Commodity Futures Cross Hedging of Foreign Exchange Exposure

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I. INTRODUCTION

The problem of hedging foreign exchange risk using currency futures contracts has been thoroughly examined and the general results and performance of "direct" hedging strategies (i.e., covering a major currency such as the yen with a yen futures contract) are well known (see Dale (1981), Grammatikos, and Saunders (1983), Hill and Schneeweis (1981, 1982)). Recent changes in the volume and nature of third world trade and capital flows, however, raise a new question: how does a trader or investor cover foreign exchange risk when the expected future cash flow is denominated in a minor currency? Forward and futures markets do not yet exist for these currencies. Historically, some LDC nations have coped with this problem by pegging. Today, many minor currency nations allow their exchange rates to compete directly in the system of the "dirty float." A means of reducing foreign exchange risk for these currencies is not straightforward.

This study investigates one approach by which this "cross hedging" problem may be addressed. A variety of commodity futures contracts are employed to reduce minor currency foreign exchange exposure. Results are compared to an all-inclusive currency futures benchmark hedging strategy. Unlike earlier currency futures hedging and cross hedging studies, a hedging hypothesis forms the basis for the construction of tested strategies. *Ex ante* performance is emphasized, using a relatively large sample size.

II. LITERATURE REVIEW

Several studies have examined the hedging performance of commodity futures for both direct and cross hedging strategies (e.g., see Chen, Sears, and Tzang (1987), Eaker and Grant (1987), Miller and Luke (1982), Senchak and Easterwood (1983), and Sheales and Tomek (1987)). Other researchers have applied currency futures to the problem of reducing major currency foreign exchange exposure. Dale (1981), Grammatikos and Saunders (1983), and Hill and Schneeweis (1981, 1982) have estimated *ex post* measures of "optimal" hedge ratios and hedging effectiveness, using the Ederington (1979)[1]

[1]Although the minimum-variance methodology, as applied to futures hedging, is often attributed to Ederington; earlier work in futures portfolio theory by Johnson (1960) and Stein (1961), as well as the original Markowitz (1952) study, should be credited also.

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The Journal of Futures Markets, Vol.10, No. 3, 287–306 (1990)

CCC 0270-7314/90/030287-20$04.00

minimum-variance methodology, for strategies designed to reduce foreign exchange risk. Although results of these currency futures studies suggest direct hedging strategies to be effective, their approach is somewhat simplistic because it ignores the need for actual hedgers to implement optimal hedge ratio estimates *ex ante,* thereby lowering hedging performance.

Hedging effectiveness is more likely to be eroded *ex ante* in the presence of intertemporal hedge ratio instability. Grammatikos and Saunders (1983) and Marmer (1986) tested for instability in direct strategy hedge ratios involving yen, deutschmark, pound, and Canadian dollar futures. Instability was not determined to be a large problem for these major currencies. Eaker and Grant (1987), although not testing directly for instability, obtained empirical results for *ex ante* currency cross hedging strategies which suggest hedge ratio variability.

III. CROSS HEDGING FOREIGN EXCHANGE RISK

This study emphasizes *ex ante* hedging strategies, although *ex post* performance is estimated for comparison purposes. Commodity futures cross hedging strategies of minor currency foreign exchange risk are examined. These strategies address the growing need for additional hedging instruments among LDC and other third world participants in world trade and money markets. The focus of this study upon *ex ante* hedging strategies allows close study of the hedge ratio instability problem, which appears to be significant for minor currencies.

Because the choice of an appropriate hedging instrument is not obvious for minor currencies (i.e., there are no direct hedging alternatives, only numerous cross hedging possibilities), an empirical test of commodity futures strategies is performed, with results compared to a currency futures benchmark portfolio.

The success of any hedging instrument must be related to the strength (and stability) of the correlation between movements in the spot price and the futures (hedge) price. Traditional "flow" theories of exchange rate determination argue that exchange rates reflect underlying supply and demand characteristics for currencies. Changes in exchange rates should be generated by changes in the demand (supply) for goods and services exported (imported). Demand changes are influenced by export price changes.[2] So a positive correlation[3] should exist between exchange rate movements and export commodity (and commodity futures) price changes.

This correlation is the basis for the cross hedging strategies tested in this study. A "primary export commodity" hypothesis is proposed, where futures contracts of commodities representing a major proportion of a nation's total exports are implemented as hedges against minor currency movements. In its most general form, this hypothesis should be supported if export commodity futures cross hedges are successful in reducing foreign exchange risk. A "strict" version of this hypothesis proposes that a positive relationship should exist between "export rank" (i.e., relative intra-country ranking, in terms of percentage of total country exports, of various export commodities) and hedging effectiveness. For example, soybean futures should be a more successful cross hedge of the Brazilian cruziero than coffee futures because soybeans represent a larger proportion of Brazil's exports in the sample period. Thus commodity futures, corresponding to the several leading export commodities of minor currency nations, are included in the study.

[2]This is simply a roundabout way to describe the purchasing power parity theorem which is widely accepted to determine exchange rates, at least in the long run.

[3]The nature of the correlation depends upon how one defines an exchange rate. An exchange rate is defined herein as "indirect" quotes, i.e., the price of the home currency in terms of some foreign currency numeraire.

The "strict" form of the primary export commodity hypothesis also would suggest that the greater the world market share for a commodity held by a country, the stronger the size of the exchange rate/futures price correlation, and the more successful the hedge. Therefore, petroleum futures should be a more effective cross hedge of the Mexican peso, which held roughly 5% of world market share in petroleum during the sample period, than for the Norwegian krone (1%). Therefore, various countries holding large world market shares in the same (futures) commodity markets are included in the study. This permits full testing of the hypothesis, and its expected positive relationship (intra-commodity) between market share and cross hedging effectiveness.

IV. DATA

Country selection was the first step in assembling the data. An adequate number of minor currency nations which export a commodity traded on world futures exchanges were first identified. Country exports of the commodity also needed to represent a large proportion of world market share. In addition, the minor currency itself could not be pegged to any major currency at any time during the sample period, and also must be relatively free of trade or capital flow restrictions. The Commodity Research Bureau *Commodity Yearbook*, the International Monetary Fund *International Financial Statistics*, and the IMF *Exchange Arrangements and Exchange Restrictions* provided the necessary information concerning export percentage and rank, proportion of world market share and rank, and restrictions.

Monthly[4] spot prices were collected for each of the 13 minor currencies from the IMF *IFS* tape. Corresponding settlement[5] prices were obtained for 15 "primary export commodity" futures contracts from the CRB *Commodity Yearbook*, the *Wall Street Journal*, and the *London Financial Times*. Gold futures, and the 5 currency futures prices used in the benchmark strategy, came from the Chicago Mercantile Exchange's *IMM Yearbook*.

A summary of contract type, listed exchange, contract units, and trading dates for each futures is presented in Appendix 1. Due to various and differing trading histories, the futures contracts included in the study represent a sample which ranges in size from 149 monthly observations (August 1973 to December 1985) for the "oldest" contracts, to 34 monthly observations for the most recently-created contract (petroleum).

V. EMPIRICAL TESTS AND RESULTS

A. Empirically-Testable Hedging Model

The general cross hedging model is based upon the mean-variance objective function:

$$\min_{\beta_i \beta_j} \operatorname{Var}(C_{Ht}) = \operatorname{Var}(C_{st}) + \sum \beta_i^2 \operatorname{Var}(C_{fit}) + 2 \sum \beta_i \operatorname{cov}(C_{st}, C_{fit}) + 2 \sum \sum \beta_i \beta_j \operatorname{cov}(C_{fit}, C_{fjt}) \quad (1)$$

[4]Only a few of the selected minor currencies had spot rates reported on a daily basis over the entire sample period. Because of the availability of monthly data on the *IFS* tape, a larger cross-sectional dataset was constructed, rather than one with 1–5 countries and a larger number of observations for each one.

[5]Settlement prices are determined by futures exchanges after trading has ended each day. They are meant to be representative of a closing price, and are determined by evaluating futures prices during some "closing period." Settlement prices are treated as closing prices in this study.

subject to:

$$C_{0Ht} = E(C_{st}) + \sum \beta_i E(C_{fit}) \tag{2}$$

where

C_{st}, C_{fit} = the price change during period t of the spot and i^{th} futures contracts, respectively;

C_{0Ht} = the target expected change in value during period t of a portfolio invested in a fixed level of spot currency and n futures contracts, each in proportion β_i.

β_i = the proportion of integer number of contracts. Thus β_i would equal the hedge ratio with $\beta_i < 0$ representing a short position and $\beta_i > 0$ representing a long futures position.

Ederington (1979) and Anderson and Danthine (1981), among others, have demonstrated that this problem may be restated as one of determining the minimum risk hedge ratio, β_i^*, equal to the value of β_i for which the unconstrained objective function (1) reaches a minimum. Empirically, these hedge ratios may be determined by a multivariate OLS regression of the single spot position on the multiple futures contracts (see Appendix 2 for proof). The empirical hedging regression equation is of the general form.

$$C_{st} = a + \beta_1 C_{f1t} + \beta_2 C_{f2t} + \ldots + \beta_n C_{fnt} + u_t \tag{3}$$

The measure of hedging effectiveness, e, for the minimum risk hedges (β_i^*, $i = 1, 2, \ldots n$) reduces to the coefficient of determination (r^2) for the above regression (see Appendix 2).

The model in its empirically-testable form (eq. 3) is used to examine performance of the "primary export commodity" strategies. Emphasis is placed upon *ex ante* (out-of-sample) results. This type of across-holding period performance is examined by partitioning the sample data into three subperiods.[6] A "naive" out-of-sample strategy is used, where prior subperiod hedge ratio estimates are implemented into the subsequent holding period. The specific model form adopted for this study is logarithmic (log-log) which generates hedge ratio estimates interpretable as elasticity measures. This model form is essentially a "unitless" percentage change model, employed because of unit problems associated with cross hedging several minor currencies while using a US dollar numeraire.[7]

B. Empirical Results

An examination of in-sample performance of commodity futures hedging strategies is a test of the "primary export commodity" hypothesis. Table I reports *ex post* estimates of variance-minimizing OLS hedge ratios and hedging effectiveness for thirteen minor currencies. Sixteen commodity futures contracts are used as single and portfolio hedges against foreign exchange risk. Table I is organized as follows: column one describes the particular spot currency being hedged. The second column reports the futures hedge used. "Export rank" is a relative ranking of the commodity among all the minor cur-

[6]The choice of subperiod partitions was guided by the need for adequate sample size using monthly data. For the oldest contracts, the subperiods were approximately 51 months each.

[7]A noniterative Cochrane-Orcutt autocorrelation-corrected model also was estimated *ex post* and *ex ante*. Because the log-log (elasticity) model is used, these GLS estimates are still variance-minimizing. The GLS hedge ratio estimates are unbiased and more efficient than the OLS hedge ratios. Cochrane-Orcutt results were similar to OLS effectiveness measures presented.

Table I
COMMODITY FUTURES CROSS HEDGING RESULTS
(IN-SAMPLE HEDGE RATIOS AND EFFECTIVENESS FOR PERIOD 8/31/73 THROUGH 12/31/85)

Spot	Futures	Export Rank	World Export	Hedge Ratios Beta1	Beta2	Beta3	Beta4	Hedging Effect	*F*	*N*
Australia (Dollar)	Wheat	2	6(5%)	−0.1229				0.0333	3.24	96
				(−1.800)				(0.0230)		
	Wool	3	1(30%)	−0.0483				0.0135	1.74	129
				(−1.319)				(0.0057)		
	Cattle	5	6(2–3%)	0.1322				0.0145	1.52	105
				(1.232)				(0.0049)		
	Portfolio			−0.6928	−0.1105	0.5784		0.3343	39.17	82
				(−5.957)	(−3.027)	(5.226)		(0.3087)		
Brazil (Cruziero)	Soybeans	1	2(20%)	−5.0721				0.1255	12.77	91
				(−3.595)				(0.1157)		
	Coffee	2	1(25%)	−2.9578				0.0776	8.50	103
				(−2.914)				(0.0685)		
	Orange Juice	4	1(30%)	6.253				0.4725	91.36	104
				(9.558)				(0.4673)		
	Sugar	5	1(10%)	−1.9851				0.3099	41.76	95
				(−6.463)				(0.3025)		
	Portfolio			−1.8203	0.8993	5.074	−0.8044	0.5483	105.61	92
				(−1.336)	(.991)	(6.447)	(−2.151)	(0.5275)		
China (Yuan)	Sugar	2	5(4%)	−0.3044				0.5830	132.82	97
				(−11.524)				(0.5786)		
Columbia (Peso)	Coffee	1	2(10%)	−0.3848				0.0289	3.07	105
				(−1.752)				(0.0195)		
Finland (Markka)	Lumber	2	−(<1%)	−0.7508				0.2714	37.62	103
				(−6.134)				(0.2642)		
India	Cotton	3	4(8%)	−0.2319				0.0388	4.16	105

Table I
COMMODITY FUTURES CROSS HEDGING RESULTS
(IN-SAMPLE HEDGE RATIOS AND EFFECTIVENESS FOR PERIOD 8/31/73 THROUGH 12/31/85) continued

Spot	Futures	Export Rank	World Export	Hedge Ratios Beta1	Beta2	Beta3	Beta4	Hedging Effect	*F*	*N*
(Rupee)				(−2.048)				(0.0295)		
Kuwait	Petroleum	1	13(1–2%)	−0.092				0.1911	7.56	34
(Dinar)				(−2.749)				(0.1658)		
Mexico	Petroleum	1	4(5%)	−3.127				0.6303	54.56	34
(Peso)				(−7.386)				(0.6187)		
	Cotton	2	9(2%)	−0.457				0.0648	7.21	106
				(−.639)				(0.0595)		
	Coffee	3	6(3%)	0.0101				0.0146	1.53	105
				(.109)				(−0.0096)		
	Silver	4	2(12.5%)	−0.563				0.0691	7.20	99
				(−2.683)				(0.0595)		
	Portfolio			−1.0164	−1.9312	1.335	−0.2776	0.9275	1215.34	99
				(2.348)	(−4.059)	(6.361)	(−1.653)	(0.9252)		
Nigeria	Petroleum	1	12(2–3%)	−0.9399				0.6931	72.27	34
(Naira)				(−8.500)				(0.6835)		
	Cocoa	2	3(14%)	−0.6737				0.2771	39.86	106
				(−6.344)				(0.2701)		

Table I
COMMODITY FUTURES CROSS HEDGING RESULTS
(IN-SAMPLE HEDGE RATIOS AND EFFECTIVENESS FOR PERIOD 8/31/73 THROUGH 12/31/85) continued

Spot	Futures	Export Rank	World Export	Hedge Ratios Beta1	Beta2	Beta3	Beta4	Hedging Effect	*F*	*N*
Morocco	Orange	2	8(3%)	1.078				0.4713	92.71	106
(Dirham)	Juice			(9.629)				(0.4662)		
Norway	Petroleum	1	16(1%)	−0.5073				0.2598	11.23	34
(Krone)				(−3.352)				(0.2367)		
	Aluminum	2	5(5%)	0.4918				0.7304	222.15	84
				(14.906)				(0.7271)		
Peru	Copper	1	7(4–5%)	−2.6849				0.1147	13.47	106
(Inti)				(−3.671)				(0.1062)		
South Africa	Gold	1	1(49%)	−0.1303				0.0189	1.87	99
(Rand)				(−1.368)				(0.0088)		
	Platinum	3	2(40%)	−0.185				0.0477	5.26	107
				(−2.292)				(0.0386)		
	Portfolio			0.822	−1.1856			0.3410	49.68	99
				(5.148)	(−6.850)			(0.3273)		
Mean Effectiveness	+.2751									
Variability	.2630									

rency nation's exported commodities. This rank is obtained from an average of (US dollar-denominated) export figures reported in the IMF *International Financial Statistics* book, calculated during the 1973–1985 sample period. Column four describes "world export" and provides market share ranking and percentages. The number reported outside the parenthesis is country ranking of commodity (US dollar-denominated) exports relative to other countries exporting the same commodity. The percentage number inside the parenthesis is the average proportion of world market share held by the exporting country during the overall sample period. Market share ranking and percentage averages were determined from export figures in the CRB *Commodity Yearbook*. The next four "beta" columns present estimates of variance-minimizing hedge ratios for single and portfolio commodity hedging strategies. Size of the estimates is reported above, with t-statistics shown below in parenthesis. Two measures of hedging effectiveness are presented in ninth column. The top measure is the standard OLS measure. The number reported directly below in parenthesis this estimate is the "adjusted" r-squared which has been corrected for degrees of freedom.[8] An F-statistic of overall model significance and number of observations in the sample (limited in some cases by commodity futures trading history) are presented in the final two columns of Table I. Mean hedging effectiveness and performance variability (standard deviation) are found at the end of the table.

Although commodity hedging performance is variable across countries, in-sample hedging effectiveness results support the "primary commodity export" hypothesis. For the single commodity strategies, statistical significance of hedge ratios, hedging effectiveness measures, and F-statistics are moderate. Hedging performance ranged from +.0146(−.0096) for a coffee futures cross hedge of the Mexican peso, to +.7304(.7271) for an aluminum futures cross hedge of the Norwegian krone. Mean hedging effectiveness for the single futures strategies is +.2497. Commodity futures portfolio hedging strategies are more successful in reducing risk. Of the four strategies examined, performance ranged from +.3343(.3087) for a 3-commodity futures hedge of the Australian dollar, to +.9275(.9252) for a 4-commodity hedge of the peso. Mean performance for portfolio hedges is +.5378 (i.e., a 53.78% foreign exchange risk reduction, relative to an unhedged position).

In its general form, the "primary export commodity" hypothesis proposed in section three cannot be rejected. Primary export commodity futures hedges provide significant risk reductions. Although results are variable across contracts, many commodity cross hedging approaches (particularly commodity portfolios strategies) greatly reduce minor currency foreign exchange exposure. Results from Table I, however, suggest that the "strict" form of the hypothesis is rejected. Expected positive relationships between hedging effectiveness and commodity export rank (intra-country), and effectiveness and world market share (intra-commodity) are not observed consistently in the results.

In-sample hedging effectiveness measures (Table I) are useful for examining the degree of empirical support of the hedging hypothesis proposed in section three. However, out-of-sample effectiveness measures are more useful and more realistic estimates of performance available to actual hedgers. Hedge ratio and (in-sample and out-of-sample) hedging effectiveness estimates for three subperiods are reported in Table II. Fifteen single and four portfolio commodity cross hedging strategies are tested using a "naive" out-of-sample approach, where hedge ratios estimated in the prior subperiod are imple-

[8]The adjusted effectiveness measure is more appropriate for comparisons of strategies with differing portfolio sizes. Several commodity futures portfolios, as well as the "benchmark" currency futures portfolio, can be compared to the single commodity hedging strategies using this adjusted r-squared measure.

Table II
COMMODITY FUTURES "NAIVE" OUT-OF-SAMPLE CROSS HEDGING EFFECTIVENESS
(MONTHLY HOLDING PERIODS FOR SAMPLE PERIOD 08/31/73 to 12/31/85)

Spot	Futures	Period 1 Optimal	Period 2 Opptimal	1 into 2	Period 3 Optimal	2 into 3	*N* per Period
Australia	Wool	0.2669	0.0074		0.7003		49
(Dollar)		$e = .4708$	$e = .0413$	$e\hat{} = -1.124$	$e = .9651$	$e\hat{} = .0203$	
Brazil	Soybeans	2.7747	−3.007		−4.5842		31
(Cruziero)		$e = .2766$	$e = .5608$	$e\hat{} = -1.5125$	$e = .6815$	$e\hat{} = .6009$	
China	Sugar	−0.082	−0.1762		−0.4335		32
(Yuan)		$e = .5711$	$e = .9321$	$e\hat{} = .6657$	$e = .7347$	$e\hat{} = .4759$	
Columbia	Coffee	0.0025	−0.4084		1.5211		35
(Peso)		$e = .0001$	$e = .2498$	$e\hat{} = -.0031$	$e = .5480$	$e\hat{} = -.0338$	
Finland	Lumber	−0.2562	−0.4949		−0.2683		34
(Markka)		$e = .1743$	$e = .2090$	$e\hat{} = .1604$	$e = .3361$	$e\hat{} = .0964$	
India	Cotton	−0.1461	−0.5528		−0.6719		35
(Rupee)		$e = .2137$	$e = .6096$	$e\hat{} = .2796$	$e = .6827$	$e\hat{} = .6613$	
Kuwait	Petroleum	−0.0172	−0.2292		0.1532		12
(Dinar)		$e = .0366$	$e = .8205$	$e\hat{} = .1185$	$e = .2373$	$e\hat{} = -1.2417$	
Mexico	Silver	0.0026	−0.4474		−1.121		33
(Peso)		$e = .3601$	$e = .0944$	$e\hat{} = -.0011$	$e = .7788$	$e\hat{} = .4976$	
Morocco	Orange Juice	−0.133	0.731		0.3648		35
(Dirham)		$e = .0788$	$e = .5017$	$e\hat{} = -.1992$	$e = .2425$	$e\hat{} = -.0017$	
Nigeria	Cocoa	−0.0321	−0.3785		0.0065		35
(Naira)		$e = .1670$	$e = .4419$	$e\hat{} = .0718$	$e = .0001$	$e\hat{} = -.1184$	
Norway	Aluminum	−0.0081	0.2885		0.1622		29
(Krone)		$e = .0010$	$e = .5730$	$e\hat{} = -.0326$	$e = .1436$	$e\hat{} = .0565$	
	Petroleum	−0.254	−0.9857		0.3864		12
		$e = .1017$	$e = .6686$	$e\hat{} = .3002$	$e = .1045$	$e\hat{} = -1.2124$	

Table II
COMMODITY FUTURES "NAIVE" OUT-OF-SAMPLE CROSS HEDGING EFFECTIVENESS
(MONTHLY HOLDING PERIODS FOR SAMPLE PERIOD 08/31/73 to 12/31/85) continued

Spot	Futures	Period 1 Optimal	Period 2 Opptimal	1 into 2	Period 3 Optimal	2 into 3	N per Period
Peru	Copper	1.4379	−2.4854		−5.8066		35
(Inti)		e = .6072	e = .8021	$e^{\wedge}$ = −1.1965	e = .5944	$e^{\wedge}$ = .4000	
South Africa	Gold	−0.0651	−0.5836		−2.4165		33
(Rand)		e = .8259	e = .6645	$e^{\wedge}$ = .1400	e = .7717	$e^{\wedge}$ = .3277	
	Platinum	−0.0395	−0.5185		−1.4646		36
		e = .7664	e = .8280	$e^{\wedge}$ = .1214	e = .6559	$e^{\wedge}$ = .3822	
Australia	Wheat	0.0331	−0.3689		−0.0569		30
(Dollar)	Wool	−0.0058	0.0219		0.7512		
	Cattle	−0.0346	0.2562		−0.4168		
		e = .0340	e = .7430	$e^{\wedge}$ = −.1360	e = .8799	$e^{\wedge}$ = .0167	
Brazil	Soybeans	0.0918	0.1163		−1.7842		23
(Cruziero)	Coffee	0.6044	0.2272		4.0661		
	Orange Juice	0.2158	−1.4608		−0.503		
	Sugar	0.7018	−1.2617		−1.3034		
		e = .9457	e = .8468	$e^{\wedge}$ = −1.2643	e = .9330	$e^{\wedge}$ = .5518	
Mexico	Petroleum	0.5584	−0.3281		1.4144		12
(Peso)	Cotton	−0.3468	−0.6744		−4.2443		
	Coffee	1.5360	−0.1228		1.2407		
	Silver	−0.1392	−0.0508		1.0307		
		e = .9457	e = .8889	$e^{\wedge}$ = −.3622	e = .9377	$e^{\wedge}$ = .1305	
Soouth Africa	Gold	−0.0866	0.0425		−3.1886		33
(Rand)	Platinum	0.0228	−0.5689		0.5311		
		e = .8339	e = .8003	$e^{\wedge}$ = .1216	e = .7805	$e^{\wedge}$ = .3910	

mented into the subsequent holding subperiod. For comparison purposes, a "benchmark" currency futures portfolio strategy is tested for subperiods identical to the commodity strategies. The benchmark strategy includes all currency futures contracts which have traded uninterrupted on the IMM since 1973.[9] Table III presents results of these corresponding currency hedges.

The first column of Table II reports the spot minor currency hedged by each strategy. Column two identifies the futures contract(s) used to hedge the spot. The third column reports in-sample hedge ratio and hedging effectiveness results for the first subperiod. Directly across from the commodity futures listed in column two is the "optimal" (OLS) hedge ratio for that futures contract in subperiod one. Underneath all futures hedge ratios in column three is the hedging effectiveness measure (e). Column four of Table II reports the same in-sample hedge ratio and hedging effectiveness estimates as column three, this time for the second data subperiod. The fifth column, "1 into 2," shows results of a naive out-of-sample strategy. Optimal (in-sample) hedge ratios estimated from subperiod one are implemented into the second subperiod. An out-of-sample hedging effectiveness measure, "$e\hat{}$," is presented in column five. Note that with out-of-sample strategies, it is possible to actually increase foreign exchange exposure with the hedge relative to an unhedged position. Such performance is indicated by an $e\hat{}$ measure with a negative sign. Column six reports optimal in-sample hedge ratios and hedging effectiveness measures for the third subperiod. The seventh column shows OLS out-of-sample performance for the naive strategy in subperiod three. The eighth column reports the number of observations in each subperiod, which is variable across contracts, due to the differing trading histories of various futures (see Appendix 1).

Table III is constructed similarly to Table II, since results of the currency futures benchmark portfolios are to be compared to the performance of the commodity strategies. OLS hedge ratios for the British pound, Canadian dollar, Japanese yen, Swiss franc, and West German deutschmark are presented for each subperiod. Subperiods correspond to the commodity strategies. In-sample hedging effectiveness (e), and naive out-of-sample performance ($e\hat{}$) are reported in Table III across subperiods. The thirteen minor currencies examined in Table II are hedged with the benchmark currency futures portfolio strategy (Table III).

Commodity cross hedging strategies are equally as successful as the benchmark currency portfolio strategy, when *ex ante* performance is measured. This is not true for the *ex post* measures where the currency strategy clearly dominates. OLS in-sample mean effectiveness for currencies is $e = .8903$ while commodity mean $e = .5207$ across contracts and countries. For a case-by-case comparison of in-sample strategies for each minor currency, the benchmark portfolio strategy outperforms the corresponding commodity strategy for 49 of 56 trials. However, out-of-sample results for the naive strategies are quite different. It is clear from both Tables II and III that a substantial "drop" or discrepancy in performance is encountered from in-sample to out-of-sample. Mean *ex ante* hedging effectiveness for currency strategies drops to $e\hat{} = -.0403$, and commodity strategy average performance falls to $e\hat{} = -.0487$. The negative sign on both these means indicates that cross hedging actually *increases* foreign exchange exposure relative to an unhedged spot position.

The cause of this discrepancy between in-sample and out-of-sample cross hedging performance appears to be intertemporal instability of hedge ratios. The instability is

[9]These five currency futures are the British pound, Canadian dollar, West German deutschmark, Japanese yen, and Swiss franc.

Table III
CURRENCY FUTURES "BENCHMARK" PORTFOLIO OUT-OF-SAMPLE CROSS HEDGING EFFECTIVENESS
(MONTHLY HOLDING PERIODS FOR SAMPLE PERIOD 08/31/73 to 12/31/85)

Spot	Futures	Period 1 Optimal	Period 2 Optimal	1 into 2	Period 3 Optimal	2 into 3
Australia	*BP*	0.4595 e = .9072	0.1665	e = .7307	0.1260	e = .7984
(Dollar)	*CD*	1.1948	0.2771		1.8900	
	JY	0.3955	0.161		−0.4011	
	SF	−0.2007	0.084	$e^{\wedge}$ = −1.5269	0.9121	$e^{\wedge}$ = .2009
	DM	−0.2474	−0.2477		−0.5725	
Brazil	*BP*	−10.9607 e = .8338	−5.0322	e = .8894	2.7186	e = .9426
(Cruziero)	*CD*	15.661	13.0123		13.2793	
	JY	10.4727	8.7701		−7.9907	
	SF	2.0158	2.727	$e^{\wedge}$ = −2.0120	2.5496	$e^{\wedge}$ = −.0217
	DM	−1.6043	−2.4639		2.0987	
China	*BP*	0.12 e = .9449	0.3108	e = .9627	0.2608	e = .9240
(Yuan)	*CD*	−0.1003	−0.2741		3.1288	
	JY	−0.1928	−0.0568		−0.2519	
	SF	0.1196	−0.021	$e^{\wedge}$ = .7150	0.0533	$e^{\wedge}$ = .3734
	DM	0.6632	0.424		0.0912	
Columbia	*BP*	0.5095 e = .9775	−0.9616	e = .8930	0.1922	e = .9362
(Peso)	*CD*	1.0503	2.0332		4.0526	
	JY	0.3448	0.5399		−1.8196	
	SF	−0.8652	−0.9635	$e^{\wedge}$ = −.1148	0.6999	$e^{\wedge}$ = .0899
	DM	0.397	1.7567		0.3784	
Finland	*BP*	0.1955 e = .8120	0.3195	e = .9461	0.7271	e = .9286
(Markka)	*CD*	0.4395	0.3563		−0.2815	
	JY	−0.4304	−0.0361		−0.0648	
	SF	−0.0223	−0.0014	$e^{\wedge}$ = .5505	0.1815	$e^{\wedge}$ = .8608
	DM	0.7008	0.3855		0.0131	

Table III
CURRENCY FUTURES "BENCHMARK" PORTFOLIO OUT-OF-SAMPLE CROSS HEDGING EFFECTIVENESS (MONTHLY HOLDING PERIODS FOR SAMPLE PERIOD 08/31/73 to 12/31/85) continued

Spot	Futures	Period 1 Optimal	Period 2 Optimal	1 into 2	Period 3 Optimal	2 into 3
India	*BP*	0.2915 e = .9515	0.2832	e = .8492	0.2064	e = .9848
(Rupee)	*CD*	0.359	0.5012		0.9093	
	JY	0.146	0.1548		−0.3571	
	SF	−0.2064	−0.0675	$e\hat{}$ = .4561	0.3016	$e\hat{}$ = .8748
	DM	0.6086	0.2126		0.185	
Kuwait	*BP*	0.0002 e = .8996	0.1099	e = .8012	0.0798	e = .9334
(Dinar)	*CD*	−0.0559	0.1034		0.036	
	JY	−0.0287	0.1013		0.1201	
	SF	−0.023	0.0079	$e\hat{}$ = .0102	−0.0165	$e\hat{}$ = .8842
	DM	0.2415	0.0368		0.0922	
Mexico	*BP*	1.8428 e = .9055	−0.0937	e = .8459	4.406	e = .8718
(Peso)	*CD*	1.4403	0.3148		5.0732	
	JY	0.7946	0.167		−2.6583	
	SF	1.9769	−0.3941	$e\hat{}$ = −3.8764	−0.5482	$e\hat{}$ = .0305
	DM	−3.8631	0.6043		−1.5362	
Morocco	*BP*	0.3744 e = .6301	−0.184	e = .9706	0.2195	e = .9518
(Dirham)	*CD*	−0.3519	0.7848		1.7372	
	JY	−0.0513	0.2283		−0.9251	
	SF	0.2294	−0.3562	$e\hat{}$ = .3045	0.1204	$e\hat{}$ = .6500
	DM	0.0045	1.5008		1.0828	
Nigeria	*BP*	0.105 e = .6812	0.7917	e = .9114	0.0726	e = .8808
(Naira)	*CD*	0.0819	0.2364		1.6071	
	JY	−0.3267	−0.0933		−0.4989	
	SF	0.2175	−0.1291	$e\hat{}$ = .3699	0.2499	$e\hat{}$ = .5600
	DM	0.0059	0.0766		0.0284	

Table III
CURRENCY FUTURES "BENCHMARK" PORTFOLIO OUT-OF-SAMPLE CROSS HEDGING EFFECTIVENESS (MONTHLY HOLDING PERIODS FOR SAMPLE PERIOD 08/31/73 to 12/31/85) continued

Spot	Futures	Period 1 Optimal	Period 2 Optimal	1 into 2	Period 3 Optimal	2 into 3
Norway	*BP*	0.051 e = .8751	0.1524	e = .9284	0.6659	e = .9633
(Krone)	*CD*	0.0473	0.628		0.2121	
	JY	−0.5683	0.0928		−0.0085	
	SF	−0.0556	−0.0548	$e^{\wedge}$ = −.1600	0.2563	$e^{\wedge}$ = .8516
	DM	1.0983	0.5256		0.0133	
Peru	*BP*	1.7555 e = .9519	−2.7933	e = *.8981*	*1.4331*	e = .9296
(Inti)	*CD*	0.353	7.7276		12.3003	
	JY	−1.33	1.5913		−5.2365	
	SF	−0.0368	−3.1592	$e^{\wedge}$ = .5155	1.5648	$e^{\wedge}$ = .1215
	DM	−0.2485	4.8528		1.8308	
South Africa	*BP*	0.5652 e = .9044	0.0841	e = .8799	−0.1192	e = .8973
(Rand)	*CD*	0.4718	−0.2313		5.5333	
	JY	−0.2771	0.0556		−0.8023	
	SF	−0.6599	0.045	$e^{\wedge}$ = .2510	0.2154	$e^{\wedge}$ = .0101
	DM	1.1893	0.0134		0.5737	

evident in both Tables II and III via comparison of optimal hedge ratios for the same futures contracts across subperiods. These changes in risk-minimizing hedge ratios undermine the naive (prior period) out-of-sample strategies, and causes variable *ex ante* cross hedging performance (e.g., Brazil in Table II and Norway in Table III). One measure of the swings in out-of-sample hedging effectiveness is the standard deviation of $e\hat{}$ across strategies. Commodity cross hedging effectiveness standard deviation is .5924, which is lower than currency benchmark effectiveness deviation at 1.0409. Further evidence of relative commodity cross hedging effectiveness stability is trial-by-trial comparison of performance when out-of-sample effectiveness is negative for either strategy. Of these fifteen occurrences, ten were worse (more negative) for the currency portfolio strategies. For example, cross hedging Mexican peso risk in subperiod two (1 into 2) resulted in $e\hat{} = -.0011$ for the commodity (silver) approach, while causing an $e\hat{} = -3.8764$ (i.e., a 387.64% *increase* in foreign exchange exposure) for the benchmark currency portfolio.

Mean hedging effectiveness is roughly equal *ex ante* for both the commodity and currency strategies. Single commodity cross hedges equal the currency portfolios in performance. However, commodity portfolio strategies outperform currency benchmarks. Using OLS measures of out-of-sample hedging effectiveness, the commodity strategies are more effective in reducing minor currency foreign exchange risk than the benchmark currency portfolio in nineteen of thirty-eight trials. As discussed above, some of this higher relative effectiveness is due to greater instability of currency performance. Commodity portfolio strategies have greater hedging effectiveness than the currency portfolio benchmarks in six of eight trials. Mean out-of-sample effectiveness for the four commodity portfolio strategies examined was $e\hat{} = -.0689$, while mean performance for the same four currency benchmarks is $e\hat{} = -.8681$.

VI. SUMMARY AND CONCLUSIONS

This study investigates one potential method of reducing minor currency foreign exchange risk. By using a "primary export commodity" hypothesis as a basis of cross hedge construction, commodity futures contracts are implemented against unanticipated movements of thirteen minor currencies over a 1973–1985 sample period. The generally-accepted Ederington (1979) methodology is employed, with an emphasis upon *ex ante* hedging effectiveness. These types of out-of-sample tests are more realistic and more indicative of the performance available to actual hedgers. First, the "primary export commodity" hypothesis is empirically tested using *ex post* strategies. Results support this hedging hypothesis in its most general form, since commodity cross hedging strategies are successful in reducing minor currency foreign exchange risk. A "strict" form of the hypothesis, which predicts a positive relationship between commodity export rank and hedging effectiveness (intra-country) and a similar positive relationship between hedging performance and country world market share (intra-commodity) was not supported consistently by empirical results.

Commodity cross hedging performance is estimated *ex ante,* with results compared to a simple currency futures benchmark portfolio. A "naive" out-of-sample strategy is employed for both commodities and currencies for corresponding subperiods. One result obtained is a large "drop" or discrepancy between in-sample and out-of-sample performance. Although mean hedging effectiveness had been higher *ex post* for the currency futures benchmarks, commodity and currency strategies mean *ex ante* effectiveness measures are identical in size and both are negative. The negative sign indicates that foreign exchange risk is actually *increased* by the commodity and currency cross hedges, rela-

tive to an unhedged position. These results suggest that generally-accepted in-sample measures may overstate the "real world" hedging performance.

The cause of this "drop" seems to be intertemporal instability of hedge ratios. Examination of hedge ratios across subperiods and calculation of currency and commodity effectiveness variability (standard deviation) suggest that the currency futures cross hedging strategies are somewhat more susceptible to large swings in performance. A trial-by-trial comparison of *ex ante* effectiveness shows single commodity cross hedges equal to the currency futures portfolios while commodity portfolio hedges outperform the benchmark. These results suggest export commodity futures to be an equally effective, and perhaps more stable, alternative to currency contracts for hedging minor currency exposure. For example, a hedger should consider soybean futures just as seriously as pound or deutschmark futures when constructing a cross hedge *ex ante* against movements in the Brazilian cruziero.

APPENDIX 1

DESCRIPTION OF FUTURES CONTRACT DATA (CHARACTERISTICS OF INCLUDED CURRENCY AND COMMODITY FUTURES CONTRACTS, INCLUDING PER UNIT DENOMINATIONS, TRADING DATES, AND PLACE OF TRADE)

Futures	Currencies Hedged	Contract	Included Trading Dates	Denomination	Exchange	Data Source
Aluminum	Norwegian Krone	"nearest" (3-month)	10/31/78 to 1985	British pounds per tonne	London Metal Exchange	London Finan. Times
British Pound	All minor currencies	"nearest"	08/31/73 to 1985	US dollars per British pound	IMM of Chicago Merc. Exchange	IMM Yearbook
Canadian Dollar	All minor currencies	"nearest"	08/31/73 to 1985	US dollars per Canadian dollar	IMM of Chicago Merc. Exchange	IMM Yearbook
Cattle	Australian dollar	June	04/29/77 to 1985	cents per pound	Chicago Mercantile Exchange	CRB Commodity Yearbook
Cocoa	Nigerian naira	March	03/31/77 to 1985	dollars per ton	NY Coffee, Sugar & Cocoa Exchange	CRB Commodity Yearbook
Coffee	Mexican peso	"nearest" (3-month)	04/29/77 to 1985	cents per pound	NY Coffee, Sugar & Cocoa Exchange	Wall Street Journal
Copper	Peruvian inti	May	03/31/77 to 1985	cents per pound	NY COMEX	CRB Commodity Yearbook
Cotton	Indian rupee	May	03/31/77 to 1985	cents per pound	NY Cotton Exchange	CRB Commodity Yearbook
Gold	South African rand	"nearest"	10/31/77 to 1985	dollars per ounce	IMM of Chicago Merc. Exchange	IMM Yearbook
Japanese Yen	All minor currencies	"nearest"	08/31/73 to 1985	US dollars per Japanese yen	IMM of Chicago Merc. Exchange	IMM Yearbook
Lumber	Finnish markka	May	06/30/77 to 1985	dollars per 1000 feet	Chicago Mercantile Exchange	CRB Commodity Yearbook

DESCRIPTION OF FUTURES CONTRACT DATA (CHARACTERISTICS OF INCLUDED CURRENCY AND COMMODITY FUTURES CONTRACTS, INCLUDING PER UNIT DENOMINATIONS, TRADING DATES, AND PLACE OF TRADE) continued

Futures Trading Dates	Currencies Hedged	Denomination	Included Contract	Exchange		Data Source
Orange Juice	Moroccan dirham	May	03/31/73 to 1985	cents per pound	NY Cotton Exchange	CRB Commodity Yearbook
Platinum	South African rand	April	02/28/77 to 1985	dollars per ounce	NY COMEX	CRB Commodity Yearbook
Petroleum	Kuwaiti dinar Mexican peso Nigerian naira Norwegian krone	December	03/31/83 to 1985	dollars per barrel	NY COMEX	CRB Commodity Yearbook
Silver	Mexican peso	December	10/31/77 to 1985	dollars per ounce	NY COMEX	CRB Commodity Yearbook
Soybeans	Brazilian cruziero	May	03/31/78 to 1985	cents per bushel	Chicago Board of Trade	CRB Commodity Yearbook
Sugar	Brazilian cruziero Chinese yuan Indian rupee	March	12/21/77 to 1985	cents per pound	NY Coffee, Sugar & Cocoa Exchange	CRB Commodity Yearbook
Swiss franc	All minor currencies	"nearest"	08/31/85 to 1985	US dollars per Swiss franc	IMM of Chicago Merc. Exchange	IMM Yearbook
West German Deutschmark	All minor currencies	"nearest"	08/31/85 to 1985	US dollars per deutschmark	IMM of Chicago Merc. Exchange	IMM Yearbook
Wheat	Australian dollar	May	04/29/77 to 03/29/85	cents per bushel	Chicago Board of Trade	CRB Commodity Yearbook
Wool	Australian dollar	"nearest" (3-month)	08/31/73 to 08/30/85	Australian cents per kilogram	Sydney COMEX	London Finan. Times

Appendix 2

The assumed objective of the individual hedger is to receive the maximum possible degree of risk (variance) reduction through an appropriate choice of a futures hedge position. This follows directly from the objective function:

$$\underset{\beta_i \beta_j}{\text{Min}} \ \text{Var}(C_{Ht}) = \text{Var}(C_{st}) + \sum \beta_i^2 \ \text{Var}(C_{fit}) + 2 \sum \beta_i \ \text{cov}(C_{st}, C_{fit}) + 2 \sum \sum \beta_i \beta_j \ \text{cov}(C_{fit}, C_{fjt}) \tag{A-1}$$

subject to:

$$C_{OHt} = E(C_{st}) + \sum \beta_i E(C_{fit}) \tag{A-2}$$

Since the system (A-1 and A-2) is homogeneous of degree zero, the problem may therefore be stated as one of determining the minimum risk hedge ratios (β_i^*'s) equal to the value of β_i (for all i) for which the unconstrained objective function (A-1) reaches a minimum. Minimum risk hedge ratios may be determined by setting the partial derivative of the portfolio variance with respect to β_i equal to zero and solving for β_i.

$$\frac{\delta \text{Var}(C_{Ht})}{\delta \beta_i} = 2\beta_i \ \text{Var}(C_{fit}) + 2 \ \text{cov}(C_{st}, C_{fit}) = 0 \tag{A-3}$$

assuming all "cross-covariances" between futures are zero (i.e., no multicollinearity). Solving for β_i:

$$\text{Hedge Ratio} = \beta_i^* = \frac{-\text{cov}(C_{st}, C_{fit})}{\text{Var}(C_{fit})} \qquad (i = 1, 2, \ldots n) \tag{A-4}$$

Which is consistent with the findings of Ederington (1979) and others for the single futures case. β_i is numerically equivalent to the negative of the slope coefficient of a regression of the spot currency position on the multiple futures contracts (see Anderson and Danthine (1981)).

The measure of hedging effectiveness (e) for the minimum risk hedge position (β_i^*, $i = 1, 2, \ldots n$) is determined to be the reduction in variance as a proportion of total variance which results from adopting a hedged ($\beta_i = 0$ for some i) as opposed to an unhedged ($\beta_i = 0$ for all i) position. This reduces to the coefficient of determination for a multiple regression of the spot position on the futures contracts positions.

$$e = \frac{\text{Var}(C_{st}) - \text{Var}(C_{Ht})}{\text{Var}(C_{st})} = 1 - \frac{\text{Var}(C_{Ht})}{\text{Var}(C_{st})} \tag{A-5}$$

by substitution of (A-1) and (A-4) into (A-5) above (again assuming crossproducts between futures are equal to zero):

$$e = \frac{\text{cov}(C_{st}, C_{fit})^2}{\text{Var}(C_{st}) \ \text{Var}(C_{fit})} = r^2 \tag{A-6}$$

Note from (A-6) that the higher the correlation between spot and futures price changes (first differences or percentages), the more effective are futures contracts as cross hedges of a fixed spot position. Total risk reduction (i.e., a perfect hedge) would be observed for $e = r^2 = 1.0$.

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