SHORT-TERM FOREIGN ASSETS AND PORTFOLIO RISK

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INTRODUCTION

It is well established that international equity diversification lowers portfolio risk because of the low correlation of returns between national equity markets [Adler and Dumas, 1983; Errunza, 1983; Ibbotson, Carr, and Robinson, 1982; Joy et. al 1976; Solnik; 1993]. Solnik [1993] shows that the addition of foreign equities to a purely domestic portfolio can reduce risk to less than half that of a purely domestic portfolio of equal size and that maximum risk reduction occurs with as few as forty stocks spread equally over the world's major equity markets. In addition to the equalization of relative product and factor prices, risk reduction through the international diversification of equity portfolios is another gain from international exchange [Grubel and Fadner, 1971]. An interesting aspect of internationally diversified equity portfolios is that although returns are subject to exchange-rate movements, such exchange-rate movements, as Grubel and Fadner [1971] show, may decrease or increase the gains from international diversification. For equities, Raymond and Weil [1989] find that from 1976 to 1979, exchange-rate changes reduced but not completely offset the benefits from diversifying internationally.[1]

The issue addressed in this study is the effect of exchange-rate changes on the risk of holding domestic versus foreign short-term assets in a two-period portfolio model. In a two-period model, the nominal return on short-term assets can be considered non-stochastic, so the question of diversification benefits due to the correlation between nominal returns does not arise. It is generally thought, therefore, that foreign short-term assets must have greater risk than domestic assets because of the risk of exchange-rate changes. Many textbooks indirectly reinforce this idea by providing an explanation of how the forward market can be used to eliminate exchange risk [Kenen, 1994; Yarbrough and Yarbrough, 1994]. Although the use of the forward market (covering) can eliminate the uncertainty of *exchange-rate changes*, a covered foreign short-term asset does not always, as such explanations indirectly imply, have less *total* risk than a foreign short-term asset that is exposed to exchange-rate changes. Although the forward market will eliminate the risk due to exchange-rate movements, it is *total* portfolio risk that is relevant. This study disputes the view that covering in the forward market necessarily produces lower total portfolio risk than taking a speculative position in foreign short-term assets. It will be shown, first, that if returns are measured in *real terms*, then a foreign covered short-term asset will have the same *total* risk as a domestic short-term asset, and second, that a diversified portfolio containing both domestic *and* foreign short-term assets exposed to exchange risk will generally have lower risk than domestic short-term assets or foreign covered short-term assets. This second idea is consistent with the risk reduction possible with international diversification in equity markets. In general, internationally diversified portfolios produce lower risk than purely domestic portfolios.

In the debate over exchange-rate systems, floating-rate proponents argued that the emergence of forward and futures foreign-exchange markets would provide a vehicle for eliminating the risk of exchange-rate changes for short-term assets [Friedman, 1953; Johnson, 1969; Sohmen, 1969]. Although forward transactions are not perfectly suited for uncertain future payments and receipts, or for long-term obligations, they can be precisely sized and timed for short-term assets held to maturity. Khoury and Chan [1988] survey the hedging preferences of 73 U.S. industrial, service, and financial companies and find that the most popular form of hedging is the forward market. The question of the risk of covered and speculative portfolios is therefore quite relevant.

Edgerington [1979] addresses a related question in financial markets and shows that complete hedging of exposure through financial futures does not produce the optimal portfolio. Edgerington derives a risk-minimizing hedge ratio that is less than 100 percent in order to show that even extremely risk-averse individuals will not completely hedge their positions in the futures market. Cornell and Reinganum [1981] and Swanson and Caples [1987] have shown similar results for foreign-exchange exposure. These models differ from the model developed here in three very important ways. First, the Edgerington model, as applied to foreign exchange exposure, is expressed in nominal terms, so the optimal hedge ratio does not depend upon inflation risk. Second, the Edgerington model assumes that the forward market is not precisely timed, thus requiring a series of forward transactions to cover a given position. This element of uncertain forward prices introduces risk to the forward cover and is the cause of a less-than-100-percent optimal hedge ratio. The model developed in this study demonstrates that perfectly timed, 100 percent forward cover can be more risky than an uncovered foreign-exchange position and in general will be more risky than an internationally diversified portfolio of short-term assets, where the foreign short-term assets in the portfolio are exposed to exchange risk. Thus for a high level of risk aversion, even when the forward contract is perfectly timed, thereby eliminating forward price uncertainty, 100 percent forward cover is not optimal because it does not minimize portfolio risk. Third, the hedge-ratio literature calculates the proportion of a given speculative position that should be covered in the forward market. The hedge-ratio literature addresses how firms with given foreign cash flows should hedge their positions. The model presented below is concerned with the optimal portfolio proportions of domestic and foreign short-term assets — in the optimal structure of asset portfolios.

In the next section a simple model is developed to demonstrate that the risk of a speculative (uncovered) position in a foreign short-term asset is a combination of the risk of exchange-rate changes, the risk of inflation, and the co-movement of exchange-rate changes and inflation. It is shown that the risk of a covered position is simply the risk of inflation, so the risk of a covered position may exceed the risk of a speculative position if inflation and exchange-rate changes are not independent. I also present *ex post* estimates of the risk of speculative and covered positions in foreign short-term assets. I then extend the model to demonstrate that total portfolio risk-minimization requires that the portfolio include both domestic and uncovered foreign short-term assets. Some *ex post* estimates of the optimal bilateral holdings of domestic and foreign uncovered short-term assets and the consequent reduction in risk are also provided. I then present the multilateral case, along with *ex post* estimates of optimal multilateral holdings of domestic and foreign uncovered short-term assets, and the consequent reduction in risk. Summary and conclusions follow in the last section.

INTERNATIONAL SHORT-TERM ASSETS AND RISK: INDIVIDUAL ASSETS

Covered interest-rate-parity (IRP) is expressed as the equality of the rate of return on a nominally riskless domestic asset with the rate of return on a nominally riskless foreign asset, whose known proceeds are sold for the same maturity in the forward market. Letting i and i^* be, respectively, the domestic and foreign nominally riskless rate of return on assets with an n-day maturity, IRP can be stated as

$$i = i^* + f, \tag{1}$$

where f is the percent gain (or loss if negative) on the forward contract.[2]

Because Equation (1) contains no stochastic variables, it is assumed that the returns in each market are riskless. With no risk, arbitrage will force Equation (1) to hold, except for transaction costs. The nominal return on an uncovered (speculative) short-term foreign asset is $i^* + \tilde{s}$, where $\tilde{s}$ is the n-day, uncertain appreciation of the spot rate. (A tilde is used to indicate a stochastic variable.) Because the spot rate is stochastic, an uncovered foreign short-term asset is generally presumed to be more risky than a domestic short-term asset or a foreign covered short-term asset. According to this analysis, risk can be eliminated by using the forward market.[3]

The problem with this approach is that the domestic interest rate, i, is not a correct *description* of the return on domestic assets, nor is $i^* + f$ a correct description of the return on foreign assets. The relevant description of returns is expressed in real terms. Letting $\tilde{r}$ be the real return on domestic short-term assets, $\tilde{r}_c^*$ be the real return on covered foreign short-term assets, and $\tilde{p}$ the domestic rate of inflation, the real return on a domestic short-term asset is

$$\tilde{r} = i - \tilde{p}, \tag{2}$$

and the return on a covered short-term foreign asset is

$$\tilde{r}_c^* = i^* + f - \tilde{p}. \tag{3}$$

Both domestic and foreign covered assets are risky due to uncertain inflation. Using $v(\ )$ to indicate variance, the variance of both equations (2) and (3) is $v(\tilde{p})$. With inflation as the only stochastic element of domestic and foreign covered returns, both domestic and foreign covered assets have identical risk characteristics. Because domestic and foreign covered assets are stochastically equivalent, their returns will be identical, so from equations (2) and (3), $i = i^* + f$. Even when uncertain inflation is considered, the conventional IRP condition will hold.

Uncertain inflation does, however, make a difference in the relative risk of an uncovered foreign position. Letting $\tilde{r}_s^*$ be the real return on an uncovered (speculative) short-term foreign asset,

$$\tilde{r}_s^* = i^* + \tilde{s} - \tilde{p}. \tag{4}$$

The risk of the speculative position, as measured by the variance of the real return, is

$$v(\tilde{r}_s^*) = v(\tilde{s}) + v(\tilde{p}) - 2c(\tilde{s}, \tilde{p}), \tag{5}$$

where $c(\tilde{s}, \tilde{p})$ is the covariance of $\tilde{s}$ with $\tilde{p}$. If $c(\tilde{s}, \tilde{p}) = 0$, then the foreign speculative position is riskier than a domestic asset (or a covered foreign asset) by $v(\tilde{s})$, the variability of the spot rate, which is the conventional view of the difference between the risk of a foreign speculative position relative to a foreign covered position. However, the risk of a foreign uncovered position ($v(\tilde{r}_s^*)$), when measured in real terms, will be greater than the risk of a foreign covered position ($v(\tilde{r}_c^*)$) only when $v(\tilde{s}) > 2c(\tilde{s}, \tilde{p})$.[4]

If $c(\tilde{s}, \tilde{p})$ is positive, then the speculative foreign position offers some diversification from inflation that is not possible with a covered position. If the price of foreign currency and the domestic rate of inflation move together, then the movement of the exchange rate offers some protection from inflation. The loss of purchasing power is offset, to some extent, by a greater domestic currency value of the foreign asset.[5] If $c(\tilde{s}, \tilde{p})$ is negative, then a foreign speculative position is riskier than the simple movement of the spot rate. As domestic inflation increases, the domestic currency value of the foreign currency falls. Both inflation and the depreciated exchange rate erode the real value of the foreign asset.

There is no theoretical presumption that $c(\tilde{s}, \tilde{p})$ must be positive or negative in the short run. If relative purchasing-power parity holds, then given the foreign inflation rate, an increase in domestic inflation will be associated with an appreciation of the foreign currency, so the covariance of exchange-rate changes and domestic inflation will be positive. However, exchange-rate changes may occur as a result of changes in the foreign inflation rate and changes in the real exchange rate, so the covariance of the exchange-rate changes and domestic inflation could take on any sign. The sign of the covariance will be specific to a particular exchange-rate and domestic inflation episode.

TABLE 1
Variances of Returns for Foreign Speculative and Foreign Covered Positions: U.S. Perspective

Year	Covered	Speculative Canada	Speculative Germany	Speculative Japan	Speculative U.K.
1974	0.00000501	0.00007812	0.00098303	0.00077342	0.00029408
1975	0.00000445	0.00004709	0.00113670	0.00024102	0.00045242
1976	0.00000203	0.00043247	0.00018537	0.00009294	0.00091476
1977	0.00000489	0.00015737	0.00040347	0.00029845	0.00038320
1978	0.00000293	0.00009871	0.00229807	0.00265000	0.00117823
1979	0.00000146	0.00017705	0.00057229	0.00065802	0.00104202
1980	0.00001344	0.00024052	0.00142840	0.00131413	0.00081686

From a U.S. perspective, the variance of the return on a covered position is the variance of U.S. inflation, so the variance of covered returns is identical for all countries.

If the covariance of exchange-rate changes and domestic inflation is negative or zero, then covered assets will always have lower risk than uncovered assets. If, however, the covariance of exchange-rate changes and domestic inflation is positive and of sufficient size, then covered assets will have higher risk than uncovered assets.

The *ex post* end-of-year variances of monthly real returns for each year from 1974-80 for Canada, Germany, Japan and the United Kingdom presented in Table 1 give us a sense of the degree to which the movement of domestic inflation and foreign exchange rates affects the risk associated with a speculative position in a short-term foreign asset relative to a domestic short-term asset (which is equivalent to a foreign covered short-term asset). The exchange rate data are end-of-period values taken from the IMF's *International Financial Statistics*, Supplement Series, No.1, 1981. The U.S. inflation data are constructed from consumer price levels with a base year of 1975, as presented in the IMF's *International Financial Statistics*, Supplement Series, No.2, 1981. The U.S. is assumed to be the domestic country.[6]

In every case, the risk of a covered position in foreign short-term assets, as measured by the variance of U.S. inflation (which is equivalent to the risk of a domestic position in short-term assets) is less than the risk of a speculative position in foreign short-term assets. Although exchange-rate changes and U.S. inflation are positively related for a number of years for each country, the positive covariance is not of sufficient size to produce a lower risk than a foreign covered position. In those years for which the covariance is positive, it is much smaller than the variance of exchange-rate changes, offering only a small amount of diversification from inflation. The covariance of exchange-rate changes and U.S. inflation is also negative for a number of years, thereby adding to the risk of exchange-rate changes.

BILATERAL PORTFOLIOS

Although the yearly variances of real monthly returns for Canada, Germany, Japan and the United Kingdom from 1974 to 1980 show that a speculative foreign short-term asset position is riskier than covered foreign asset positions, it does not necessarily follow that the optimal short-term asset portfolio should contain no speculative foreign short-term assets. Assets cannot be evaluated for risk independently. In general, minimum portfolio risk will not be produced by holding only the lowest risk asset. In the presence of diversification benefits, minimum risk will be produced by holding a portfolio of assets. The case of two-asset portfolios is developed here because of the intuitive appeal of the bilateral model. For a two-asset portfolio made up of domestic short-term assets (or the equivalent, covered foreign short-term assets), and foreign short-term speculative assets, the variance of the portfolio return is

(6) $$V = w_1^2 v(\tilde{r}) + w_2^2 v(\tilde{r}_s^*) + 2w_1 w_2 c(\tilde{r}, \tilde{r}_s^*),$$

where V = the variance of the portfolio,
w_1 = the proportion of total short-term assets held in the domestic asset, and
w_2 = the proportion of total short-term assets held in the foreign uncovered asset ($w_1 + w_2 = 1$).

If the minimum-variance portfolio contains foreign speculative short-term assets, then diversification into foreign speculative short-term assets will produce lower portfolio risk than holding purely domestic short-term assets, or equivalently, purely covered foreign short-term assets. The fraction of total short-term assets held in the foreign uncovered asset, w_2, that minimizes portfolio variance is

(7) $$w_2^m = c(\tilde{s}, \tilde{p})/v(\tilde{s}).$$ [7]

The optimal fraction of the foreign speculative short-term asset, w_2^m, is zero only if $c(\tilde{s}, \tilde{p})$ is zero. If, in general, $c(\tilde{s}, \tilde{p})$ is nonzero, then the introduction of stochastic inflation makes 100 percent forward cover more risky than a portfolio containing speculative foreign short-term assets. Even if forward contracts can be perfectly timed and sized, 100 percent forward cover is riskier than holding some foreign speculative short-term assets.

If changes in the foreign exchange rate and inflation are positively related, i.e., $c(\tilde{s}, \tilde{p}) > 0$, then by equation (7), risk will be minimized by holding foreign speculative short-term assets equal to w_2^m as a fraction of total short-term assets. A purely domestic position or its risk equivalent, a covered foreign short-term asset position, must bear the inflation risk fully. A foreign speculative position, however, diversifies away some of the inflation risk. In this case, an increase in domestic inflation is accompanied by an appreciation of the foreign exchange rate, offsetting some of the purchasing power loss due to inflation.

If the foreign exchange rate and inflation are negatively related, i.e., $c(\tilde{s}, \tilde{p}) < 0$, then by equation (7), the speculative position in foreign short-term assets that minimizes risk is negative. Risk will be minimized by borrowing foreign currency in an amount equal, in absolute value, to w_2^m as a fraction of total short-term assets. In this case, an increase in domestic inflation is associated with a depreciation of the foreign exchange rate. The foreign liability will decrease in terms of domestic currency units, offsetting some of the purchasing power loss due to inflation.[8]

Only if domestic inflation and changes in the foreign exchange rate are unrelated, i.e., $c(\tilde{s}, \tilde{p}) = 0$, does a 100 percent covered position produce lowest risk. In this case a foreign position should be completely covered in the forward market. However, foreign assets need not be held because they produce the same risk (inflation risk) as a domestic asset, and by IRP, the return will be the same as the domestic asset. Domestic assets will be preferred because they avoid the transaction charges of dealing in the forward market.

The limits of diversification can be determined by writing equation (7) as

(8) $$w_2^m = R(\tilde{s}, \tilde{p})[v(\tilde{p})/v(\tilde{s})]^{1/2},$$

where $R(\tilde{s}, \tilde{p})$ is the correlation coefficient between changes in the exchange rate and the inflation rate. Substituting this into equation (6) gives the value of the minimum-variance portfolio as

(9) $$V^m = v(\tilde{p})[1 - R^2(\tilde{s}, \tilde{p})].$$

As $R(\tilde{s}, \tilde{p})$ approaches 1.0 or -1.0, V^m approaches zero. If domestic inflation and changes in the foreign exchange rates are perfectly correlated, or perfectly inversely correlated, then all risk can be diversified away. If $R(\tilde{s}, \tilde{p}) = 0$, then by Equation (9), the value of the minimum-variance portfolio is $v(\tilde{p})$; inflation risk is completely non-diversifiable. If inflation and changes in the exchange rate are unrelated, then by equation (8), the minimum-variance portfolio contains no foreign speculative short-term assets; the minimum-variance portfolio is composed solely of domestic short-term assets and/or covered foreign short-term assets.

Table 2 presents the optimal holdings of speculative foreign short-term assets in each bilateral case and the ratio of the variance of the optimal portfolio of short-term assets to the variance of a portfolio of covered foreign short-term assets. For most years and countries the variance of the two portfolios is similar; the ratio of the optimal to the covered portfolio is approximately unity. However, the optimal portfolio considerably reduces risk in some years. For example, in 1978 a U.S. institution could have reduced risk to 73.5 percent of that produced from covering Canadian short-term assets (or holding only domestic short-term assets) by holding 8.23 percent of its short-term assets in Canadian uncovered short-term assets. It appears that significant risk reduction is possible by holding speculative foreign short-term assets in selected years.

These findings suggest that covering all foreign short-term asset exposure may create more risk than necessary. Some exposure to foreign-exchange risk may offset some of the risk caused by domestic inflation. As in the case of international equity

TABLE 2
Optimal Weights of Foreign Speculative Assets, and Consequent Risk Reduction Relative to the Covered Portfolio: Bilateral Cases

Year	Canada		Germany		Japan		U.K.	
	w_2^m	$V^m/v(r_c^*)$	w_2^m	$V^m/v(r_c^*)$	w_2^m	$V^m/v(r_c^*)$	w_2^m	$V^m/v(r_c^*)$
1974	0.0081	0.999	-0.0117	0.974	0.0346	0.803	-0.0170	0.984
1975	0.0316	0.990	-0.0326	0.746	0.0121	0.992	-0.0209	0.958
1976	-0.0022	0.999	-0.0355	0.894	0.0119	0.993	-0.0108	0.949
1977	-0.0435	0.946	-0.0162	0.979	-0.0018	0.999	-0.0536	0.799
1978	0.0823	0.735	0.0010	0.999	0.0133	0.834	0.0033	0.966
1979	-0.0005	0.999	0.0106	0.955	0.0266	0.665	0.0117	0.899
1980	0.0099	0.998	-0.0100	0.990	0.0080	0.994	-0.0023	0.999

diversification, domestic firms with no international payments and receipts can reduce inflation risk by holding foreign assets or borrowing in foreign markets.

MULTILATERAL PORTFOLIOS

In the multilateral case, diversification benefits will be produced not only by the relationship between exchange-rate changes and domestic inflation, but also by the relationship between exchange-rate changes and inflation rates of different countries. The variance of the portfolio of short-term assets in the multilateral case is

$$V = \Sigma_i \Sigma_j w_i w_j c(\tilde{r}_i, \tilde{r}_j) \tag{10}$$

where w_i is the weight of country i's short-term asset and $c(\tilde{r}_i, \tilde{r}_j)$ is the covariance between the return on country i's short-term asset and the return on country j's short-term assets. For $i = j$, the covariance is equal to the variance of country i's short-term asset.

The minimum variance can be found by finding the set of weights (w_i) that satisfies the first-order conditions to the Lagrangian

$$L = \Sigma_i \Sigma_j w_i w_j c(\tilde{r}_i, \tilde{r}_j) + \delta(\Sigma w_i - 1) \tag{11}$$

where δ is the Lagrangian multiplier. Table 3 gives the set of *ex post*, optimal, year-end weights for the countries indicated, and the ratio of the optimal variance to the variance of the covered position.[9] In each case, the U.S. was defined as the domestic country. The reduction in risk with modest speculative positions in foreign short-term assets is notable. For example, in 1978 risk can be reduced to 48.7 percent of that produced by covering foreign-exchange exposure by lending 7.7 percent of the value of short-term assets in Canada, lending 2.3 percent in Japan, borrowing 1.7 percent in Germany, and borrowing 0.1 percent in the United Kingdom.

TABLE 3
Optimal Weights of Foreign Speculative Assets, and Consequent Risk Reduction Relative to the Covered Portfolio: Multilateral Cases

Year	US	Canada	Germany	Japan	U.K.	$V^m/v(\tilde{r}_c^*)$
1974	0.977	0.036	-0.054	0.096	-0.055	0.276
1975	0.998	0.030	-0.035	0.001	0.005	0.728
1976	1.020	-0.003	-0.039	0.037	-0.015	0.791
1977	1.137	-0.093	0.063	-0.002	-0.104	0.573
1978	0.919	0.077	-0.017	0.023	-0.001	0.487
1979	0.972	-0.001	0.000	0.025	0.004	0.655
1980	0.969	0.054	-0.022	0.015	-0.015	0.954

Weights may not add to unity due to rounding.

CONCLUSION

For high levels of risk aversion, intuition and standard texts suggest that foreign short-term assets be covered in the forward market. However, in the presence of stochastic inflation, 100 percent forward cover does not necessarily produce lower risk than a portfolio containing some foreign speculative short-term assets. If domestic inflation and foreign exchange rates are related, then risk minimization occurs when there is exposure to exchange-rate changes. Risk-minimizing exposure is produced by taking a long (short) position if exchange rates and domestic inflation are positively (negatively) correlated. As with diversified equity portfolios, short-term assets should be held in a number of currencies. As the *ex post* analysis of the previous section demonstrates, significant risk reduction can be achieved with relatively small foreign short-term asset positions. The amount of risk reduction ranges from 4.6 percent (1.0 - 0.954) for 1980 to 72.4 percent (1.0 - .276) for 1974. The largest optimal foreign exchange position occurs in 1977 when risk minimization requires borrowing in the United Kingdom an amount equal to 10.6 percent of the value of short-term assets. As is the case with equity diversification, an actor with no foreign payables or receivables can reduce risk through international diversification.

It is important to emphasize that the potential risk reduction through speculation in foreign short-term assets was demonstrated *ex post* and therefore represents the maximum risk reduction possible with perfect foresight. In order to make *ex ante* decisions about short-term asset allocation, it is necessary to model and predict the relationship between domestic inflation and changes in exchange rates in the short run.

NOTES

This research was supported by a summer grant from Muhlenberg College. The author thanks Gordon Weil, Wayne Morra, the editor, and two anonymous referees for their supportive comments on the manuscript.

1. See Grubel and Fadner [1971] for an earlier statement on exchange-rate changes and international diversification. Grubel and Fadner's empirical measures are, however, confined to the limited movement of exchange rates during the Bretton Woods period.
2. Letting S be the current spot rate, and F the current forward rate, both on an n-day forward contract, $f = (F-S)/S$. Equation (1) is an approximation of the more precise IRP expression $(1+i) = (1+i)F/S$.
3. The risk equivalent of using the forward market can be produced by short-term borrowing and lending in the forward market. The exchange risk of a foreign receivable (payable) can be eliminated by borrowing (lending) in the foreign currency for the same amount and term as the receivable (payable).
4. Wihlborg [1978] and Yeager [1976] make similar arguments about the risk of domestic short-term assets and foreign short-term assets in the presence of purchasing-power parity. Clark [1973] and Yeager [1976] also show that exporters and importers of goods may lose from forward cover.
5. The risk of the speculative position can be written as $v(\tilde{r}_s^*) = v(\tilde{s}) + v(\tilde{p}) - 2\sigma(\tilde{s})\sigma(\tilde{p})R(\tilde{s}, \tilde{p})$ where σ is the standard deviation of the indicated variable, and R is the correlation coefficient of the indicated variables. If the change in the foreign-exchange rate and the inflation rate are perfectly correlated so that $R = 1.0$, then $v(\tilde{r}_s^*) = [\sigma(\tilde{s}) - \sigma(\tilde{p})]^2$. The risk of the speculative position can be diversified away completely only if the standard deviation of changes in the exchange rate equals the standard deviation of the inflation rate. A well-known characteristic of floating exchange rates is the high variability of exchange rates relative to price levels and inflation. Table 1 verifies this characteristic for monthly data from 1974-80.
6. The period 1974-80 was chosen simply because of the ease of data collection. The IMF Supplement Series provides the necessary data for a common base year for each country. It is recognized that this time period is one of volatile exchange rates and inflation and that the results in Table 1 may differ across time periods. However, as long as the covariance of exchange rates and inflation is not zero, there will be diversification benefits from holding uncovered assets for any time period.
7. Equation (7) can be derived by first substituting equation (2) and (4) into equation (6) and letting $w_1 = 1 - w_2$. The resulting expression is then differentiated with respect to w_2, set equal to zero, and solved for w_2.
8. The effect of diversification benefits on portfolio variance can be seen by substituting $w_1 = 1 - w_2$, and $w_2^m = c(\tilde{s}, \tilde{p})/v(\tilde{s})$ into the portfolio variance as expressed by equation (6). This gives the minimum portfolio variance as $V^m = v(\tilde{p}) - w_2^m c(\tilde{s}, \tilde{p})$. The risk of a domestic short-term asset, or a covered foreign short-term asset is $v(\tilde{p})$. If the value of $c(\tilde{s}, \tilde{p})$ is nonzero, then by borrowing in the foreign market ($w_2^m < 0$), or by lending in the foreign market ($w_2^m > 0$), risk can be reduced below $v(\tilde{p})$.
9. The optimal weights were found by first arranging the first-order conditions in matrix form. Solving for the weights then requires a simple matrix inversion and multiplication. The value of the minimum variance was found by calculating **W'CW**, where **W** is the column vector of optimal weights, and **C** is the variance-covariance matrix of returns. Optimal weights and relative variances were calculated for every month of the data using the past twelve months of the data. Only the end-of-year optimal weights and relative variances are provided in Table 3. The end-of-year optimal weights are representative of within-year optimal weights.

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