} \beta^i s_{t-i}^* - \sum_{i=0}^{t-2} \beta^i s_{t-1-i}^* \right] - (1-\beta)\beta^{t-1} s_0 \\ &= (1-\alpha)s_x \left[\left[\sum_{i=0}^{t-1} \beta^i s_{t-i}^* - \sum_{i=0}^{t-2} \beta^i s_{t-1-i}^* \right] - \beta^{t-1} s_0 \right] \end{aligned}$$

where in the second equality we use $(1-\beta) = s_x(1-\alpha)$.

Special cases

Case 1: $s_t^* = s^*$

When the target exchange rate is the same in every period, B2 implies

$$\text{B4} \qquad s_t = \beta^t s_0 + (1-\alpha)s_x s^* \sum_{i=0}^{t-1} \beta^i .$$

In the very long run, we have

$$\text{B5} \qquad \lim_{t \to \infty} s_t = \frac{(1-\alpha)s_x s_0^*}{1-\beta} = s_0^* ,$$

where the second equality follows because $(1-\beta) = (1-\alpha)s_x$. The rate of change in the exchange rate in each period is now governed by:

$$\text{B6} \qquad \begin{aligned} \Delta s_t &= (1-\alpha)s_x s^* \left[\sum_{i=0}^{t-1} \beta^i - \sum_{i=0}^{t-2} \beta^i \right] - (1-\beta)\beta^{t-1} s_0 = \\ &\beta^{t-1}(1-\alpha)s_x(s^* - s_0). \end{aligned}$$

It follows from equation B6 that as $t \longrightarrow \infty$, β^{t-1} and Δs_t asymptotically approach zero. Equation (B6) corresponds to equation (16) in the text.

Case 2: $s_t^* = s^*$; $s_x = 1$

From the definition of β given earlier, this case implies that $\beta = \alpha$. Equation B6 then becomes

$$\text{B7} \qquad \Delta s_t = (1-\alpha)\alpha^{t-1}(s^* - s_0) .$$

This is the case plotted in Chart 1.

Case 3: $s_t^* = (1+\phi)s_{t-1}^*$

Given an initial target exchange rate s_0^*, the target exchange rate in each period is given by:

B8 $\quad s_t^* = (1+\phi)^t s_0^*$.

Substituting into equation B2, the spot rate is now given by:

B9 $\quad s_t = \beta^t s_0 + (1-\alpha)s_x s_0^* \sum_{i=0}^{t-1} \beta^i (1+\phi)^{t-i}$.

It is apparent from equation B8 that s_t now grows without bound. Intervention cannot prevent this. It can also be shown that the rate of change in the exchange rate will accelerate indefinitely. To see this, note that the change in the spot exchange rate is now:

B10 $\quad \Delta s_t =$

$$(1-\alpha)s_x \left[s_0^* \left(\sum_{i=0}^{t-1} \beta^i (1+\phi)^{t-i} - \sum_{i=0}^{t-2} \beta^i (1+\phi)^{t-1-i} \right) - \beta^{t-1} s_0 \right]$$

$$= (1-\alpha)s_x \left[s_0^* \left((1+\phi)^t - (1-\beta) \sum_{i=0}^{t-2} \beta^i (1+\phi)^{t-1-i} \right) - \beta^{t-1} s_0 \right]$$

$$= (1-\alpha)s_x \left[s_0^* (1+\phi)^t \left(1 - \frac{(1-\beta)}{(1+\phi)} \sum_{i=0}^{t-2} \left[\frac{\beta}{(1+\phi)} \right]^i \right) - \beta^{t-1} s_0 \right] .$$

To simplify notation, define $z_t \equiv 1 - \frac{(1-\beta)}{(1+\phi)} \sum_{i=0}^{t-2} \left[\frac{\beta}{(1+\phi)} \right]^i$;

$t = 2,3,\ldots$, where $z_t = 1$ when $t = 1$ and

$$\lim_{t \to \infty} z_t = \frac{\phi}{(1-\alpha)s_x + \phi} .$$

Rewriting B10,

B10′ $\quad \Delta s_t = (1-\alpha)s_x \left(s_0^* (1+\phi)^t z_t - \beta^{t-1} s_0 \right)$; $t = 1,2,\ldots$.

Equation B10′, which is equation (22) in the text, shows that the appreciation in the exchange rate now accelerates.

References

Branson, William H., and Dale W. Henderson. 1985. "Specification and Influence of Asset Markets." In *Handbook of International Economics* Volume II, ed. R.W. Jones and P.B. Kenen. Amsterdam: North Holland.

Central Bank of China. *Financial Statistics, Taiwan District, Republic of China* various issues.

Central Bank of China, Economic Research Department. 1989. *Flow of Funds in Taiwan District, Republic of China, 1965-1988* (December).

Cheng, Hang-Sheng. 1986. "Financial Policy and Reform in Taiwan, China." In *Financial Policy and Reform in Pacific Basin Countries*, ed. H. Cheng. Lexington, Mass.: Lexington Books.

Edwards, Sebastian, and Mohsin S. Khan. 1985. "Interest Rate Determination in Developing Countries: A Conceptual Framework." *IMF Staff Papers* 32 (September).

Flood, Robert P., and Robert J. Hodrick. 1985. "Central Bank Intervention in a Rational Open Economy: A Model with Asymmetric Information." In *Exchange Rate Management Under Uncertainty*, ed. J.S. Bhandari. Cambridge, Mass.: MIT Press.

Krugman, Paul. 1979. "A Model of Balance of Payments Crises." *Journal of Money Credit and Banking* 11 (August) pp. 311-325.

Kuo, Shirley. 1989. "Liberalization of the Financial Market in Taiwan in the 1980s." The International Commercial Bank of China *Economic Review* (July-August).

Lessard, D.R., and J. Williamson, eds. 1987. *Capital Flight and Third World Debt*. Washington, D.C.: Institute for International Economics.

Liang, Kuo-shu. 1988. "Financial Reform, Trade and Foreign-Exchange Liberalization in the Republic of China." The International Commercial Bank of China *Economic Review* (March-April).

Niehans, Jurg. 1991. "Capital Mobility with Transaction Costs: A Concept and Applications." Working Paper PB91-03 (April). Center for Pacific Basin Monetary and Economic Studies, Federal Reserve Bank of San Francisco.

Obstfeld, Maurice. 1989. "Peso Problems, Bubbles and Risk in the Empirical Assessment of Exchange-Rate Behavior." In *Financial Risk: Theory, Evidence and Implications*, ed. Courtenay C. Stone. Proceedings of the Eleventh Annual Economic Policy Conference of the Federal Reserve Bank of St. Louis. Boston: Kluwer.

Sargent, Thomas J. 1987a. *Macroeconomic Theory*. Orlando: Academic Press.

Sargent, Thomas J. 1987b. *Dynamic Macroeconomic Theory*. Cambridge, Mass., Harvard University Press.

Shea, Jia-Dong. 1990. "Financial Development in Taiwan: A Macro Analysis." Presented at Conference on Financial Development in Japan, Korea and Taiwan sponsored by the Institute of Economics, Academia Sinica, ROC and The Pacific Basin Studies Program, Columbia University. Taipei, Taiwan, August 27-28.

Wang, Yen-Kyun, and Wan-Soon Kim. 1990. "A Reform on the Forward Foreign Exchange Market and Foreign Exchange Rate Determination Policy in Korea, with Foreign Exchange Policy Experiences of Taiwan." In *Economic Development in East Asia and Southeast Asia: Essays in Honor of Professor Shinichi Ichimura*, ed. Seiji Naya and Akira Takayama.

Yang, Ya-Hwei. 1990. "A Micro Analysis of Financial Development in Taiwan." Presented at Conference on Financial Development in Japan, Korea and Taiwan sponsored by the Institute of Economics, Academia Sinica, ROC and The Pacific Basin Studies Program, Columbia University, August 27-28 Taipei, Taiwan.

Yin, Norman. 1990. "The Progression and Development of Money Games." (In Chinese.) Presented at Conference on Social Reconstruction: Money Games and Their Eeffects on Society, sponsored by the China Time Foundation. August 16-18 Taipei, Taiwan.