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On the Effects of Sterilized Intervention: An Analysis of Weekly Data

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I. Introduction

It is by now widely accepted that sterilized intervention--intervention which alters the currency composition of interest-bearing government debt but does not affect the path of the monetary base--has no significant long-term impact on the exchange rate. More controversial is the question of whether sterilized intervention has even a short-run impact on the exchange rate. If it does have a short-run effect, then sterilized intervention can be used to temporarily offset disturbances, even if it cannot be used to alter long-run trends. 1/

In theory, sterilized intervention operates on the exchange rate either by altering public perceptions of future monetary policy or by affecting the exchange rate risk premium. 2/ The present paper focuses entirely on the latter "portfolio balance" channel, asking whether sterilized intervention can influence the exchange rate by shifting exchange rate risk between public and private sector portfolios. It may seem misguided to abstract from the effects of sterilized intervention on expectations, when this channel might well be of greater empirical

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1/ The conclusions stated above are consistent with the recent report of the inter-central bank working group on exchange market intervention. Note also that the present paper is concerned with effects of sterilized intervention on exchange rates between countries with integrated, highly developed capital markets.

2/ The exchange rate risk premium is defined here as the "uncovered" interest rate differential on two bonds identical in all respects except for currency of denomination. The uncovered interest differential is the interest differential adjusted for the expected rate of appreciation or depreciation of the exchange rate.

significance than the portfolio balance channel, but there is a strong argument for doing so. If the only effect of sterilized intervention is that it changes the public's expectations about the government's targets for the growth rate of money, then sterilized intervention cannot be properly regarded as an independent tool of monetary policy. In particular, sterilized intervention operations and monetary base operations could not be used to consistently achieve independent external and domestic targets.

Given the important policy significance of the portfolio balance effect, it is not surprising that there have been many attempts to quantify it. Unfortunately, the success of these efforts has been extremely limited. Most of the recent studies surveyed in Section II conclude that it is very difficult to uncover a statistically significant portfolio balance effect. There are three possible interpretations of these predominantly negative findings. One is that asset holders are not concerned with exchange rate risk and are concerned only with expected rates of return. Another is that asset holders do care about exchange rate risk, but that changes in the currency composition of government debt have only a very small impact on the exchange rate risk premium. A third possibility is that it is hard to detect a portfolio balance effect because the relevant theoretical models are very difficult to implement empirically. The data problems and the aggregation problems which plague all macro-econometric work are especially severe when it comes to estimating portfolio balance exchange rate models.

The present paper attempts to improve on the treatment of one particular problem: time aggregation. Previous efforts to estimate portfolio balance equations have been based on monthly or quarterly data. Such data necessarily contain less information about the very short-run effects of intervention than do weekly or daily data. Here we examine weekly data for the Canadian dollar/U.S. dollar exchange rate. The weekly data set also includes Canadian and U.S. interest rates, interest-bearing debts, and monetary bases, as well as the Canadian Exchange Fund. 1/

The results reported in this study are not supportive of the existence of a portfolio balance effect. When estimating over the entire sample period, I am unable to find any regression in which the portfolio balance variables enter significantly with the right sign. This failure persists across different model specifications, estimating techniques, data sources, and subsamples. Thus, the results are no more encouraging than those reported elsewhere in the literature.

1/ The data set, described in Appendix A, also includes monthly and quarterly data. These data are incorporated into some of the weekly regressions, using the mixed frequency estimation technique discussed in Appendix B. Some data are even available on a daily basis, but we argue below that these data are insufficient to construct a powerful test of the portfolio balance effect.

Section II below reviews the empirical literature on portfolio balance models of exchange rate determination. The main empirical evidence in support of the portfolio balance effect turns out to be the explanatory power of the cumulated current account in exchange rate equations. To the extent that current account surpluses and deficits reflect differences in national savings rates, the portfolio balance model predicts that a current account surplus will be accompanied by an appreciating exchange rate. 1/ Holding the supply of government bonds and high-powered money constant, the exchange rate appreciates as the (relative) real wealth of a country's citizens rises. It appreciates because a country's own citizen's have a relative preference for home-country currency denominated assets. But there are a number of reasons to be reluctant to embrace the empirical correlation between cumulated current accounts and exchange rates as solid evidence of a portfolio balance effect. One is that such a correlation can easily arise in models in which there is no portfolio balance effect. Another reason is that the current account has not been the only source of changes in real wealth for the major industrial countries. A significant portion of savings goes into capital stock investment, and real wealth also changes due to real capital gains and losses. Small percentage changes in the market valuation of the capital stock (the stock and corporate bond markets) or in long-term interest rates have effects on private sector wealth which swamp the effects of observed current account surpluses and deficits. Third, the correlation between major industrial country cumulated current accounts and exchange rates has not been as pronounced over the past few years as it was during some earlier years. 2/ Finally, it has proven very difficult to come up with more direct evidence on the portfolio balance effect; i.e., evidence that the exchange rate risk premium responds as predicted to changes in the relative supplies of assets denominated in different currencies.

Section III of the paper discusses some of the estimation problems involved in testing for a portfolio balance effect in the highly aggregative model used here. Section IV contains the main results, and Section V compares the scale of foreign exchange market intervention with the total size of outside debt and with government bond auctions. The latter section concludes that exchange market intervention is not necessarily small relative to the unanticipated component of outside debt. This implies that if there is a portfolio balance effect and if unanticipated changes in the relative supplies of outside assets have a greater effect than anticipated changes, then sterilized intervention may be a potentially important independent macroeconomic policy tool.

1/ This is a partial equilibrium effect. The correlation between the exchange rate and the current account depends on the source of the disturbance and may also depend on whether the disturbance is anticipated or unanticipated.

2/ See, for example, Meese and Rogoff (1983).

II. Previous Tests for the Existence of a Portfolio Balance Effect

The portfolio balance model of exchange rate determination generalizes the simpler monetary model by positing that assets denominated in different currencies are imperfect substitutes due to exchange rate risk. 1/ Private agents are assumed to consider both risk and expected rate of return when allocating their wealth across alternative assets. Therefore, the interest rates on bonds denominated in different currencies need not be equal in market equilibrium, even when rates of return are adjusted for the expected rate of change of the exchange rate. That is, uncovered interest parity (Fisher open parity) does not necessarily hold under imperfect substitutability and there can be an exchange rate risk premium.

Sterilized intervention has an effect in the portfolio balance model because it alters the currency composition of outside assets. 2/ By shifting exchange rate risk between public and private sector portfolios, sterilized intervention affects both the exchange rate risk premium (the uncovered interest rate differential) and the exchange rate itself. A number of authors have provided empirical evidence on whether the exchange rate risk premium is a function of the relative supplies of outside assets denominated in different currencies. As will be evident from the discussion below, strong and robust evidence of the existence of a portfolio balance effect is hard to come by. 3/

Frankel (1982a) estimates an equation for the deutsche mark/dollar exchange rate in which the dependent variable is the "ex-post" uncovered interest rate differential. The ex-post uncovered interest rate differential is constructed by using the actual realized rate of exchange rate appreciation in place of its unobservable expected value. Use of this expectations proxy implicity assumes that market participants have

1/ Henderson (1984) assesses the theoretical role for sterilized intervention in a rational-expectations, portfolio-balance, macroeconomic model.

2/ Outside assets are those assets which do not net out when aggregating across the private sector; that is, government bonds and the monetary base. Sterilized intervention has no effect in models where infinitely-lived homogeneous agents perfectly anticipate future tax liabilities, in which case the distinction between inside and outside assets is meaningless. (The infinitely-lived agent assumption can be relaxed where all agents leave bequests to their infinitely-lived family units.) Obstfeld (1982) and Stockman (1979) rigorously demonstrate the impotence of sterilized intervention in such models, even where assets are imperfect substitutes due to exchange rate risk.

3/ Genberg (1981) surveys the early empirical literature on sterilized intervention. He concludes that the evidence is mixed and difficult to reconcile.

unbiased, forward-looking (rational) expectations. (Finding a good proxy for expectations is one of the greatest problems a researcher faces in estimating portfolio balance equations.) For explanatory variables, Frankel employs portfolio balance variables such as the relative supplies of central government bonds (or alternatively bonds and high-powered money) denominated in deutsche marks versus dollars. Frankel finds that the portfolio balance variables do not enter significantly in his quarterly equations, and indeed the key coefficients are of the wrong sign. He concludes that his results do not allow him to reject the hypothesis that bonds denominated in different currencies are perfect substitutes. One can also interpret his results as showing the difficulties involved in measuring a portfolio balance effect on highly aggregative data. In a subsequent paper, Frankel (1982b) attempts to increase the power of his test by (a) using monthly data, (b) jointly estimating equations for six currencies (the U.S. dollar, deutsche mark, pound sterling, yen, French franc, and the Canadian dollar), and (c) imposing stronger theoretical restrictions on his portfolio balance model. Although the coefficients then have the right sign, they are not statistically significant, and Frankel is still unable to reject perfect substitutibility. Frankel's work follows that of Dooley and Isard (1983), who do not perform formal hypothesis tests, but instead estimate a regression subject to a grid of prior constraints. They conclude that the exchange rate risk premium can account at most for only a small percentage of quarterly deutsche mark/dollar movements. 1/

The Dooley-Isard-Frankel approach concentrates on the equation for the uncovered interest rate differential. There are other studies which provide evidence on the portfolio balance effect within the context of a more complete model of exchange rate determination. The results are mixed. Artus (1976, 1981) and Branson, Haltunnen and Masson (1977, 1979) obtain results supportive of a portfolio balance effect between deutsche mark-denominated and U.S. dollar-denominated assets; Haas and Alexander (1979) obtain similar conclusions for Canadian dollar- and

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1/ The Dooley-Isard-Frankel approach bears a formal resemblance to the voluminous "exchange market efficiency" literature (examples are Hansen and Hodrick (1980), Hakkio (1981), Longworth (1981), Cumby and Obstfeld (1981) and Meese and Singleton (1982)). In the efficiency literature, the null hypothesis is that assets are perfect substitutes and exchange markets are efficient; the alternative hypothesis is that one or both of these conditions fail. The null hypothesis is rejected in almost every recent exchange market efficiency study. Some authors specifically attribute rejection to a (time-varying) risk premium. But they do not have strong grounds for doing so, because their specifications do not closely embody a well-specified model of the risk premium. (Hansen and Hodrick (1983) is an attempt to improve on this situation.) The Dooley-Isard-Frankel test rejects perfect substitutibility only if the data conform to the portfolio balance model.

U.S. dollar-denominated assets; and Loopesko (1983) provides indirect evidence of a portfolio balance effect across deutsche mark- and dollar-denominated assets, as well as across yen- and dollar-denominated assets. Martin and Masson (1979), on the other hand, are unable to provide evidence in favor of their four-country portfolio balance model. (Their model includes the U.S., Canada, Japan and Western Europe.) And Symansky, Haas and Hooper (1981) are unable to reject perfect substitutibility under rational expectations for any of four currencies (the deutsche mark, yen, Canadian dollar and pound sterling) against the U.S. dollar.

While a detailed comparison of the above studies is beyond the scope of this paper, we shall emphasize one unifying characteristic of those studies which are supportive of the portfolio balance model. In all cases, the support is primarily based on the explanatory power in exchange rate equations of either (cumulated) net private capital flows or the (cumulated) current account. 1/ (Net private capital flows and the current account are closely related, since net private capital flows are measured in these studies as the current account adjusted for changes in reserves.) It is true that, to the extent current account surpluses and deficits reflect differences in national savings rates, the portfolio balance model predicts that a current account surplus will be accompanied by an appreciating exchange rate. Because German citizens have a stronger preference for deutsche mark-denominated assets than do U.S. citizens, one would expect the deutsche mark to appreciate against the dollar whenever, holding the supplies of outside assets constant, the marketable wealth of German citizens increases and the marketable wealth of U.S. citizens decreases. But it is not clear how much of variations in U.S. and German real private wealth are reflected in current account surpluses and deficits. Even small percentage changes in the market value of the U.S. or German capital stocks (as reflected by changes in the stock and corporate bond markets) can alter U.S. and German private wealth by tens of billions of dollars. Fluctuations in long-term government bond yields similarly have a large impact on net private wealth. For these reasons, and because the current account and the exchange rate are likely to be jointly determined endogenous variables in any reasonable macroeconomic model, one must be somewhat cautious in interpreting the explanatory power of the current account in exchange rate equations as support for the portfolio balance model.

The studies cited thus far have involved small-scale econometric models. Hooper, Haas, Symansky and Stekler (1982) report on extensive efforts to try to implement the portfolio balance theory within the

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1/ Driskell (1981) and Driskell and Sheffrin (1982) give a portfolio balance interpretation to the explanatory power of the trade balance for the Swiss franc/dollar rate. Hooper and Morton (1982) and Hooper, Haas, Symansky and Stekler (1982) also demonstrate the explanatory power of the cumulated current account. Meese and Rogoff (1983) show that the cumulated current account may not be as useful an explanatory variable in exchange rate equations over the more recent sample period.

Federal Reserve Board's Multi-Country Model. The Multi-Country Model is a large-scale econometric model consisting of quarterly models of Canada, Germany, Japan, the United Kingdom and the United States as well as abbreviated OPEC and rest-of-world sectors. Hooper _et al_. explore numerous approaches, involving alternative econometric techniques, simplifying assumptions, data sets, and expectational hypotheses. Despite their exhaustive efforts, Hooper _et al_. conclude that they are unable to provide empirical support for the portfolio balance model. Nevertheless, because their priors are strong that the portfolio balance approach has quantitative significance, Hooper _et al_. are reluctant to draw any strong conclusions.

A final empirical study which must be mentioned is that of Obstfeld (1982). Obstfeld assumes that there is no exchange rate risk premium and instead postulates that political risk (fear of capital controls, tax changes or default) is the motive for portfolio diversification. 1/ Obstfeld finds that intervention involving a trade of home-country backed assets for foreign-country backed assets has only a small temporary impact. However, even if political risk is a major factor in portfolio selection, it does not necessarily follow that sterilized intervention is effective. Suppose, for example, that political risk arises due to fear of tax changes or capital controls. Then sterilized intervention might not have any effect because it does not change the total supply of bonds held within a country's borders. If instead political risk arises through fear of default, then a sterilized intervention operation which involves only a redenomination of a given government's debt will have no effect.

Dooley and Isard (1983) argue that researchers may have to estimate more general versions of the portfolio balance model in order to properly measure the exchange rate risk premium. We have already mentioned political risk as one factor that might be taken into account in modeling exchange rate risk. Dooley (1982) argues that developing country governments should be modeled separately from the world private sector. Indeed, there are numerous plausible disaggregations. It would be natural to treat banks and corporations separately from the household sector, and to include capital in the portfolio decision. 2/ Because the potential disaggregations are limitless, one can never completely reject the portfolio balance model. (Unfortunately the data limitations become severe at even modest levels of disaggregation; Hooper _et al_. (1982) discuss this problem.)

1/ Dooley and Isard (1980, 1983) and Dooley (1982) also cite political risk as a factor in portfolio choice.

2/ It would also be interesting to further explore multi-currency frameworks as in Martin and Masson (1979), von Furstenberg (1981), and Hooper _et al_. (1982).

III. Testing for a Portfolio-Balance Effect Using Weekly Data for the Canadian Dollar/United States Dollar Exchange Rate

All of the studies surveyed in the previous section are based on monthly or quarterly data. But if the effects of intervention are highly transitory, it may be difficult to detect a portfolio balance effect with such low frequency observations. 1/ Therefore, the analysis below is based primarily on weekly data. 2/ It is possible, of course, that the portfolio balance effect is so small and so transitory that it cannot even be captured with weekly data. However, if this is the case then the portfolio balance effect is unlikely to be of great macroeconomic significance.

The test employed here is based on a highly aggregative version of the portfolio balance model. Nevertheless, a number of estimation issues must be resolved in order to properly interpret the results.

When assets are perfect substitutes and there is no exchange rate risk premium, then uncovered interest rate parity holds:

$$(1) \quad r_t - r^*_t = s^e_{t+1} - s_t,$$

where "t" subscripts denote time, r_t is the interest rate on Canadian dollar bonds, r^*_t is the interest rate on U.S. dollar bonds, s_t is the logarithm of the Canadian dollar/U.S. dollar exchange rate and s^e_{t+1} is the expected value of the logarithm of the exchange rate in period t+1, conditional on information available in period t. In the empirical analysis reported below, all interest rates and exchange rates are drawn from the same market (the London Euromarket). Thus any deviation from uncovered interest parity will presumably reflect exchange rate risk and not political risk. The portfolio balance model predicts

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1/ Quarterly data can be used to make inferences about short-run behavior. Haas and Alexander (1979) employ continuous time techniques on quarterly data to arrive at estimates of very short-run dynamics. Obviously, such extrapolations are most accurate when the data is very smooth, which is not the case for the path of exchange rates.

2/ It is even possible to use daily data since the Bank of Canada releases its daily reserve figures (with a long lag). But these reserves form only a small component of outside nominal assets; information on a much larger component is available weekly. Pippenger and Phillips (1973) analyse daily Canadian intervention and exchange rate data from the 1950's. One problem with their analysis is that such data does not allow one to distinguish whether intervention affects the exchange rate through a portfolio balance effect or by altering expectations of future monetary policy.

that the exchange rate risk premium (the uncovered interest rate differential) on Canadian dollar-denominated assets will be on an increasing function of their relative supply: 1/

$$(2) \quad [r - r^* - \Delta s^e]_t = \alpha + \beta[A/SA^*]_t + \varepsilon_t,$$

where $\beta > 0$, $\Delta s^e_t \equiv s^e_{t+1} - s_t$. A is the net supply of outside Canadian dollar denominated assets, A* is the net supply of outside U.S. dollar denominated assets, S is the level of the exchange rate, and ε is a structural disturbance term. In most versions of the portfolio balance model, the asset stocks A and A* are postulated to be the net supplies of interest-bearing government debt. Fama and Farber (1979) stress that bonds and money are both nominal assets which bear the same degree of exchange rate risk. Thus one might include the monetary bases (high-powered money) together with interest-bearing debt in A and A*. Note that $\beta > 0$. A rise in the relative supply of Canadian-dollar denominated assets must be accompanied by an increase in the interest rate on Canadian dollar assets relative to the interest rate on U.S. dollar assets (adjusted for the expected rate of change of the exchange rate).

It is impossible to estimate equation (2) directly since the expected value of the future spot rate, s^e_{t+1}, is unobservable. Nor can the forward rate f_t be used as a proxy for s^e_{t+1}. As long as covered interest parity obtains 2/, f_t equals s^e_{t+1} if and only if uncovered parity holds (equation (1)). And the whole point of the portfolio balance model is that uncovered interest parity does not hold because there is an exchange rate risk premium. So the approach taken here, following Dooley and Isard (1982), and Frankel (1982), will be to assume rational expectations:

$$(3) \quad s_{t+1} = s^e_{t+1} + \theta_{t+1},$$

1/ Frankel (1982a) uses this specification (among others). This equation can only be regarded as structural when all agents have identical portfolio preferences. Dooley and Isard (1983) include domestic and foreign wealth proxies in their exchange rate risk premium equation, but these variables are very difficult to measure, especially on weekly data. To account for wealth, I include a time trend in some of the regressions.

2/ Covered interest parity implies that the forward premium equals the interest rate differential. Arbitrage ensures that covered interest parity holds exactly when all data are taken from the same trading room at the same time of day.

where θ_{t+1} is a forecast error which is uncorrelated with any information dated period t or earlier. Substituting equation (3) into equation (2) yields: 1/

$$(4) \quad [r - r^* - \Delta s]_t = \alpha + \beta[A/SA^*]_t + \varepsilon_t + \theta_{t+1}.$$

Estimation of equation (4) is much simpler if one only worries about consistency under the null hypothesis $\alpha = \beta = 0$; that is, that there is no exchange rate risk premium. Frankel (1982a, b) takes this approach. When $\alpha = \beta = 0$, equation (4) collapses to

$$(5) \quad [r - r^* - \Delta s]_t = \theta_{t+1}.$$

Treating $\alpha = \beta = 0$ as the null hypothesis allows one to consistently estimate equation (4) by ordinary least squares. One problem with Frankel's approach is that ordinary least squares is not necessarily consistent under the alternative hypothesis, $\beta > 0$, and therefore may lack power. As an extreme example, suppose sterilized intervention is used to fully offset all shocks to portfolio demand (ε) thereby stabilizing the exchange rate risk premium. The probability limit of the ordinary least squares estimate of β in equation (4) would be zero regardless of the true size of β and in spite of the fact that sterilized intervention works. Even in the absence of a central bank reaction function, the exchange rate S is surely endogenous in (4). 2/ Hooper *et al.*, (1982), who estimate some equations of the same general form as equation (4), attempt to deal with this problem by employing an instrumental variables technique. The instrumental variables approach has its disadvantages, though. It is not easy to find legitimate instrumental variables, especially for weekly regressions. 3/

1/ The specification given in (4) assumes instantaneous portfolio adjustment. But it is completely consistent with models in which, due to slow goods market adjustment or wealth accumulation, unanticipated intervention has a greater effect than anticipated intervention.

2/ The endogeneity of A/SA^* is not the only statistical problem which must be negotiated under the alternative hypothesis $\beta > 0$. The disturbance term will have a moving average component if cov $[\varepsilon_{t+1}, \theta_{t+1}] \neq 0$. This covariance is unlikely to be zero, since the structural disturbance to the risk premium, ε_{t+1}, is almost certainly going to be a component of the exchange rate forecast error, θ_{t+1}. The composite nature of the disturbance term introduces some subtle estimation problems, which are surveyed in Cumby, Huizinga and Obstfeld (1983) as well as in Hayashi and Sims (1983). For example, it is not correct to allow for a first-order autoregressive process in the structural disturance term ε by using Fair's method. (See also Flood and Garber [1980].)

3/ Hooper *et al.* use quarterly data. Note that $[r - r^* - \Delta s]_{t-1}$ is

In addition to the hypotheses embodied in equations (1) and (2), we should also consider the possibility that there are deviations from uncovered interest parity, but that the portfolio balance model is of no help in explaining them:

$$(6) \quad [r - r^* - \Delta s^e]_t = \eta_t,$$

where η_t is a serially correlated disturbance term. Note that equation (6) may be nested within equation (4). Substituting equation (3) into equation (6) yields:

$$(7) \quad [r - r^* - \Delta s]_t = \eta_t + \theta_{t+1}.$$

There are two interpretations of equation (7). One is that there is a time-varying exchange rate risk premium which is independent of (A/SA*); i.e., there is an exchange rate risk premium but it has nothing to do with the standard portfolio balance variables. A second interpretation is that exchange markets are inefficient and/or that exchange market participants do not have rational expectations. Neither of the above interpretations is easy to justify. In particular, it is difficult to construct a sensible model in which assets denominated in different currencies are imperfect substitutes but in which the exchange rate risk premium does not depend on the relative supplies of government bonds and base money. 1/ And, while reasonable economists may disagree, one should be reluctant to accept the inefficiency hypothesis until all plausible structural models of the exchange rate risk premium and of rational learning have been explored.

In spite of these caveats, the possibility that equation (7) holds cannot be dismissed. There is an accumulating body of evidence that deviations from uncovered interest parity are serially correlated. 2/ (Though the evidence is not entirely convincing because it has proven so difficult to explain this serial correlation empirically with structural-model variables.) If we treat the null hypothesis as equation (7), then

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3/ (footnote continued from p. 10) definitely not a valid instrument for estimating equation (4). The reason is that θ_t is correlated with ε_t.

1/ It is not obvious that the Obstfeld - Stockman neutrality result, discussed earlier, can be reasonably extended to the case where outside assets include the monetary base.

2/ For the case of the Canadian dollar/U.S. dollar exchange rate, see Longworth (1979), Cumby and Obstfeld (1981) or Dooley and Shafer (1983).

ordinary least squares on equation (4) is consistent but inefficient, and the standard errors reported by a canned computer package will tend to understate the true OLS standard errors. 1/

IV. Results

In this section, we estimate the portfolio balance equation (4), first by using ordinary least squares and then by using an appropriate instrumental variables technique. The Friday Euromarket exchange rates and one-week time deposit bid rates employed are described in Appendix A. 2/ That appendix also describes the weekly data used in the construction of A and A*: net private holdings of Canadian government direct and guaranteed securities, net private holdings of U.S. Treasury bills, notes and bonds, the U.S. monetary base and the Canadian monetary base. 3/

Table 1 reports ordinary least squares estimates of equation (4), in which A/SA* is constructed alternately using interest-bearing assets only, and interest-bearing assets plus the monetary base. We have already discussed why OLS is consistent under the null hypothesis of perfect substitutability. 4/ Over the full sample period, the coefficients on

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1/ Even if η_t is serially uncorrelated, equation (7) will have an MA(1) error term unless cov $(\eta_{t+1}, \theta_{t+1}) = 0$.

2/ Similar data are used by Cumby and Obstfeld (1981) and by Dooley and Shafer (1983). It is important to note that these data are characterized by large and volatile bid-ask spreads. Later, we will consider results for one-month interest rates, for which there is a much deeper market.

3/ The seasonality of bond and money supplies is not necessarily a problem for estimation of equation (4). As long as equation (4) always holds, seasonality in A and A* will simply induce a seasonal component in the uncovered interest rate differential.

4/ Although the asset stock data are measured on Wednesdays, it is unlikely that exchange market participants had full access to this data when making their exchange rate forecasts on Fridays. The fact that agents only receive complete data on A and A* with a lag might tend to bias the OLS estimate of β in equation (4) downward. For example, suppose the Canadian dollar-denominated bond supply rises in week t. The portfolio balance model predicts that the Canadian dollar interest rate will rise relative to U.S. dollar interest rate (after adjusting for the expected rate of depreciation of the exchange rate). But suppose private agents take a week to fully learn of the bond supply increase, and that when they do learn, the exchange rate depreciates. If we use the realized exchange rate as a proxy for the expected value of the exchange rate, then we might falsely conclude that a Canadian bond supply increase leads to a decrease rather than an increase in the uncovered interest rate differential on Canadian dollar assets. It is possible to control for this bias by using lagged values of A/SA* or by using instrumental variables techniques.

Table 1. Ordinary Least Squares Regressions for the One Week, Ex-Post, Uncovered Interest Rate Differential 1/

	Constant ($\times 10^{-3}$)	A/SA* ($\times 10^{-2}$)	D.W.
Full Sample March 1973-December 1980			
Bonds only	2.9 (1.10)	-6.4 (-1.30)	1.4
Bonds plus the monetary base	4.1 (1.17)	-7.7 (-1.32)	1.4
Subsample March 1973-November 1976			
Bonds only	10.8 (1.56)	-21.5 (-1.58)	1.3
Bonds plus the monetary base	8.0 (1.08)	-14.3 (-1.11)	1.3
Subsample December 1976-December 1980			
Bonds only	.9 (-.20)	.0 (.00)	1.4
Bonds plus the monetary base	-.1 (-.02)	-1.1 (-.12)	1.4

1/ t-statistics are in parentheses below the estimated coefficients.

A/SA* are insignificant and of the wrong sign. This result holds up when a time trend and/or monthly seasonal dummies are included. Similar results are obtained when the lagged value of A/SA* is either included, or used in place of, A/SA*. 1/

Table 1 also reports results over two subperiods, to allow for the possibility that a structural break occurred in November 1976. That date marks an important election in Quebec as well as an apparent shift in the time series behavior of the Canadian dollar/U.S. dollar exchange rate. But the subperiod regressions yield equally poor results. The coefficients on A/SA* remain negative and insignificant. The low Durbin-Watson statistics for all the regressions in Table I indicate the possible presence of serial correlation.

Table 2 reports two-step, (non-linear) two-stage, least squares estimates, with a correction for an ARMA (1,1) error term. The auto-regressive component is assumed to result from the structural equation (2). The moving average component arises, as described in section III, because we are using the realized value of the exchange rate as a proxy for its expected value. The estimates in Table 2 are consistent whether or not assets are perfect substitutes. 2/ However, the coefficients on A/SA* in each of the regressions are again of the wrong sign; the fact that they are statistically significant over the first subsample is of little consolation. The estimates of the autoregressive coefficient are statistically significant over the full sample. Thus, while the results in Table 2 are not supportive of the portfolio balance model, they are not clearly supportive of the joint hypothesis of perfect substitutability and market efficiency either.

1/ A positive, but statistically insignificant, coefficient obtains when the explanatory variable is cumulated Canadian intervention instead of A/SA* (not reported). (Appendix A describes the construction of the cumulated intervention series.) The results reported in Table I are based on a broader and much more satisfactory measure of changes in outside Canadian dollar-denominated assets than is obtained by just using Canadian exchange market intervention.

2/ The results reported in Table 2 are based on using time as well as lags of A/SA* and $(r - r^* - \Delta s)$ as instruments. Recall that $(r - r^* - \Delta s)$ must be lagged at least two periods to be a valid instrument. Cumby et al. (1983) explain how two-step, two-stage least squares implicitly allows for conditional heteroskedasticity, provided the model contains overidentifying restrictions. That is, the estimator can allow for the fact that the market is more likely to be volatile today if it was volatile yesterday. (Recent volatility can be captured by including lagged values of $(r - r^* - \Delta s)$ as instrumental variables.)

Table 2. Two-Step, Two-Stage, Least Squares Regressions for the One Week, Ex-Post, Uncovered Interest Rate Differential

	Constant ($\times 10^{-3}$)	Time ($\times 10^{-5}$)	A/SA*	ρ
Full Sample				
Bonds only	7.0	.3	-.15	.35
	(1.30)	(.72)	(-1.34)	(1.91)
Bonds plus monetary base	12.1	.4	-.22	.38
	(1.53)	(.89)	(-1.55)	(2.04)
Subsample March 1973-November 1976				
Bonds only	14.1	.6	-.29	.24
	(2.38)	(1.39)	(-2.52)	(1.01)
Bonds plus monetary base	1.6	.8	-2.97	.27
	(2.08)	(1.93)	(-2.17)	(1.16)
Subsample December 1976-December 1980				
Bonds only	9.0	1.9	-.27	.22
	(.73)	(.79)	(-.81)	(1.00)
Bonds plus monetary base	15.2	1.9	-.35	.25
	(.94)	(.93)	(-.99)	(1.05)

Note: t-statistics are in parentheses.

In Tables 1 and 2 above, A and A* are constructed from the components of total Canadian dollar and U.S. dollar outside assets which are available on a weekly basis. These components include the monetary base and total federal interest-bearing debt (net of central bank holdings). 1/ A broader definition of outside assets would include state and local debt, as well as the debt of federal and federally-sponsored agencies. 2/ It would also fully net out the holdings of government agencies, trust funds and pension funds. Finally, it would take into account the intervention activities of foreign central banks, especially U.S. dollar intervention. Data on some of these components of broadly-defined outside debt are available monthly and some are available quarterly. Using a method of interpolation described in Appendix B, weekly series on broadly-defined outside debt can be constructed from monthly and quarterly data. The technique of interpolation makes use of related data which are available weekly. It is designed to minimize the extent to which information unavailable at time t is incorporated into the time t element of the interpolated series. (Information which becomes available only after the time an exchange rate forecast is made might well be correlated with the prediction error.) Unfortunately, as the representative results in Table 3 reveal, the interpolated weekly series do not yield results favorable to the portfolio balance model. The coefficients on A/SA* are signficant but of the wrong sign.

For all the results presented thus far, the (ex-post) uncovered interest rate differential has been constructed using seven-day Euromarket interest rates. A possible problem with these data is that the trading volume in very short-run Euromarket securities is considerably smaller than the volume in medium-term securities. To guard against any difficulties which may arise due to the thinness of the seven-day interest rate market, we shall now consider results based on one-month interest rates. 3/ The disadvantage of using the one-month ex-post uncovered interest rate differential in a weekly regression is that it greatly complicates estimation. According to the portfolio balance model, the one-month uncovered interest rate differential should depend not only on this week's value of A/SA*, but also on the expected value of the A/SA* for each of the following four weeks. (This is true even if portfolio adjustment is instantaneous.) The above problem only compounds all the previously discussed estimation problems which arise when one tries to

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1/ Federal government deposits at commercial banks can be netted out of the weekly money series; see Appendix A for a more complete description of the data.

2/ Frankel (1982a, b) and Dooley and Isard (1982, 1983) do not include state and local debt in total outside assets.

3/ The one month ex-post uncovered interest rate differential is constructed under the assumption that covered interest rate parity holds exactly.

Table 3. Two-Step, Two-Stage, Least Squares Regressions for the One Week Ex-Post Uncovered Interest Rate Differential, Using Interpolated Data

	Constant (x 10^{-3})	Time (x 10^{-4})	A/SA*	ρ
<u>Interpolation from monthly data: bonds only</u>				
Full sample	24.5	-1.8	-.12	.24
	(5.21)	(-4.93)	(-5.32)	(1.36)
Subsample March 1973-November 1976	37.6	-4.5	-.18	.12
	(4.84)	(-3.73)	(-4.98)	(.69)
Subsample December 1976-December 1980	80.2	-2.2	-.47	.34
	(3.13)	(-2.49)	(-3.13)	(1.35)
<u>Interpolation from quarterly data: bonds plus monetary base</u>				
Full sample	45.9	-1.8	-.54	.40
	(3.69)	(-4.02)	(-3.61)	(1.98)
Subsample March 1973-November 1976	25.3	-.8	-.30	.05
	(2.75)	(-1.14)	(-2.84)	(.25)
Subsample December 1976-December 1980	7.2	-2.6	-.86	.34
	(2.36)	(-2.40)	(-2.44)	(1.28)

Note: t-statistics are in parentheses.

develop an estimator which remains consistent under the hypothesis of imperfect substitutability. Therefore, we will try only to achieve the more modest goal of ensuring that the one-month uncovered interest rate differential regressions are consistent under the null hypothesis that assets are perfect substitutes. Even so, we must take into account the fact that the error term will follow a fourth-order moving average process. 1/

In the equations reported below in Tables 4 and 5, the left-hand side variable is the logarithm of the one-month forward rate minus the logarithm of the matching realized future spot rate, $f_t - s(f_t)$. 2/ To correct for the moving average disturbance term, all the equations are estimated by two-step, two-stage, least squares. 3/

The first equation in Table 4 confirms the standard result that forward rate prediction errors are serially correlated. 4/ The low R^2 statistic is consistent with another standard result; forward rate prediction errors are in large part unforecastable. Adding the relative supply of Canadian dollar denominated bonds to U.S. dollar denominated bonds (or bonds and money) adds very little explanatory power. The coefficients on A/SA* and its lagged value are insignificant both individually and jointly. Furthermore, the estimated coefficients are again of the wrong sign. 5/ The results do not fundamentally change when more lags of A/SA* are included. Allowing for a structural break in November 1976 does not change the complexion of the results, either. In Table 5, A/SA* does enter significantly over the early sample period, though with the wrong sign. A/SA* never enters significantly or with the proper sign when forward rates from the following Tuesday are used in place of Friday forward rates. Using the interpolated asset stock data series, as in Table 3 and Appendix B, similarly yields no improvement.

1/ This point is well known; see for example, Hakkio (1981). Serial correlation arises because the one-month forecasts are sampled weekly, so that each forecast has days in common with four other forecasts.

2/ $f_t - s(f_t)$ is equal to the one-month ex-post uncovered interest rate differential, provided that covered interest parity holds. The forward rate data are Friday New York opening bids. The realized spot rates are matched according to the procedure described in Riehl and Rodriguez (1977); see Appendix A.

3/ The computer program used was developed by Robert Cumby at the International Monetary Fund. The results reported in Tables 4 and 5 do not involve instrumental variables estimation. When instrumental variables are used, and if the equation is over-identified, two-step, two-stage, least squares implicitly allows for conditional heteroskedasticity. I tried using additional lags of the right-hand side variables as instruments but did not obtain significantly different results.

4/ See section II.

5/ Strictly speaking, it is incorrect to draw strong inferences from the sign of the coefficient on A/SA* in Tables 4 and 5, because we are not estimating structural equations as in Tables 1-3.

Table 4. The dependent variable is the one month Canadian dollar/ United States dollar forward rate prediction error, $f_t - s(f_t)$. The data is weekly, June 1973 - December 1980. 1/, 2/

Equation	Constant	Time ($\times 10^{-5}$)	$f_{t-5} - s(f_{t-5})$	$f_{t-6} - s(f_{t-6})$	$(A/SA^*)_t$	$(A/SA^*)_{t-1}$	R^2	Chi-squared test: all slope coefficients = 0	Chi-squared test: coefficients on $(A/SA^*)_t$, $(A/SA^*)_{t-1}$ = 0
Autoregression	.001	1.0	.12	-.20				8.2 3/	
	(.27)	(-1.00)	(1.17)	(-2.30)			.021		
Bonds only	.01	-.2	.12	-.19	-.02	-.20		9.8	.2 4/
	(.47)	(-.12)	(1.30)	(-2.34)	(-.02)	(-.24)	.027		
Bonds only	.01	-.2	.13	-.20	-.21			8.5	
	(.47)	(-.13)	(1.22)	(-2.18)	(-.46)		.027		
Bonds plus the monetary base	.03	.4	.12	-.17	-.06	-.41		10.4	.7
	(.85)	(.18)	(1.27)	(-2.17)	(-.06)	(-.46)	.027		
Bonds plus the monetary base	.02	.4	.14	-.18	-.46			8.9	
	(.84)	(.17)	(1.28)	(-2.16)	(-.83)		.027		

1/ Two-step, two-stage, least squares estimation is used to correct for a fourth-order moving average error term.
2/ t-statistics are reported in parentheses below the estimated coefficients.
3/ Significant at the 95 percent level of confidence. The other chi-squared statistics in this column are significant at the 90 percent level. (When time is not included as a regressor, all are significant at the 95 percent level.)
4/ Both entries in this column are very insignificant.

Table 5. Subperiod regressions; the dependent variable is the one month Canadian dollar/United States dollar forward rate prediction error, $f_t - s(f_t)$. 1/, 2/

Equation	Constant	Time ($\times 10^{-5}$)	$f_{t-5} - s(f_{t-5})$	$f_{t-6} - s(f_{t-6})$	$(A/SA^*)_t$	R^2	Chi-squared test: all slope coefficients = 0, 3/
Bonds only 1973(6)-1976(11)	.05	1.0	.24	-.06	-1.12	.066	14.4
	(2.89)	(0.37)	(1.66)	(-.46)	(-3.07)		
Bonds only 1976(12)-1980(12)	.02	7.9	.07	-.25	-.75	.087	20.0
	(0.36)	(1.15)	(.46)	(-3.23)	(-.72)		
Bonds plus the monetary base 1973(6)-1976(11)	.07	3.2	.25	-.07	-1.32	.066	15.9
	(3.19)	(.76)	(1.66)	(-.49)	(-3.32)		
Bonds plus the monetary base 1976(12)-1980(12)	.04	9.5	.08	-.23	-1.25	.087	20.4
	(.83)	(1.57)	(.52)	(-3.41)	(-1.12)		

1/ Two-step, two-stage, least squares estimation is used to correct for a fourth-order moving average error term.
2/ t-statistics are reported in parentheses below the estimated coefficients.
3/ The chi-square statistics are all significant at the 95 percent level.

If the earlier results using seven-day Euromarket interest rate differentials are to be characterized as disappointing, then these results for the one-month Euromarket interest rate differentials must be regarded as extremely disappointing. The portfolio balance variables do not even appear with the correct sign.

V. The Scale of Direct Sterilized Intervention in the Foreign Exchange Market Relative to the Total Stock of Outside Assets.

This section presents an analysis of the actual scale of foreign exchange market intervention operations in Canada over the historical period 1973-1980, as well as an analysis of the potential scale of sterilized intervention. In particular, we are interested in asking whether sterilized intervention is "a drop in the bucket" compared to the overall quantity of outside Canadian dollar denominated assets, or even compared with bond sales to finance government budget deficits. If the feasible scale of sterilized intervention operations is very small relative to the size of the overall market, then the independent effects of sterilized intervention may be quite limited even if the portfolio balance effect is indeed important.

At the end of 1980, privately-held, Canadian-dollar deonominated, government of Canada direct and guaranteed debt was approximately sixty billion Canadian dollars. This figure corresponds to a fairly narrow definition of outside Canadian dollar debt. If we use a broader definition, one which includes the monetary base as well as provincial and local government Canadian-dollar denominated debt, the figure would be closer to one hundred billion Canadian dollars (after netting out intragovernmental holdings). 1/ In contrast, Canada's official international reserves minus gold stood at just over three billion U.S. dollars at the end of 1980. (The book value of gold reserves at the time was just under one billion U.S. dollars, but the market value was many times higher than that.)

Of course, a country's intervention resources are not limited to its reserve holdings. A country can increase its intervention resources by borrowing from the cooperating central banks of other countries. It can also redenominate a portion of its own debt. And a country can, if it chooses, intervene through forward market operations. Forward market operations have a portfolio balance effect exactly equivalent to sterilized intervention operations. Both shift exchange rate risk between public and private sector portfolios. 2/ It is possible to conduct forward

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1/ We are assuming that foreign governments do not issue any Canadian-dollar denominated debt and that foreign-country central banks do not use the Canadian dollar as an intervention currency.

2/ The equivalence of spot and forward market operations was demonstrated by Tsiang (1959). Forward market operations do not affect the mean or variance of the path of high-powered money, provided all foreign market intervention without large holdings of foreign currency resources. (Though not without large potential taxation resources!)

Over the historical period, foreign exchange market intervention may well have comprised a very significant percentage of unanticipated changes in the total supply of Canadian dollar debt. Certainly, average weekly intervention operations were of the same scale as average weekly central government domestic bond sales and retirements. The mean absolute value of weekly Canadian exchange market intervention was approximately half the mean absolute value of the total weekly change in privately-held, Canadian-dollar denominated, government of Canada direct and guaranteed debt. 1/ And while it is very difficult to decompose a series into its anticipated and unanticipated components, it is likely that government bond sales are anticipated to a far greater degree than intervention operations. The general size of government financing needs is known months and even years in advance. Notices of bond sales are posted in the newspaper. Intervention operations, on the other hand, typically are undertaken in response to very short run developments, and are usually somewhat secretive. 2/ Therefore, if (a) small percentage changes in the total supply of outside Canadian dollar debt have a significant impact on the exchange rate risk premium, and if (b) unanticipated interventions have a greater impact on the exchange rate than anticipated interventions, then sterilized foreign exchange market intervention may be an important independent policy tool.

VI. Conclusions

The portfolio balance model predicts that the uncovered interest rate differential on assets denominated in currency A, relative to assets denominated in currency B, should be an increasing function of their relative supply. The existence of a portfolio balance effect is a necessary condition for sterilized intervention to be an independent tool of monetary policy. The voluminous exchange market "efficiency" literature does provide some weak evidence that there exists a time-varying uncovered interest rate differential (exchange rate risk premium).

2/ (footnote continued from p. 21) exchange losses or gains are offset by tax increases or decreases.

1/ The mean absolute value of weekly changes in the Canadian Exchange Fund (adjusted for SDR allocations, valuation effects, etc; see Appendix A), was ninety-eight million U.S. dollars over the period March 1973 through December 1980. Over the same period, the mean absolute value of changes in net privately-held, Canadian-dollar denominated, government of Canada direct and guaranteed debt was two hundred eight million Canadian dollars.

2/ Standard statistical techniques for decomposing a time series into its anticipated and unanticipated components similarly indicate that the unanticipated component of foreign exchange market intervention is not small relative to the unanticipated component of government bond sales.

But is has proven very difficult to demonstrate that this time-varying differential responds as predicted to changes in the relative supplies of outside assets denominated in different currencies.

In this study, we have attempted to use high-frequency weekly data to detect a portfolio balance effect in the Canadian dollar/U.S. dollar exchange rate. Unfortunately, the data have resisted all our efforts to obtain equations for the uncovered interest rate differential in which portfolio balance variables appear with statistically significant coefficients of the right sign. The results are therefore no more encouraging than those obtained in studies based on quarterly data. 1/

Because empirical estimation of portfolio balance models requires vast theoretical simplifications, the negative results presented here and elsewhere in the literature cannot be regarded as decisive. But if one wishes to ignore these results, then it is also necessary to recognize that there is, as yet, no firm quantitative evidence on the systematic independent effects of sterilized intervention.

1/ The negative results reported here for weekly Canadian/U.S. data are consistent with quarterly results for the Canadian dollar/U.S. exchange rate cited by the working group on exchange market intervention; see Jurgensen (1983), p. 19.

Data Definitions and Sources

The sample period, March 1973-December 1980, was chosen to correspond to the availability of weekly Canadian Exchange Fund data.

Seven-day ex-post uncovered interest differentials, $r - r^* - \Delta s$: Data are London closing bid rates on spot exchange rates and seven-day time deposit interest rates; the source is the Financial Times. Where seven-day interest rates are not quoted, thirty-day rates are used as a proxy. To properly align the data, it is necessary to account for the fact that the delivery lag on the standard Euro-U.S. dollar time deposit contract is two days, whereas the delivery lags on Euro-Canadian dollar time deposit contracts and U.S./Canadian dollar spot exchange rate contracts are typically one day. (While it is possible to write a spot exchange contract for same-day delivery, the standard "spot" contract is actually a one-day forward contract.) Therefore, Thursday Euro-U.S. dollar interest rate closing bid quotes are aligned with Friday closing bid quotes for the other rates. (The results reported in the text are not qualitatively affected, however, when all quotes are drawn from Fridays.)

One-month forward exchange rate contracts: Friday and Tuesday opening New York bids are taken from the DRI data base. These are aligned with spot rates one month hence (drawn from the same source). The exact procedure for calculating spot and forward "value" dates is described in Riehl and Rodriguez (1977). This procedure is followed here except (for the minor ommission) that Canadian business holidays which are not New York business holidays are ignored in calculating value dates.

Canadian Exchange Market Intervention: Monthly data on the Canadian Exchange Fund is published in the Bank of Canada Review; daily data through 1980 were obtained from the Bank of Canada. To create a series which changes only when the private sector's holdings of Canadian dollar-denominated assets changes (in other words, a series which measures intervention according to a small-country version of the portfolio balance model of section III), the following adjustments are: (1) SDR allocations made at the beginning of 1979 and 1980 are netted out. (2) The series is adjusted for the revaluation of gold and the SDR against the dollar in October 1973. (3) Beginning July 31, 1974, the Exchange Fund's reported gold, SDR and IMF reserve positions reflect a change each Wednesday and at the end of each month in the book SDR/U.S. dollar rate. These valuation effects have been removed. (4) A series of gold sales is constructed by looking at changes in the reported U.S. dollar value of gold holdings and by removing valuation effects. The intervention series is then adjusted for the fact that although these gold sales take place at market prices, they are reported as if they took place at the official (book) price. Data on the London noon price of gold and the official SDR/dollar rate are drawn from the IMF data base. (5) The IMF reconstituted gold to Canada at the official price of thirty-five SDR's per ounce in January and December 1977, December 1978 and December 1979. But because the transactions price and official price were the same for these transactions, no adjustment is required. (6) No adjustment is made for government to government interest payments on Canadian reserves, except where a time trend is removed from the series.

Weekly data on net private holdings of Canadian-dollar denominated interest-bearing assets: The data are from the Bank of Canada Review, Table 21. The series is constructed by taking government of Canada direct and guaranteed securities held outside of government of Canada accounts, payable in Canadian dollars only (series B2482), and subtracting Bank of Canada holdings of government of Canada direct and guaranteed securities (B2461). For the year 1980, series B2400 and B2508 are used in place of the discontinued B2482. (Beginning 1980, data on the percent of government securities payable in Canadian dollars is available only monthly.)

Weekly data on net private holdings of non-interest bearing Canadian dollar assets: Formed as the sum of notes in circulation plus chartered bank deposits at the Bank of Canada, series B51 and B55 in the Bank of Canada Review.

Weekly data on net private holdings of interest-bearing U.S. dollar denominated assets: These are taken from weekly sheets maintained at the Federal Reserve Board on all Treasury bill, bond and note issues and retirements. The data net out Federal Reserve System purchases.

Weekly data on net private holdings of non-interest bearing U.S. dollar denominated assets: Data are drawn from the Federal Reserve Board data base; Federal government checking accounts at member banks are subtracted from the (seasonally unadjusted) monetary base.

U.S. dollar assets are converted to Canadian dollars using the Wednesday London closing spot exchange rate.

Monthly data on net private holdings of Canadian dollar assets: Same as the weekly data except that provincial debt, payable in Canadian dollars (B3049 from the Bank of Canada Review) is added to the series on interest-bearing debt, and government of Canada and provincial government holdings of chartered bank liabilities are subtracted from the series on non-interest bearing debt.

Monthly data on net private holdings of U.S. dollar denominated interest-bearing debt: Total U.S. government interest-bearing debt; minus that part held in U.S. government accounts, by the Federal Reserve System and by state and local governments; plus the debt of Federal and Federally-sponsored agencies; minus the U.S. dollar holdings of (industrial-country) foreign central banks. These data are taken from the U.S. Board of Governors of the Federal Reserve System Annual Statistical Digest, Tables 31 and 34. (An exception is the last item, which is calculated using annual data from the IMF Annual Report on the share of U.S. dollar assets in total industrial country reserves minus gold, together with monthly data from International Financial Statistics on total industrial country reserves minus gold.) Monthly data on net private non-interest bearing U.S. dollar debt are constructed in the same manner as the weekly data.

Quarterly data on net private interest-bearing Canadian dollar debt: Essentially the same as the monthly series but includes local government, Canadian-dollar denominated, direct and guaranteed debt, and more fully nets out the holdings of government pension funds. This series was made available by Richard Haas of the Federal Reserve Board, and is used in the Board's Multi-Country model.

Quarterly data on net private, interest-bearing, U.S. dollar-denominated debt: Includes the same elements as the monthly series plus total state and local debt (minus that part held in government accounts and retirement funds). The state and local debt data are from the Federal Reserve Board data base.

The quarterly series on net private holdings of non-interest bearing U.S. and Canadian dollar debts are the same as the monthly series.

Monthly and quarterly data on U.S. dollar denominated assets are translated into Canadian dollars using end of (month/quarter) exchange rates.

Weekly Interpolation of Monthly and Quarterly Series on Broadly-Defined Outside Assets.

Certain data series which would be useful in constructing A and A*, net private Canadian dollar-denominated assets and net private U.S. dollar-denominated assets, are available only monthly or quarterly and are not available weekly. 1/ To make use of the additional information contained in these monthly and quarterly series while continuing to run weekly regressions, we employ a method of interpolation analogous to the method developed by Chow and Lin (1971). The Chow-Lin interpolation technique makes use of related weekly series to interpolate monthly or quarterly series. In adapting their method to the present context, we must be careful to avoid constructing our interpolated weekly series from a two-sided moving average of the monthly (quarterly) data. In other words, one wants to avoid making use of the April monthly figures in constructing the interpolated weekly series for March. The reason is that the error term in equation (4) of the text includes an exchange rate forecast error. An interpolated series based on a two-sided moving average would include data unavailable to private agents in making their exchange rate forecasts. Such information would almost certainly be correlated with the forecast error term in equation (4) of the text, and therefore the coefficient estimates would be biased.

The interpolation method used here is intended to minimize the problem described above. 2/ Define $R_M \equiv (A/SA^*)_M$ as the ratio of Canadian dollar assets to U.S. dollar assets, constructed from data which are available at least monthly. Similarly define $R_W \equiv (A/SA^*)_W$; R_W is constructed from data available at least weekly. The more comprehensive stock series ratio R_M cannot actually be observed on a weekly basis, but define its unobservable weekly value as R_M^W. Assume that the following relationship holds between R_M^W and R_W:

$$\text{(C1)} \quad (R_M^W)_t = a + c(R_W)_t + z_t,$$

where the error term z_t follows a first-order autoregressive process: $z_t = \rho z_{t-1} + v_t$. We can impute the coefficients of the weekly equation (C1) from a monthly regression of R_M against R_W^M, where R_W^M is the end of month value of R_W:

1/ See Appendix A for details on which data series are available weekly versus monthly or quarterly.

2/ The interpolation technique employed in this paper is not entirely adequate because the coefficient estimates themselves are based on the entire sample period; to avoid this problem it would be necessary to use rolling regressions. It is more difficult to get around the problem that published data are frequently revised, or the problem that some published data are only available with a long lag.

(C2) $(R_M)_k = a + c(R_W^M)_k + z'_k$,

where $z'_k \approx \rho^4 z'_{k-1} + v'_k$. The subscript k indicates time measured in months.

After estimating the monthly equation (C2) over the entire sample period and imputing the coefficients of the weekly equation (C1), the interpolated weekly series $\tilde{R}_M^W$ can be obtained as follows: Suppose week t is the final week of month k. Set $(\tilde{R}_M^W)_t = (R_M)_k$, and

(C3) $\tilde{z}_k = (R_M)_k - [\tilde{a} + \tilde{c}(R_W)_t]$,

where $\tilde{a}$ and $\tilde{c}$ are the estimated coefficients from (C2). Then

(C4) $(\tilde{R}_M^W)_{t+1} = \tilde{a} + \tilde{c}(R_W)_{t+1} + \tilde{\rho}\tilde{z}_k$,

(C5) $(\tilde{R}_M^W)_{t+2} = \tilde{a} + \tilde{c}(R_W)_{t+2} + \tilde{\rho}^2\tilde{z}_k$,

etc. Week t+4 or week t+5 will again be the end of a month, and the forecasting process begins anew.

The procedure for generating a weekly series from quarterly data is analogous. For all of the results reported in the text, a time trend is included in the interpolating regressions. 1/

1/ The coefficient on the time trend for the monthly regression must be normalized in the imputed weekly regression.

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