Bayes-Stein Estimators and International Real Estate Asset Allocation

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Abstract

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This article re-examines the issue of international diversification in real estate securities and attempts to address the problem of estimation error in the inputted parameters through the use of alternative techniques. The results see an increased stability in calculated portfolio allocations in comparison to the classical mean-variance tangency approach, and see significant improvements in out-of-sample performance. In addition, the minimum variance portfolio significantly outperforms a naive equally-weighted strategy. These results are also largely consistent when transaction costs are incorporated into the analysis.

Introduction

A growing literature has emerged examining the potential diversification opportunities that can arise from diversifying internationally in real estate securities. Articles such as Eichholtz (1996), Liu and Mei (1998) and Stevenson (2000) have examined this issue, finding generally supporting evidence as the attractiveness of foreign investment. Eichholtz compared the relative benefits of diversifying internationally into both real estate securities and equities, finding that real estate stocks provided greater diversification opportunities. Liu and Mei also found that property stocks provided some degree of incremental diversification benefits on an international scale. While the authors reported that currency fluctuations accounted for a larger proportion of return variability in comparison to common stocks, even if the currency risk is hedged, real estate firms do provide incremental diversification benefits.

Stevenson (2000), while finding contrary evidence as the relative attractiveness of real estate versus equities, did find that investing internationally in real estate firms provided statistically significant improvements in performance when compared to an all domestic portfolio.[1] The results were also consistent across the ten countries examined when local returns were used, under an assumption of perfect hedging ability. However, when the assumption was made that the portfolio manager did not partake in a hedged strategy, significant results were only obtained for three of the ten markets analyzed.[2] The only other proviso with regard to this study was that the gains became insignificant if the international allocation in the portfolio was constrained.

Despite the generally supportive nature of the empirical studies to have examined international diversification in real estate securities, all of the existing studies have largely relied on standard mean-variance asset allocation procedures, with little regard to the potential problems in using such a technique.[3] This article attempts to address two of the key issues concerned with mean-variance optimization, namely the sensitivity of the estimated allocations to the inputted parameters and the out-of-sample performance of the optimal portfolios. The issues are highly related and are jointly concerned with the problem of estimation error. Unconstrained standard mean-variance analysis tends to produce relatively 'undiversified' estimated allocations. As Michaud (1989) states, optimization models are in effect 'error maximizers,' producing higher estimated allocations to those securities or assets with relatively high mean returns and low risk measures. Likewise, assets with relatively low returns and high-risk measures will have low estimated allocations. The result is that standard procedures often result in corner solutions, and in part due to the undiversified nature of them, generally perform poorly on an out-of-sample basis.[4] In addition to the problem of undiversified optimal portfolios, standard optimization models do not take into account the fact that the inputted parameters are themselves subject to estimation error, and that estimated allocations are extremely sensitive to variations in the parameters. Studies such as Kalberg and Ziemba (1984) and Chopra and Ziemba (1993) have found that the estimated allocation is particularly sensitive to variations in the means. In addition, papers such as Jorion (1985) have found that despite seemingly large differences in mean returns, it is not possible to reject the null hypothesis that the returns are equal to zero.

A simple and, for a portfolio manager, practical method of reducing estimation error is to constrain the allocations, thereby forcing greater spread across the assets examined. Articles such as Frost and Savarino (1988) and Chopra (1993) have both used this technique to obtain a greater degree of diversification. One of the major problems with the use of constraints is that the choice of constraints is at best arbitrary, leading to the results being hard to generalize. This article therefore examines an alternative method of reducing estimation error, namely the Bayes-Stein shrinkage approach.

This study analyses indirect real estate security data from eleven countries over the period 1976–1998. The empirical analysis takes three primary perspectives. Initially, the impact of variations in the inputted parameters is assessed, with the analysis then turning to examining the use of Bayes-Stein estimators. Initially optimal portfolios are constructed using two alternative methods and the performance of the portfolios is then assessed. The remainder of the article is laid out as follows. Initially, a brief discussion of the Bayes-Stein approach is discussed, while the following section provides details of the data used and methodological framework adopted. The final two sections report the findings of the empirical analysis and provide concluding comments, respectively.

Bayes-Stein Estimators

The use of Bayes-Stein estimators is designed to reduce the degree of estimation error and furthermore, decrease the tendency for asset allocation studies to arrive at corner solutions. A further advantage to the use of such estimators is that empirical evidence, such as Jorion (1985) and Chopra, Hensel and Turner (1993) has provided evidence that the out-of-sample performance of optimal portfolios improves substantially. Jorion examined seven world equity markets, finding that the Bayes-Stein estimated portfolios significantly outperform the standard MVA tangency portfolio. Chopra et al. find similar results using a sixty month rolling period strategy and a sample consisting of six equity markets, five bond markets and five cash markets. Additionally, due to the increased stability in allocations obtained, the improvement over the classical mean-variance approach is further enhanced when transaction costs are incorporated into the analysis.[5]

The premise behind the Bayes-Stein approach is that due to the sensitivity of the estimated allocations to variations in the parameters, and to relatively extreme inputs, the means of the assets are 'shrunk' towards a global mean. This effectively reduces the difference between extreme observations, thus aiding in the attempt to reduce estimation error. The general form for the estimators can be defined as follows:

$$E(r_i) = w\bar{r}_g + (1 - w)\bar{r}_i. \tag{1}$$

Where $E(r_i)$ is the adjusted mean, $\bar{r}_i$ is the original asset mean, $\bar{r}_g$ the global mean and w the shrinkage factor. Jorion (1985, 1986) shows that the shrinkage factor can be estimated from a suitable prior as follows:

$$\hat{w} = \frac{\hat{\lambda}}{(T + \hat{\lambda})}. \tag{2}$$

$$\hat{\lambda} = \frac{(N + 2)(T - 1)}{(r - r_0 1)' S^{-1} (\bar{r} - r_g 1)(T - N - 2)} \tag{3}$$

Where T is the sample size and S is the sample covariance matrix. Chopra, Hensel and Turner (1993) use a slightly different approach in their analysis. They calculate the optimal portfolios under three alternative scenarios designed to reduce estimation error. Firstly, the sample means of all of the assets used are assumed to be equal to the global means for stocks, bonds and cash. The second scenario then also adds in the constraint that the within group correlation's are equal, while the third adds the further constraint that the within group variances are equal. This final scenario effectively reduces the analysis to a three-asset case of stocks, bonds and cash.

The first scenario that assumes equal means is equivalent to analyzing the minimum variance portfolio, rather than the tangency portfolio that is more commonly examined as the estimated allocation, is based purely on the variance and covariance terms. This is a scenario used by studies such as Jobson, Korkie and Rattie (1979) and Jobson and Korkie (1981). Jorion (1985) argues that unless all of the assets examined are within the same risk class, such a strategy is hard to reconcile with the idea that a risk-return tradeoff exists. While such a strategy is an extreme case of shrinkage, it is examined in this current study for a number of reasons. Firstly, Jorion's argument on this point is limited in its relevance as all of the assets used are indices of real estate securities. Secondly, the use of the minimum variance portfolio eliminates the largest potential cause of estimation error, namely the mean from the analysis, as the portfolios are determined purely by the variances and covariances. Thirdly, empirical evidence, such as Chopra, Hensel and Turner (1993) and Stevenson (1999) provide strong evidence as to the attractiveness of the strategy.

Stevenson (1999) analyzed a total of thirty-eight international equity markets including fifteen emerging markets. Due to the non-normality present in emerging market returns, two alternative downside risk measures were also utilized in addition to the conventional variance. These were Lower Partial Moment measures with target rates of zero and the individual assets mean return (the mean semi-variance). The results show that all three minimum risk portfolios out-performed the alternative Bayes-Stein and Classical tangency portfolios. The results are also similar to the findings of studies such as Haugen and Baker (1991) in the analysis of individual securities. Haugen and Baker compared the performance of minimum variance portfolios against the market in the United States, in an attempt to examine the relative performance of index funds. As the current study, like Haugen and Baker and Chopra, Hensel and Turner (1993), uses rolling portfolios. A further advantage to the analysis of the minimum variance portfolios is that the tangency portfolio by definition contains those asset classes, or securities, that have produced the best performance over the proceeding period. The strong out-of-sample performance of the MVP is therefore consistent with the literature on mean reversion.[6]

Data and Methodological Framework

A total of eleven markets are examined in this study from 1976 to 1998.[7] All eleven markets are analyzed using monthly data, with the Datastream property indices representing each of the markets with the exception of the U.S., in which case the NAREIT Index is used. An assumption is made that an investor cannot partake in short selling, due to the fact that many institutional investors are restricted in this regard. All of the data is analyzed on the basis of local returns, thereby implying perfect hedging ability. While the use of such an assumption does ignore the impact of the foreign exchange market, it does mean that additional assumptions concerning the nationality of the investor are avoided.[8] Exhibit 1 provides details of the summary statistics of the data for the overall sample period.

The study initially attempts to gauge the potential cost of the estimation error of the mean, variance and covariance. Studies such as Kalberg and Ziemba (1984) and Chopra and Ziemba (1993) have found that the importance of error in the mean is substantially greater than the relative importance of errors in the variance and covariance. The methodology used to assess the relative importance of different forms of errors is similar to that used by Chopra and Ziemba and uses the overall data set of 276 observations. Assuming that the historical estimates for the parameters are the true figures, a base optimal portfolio is calculated that maximizes the Sharpe Ratio. To assess the impact of estimation error in the mean, we replace the historical estimate $\bar{r}_i$ for asset i with $\bar{r}_i(1 + kz_i)$, where k is allowed to vary between 0.05 to 0.30 to assess the impact of different magnitudes of errors and z has a standard normal distribution. Similar corrections are then performed with respect to the variance and covariance. In each case, the remaining two parameters are left unaltered, while the procedure is completed 100 times for each

Exhibit 1 | Sample Statistics

	Mean	Std. Dev.	Variance
Australia	1.62	7.54	56.82
Belgium	0.91	6.29	39.51
Canada	1.02	9.56	91.43
France	0.79	8.40	70.61
Hong Kong	1.66	11.71	137.23
Italy	1.10	8.22	67.51
Japan	0.55	8.24	67.85
Netherlands	0.68	3.77	14.24
Singapore	1.03	11.02	121.35
U.K.	1.28	6.48	42.00
U.S.	1.19	3.62	13.11

Notes: Exhibit 1 reports the summary statistics of the eleven markets over the overall sample period, 1976–1998.

value of k for a different set of z values. The mean absolute difference from the historical estimates is then calculated for each value of k.

The portfolio analysis is undertaken on the basis of a sixty month rolling window. The optimal portfolios are then re-calculated every quarter. Three alternative portfolio construction strategies are used. Initially the classical tangency portfolio is used, while the two alternatives are the Bayes-Stein approach, using the suitable prior proposed by Jorion (1985), and the minimum variance portfolio. As the minimum variance alternative does not use the means in the calculation of the allocations, the estimates are identical whether the original or 'shrunk' mean returns are used. Portfolios based on the three alternate strategies are then constructed and the performance of them is examined on an out-of-sample basis and compared to a naive equally-weighted portfolio of the eleven markets.

Empirical Analysis

Initially the potential impact of variations in the inputted parameters is examined. Using the procedure described, the mean absolute differences from the returns obtained using the sample data is presented in Exhibit 2. It can be seen quite clearly that while the error associated with the two risk measures does generally increase with the value of z, the impact remains relatively small. In contrast however, the impact of variations in the means is substantial. At the smallest value of z, the impact of estimation error from the mean is greater than any of the values for either the variance or covariance, with the figure rising to 7.39% when z equals 0.30. The potential biases that can arise from sample means therefore, provide further justification for the use of the techniques used here.

Exhibits 3 through 5 show the rolling allocations in each of the eleven markets. While the broad patterns are similar, it can be seen that the mean-variance tangency case has the highest degree of variation. The use of the Bayes-Stein shrinkage does reduce the degree of sudden changes in the allocations, a process that is continued by the use of the minimum variance portfolio. In that case the

Exhibit 2 | Impact of Estimation Error

Z	Means (%)	Variances (%)	Covariances (%)
0.05	1.23	0.12	0.02
0.10	2.46	0.14	0.07
0.15	3.69	0.08	0.17
0.20	4.92	0.13	0.27
0.25	6.16	0.18	0.39
0.30	7.39	0.24	0.51

Exhibit 3 | MV Maximum Sharpe Ratio

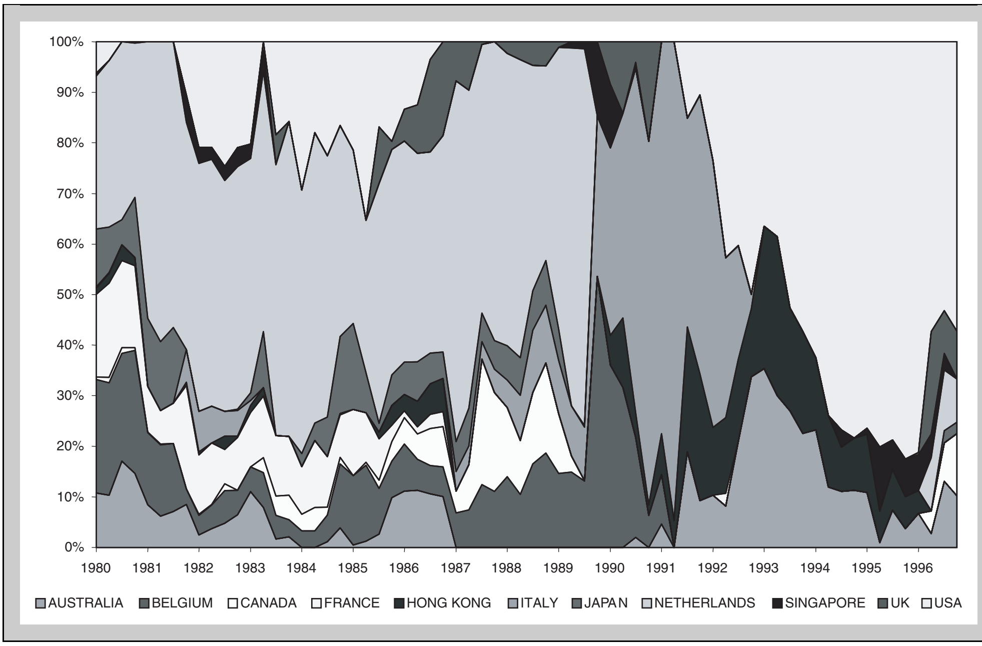

Exhibit 3 reports the rolling allocations on the basis of the maximum Sharpe ratio. All allocations are estimated on the basis of sixty month rolling windows.

portfolio is dominated in the early period by the Dutch market, while the real estate investment trust (REIT) market in the U.S. dominates the period from 1991 onwards. Due to the use of the sixty month rolling window, the portfolios are analyzed over an eighteen year period from January 1981 to the end of year 1998, with Exhibit 6 providing the summary statistics of the alternative portfolios constructed, together with the equally-weighted naive portfolio. Of the four alternatives, the classical tangency approach produces the worst performance with a mean monthly return of 0.72% and a standard deviation of 3.77%. The Bayes-Stein prior portfolio not only obtains a higher mean return, but the risk of the portfolio is also reduced, with figures of 0.78% and 3.30%, respectively. In addition, the holding period return increases from 27.19% to 38.01% over the eighteen-year period. However, of the three approaches, the minimum variance portfolios, which totally excludes the problem of estimation error resulting from bias in the means, provides a further improvement in performance, with additional increases in the return figures and reductions in the risk measures. If the results are compared against the naive strategy, it can be seen that while the equally-weighted index provides a higher return than both the classical and Bayes-Stein tangency portfolios, it does result in increased risk measures. Using the Sharpe Ratio as a further comparison of performance, it can be shown that both the Bayes-Stein and minimum variance portfolios outperform the naive portfolio.

Exhibit 4 | Bayes-Stein Prior Maximum Sharpe Ratio

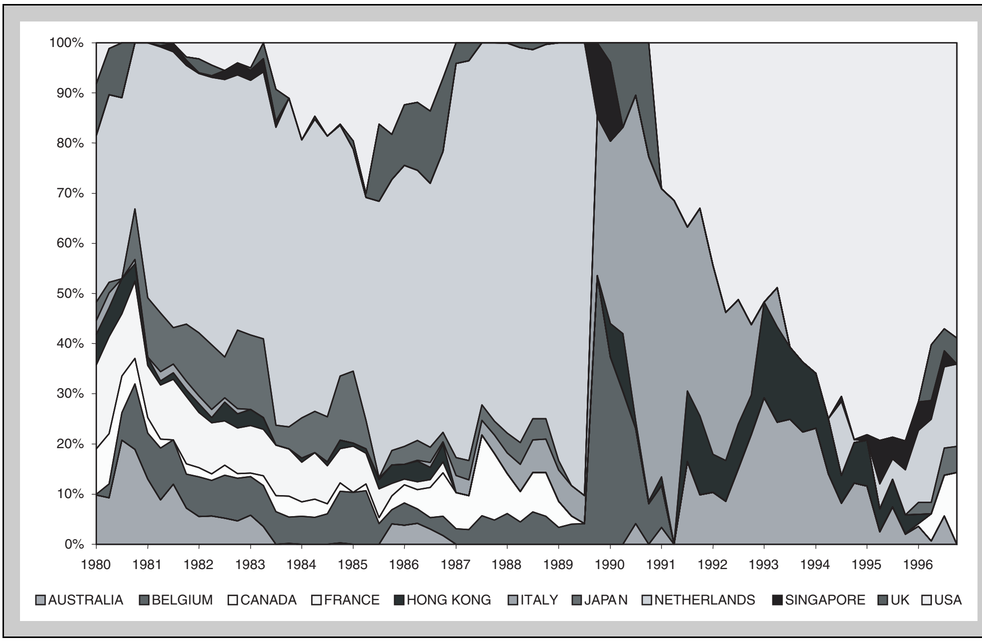

Exhibit 4 reports the rolling allocations on the basis of the maximum Sharpe ratio estimated using the Bayes-Stein returns. All allocations are estimated on the basis of sixty month rolling windows.

To more formally assess the ex post performance of the alternative portfolios, we use the Jobson and Korkie (1981) pairwise test of the equality of Sharpe Ratio. The test statistic can be displayed as:

$$t = \frac{s_j \bar{r}_i - s_i \bar{r}_j}{[2/T(s_i^2 s_j^2 - s_i s_j s_{ij})]^{1/2}} \tag{4}$$

where s_j is the standard deviation of asset j, $\bar{r}_j$ is the mean return of j and s_{ij} is the covariance between assets i and j. The results (see Exhibit 7) reveal that both the Bayes-Stein and minimum variance portfolios significantly outperformed the tangency portfolio, with t-Statistics significant at the 95% level. With regard to the naive strategy, the test results for the classical and Bayes-Stein approaches were insignificant, therefore, while it cannot be shown that the shrinkage approach leads to out-performance against an equally weighted index, it also cannot be shown that the classical optimization approach does not significantly under perform. The results do, however, confirm the strong performance of the minimum risk portfolio, with this strategy providing significant out performance against all three alternatives. It should be noted that this test has low power, as observed by

Exhibit 5 | Minimum Variance Portfolio

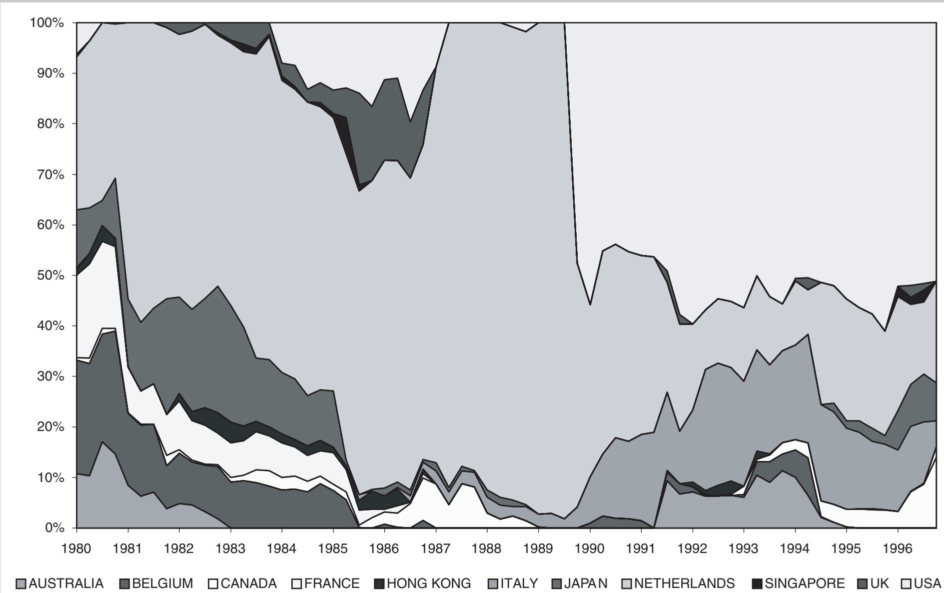

Exhibit 5 reports the rolling allocations for the minimum variance portfolios. All allocations are estimated on the basis of sixty month rolling windows.

Exhibit 6 | Out-of-Sample Performance

	Maximum Sharpe Portfolio	Bayes-Stein Maximum Sharpe Portfolio	Minimum Variance Portfolio	Naive Portfolio
Mean	0.719	0.775	0.885	0.868
Std. Dev.	3.769	3.299	2.935	4.166
Variance	14.208	10.885	8.613	17.357
Sharpe Ratio	0.191	0.235	0.302	0.208
Holding Period Return	27.193	38.008	53.515	45.736

Notes: Exhibit 6 details the summary statistics for the out-of-sample performance of the three estimated portfolios and a naïve equally-weighted portfolio.

Exhibit 7 | Statistical Comparison of Performance

	Maximum Sharpe Portfolio	Bayes-Stein Maximum Sharpe Portfolio	Minimum Variance Portfolio
Bayes-Stein Maximum Sharpe Portfolio	−2.190**		
Minimum Variance Portfolio	−2.117**	−1.560*	
Naive Portfolio	−0.382	0.508	1.557*

Notes: Exhibit 7 reports the Jobson and Korkie (1981) test for the equality of the Sharpe ratios.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

Jobson and Korkie (1981) and Jorion (1985), therefore, the finding of any significant results is to some degree surprising.

Exhibits 8 and 9 detail the corresponding results when transaction costs are incorporated into the analysis. The same rolling portfolio analysis is conducted as before, with transaction costs of 2% included each quarter when the portfolios are re-balanced. This analysis requires consideration of the returns of the individual markets and the overall portfolios during the preceding quarter, as the allocations will have effectively changed during the periods between re-balancing.

Exhibit 8 | Out-of-Sample Performance with Transaction Costs

	Maximum Sharpe Portfolio	Bayes-Stein Maximum Sharpe Portfolio	Minimum Variance Portfolio	Naive Portfolio
Mean	0.657	0.734	0.850	0.791
Std. Dev.	3.878	3.366	3.012	4.333
Variance	15.037	11.329	9.073	18.777
Sharpe Ratio	0.170	0.218	0.282	0.183
Holding Period Return	16.284	31.711	48.855	33.829

Notes: Exhibit 8 reports the summary statistics for the out-of-sample performance of the three estimated portfolios and a naïve equally-weighted portfolio with the inclusion of transaction costs of 2%.

Exhibit 9 | Comparison of Transaction Cost Adjusted Performance

	Maximum Sharpe Portfolio	Bayes-Stein Maximum Sharpe Portfolio	Minimum Variance Portfolio	Naïve Portfolio
Bayes-Stein Maximum Sharpe Portfolio	−2.369**			
Minimum Variance Portfolio	−2.190***	−1.546*		
Naive Portfolio	−0.290	0.689	1.665**	
Equally-Weighted Index	−0.848	0.186	1.233	−2.822***

Notes: Exhibit 9 reports the Jobson & Korkie (1981) test for the equality of the Sharpe ratios.
*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

The equally-weighted portfolio is also examined on a similar basis, as to maintain equal weighting will also require re-balancing every quarter. It can be seen that in each case, the mean monthly return is lower than in the original scenario, while the standard deviation is higher, resulting in a lower Sharpe Ratio. The results are broadly similar to those examined previously, with the minimum variance portfolio outperforming all other strategies in terms of risk and return. The Jobson and Korkie (1981) statistics also reveal a similar picture to that obtained with the unadjusted figures. The classical tangency portfolio significantly under-performs both the Bayes-Stein and minimum variance portfolios, while the minimum variance portfolio significantly out performs all three alternative strategies. However, when the alternative strategies are compared to the simple equally-weighted index none of them significantly outperforms, with the minimum-variance portfolio just failing to be significant at conventional levels.

Exhibits 10 and 11 more formally examine whether an investor significantly gains from investing in foreign markets. To assess this issue, the original four portfolios are compared against the individual market returns over the out-of-sample period, 1981 to 1998. It can be seen that in comparison to the classical tangency case, six of the eleven individual markets produce higher average out-of-sample mean returns. Even with the adjusted optimal portfolios, and the equally-weighted naive strategy, five of the markets produce higher returns. However, if the risk measures are compared, it can be seen that in the vast majority of cases, the greatest benefit from diversifying internationally comes from the reduction of risk. In the cases of the Bayes-Stein and Minimum Variance portfolios, none of the individual markets have lower standard deviations. Even in the case of the unadjusted

Exhibit 10 | Individual Market Performance

	Mean	Std. Dev.	Variance	Sharpe Ratio
Australia	1.602	7.716	59.537	0.208
Belgium	1.329	6.528	42.614	0.204
Canada	0.441	9.533	90.868	0.046
France	0.686	9.034	81.607	0.076
Hong Kong	1.138	11.518	132.666	0.099
Italy	0.574	7.194	51.752	0.080
Japan	0.501	8.921	79.578	0.056
Netherlands	0.522	3.465	12.006	0.151
Singapore	0.729	11.056	122.226	0.066
U.K.	0.998	6.028	36.332	0.166
U.S.	1.030	3.248	10.550	0.317

Notes: Exhibit 10 reports the performance of the individual markets analyzed for the out-of-sample period, 1981–1998.

tangency portfolio, only the U.S. and Dutch markets have lower risk measures. This is also the case with the equally-weighted portfolio. The resulting lower risk measures means that in the majority of cases, the corresponding Sharpe Ratios are lower for the individual markets.

We again use the Jobson and Korkie (1981) pairwise test of the equality of Sharpe Ratios to compare performance, the results being reported in Exhibit 11. In each case, the international diversification strategy outperforms domestic portfolios for Canada and Japan. Therefore, in the case of these markets, the perceived benefits from diversifying into international markets is further confirmed. In addition, the naive strategy significantly out-performs the Italian and French markets. The two portfolios constructed to reduce estimation error provide further evidence as to their attractiveness. The Bayes-Stein prior portfolio significantly outperforms six of the eleven markets, while the minimum variance strategy sees significant out performance in eight of the eleven cases. The only exceptions are in the case of Australia, Belgium and the U.S. The only cases where a domestic market outperforms the international strategy, thereby implying no benefits to diversifying into foreign stocks, are with regard to Australia and Belgium for the original tangency portfolio, although in neither case is the test statistic significant. The REIT market however, outperforms all four portfolios, and is statistically significant in the case of the mean-variance tangency portfolio. Therefore, these results would imply that U.S. investors in REITs gained no benefits from extending their portfolio into an international environment.

Exhibit 11 | Comparison of Performance Between Optimal Portfolios and Individual Markets

	Maximum Sharpe Portfolio	Bayes-Stein Maximum Sharpe Portfolio	Minimum Variance Portfolio	Naive Portfolio
Australia	−0.173	0.279	0.958	0.009
Belgium	−0.132	0.319	0.998	0.049
Canada	1.464*	1.912**	2.586***	1.648**
France	1.165	1.616*	2.294**	1.348*
Hong Kong	0.933	1.382*	2.055**	1.114
Italy	1.127	1.578*	2.257**	1.308*
Japan	1.364*	1.815**	2.494***	1.546*
Netherlands	0.410	0.869	1.579*	0.592
Singapore	1.266	1.715*	2.391***	1.451
U.K.	0.255	0.708	1.387*	0.438
U.S.	−1.310*	−0.855	−0.164	−1.123

Notes: Exhibit 11 reports the Jobson & Korkie (1981) test for the equality of the Sharpe Ratios.
*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

Conclusion

Much of the existing literature has ignored potential biases in a standard mean-variance approach. This article has provided preliminary evidence as to the attractiveness of addressing the issue of estimation error in asset allocation studies. The problem of estimation error is not solely a theoretical one, as has been shown here, as the use alternative techniques can lead to a reduction in the variation in the estimated portfolio allocations and can lead to improved out-of-sample performance. As with previous studies, the use of the Bayes-Stein shrinkage approach does lead to increased stability in the estimated allocations and results in improved performance. However, the greatest improvement in out of sample performance came from the use of the minimum variance portfolio. In this scenario, all estimation error arising from the sample means is eliminated as the minimum variance portfolio does not use the means in the determination of the allocations. Not only does the MVP portfolio outperform the classical tangency portfolio and the Bayes-Stein estimated portfolio, but it also significantly outperforms a naive equally-weighted strategy. These findings also hold when transaction costs are incorporated into the analysis.

Endnotes

[1] The article used the methodology proposed by Gibbons, Ross and Shanken (1989).

[2] The three markets that provided significant results when spot foreign exchange rates were used were Japan, the Netherlands and Singapore. The other markets to be examined in this study were Australia, Belgium, Canada, France, Italy, the U.K. and the U.S.

[3] In addition to the standard MVA approach, Liu and Mei (1998) also analyzed the issue using a Multifactor Latent Variable Model.

[4] See Jorion (1985) for an extended discussion on this point.

[5] See also papers such as Eun and Resnick (1988) and Stevenson (1999).

[6] See, for example, Fama and French (1988) and Poterba and Summers (1988) with respect to the evidence concerning individual stocks. In addition, papers such as Richards (1997) and Balvers, Wu and Gilliland (2000), provide evidence of mean reversion in national stock indices.

[7] The countries analyzed are Australia, Belgium, Canada, France, Hong Kong, Italy, Japan, the Netherlands, Singapore, the U.K. and the U.S.

[8] Stevenson (2000) analyzed the diversification opportunities from extending into international markets from the perspective of each of the countries examined. The study found that substantial differences can occur in the results between the assumed nationality of the investor when currency movements are taken into account.

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