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An Efficient Frontier for International Portfolios with Commodity Assets

Including commodities and
assets from emerging equity
markets in investment
portfolios produces significant
risk/return benefits.

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Summary findings

In recent years, the role of investment funds has increased in most commodity markets. Investment funds, which traditionally deal with financial markets, have been shifting between financial markets and commodity futures markets, as well as among commodity futures markets.

The popularity of investing in emerging capital markets is as high as it has been since World War I. By 1913, nearly half of a typical equity portfolio was invested in emerging markets. Today, one in every four dollars invested in foreign equity markets goes to emerging markets.

Both commodity futures and emerging capital markets are growing in popularity because they allow risk

reduction through portfolio diversification.

Satyanarayan and Varangis analyze the benefits of including commodity futures and assets from emerging markets in an investment portfolio.

They also try to calculate the optimal composition of assets. The calculated optimal weights show that a considerable proportion of an investment portfolio could be invested in commodity futures and emerging market assets. The weights calculated are higher than those funds usually used, signifying the potential for further expansion of these assets in a portfolio.

Finally, including commodity futures and assets from emerging markets in investment portfolios produces a significant risk/return benefit.

This paper — a product of the International Trade Division, Policy Research Department — is part of a larger effort in the department to explore the role of commodities as assets. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Dawn Gustafson, room S7-033, extension 33732 (30 pages). March 1994.

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**AN EFFICIENT FRONTIER FOR INTERNATIONAL PORTFOLIOS
WITH COMMODITY ASSETS**

By

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and

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INTRODUCTION

An increasing amount of attention has recently been devoted to the notion of commodities as traded assets. This notion is, however, not new. Dusak (1973, p.1388) in extending the Capital Asset Pricing Model (CAPM) to investigate commodity market risk premiums noted that "...futures markets are no different in principle from the markets for any other risky portfolio assets...they (futures market assets) are all candidates for inclusion in the investor's portfolio". Recent years have witnessed the increasing role of investment funds in most commodity markets. Investment funds, traditionally dealing with financial markets, have now been diversifying into commodity futures markets.

Claessens and Varangis (1994) in a discussion of commodity risk management in developing countries argue that the increased tradability of commodities necessitates a re-interpretation of the rate of return for commodities. A commodity that trades as a financial asset, if left untraded, forgoes the opportunity cost of money (interest rate)¹. Commodity rates of return should reflect this opportunity cost; thus the appropriate rate of return on a commodity should equal the spot return (percentage change in the spot or cash commodity price) plus the opportunity cost of money. Claessens and Varangis point out that commodity assets, in addition to offering high rates of return, also offer significant risk management benefits since commodity assets are generally negatively correlated with other assets.

¹This is particularly true for the more storable commodities such as metals. The tradability of commodities implies that commodity prices are more interest rate sensitive. Palaskas and Varangis (1989), for instance, found that a 1% increase in the real interest rate lead to a 2.2% decrease in the price of metals but only a 1.2% decrease in the price of less storable agricultural commodities.

In addition to commodities, the popularity of investing in emerging capital markets has been increasing in recent years. Today one in every four dollars invested in foreign equity markets goes to emerging stock markets. According to *Risk Magazine* (1993), in 1992 alone, \$14 billion flowed into foreign emerging market equities, taking total foreign holdings to about \$86 billion. Key vehicles are the proliferating country funds, regional funds and global emerging market funds. According to the same article, the high risks involved in foreign equity markets have led to the growing popularity of global emerging market funds, which seek to reduce risk through diversification (note that the correlation between emerging markets is mostly quite low).

The objective of this paper is to construct an international portfolio that includes commodity assets as well as assets from developed and emerging markets to evaluate the risk-return characteristics of such a portfolio. The returns from commodity assets is measured by the recently developed Goldman Sachs Commodity Index (GSCI) which incorporates the notion that commodity asset returns must include an opportunity cost of money component. The composition of the optimal international portfolio is examined and an efficient frontier for the international assets is derived.

The outline of the paper is as follows. Section 1 describes the salient features of the Goldman Sachs Commodity Index and the return-risk characteristics of commodity assets. Section 2 analyses the return-risk structure of the international portfolio while Section 3 derives the optimal composition of the international portfolio and the efficient frontier of assets. Section 4 remarks on the policy implications of the study.

I. COMMODITY MARKET INVESTMENTS AND THE GSCI

The growing interest in commodities as traded assets prompted Goldman Sachs to develop the Goldman Sachs Commodity Index (GSCI) in 1991. The GSCI incorporates the notion that the returns on commodity assets must include an opportunity cost component. The return on this index replicates the return from a fully collateralized portfolio of commodity futures². The GSCI is constructed in a manner similar to a capitalization-weighted stock market index except that the commodity futures are weighted according to the dollar value of the commodities world production. In 1992, for instance, the GSCI dollar weights were as follows: 48% energy futures, 23% livestock futures, 21% agricultural futures and 8% metals futures. Since 1982, the weights have generally shifted away from agricultural and livestock futures and towards energy futures.

The total returns from the GSCI are made up of three components - the return from T-bills (the opportunity cost component), the spot return (changes in the commodities prices) and the "roll yield". Table 1 shows the breakdown of total returns by each of these three components over the 1970-1992 period. The roll yield essentially represents the loss or gain from trading futures contracts. In general, the most active futures contract (usually the first nearby contract) is held until a month before its expiration when it is "rolled over" by selling it and purchasing the second nearby contract. The profit or loss from this represents the roll yield. If a commodity is in backwardation, the roll yield is positive because the futures price increases towards the spot price as the maturity date approaches. Over the 1970-1992 period, since commodity futures

²The return on the GSCI is calculated on the assumption that the investor posted collateral consisting of US T-bills equal to the value of the futures prices.

prices were generally in backwardation, the roll yield was positive. Table 1 indicates that the total annual return on the GSCI over this period was 13.81%. Of this, 7.49% was attributable to the T-bill yield, 3.74% to the roll yield and 2.58% to the spot return. Over the same period, the return on the S&P 500 index was 10.84%. Clearly, investment in the GSCI over the 1970-1992 period would have been attractive.

The attractiveness of commodity investments is further reinforced by noting that over the 1970-1992 period, Goldman Sachs estimated the quarterly correlation between the GSCI and the S&P 500 to have been -.32. (Over the sub-period 1970-1981 and 1982-1992, the correlation was -.43 and -.20, respectively). Thus, investment in the GSCI as part of a larger portfolio would not only have raised total returns it would also have decreased total risk. The risk diversification benefits of commodity assets, therefore, merit some consideration. Our paper examines the larger role of commodity assets in international portfolios composed also of assets from both developed and emerging markets.

TABLE 1: Goldman Sachs Commodity Index Return Components, 1970-92

Year	Spot Return(%)	Roll Yield(%)	T-Bill Yield(%)	Total Return(%)	S&P 500 Return (%)
1970	4.80	2.73	6.53	14.06	3.93
1971	6.47	8.22	4.44	19.14	13.38
1972	27.35	3.88	4.13	35.35	17.38
1973	39.64	9.07	7.22	55.94	-15.86
1974	18.82	6.41	8.07	33.30	-30.75
1975	-36.41	11.55	5.96	-18.90	31.63
1976	-14.88	- 2.92	5.11	-12.68	21.38
1977	0.78	3.73	5.35	9.86	- 7.46
1978	19.21	0.92	7.34	27.46	6.35
1979	20.84	- 2.09	10.37	29.13	16.92
1980	12.21	-13.60	11.90	10.51	28.08
1981	-28.70	-11.98	14.53	-26.15	- 5.03
1982	- 0.09	0.01	11.02	10.94	19.40
1983	7.03	- 0.79	8.82	15.06	20.31
1984	-10.02	1.18	9.88	1.04	6.08
1985	0.26	1.62	7.66	9.54	27.88
1986	-20.78	16.70	6.10	2.02	16.95
1987	3.13	12.25	5.95	21.33	5.10
1988	11.52	6.30	6.81	24.63	15.54
1989	11.68	12.44	8.29	32.41	27.38
1990	5.96	11.84	7.73	25.52	- 3.22
1991	-21.78	9.92	5.53	- 6.33	26.66
1992	2.28	- 1.48	3.53	4.33	7.39
Continuously Compounded Annual Returns	2.58	3.74	7.49	13.81	10.84

NOTES: All returns are calculated as changes in logarithms.

Data Sources: GSCI-Goldman Sachs S&P 500-Ibbotson Associates.

II. THE RETURN-RISK STRUCTURE OF THE INTERNATIONAL PORTFOLIO

The recent development of capital markets in a number of countries has increased the opportunity for diversifying portfolios internationally. The interest in country funds in recent years, especially in "emerging markets" (i.e., the newly liberalized markets of developing countries in Asia, Europe, Latin America and Africa) testifies to this growing awareness on the part of portfolio managers. The focus on emerging markets is motivated by the fact that many of these markets have increasingly moved towards market-based systems, liberalized stock and currency markets, and loosened restrictions on foreign investor participation. Developing countries as a group, moreover, are growing faster than the developed countries and are expected to do so in the future. The World Bank, for example, projects that over the next decade, developing countries will grow at 4.7% a year as compared to 2.7% for the seven major developed economies. In 1992, of the world's 15 best performing stock markets, 12 were emerging markets, including all of the top six markets. Investment in these markets can, however, be extremely risky. Divecha, Drach, and Stefek (1992) cite the instance of the Taiwanese stock market which went from 5,000 points at the beginning of 1990 to 12,600 in the first quarter and collapsed to 2500 points in the third quarter. The Taiwanese market is, however, only the fourth or fifth most risky emerging market.

Besides certain obvious risks (political instability, low liquidity, unreliable information, insider trading, exchange rate risk³, etc.) emerging stock markets tend to be risky for other reasons related to their economic and market structure. Unlike developed markets which have diverse sectors that are differently affected by market shocks, emerging markets because of less diversified industrial bases are more susceptible to macroeconomic shocks. Also, because of low liquidity, the stock markets in these countries tend to be concentrated in a few large stocks. These factors tend to accentuate market shocks.

The volatility of emerging markets should, however, be balanced against the fact that these markets exhibit very low or negative correlations with the less risky developed markets. Thus, portfolios composed of stocks from developed and emerging markets offer significant risk diversification potential.

We constructed an international portfolio of 14 assets. Besides commodity market investments, as represented by the GSCI, we chose stocks from developed and emerging markets. Among the developed markets we chose the United States, United Kingdom, Japan, Germany, Switzerland, France, and Hong-Kong. From the emerging markets we chose Taiwan, Korea, Mexico, Thailand, Brazil, and India⁴. Table 2 reports monthly average returns (in

³Exchange rate risk may, however, not be a significant issue in international investment. Solnik and Noetzlin (1982) found exchange rate risk for stocks of developed markets to be a small part of aggregate investment risk and Errunza and Losq (1987) found a similar result for emerging markets. The insignificance of the currency factor is due to the fact that currency volatility and stock market volatility are generally weakly or negatively correlated.

⁴The data for the developed markets is from the MSCI (Morgan-Stanley Capital Markets International) index and the data for the emerging markets is from the IFC (International Financial Corporation) Emerging Markets Database. We chose the emerging markets on the basis of both risk diversification potential and market liquidity. We used market capitalization as an indicator of the latter.

TABLE 2: Return and Risk Statistics for Selected Stock Markets - Dec. 1984/June 1992

	Average Return (%)	Standard Deviation (%)	Coefficient of Variation
<u>DEVELOPED MARKETS</u>			
United States	1.42	4.85	3.42
United Kingdom	1.43	5.75	4.02
Japan	.66	6.60	10.0
Germany	1.29	7.22	6.0
Switzerland	1.10	5.76	5.24
France	1.63	6.62	4.06
Hong Kong	2.68	7.92	2.96
<u>EMERGING MARKETS</u>			
Taiwan (China)	3.33	15.61	4.69
Korea	1.91	8.73	4.57
Mexico	4.65	13.90	2.99
Thailand	2.61	8.58	3.29
Brazil	2.97	22.28	7.50
India	2.24	10.19	4.55
Europe	1.67	5.64	3.38
EAFE (Europe, Asia & Far East)	1.12	6.78	6.05
World	1.15	5.03	4.37
GSCI (Goldman Sachs Commodity Index)	1.42	4.80	3.38

Sources: Developed Markets--MSCI (Morgan-Stanley Capital Markets International).
Emerging Markets--EMDB (Emerging Markets Database) of the IFC.

US dollars)⁵, standard deviations and coefficients of variation for these markets over the Dec.84-Jan.92 period. The data show that the emerging markets have performed better but these markets are also more risky in absolute terms. Notice, however, that if we consider risk per unit of return (i.e., the coefficient of variation), the emerging markets do not compare unfavorably with the developed markets. Japan and Germany, in particular, have been risky on this adjusted basis. Over the same period, the monthly return and standard deviation of the GSCI was 1.42% and 4.80%; the associated coefficient of variation of 3.38 compares favorably with most other markets.

The attractiveness of commodity market investments is, however, better conveyed by Table 3 which shows the market correlation structure. The GSCI stands out as it is negatively correlated with all developed markets and with three of the emerging markets. However, even the positive correlation between the GSCI and the other emerging markets can hardly be considered significant. These results indicate substantial potential for risk diversification by including commodity assets in international portfolios. Table 3 also implies that, in general, emerging markets are less correlated with each other than developed markets are and as a group, emerging markets generally exhibit low correlation with developed markets. The economic reasoning behind this is that emerging markets tend to have little or no economic links with each other and restrictions on outside participation in these markets essentially insulate these markets from international trends. Consider, for example, the Indian market which is negatively correlated with all but one of the developed markets and exhibits either negative or low positive

⁵The data, therefore, captures the risk of security returns in foreign markets as well as the exchange risk associated with converting foreign currencies into dollars.

TABLE 3: Correlations of Monthly Average Returns between the GSCI,
and Developed and Emerging Stock Markets (Dec. 84 - Jun. 92)

	USA	UK	JAP	GER	SWZ	FRA	HKG	TAI	KOR	MEX	THI	BRZ	IND	GSCI	WLD
USA	1.00														
UK	.77	1.00													
JAP	.38	.40	1.00												
GER	.48	.50	.31	1.00											
SWZ	.60	.59	.40	.69	1.00										
FRA	.59	.54	.46	.66	.63	1.00									
HKG	.53	.60	.26	.40	.55	.39	1.00								
TAI	.14	.21	.33	.25	.17	.22	.16	1.00							
KOR	.26	.31	.36	.06	.31	.17	.11	.04	1.00						
MEX	.40	.38	.28	.32	.42	.31	.30	.35	.16	1.00					
THI	.34	.38	.33	.30	.44	.28	.45	.40	-.01	.37	1.00				
BRZ	.12	.07	.15	.16	.20	.08	.14	.07	.03	-.008	.05	1.00			
IND	-.08	-.10	-.27	-.005	-.03	.04	-.04	-.11	-.05	.02	.08	.03	1.00		
GSCI	-.19	-.07	-.16	-.10	-.17	-.14	-.18	-.21	.04	-.02	-.22	.03	.11	1.00	
WLD	.71	.68	.73	.50	.57	.60	.49	.27	.41	.26	.36	.10	-.11	-.12	1.00

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Notes: The following abbreviations are used--Japan (JAP), Germany (GER), Switzerland (SWZ), France (FRA), Hong Kong (HKG), Taiwan (TAI), Korea (KOR), Mexico (MEX), Thailand (THI), Brazil (BRZ), India (IND), Goldman-Sachs Commodity Index (GSCI), World Portfolio (WLD).

91 observations were used for the Developed Markets and 90 observations for the Emerging Markets and the GSCI.

Data sources: See Tables 1 and 2.

correlation with other emerging markets. It is interesting to recall in this context that the Indian stock market was doing well in October 1987 when stock markets world-wide crashed. It is, however, this fact that emerging markets are not well integrated with the global economy that makes these markets interesting from the viewpoint of international portfolio diversification.

III. AN EFFICIENT FRONTIER SET FOR INTERNATIONAL ASSETS

This section explores the optimal composition of the international portfolio and derives an efficient frontier for international assets. In the Markowitz mean-standard deviation portfolio model, a portfolio is efficient, "...if no portfolio with the same or higher expected return has lower standard deviation". (Fama and Miller, 1972, p.220).

The expected return on the portfolio, $E(R_p)$, is simply the weighted average of the individual asset returns in the portfolio. Thus,

$$E(R_p) = \sum_{i=1}^N w_i E(R_i)$$

where:

w_i = weight of asset i in the portfolio

$E(R_i)$ = expected return of asset i

The standard deviation of the portfolio (σ_p) is a weighted average of the standard deviation of the individual asset returns and the covariances between the asset returns. Thus,

$$\sigma_p = \left[\sum_{i=1}^N w_i^2 \sigma_i^2 + \sum_{i=1}^N \sum_{j=1, j \neq i}^N w_i w_j \sigma_{ij} \right]^{1/2} = \left[\sum_{i=1}^N \sum_{j=1}^N w_i w_j \sigma_{ij} \right]^{1/2}$$

The mean-standard deviation frontier set can be derived by minimizing the standard deviation of the portfolio at different given levels of return subject to certain constraints. The optimal

investment proportions are the solution to the following quadratic programming problem⁶:

MINIMIZE σ_p

subject to

$$E(R_p) = E(R_e)$$

$$\sum_{i=1}^N w_i = 1 \text{ and } w_i \geq 0 \text{ for } i = 1, \dots, N$$

where:

$E(R_e)$ = given level of return

The constraints imply that the sum of the weights of the individual assets must equal 1 and the non-negativity restriction on w_i precludes short-selling⁷.

The solution to this non-linear programming problem for the 14-asset international portfolio is reported in Table 4 and graphed in Figure 1⁸. Notice in Table 4 that two of the developed markets, the United Kingdom and Germany, are never held in the optimal portfolio and the weight of the French market in the optimal portfolio is less than 1%. The reason for the exclusion of the UK market is that it is highly correlated with the US market - a market which has almost the same mean return as the UK market but a lower standard deviation. The German market is probably excluded because of its high correlation with other European markets and because its return is lower and risk considerably higher than the US market.

⁶This problem was solved using a quadratic programming algorithm available in the GAMS (General Algebraic Modeling System) package developed by the World Bank.

⁷The portfolio model includes 14 assets. Thus, the standard deviation of the portfolio (σ_p) contains 14 standard deviation elements and $(1/2) \cdot (14-1) \cdot (14)$ or 91 different covariance elements.

⁸Table 4 and Figure 1 show the results of minimizing standard deviation at given rates of return to derive the mean-standard deviation frontier set. Notice that the efficient set, however, corresponds only to rates of return equal to and greater than 1.4727.

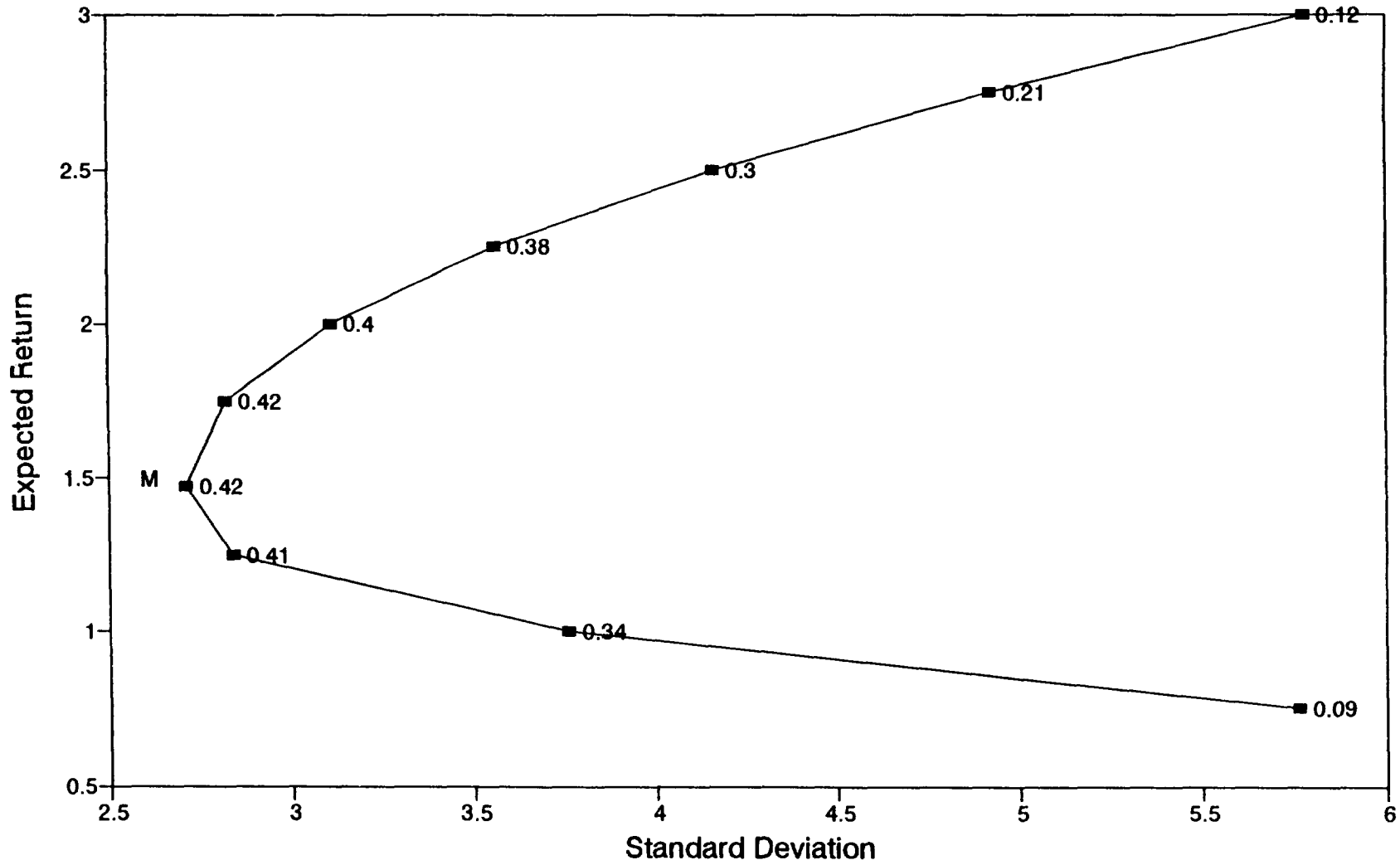
TABLE 4: Composition of the Optimal International Portfolio

Rate of Return (Re)	USA	UK	JAP	GER	SWZ	FRA	HKG	TAI	KOR	MEX	THI	BRZ	IND	GSCI	Sum of Weights	Portfolio Standard Deviation
0.75			.858		.056									.086	1	5.76
1.0			.474		.187									.339	1	3.76
1.25	.175		.228		.131								.055	.410	1	2.84
1.4727*	.254*		.123*		.056*		.017*	.024*	.006*		.021*		.084*	.415*	1*	2.71*
1.50	.253		.115		.048		.023	.026	.010		.025		.084	.415	1	2.72
1.75	.225		.034			.002	.079	.045	.051		.060	.002	.087	.415	1	2.82
2.00	.126					.006	.128	.053	.073	.030	.073	.010	.097	.403	1	3.11
2.25	.009						.181	.057	.088	.074	.078	.017	.111	.385	1	3.56
2.50							.205	.061	.076	.138	.060	.027	.131	.301	1	4.16
2.75							.227	.066	.061	.204	.040	.037	.152	.213	1	4.92
3.00							.250	.071	.047	.269	.020	.048	.173	.124	1	5.78

NOTE: Starred values represent return, weights and standard deviation of the minimum-risk portfolio.

Date Sources: See Tables 1 and 2.

**FIGURE 1
MEAN-STD.DEVIATION FRONTIER**



NOTE: The numbers on the Mean-Standard Deviation Frontier refer to the percentage of the portfolio investment in the riskiest asset. M is the minimum variance portfolio.

Emerging markets, as a whole, are better represented than developed markets in the international portfolio because emerging markets are not as correlated with each other as are the developed markets. Among the emerging markets, the Indian market is the most heavily represented. This is hardly surprising given its negative correlation with most other markets.

We previously noted that over the sample period the rates of return in emerging markets exceeded those of the developed markets. The outcome of this is shown in Table 5 which presents the results of Table 4 in a summary form for the developed and emerging markets. The optimal international portfolio is clearly biased towards investment in the emerging markets at higher required rates of return. Speidell and Sappenfield (1992, p.67) in an analysis of global diversification write that: "Conservative assumptions suggest optimal emerging market weightings of 10% to 15%....". Our results suggest that this percentage is appropriate for a risk-minimizer (the minimum-risk portfolio implies a 14% investment in emerging markets) but for less risk averse investors, the optimal emerging market weighting is more likely to be between 25% and 50%.

Tables 4 and 5 reinforce our earlier notions regarding the return-risk benefits of commodity market investments but it is still surprising to see how heavily the GSCI is represented in the international portfolio. The minimum-risk international portfolio, for instance, implies a 42% investment in the GSCI. This proportion decreases at higher required rates of return but it would seem that at most reasonable levels of risk, the optimal proportion of commodity market investments in the international portfolio would still be at least 30%.

We also computed the optimal international portfolio without commodity assets. The composition of this portfolio is reported in Table 6 and graphed in Figure 2 which compares the

TABLE 5: Composition of the Optimal International Portfolio for Developed and Emerging Stock Markets

Rate of Return (Re)	Developed Markets	Emerging Markets	GSCI	Portfolio Standard Deviaton
.75	.91	.00	.09	5.76
1.0	.66	.00	.34	3.76
1.25	.53	.06	.41	2.84
1.47*	.45*	.14*	.42*	2.711*
1.5	.44	.15	.42	2.713
1.75	.34	.25	.42	2.82
2.00	.26	.34	.40	3.11
2.25	.26	.34	.40	3.56
2.50	.21	.49	.30	4.16
2.75	.23	.56	.21	4.92
3.0	.25	.63	.12	5.78

NOTE: Starred values represent return, weights and standard deviation of the minimum-risk portfolio. Weights do not sum exactly to 1 because of rounding up.

Data sources: See Tables 1 and 2.

TABLE 6: Composition of the Optimal International Portfolio Without Commodity Assets

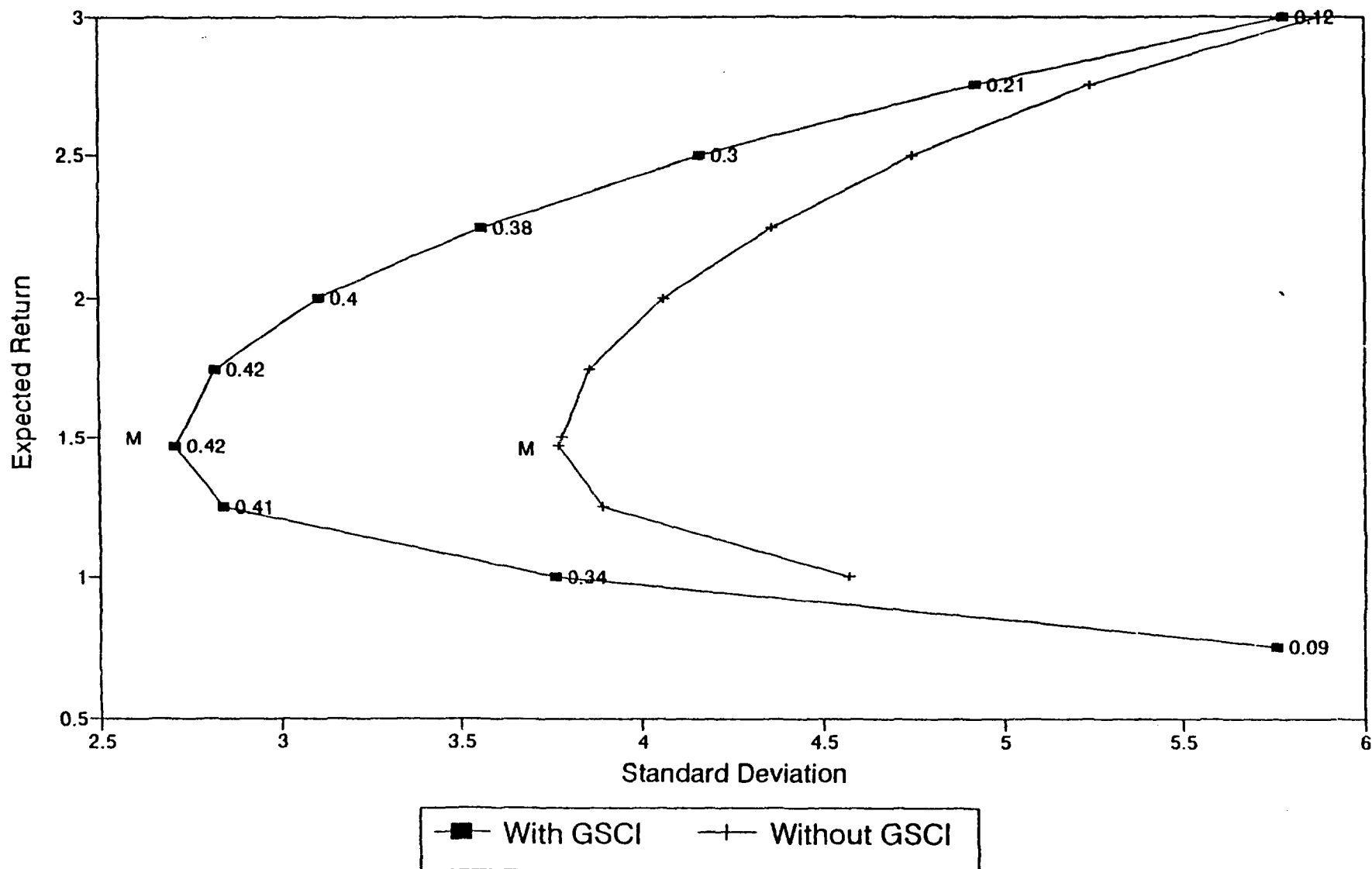
Rate of Return (Re)	USA	UK	JAP	GER	SWZ	FRA	HKG	TAI	KOR	MEX	THI	BRZ	IND	Sum of Weights	Portfolio Standard Deviation
1.00	.100		.527		.286								.087	1	4.57
1.25	.334		.337		.161								.168	1	3.89
1.47*	.407*		.217*	.028*	.061*		.012*	.014*	.063*		.001*		.196*	1*	3.77*
1.50	.405		.208	.030	.049		.020	.016	.069		.006		.197	1	3.78
1.75	.381		.129	.029			.071	.033	.108		.041	.008	.199	1	3.86
2.00	.342		.053	.007			.114	.048	.137	.016	.064	.016	.202	1	4.06
2.25	.264					.017	.151	.055	.160	.048	.078	.023	.203	1	4.36
2.50	.136					.008	.205	.059	.171	.093	.083	.030	.214	1	4.75
2.75	.008						.259	.063	.182	.138	.088	.038	.224	1	5.24
3.00							.270	.069	.120	.229	.049	.048	.215	1	5.88

NOTE: Weights may not sum exactly to 1 because of rounding up.

*Starred values represent return, weights and standard deviation of the minimum-risk portfolio.

Data sources: See Tables 1 and 2.

FIGURE 2 : MEAN-STANDARD DEVIATION FRONTIERS WITH AND WITHOUT GSCI



NOTE: The numbers on the Mean-Standard Deviation Frontier refer to the percentage of the portfolio invested in commodity assets. M stands for the minimum-risk portfolio.

mean-standard deviation frontier sets with and without commodity assets. In Figure 2, the efficient frontier with commodity assets lies everywhere higher than the portfolio without commodity assets, implying that for the same levels of return (risk), the portfolio with commodity assets provides lesser (higher) risk (return).

The above results imply investment weights in emerging markets that are substantially in excess of actual international investment. By most rough estimates, the weight of emerging markets in institutional portfolios is less than 1%.⁹ What then accounts for our results? It could be argued that since these results are both ex-post and sample-specific they bear little relation to ex-ante investment decisions and a different sample would lead to different results. There is, however, evidence that cross-country correlations are relatively stable over time (see Watson, 1980). Levy and Lerman (1988) argue that the ex-ante versus ex-post and sample-dependent arguments are not particularly convincing in explaining the divergence between actual behavior and optimizing behavior because the inter-temporal stability of cross-country correlations endow ex-post portfolios with good ex-ante predictive ability. Levy and Lerman (1988, p.61) instead suggest that the divergence between real and optimizing behavior may be attributable to 'behavioral imperfection'. According to Levy and Lerman:

"Despite the demonstrated advantages of international diversification, investors still find it easier to stick close to their domestic markets, largely ignoring international opportunities. The observed bias of investors everywhere toward their domestic stocks is usually attributed to various barriers to international investment, which may result from lack of

⁹However, the increase in the rate of investment in emerging markets has been exponential. The Wall Street Journal (Sept.24, 1993) reports that current investment in emerging markets is about \$50 billion, up from \$500 million five years ago - an increase of about 10,000%.

information, discriminatory taxation, restrictions on funds flow, or simply fear of expropriation. Our results, of course, ignore these imperfections and indicate what would happen if investors felt no inhibition against diversifying internationally".

This argument seems perfectly suited to explaining our results.

As pointed out earlier, most conservative estimates suggest emerging market investment weights of 10% to 15%. Moreover, the operating guidelines of some institutional funds limit the percentage invested in specific types of assets such as emerging market equities. We, therefore, constrained the share of emerging markets to 10% and constructed two versions of this constrained model. Table 7 reports results on the optimal composition of an international portfolio with both the commodity asset and the emerging market weights constrained to 10%. Table 8 reports results for an international portfolio without commodity assets but with emerging market weights constrained to 10%. The composition of these constrained portfolios are worth considering since they provide us with some notion of the contribution of each asset type to the risk-return characteristics of the international portfolio. Figure 3 summarizes these results by graphing the mean-variance frontier of all four portfolios considered so far. Clearly, the unconstrained portfolio performs best with the most constrained portfolio performing the worst, implying that inclusion of commodity and emerging market assets in international portfolios substantially enhance return-risk benefits.

TABLE 7: Composition of the Constrained International Portfolio [Emerging Markets = 10%, GSCI = 10%]

Rate of Return (Re)	USA	UK	JAP	GER	SWZ	FRA	HKG	TAI	KOR	MEX	THI	BRZ	IND	GSCI	Sum of Weights	Portfolio Standard Deviation
1.00	.061		.500		.279								.060	.100	1	4.23
1.25	.378		.266		.156								.100	.100	1	3.52
1.31*	.439*		.218*	.014*	.119*		.010*						.100*	.100*	1*	3.50*
1.50	.452		.171	.030	.035		.113						.100	.100	1	3.58
1.75	.423		.080			.074	.223	.011					.089	.100	1	3.89
2.00	.359					.120	.320	.015		.022			.063	.100	1	4.39
2.25	.216					.144	.440	.003		.066			.031	.100	1	5.05
2.50	.062					.165	.573			.100				.100	1	5.84
2.75							.799			.100				.100	1	6.84

NOTE: Weights may not sum exactly to 1 because of rounding up.

*Starred values represent return, weights and standard deviation of the minimum-risk portfolio.

Data sources: See Tables 1 and 2.

TABLE 8: Composition of the Constrained International Portfolio Without Commodity Assets [Emerging Markets = 10%]

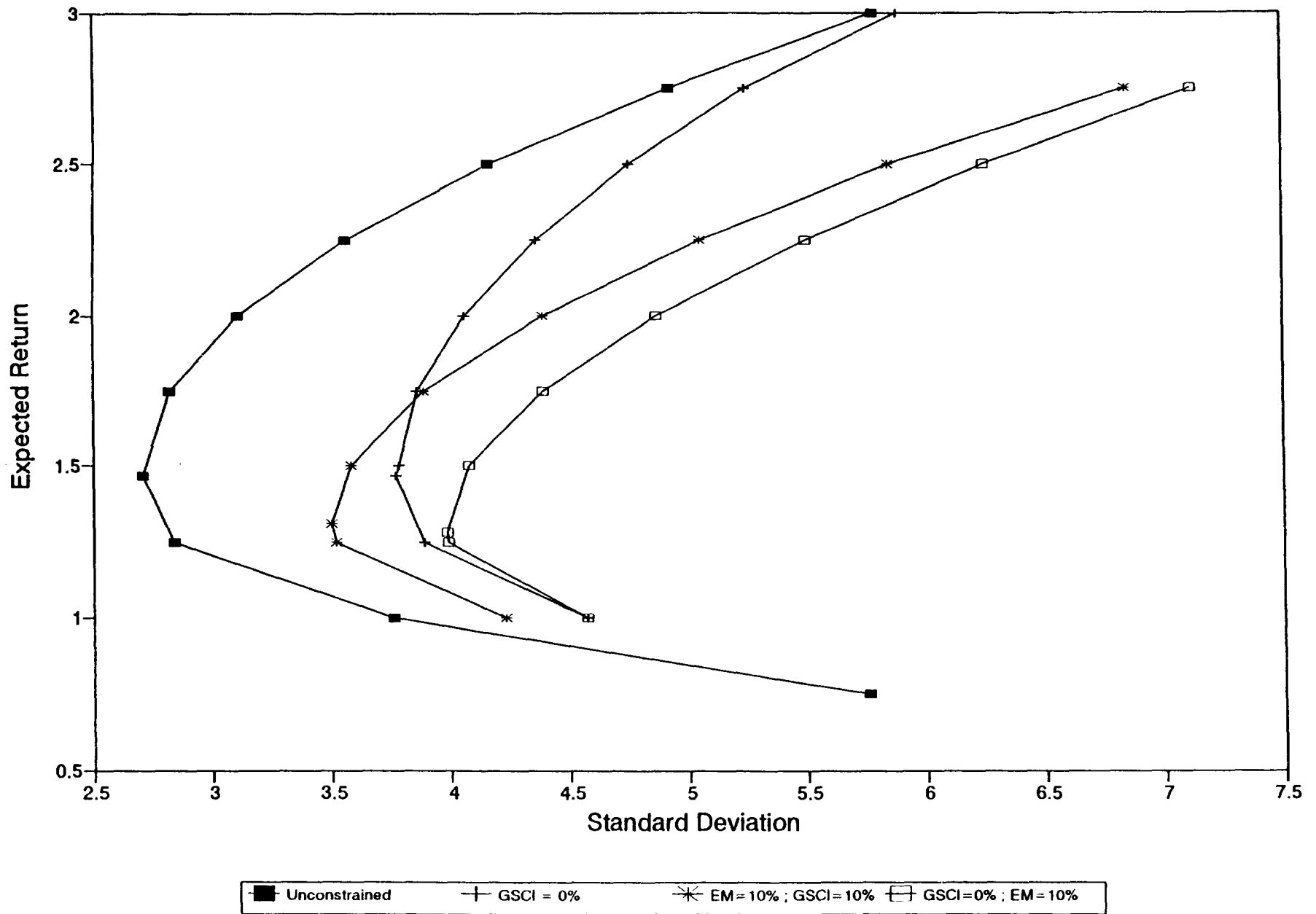
Rate of Return (Re)	USA	UK	JAP	GER	SWZ	FRA	HKG	TAI	KOR	MEX	THI	BRZ	IND	Sum of Weights	Portfolio Standard Deviation
1.00	.100		.527		.286								.087	1	4.57
1.25	.467		.264	.013	.155								.100	1	3.99
1.28*	.493*	.011*	.238*	.021*	.135*		.003*						.100*	1*	3.98*
1.50	.515		.184	.039	.038	.001	.123						.100	1	4.08
1.75	.476		.098			.085	.241	.001					.099	1	4.39
2.00	.429		.001			.136	.334	.009		.016			.074	1	4.87
2.25	.287					.159	.454			.059			.041	1	5.49
2.50	.143					.179	.578			.096			.004	1	6.24
2.75						.121	.779			.100				1	7.12

NOTE: Weights may not sum exactly to 1 because of rounding up.

*Starred values represent return, weights and standard deviation of the minimum-risk portfolio.

Data sources: See Tables 1 and 2.

† FIGURE 3: COMPARISON OF UNCONSTRAINED AND CONSTRAINED FRONTIERS



We also calculated the risk-minimizing weight of the GSCI in a portfolio composed of the GSCI and individual stock market assets.¹⁰ The results for this two-asset, minimum-risk (standard deviation) portfolio provides some sense of the risk-minimization benefit held out by the GSCI for individual markets. These results are reported in Table 9. The investment weights in the GSCI range from a low of 51% for the US market to a high of 96% for the Brazilian market. The heaviest weightings of the GSCI are in the emerging market portfolios since these markets are much more volatile and there are consequently greater risk-minimization benefits by investing in commodity assets. Notice, for instance, that the minimum-risk portfolio for Brazil implies a 96% investment in the GSCI which reduces the Brazilian market standard deviation of 22.28 to a considerably smaller standard deviation of 4.72. (Notice, however, that the expected return is lowered from 2.97 to 1.48.) Among the developed markets, investment in commodity markets raises returns for Japan, Germany and Switzerland while simultaneously reducing risk in all three markets. For the aggregated market indices, the risk-minimizing commodity market weights are: 66% (EAFE), 58% (Europe) and 52% (World Portfolio). A 52% investment in the GSCI increases returns on the world portfolio from 1.15 to 1.29 while reducing risk from 5.06 to 3.26. Notice that the GSCI weight of 52% in the minimum-risk world portfolio roughly confirms the 42% weight (see Table 5) we arrived at for our minimum-risk international portfolio. The difference is due to the fact that the international portfolio includes

¹⁰The risk-minimizing weights are solved from a two asset (X, Y) portfolio model where the risk-minimizing weight of the individual market asset is w_x^* and that of the GSCI is w_y^* . The risk-minimizing weights are then given by:

$$w_x^* = [\sigma_y^2 - \text{cov}(X, Y)] / [\sigma_x^2 + \sigma_y^2 - 2 \text{cov}(X, Y)] ; \quad w_y^* = (1 - w_x^*)$$

TABLE 9: Weights, Return, & Standard Deviation of the Minimum-Risk Portfolio for International Stock Markets

Market	Weight of the Market	Weight of GSCI	Expected Return	Portfolio Standard Deviation
United States	.49	.51	1.42	3.1
United Kingdom	.41	.59	1.42	3.5
Japan	.36	.64	1.14	3.6
Germany	.32	.68	1.38	3.8
Switzerland	.42	.58	1.29	3.4
France	.36	.64	1.50	3.6
Hong Kong	.30	.70	1.80	3.8
Taiwan (China)	.13	.87	1.67	4.2
Korea	.22	.78	1.53	4.3
Mexico	.11	.89	1.78	4.5
Thailand	.28	.72	1.75	3.8
Brazil	.04	.96	1.48	4.7
India	.15	.85	1.54	4.5
EAFE (Europe, Asia and Far East)	.34	.66	1.32	3.8
Europe	.42	.58	1.52	3.6
World	.48	.52	1.29	3.3

Data sources: See Tables 1 and 2.

only a sample of world markets. This result, if anything, implies an even greater role for commodity assets in risk-minimization. These results unambiguously testify to the considerable risk-return benefits from investing in commodity market assets.

We also considered the effect of including international bonds in the portfolio. (These results are not reported here.)¹¹ The diversification benefits of bonds in international portfolios have been reported by Levy and Lerman (1988) and Grauer and Hakansson (1987). Both papers report gains from international diversification of stocks and bonds for highly risk-averse investors. Since bonds typically carry less risk (and therefore less return) than stocks and are, moreover, negatively correlated with stocks, they may substitute for commodity investments for very risk averse investors. The percentage of investment in the GSCI, in fact, decreases for very risk averse investors but the optimal investment weight in commodities continues to be strong for less risk-averse investors with higher required rates of return.

¹¹We included government bonds from the United States, Germany and Japan and calculated the optimal composition of the international bond-stock portfolio with commodity assets. This bond-stock portfolio outperformed other portfolios at low mean rates of return.

IV. CONCLUSION

This paper analyses returns and risks from investing in an international portfolio composed of assets from developed and emerging stock markets and the new opportunities for investment in commodity market assets as represented by the GSCI. The optimal composition of the international portfolio and the mean-standard deviation frontier for different investment sets were calculated. These results are potentially useful because the inter-temporal stability of cross-market correlations endow ex-post portfolios with good ex-ante predictive ability.

The results of this paper point out to the important role commodities and emerging market stocks could play in an investor's portfolio. The results from the optimal composition of an international portfolio also indicate that the shares of commodities in an investor's portfolio could well increase above of what is typically today is invested in commodities. Our results indicate that commodities could account for between 20-40% of an international investment portfolio. For commodity markets the implication of these results is the increased participation of investors, mainly investment funds, into commodity markets could increase the liquidity and the possibilities for arbitrage in these markets. The increased liquidity is likely to bring more opportunities for large commodity producers to enter and exit commodity futures markets without affecting prices.¹² However, the role of the investment funds in commodities has caused some skepticism among certain analysts. It is felt that because investment funds trade commodities mainly based on technical analysis rather than fundamentals and also because of their size, they could result in short-lived deviations between futures and spot prices, causing

¹²Large developing country producers that need significant liquidity in commodity futures/options markets are Venezuela and Mexico for oil; Côte d'Ivoire and Ghana for cocoa; and Brazil and Colombia for coffee, amongst others.

problems for commodity hedgers--typically commodity producers and users. Also, because investment funds enter and exit the market with high frequency and given their size, they could lead to increases in the short-term price volatility. For example, a commodity price decline that could trigger sales by one investment fund could be reinforced by this fund's sales and trigger sales by other funds. These skepticisms, however, have yet to be formally empirically tested.

With regard to emerging equity markets, our main results imply that optimal emerging market weights are higher than those previously stated in the literature and that there are considerable return-risk benefits from investing in commodity markets. The minimum-risk portfolio we constructed implies about a 14% investment in emerging markets but for less risk averse investors, the optimal emerging market weighting is more likely to be between 25% and 50%, depending upon the degree of risk aversion. The difference between our results and previous results is due to the inclusion of commodity assets which have considerable risk-minimization benefits, so that the higher-return emerging markets are now more heavily represented in the international portfolio. This has the effect of increasing returns at given levels of risk or effectively shifting upwards the efficient frontier.

In the future, as emerging markets become more liberalized and develop greater economic and trade links with the global economy, the correlation among emerging markets and between emerging and developed markets is bound to increase. This means that the risk diversification benefits currently provided by emerging markets may not continue to be so large. Divecha, Drach, and Stefek (1992, p.50), for instance, advise that "...there is a 'diversification free lunch' currently available - one should indulge while the opportunity exists". If emerging markets do lose their risk diversification potential, commodity assets could well become even more important.

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