Ex-Ante and Ex-Post Performance of Optimal REIT Portfolios

Executive Summary. *This study examines the out-of-sample performance of equity real estate investment trust portfolios based on the NAREIT sector indices. The article examines the use of alternative techniques to reduce estimation error and this improves out-of-sample performance. The findings reveal that unlike previous studies of the capital markets, the tangency portfolios tend to out-perform out-of-sample, despite the instability in the weights and the presence of corner solutions. The minimum-variance portfolio continues to under-perform despite the reduction in estimation error.*

by Simon Stevenson*

Introduction

The majority of conventional portfolio/asset allocation studies tend not to robustly address the issue of estimation error or the out-of-sample performance of optimally estimated portfolios. The majority of empirical studies have found that optimal portfolios tend to perform badly out-of-sample, and much of this underperformance can be attributed to estimation error and problems in the estimation of the portfolio allocations. Portfolio optimizers are extremely sensitive to the inputted parameters and further more if not constrained have a tendency to arrive at corner solutions. The fact that optimal portfolios are therefore often not diversified and contain large allocations in a small number of assets goes against the principles of diversification and can lead to poor ex-post performance. These problems are further exacerbated when the portfolios are examined on a rolling basis due to instability in the portfolio weights due to the optimizer's sensitivity to the inputs.

This study examines the performance of optimal real estate investment trust (REIT) portfolios out-of-sample through the use of NAREIT sector indices. The use of such a dataset also allows an examination of potential trading strategies available to REIT mutual funds. Such funds have grown considerably over the last decade together with the general growth in REITs. Gallo, Lockwood and Rutherford (2000) note that in 1990 there were only two real estate-based mutual funds in the United States. In 2002, NAREIT lists sixty-three such funds. These funds invest the majority of their portfolios in REITs; therefore the predicable nature of the trusts is of interest to the funds.

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The cyclical nature of real estate may induce a degree of predictability into REIT returns that can therefore be exploited by real estate mutual fund managers.

A number of articles have examined alternative methods to improve performance by attempting to reduce estimation error. One of the simplest means of reducing estimation error is to use constraints. The primary advantage to such an approach is that it overcomes the problem of corner solutions, with studies such as Chopra, Hensel and Turner (1993) examining the use of constraints in the capital markets. However, one of the major problems with this technique is that the choice of constraints is at best arbitrary, leading to the results being hard to generalize. Two of the most common alternatives methods used to reduce estimation error are Bayes-Stein estimators and the analysis of the minimum-variance portfolio. Bayes-Stein estimators are used to reduce estimation error and the tendency to arrive at corner solutions. Such an approach reduces the differences between extreme observations in the sample means by effectively shrinking them towards a specified global mean. The approach used here is that proposed by Jorion (1985, 1986), which provides an empirical means of estimating the shrinkage weight. The use of the minimum variance portfolio weights has the advantage in that the portfolio weights are purely determined by the two risk parameters. A number of studies, such as Chopra and Kiemba (1993) and Stevenson (2001b) have found that portfolio optimizers are particularly sensitive to variations in the means. Therefore, the use of the minimum variance portfolio eliminates the largest cause of estimation error from the estimation process.

Previous studies to have used either the shrinkage or minimum-variance approach include Jorion (1985), Chopra and Kiemba (1993) and Stevenson (2001a). Jorion examined seven world equity markets, finding that the Bayes-Stein estimated portfolios significantly outperform the standard mean-variance tangency portfolio. Chopra and Kiemba 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. Stevenson analyzed thirty-eight international equity markets, with the additional analysis of two alternative downside risk measures due to the inclusion of emerging markets in the sample and the fact that such markets generally display non-normal distributions. The results show that all three minimum risk portfolios out-performed the alternative Bayes-Stein and classical portfolios on an out-of-sample basis.[1]

Relatively few studies have examined the out-of-sample performance of real estate security portfolios. Stevenson (2001b) examines the performance of minimum-variance and Bayes-Stein portfolios of international real estate securities in a similar fashion to that adopted in the current study. The results find that the minimum-variance approach results in significant out-performance ex-post of both the classical and Bayes-Stein tangency portfolios. The Bayes-Stein also provides significant improvements in performance relative to the classical mean-variance tangency portfolio. These results are however, not confirmed by Lee and Stevenson (2000) with regard to the direct market in the United Kingdom. This study finds that the classical tangency portfolio outperforms both the minimum variance portfolio and in most scenarios the Bayes-Stein tangency portfolios. This finding is possibly due to the cyclical nature of real estate and the smoothed nature of returns. This would imply that performance persistence over short horizons means that the classical tangency portfolio would tend to outperform, as it contains the best performing portfolio during the portfolio creation time periods. These sectors or assets would then tend to continue to outperform over the short term. Stevenson (2002) finds some supporting evidence in this regard with respect to international real estate security markets through the examination of the out-of-sample performance of winner and loser portfolios. The winner portfolios consistently outperform up to horizons of sixty months, and significantly so up to twelve month time frames.

These results are also consistent with the literature examining the predictability and performance persistence of REITs. Studies such as Liu and Mei (1992) and Mei and Liao (1998) find that REITs are more predictable than stocks or fixed income securities. Findings of predictability are also observed by Mei and Gao (1995) and Cooper, Downs and Patterson G (1999). Nelling and Gyourko (1998) also find evidence of predictability in REIT returns; however, transaction costs offset the improvements in performance of portfolios based on the analysis. Graff and Young (1997) also find mixed evidence with positive momentum effects only observed for twelve-month horizons.

The remainder of this article is laid out as follows. The following section provides details of the data used and the methodological framework adopted in the paper. Next, the empirical evidence is reported. The last section provides concluding comments.

Data Requirements & Methodological Framework

The data used in this study comprises sectors of the NAREIT indices for the period January 1994 to March 2002. A total of sixteen sectors are defined by NAREIT, with the summary statistics for each sector over the entire sample period displayed in Exhibit 1. Only Equity REITs were examined in order to provide a clean data set and to avoid problems concerning the portfolio mixes of some of the REITs. Total returns were used throughout the analysis. The empirical tests are based on rolling portfolios estimated using twenty-four months of data. Therefore, the first allocations are estimated using the return and risk parameters for 1994 and 1995. The allocations are re-estimated each quarter with the portfolio weights altered accordingly. It should be noted that the Mixed REIT sector does not have data available until January 1996 but was included as so as sufficient data was available.

Exhibit 1

Summary Statistics, Overall Sample Data

	Mean Return	Std. Dev.	Variance
Apartment	0.988	3.638	13.232
Diversified	0.664	3.524	12.421
Free Standing	0.976	3.851	14.829
Health Care	0.875	4.255	18.102
Industrial	1.143	3.726	13.883
Industrial/Office	1.292	3.853	14.846
Lodging/Resorts	0.450	7.155	51.194
Manufactured Homes	0.947	3.752	14.076
Mixed	1.244	4.023	16.186
Office	1.291	4.312	18.589
Regional Malls	1.073	3.754	14.089
Residential	0.986	3.555	12.640
Retail	0.914	3.210	10.302
Self Storage	1.233	4.125	17.018
Shopping Centers	0.880	3.111	9.678
Specialty	0.018	6.587	43.390

Notes: Exhibit 1 displays the summary statistics for the NAREIT sectors over the entire sample period. The Mixed REIT sector does not have data available until January 1996.

Three alternative types of optimal portfolios are examined, namely the classical tangency portfolio that maximizes the Sharpe Ratio, the equivalent portfolio using the Bayes-Stein adjusted returns and the minimum variance portfolio. It is assumed that investors cannot partake in short selling, as Jorion (1992) shows that short selling can increase the impact of estimation error. In addition to the optimized portfolios, simple equally-weighted winner and loser portfolios are also estimated using the same rolling periods. The constituents of the winner portfolio are defined as those sectors that ranked on a risk-adjusted basis in the top six. The loser portfolio contains the six worst performing sectors.

The general form for the Bayes-Stein 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, $\bar{r}_g$ is the specified global mean and w the shrinkage factor. Jorion (1985, 1986) shows that the shrinkage factor can be estimated from a suitable prior as follows:

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

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

Where T is the sample size, S is the sample covariance matrix and r_0 can be shown to be the mean return of the minimum-variance portfolio. For the empirical tests, the overall NAREIT Equity Index is used as the global mean.

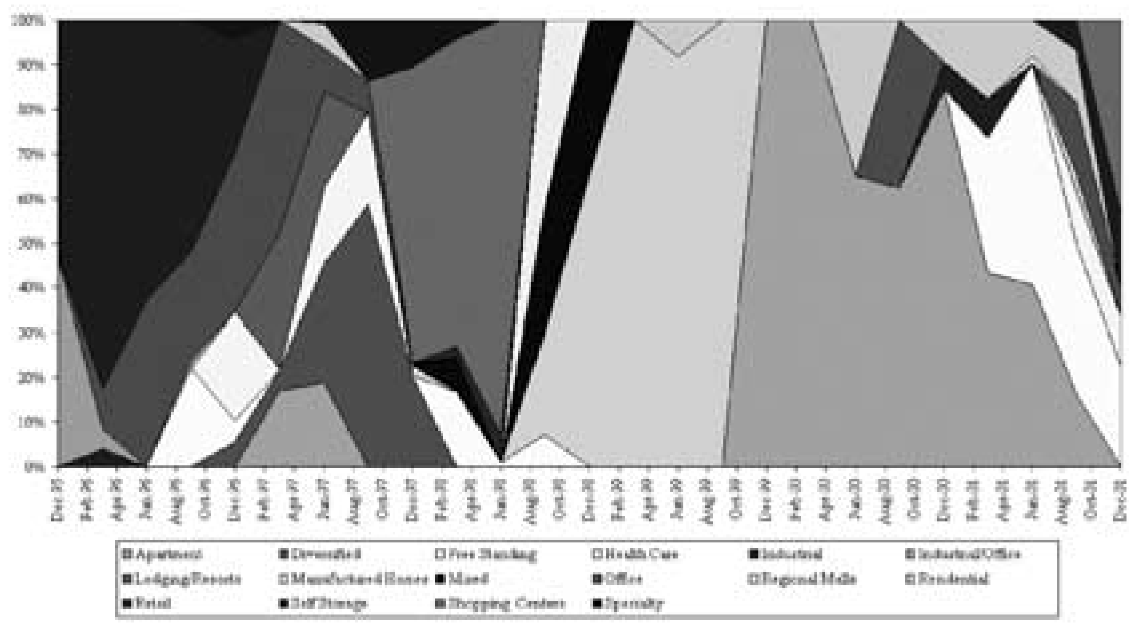
Empirical Results

Exhibits 2 though 4 graphically display the rolling allocations under each portfolio scenario. The instability in the optimal portfolios, and particularly in the classical tangency portfolio, is evident. The rolling allocations see large swings between sectors even when only one quarter of data is altered. For example, in late 1999 the classical tangency portfolio switches from 100% in Health Care REITs to 100% in the Apartment sector in one quarter, with only 25% of the observations changed. This highlights the problems of corner solutions and the relatively undiversified nature of the optimal portfolios, which has often been felt to be the primary reason behind the poor out-of-sample performance of the classical tangency portfolios. The Bayes-Stein allocations provide slightly more stability in the allocations and also tend to include a greater number of sectors, however, they are still relatively undiversified at times and sharp changes in the allocations are still observed in some periods. The minimum-variance portfolio is generally the most stable and diversified portfolio of the three, highlighting the potential advantages behind its application. As stated previously, the minimum-variance portfolio bases the allocations purely on the two risk parameters with the mean not coming into consideration. As the mean has been found to be the primary cause of estimation error, this also provides further rationale behind its use.

The out-of-sample performance of the portfolios, together with the simple winner and loser portfolios, are displayed in Exhibit 5. In addition, the NAREIT Equity REIT Index is also displayed alongside a simple equally-weighted portfolio of the sixteen sectors. It is immediately evident that the results are not in line with those reported by Stevenson (2001b) with regard to international real estate security markets. It can be seen that the two tangency portfolios, the ranked winner portfolio and the equally-weighted portfolio, outperform the NAREIT benchmark on a risk-adjusted basis. The only portfolios that underperform the benchmark are the ranked loser portfolio and the minimum-variance portfolio. These results are in marked contrast to those reported by

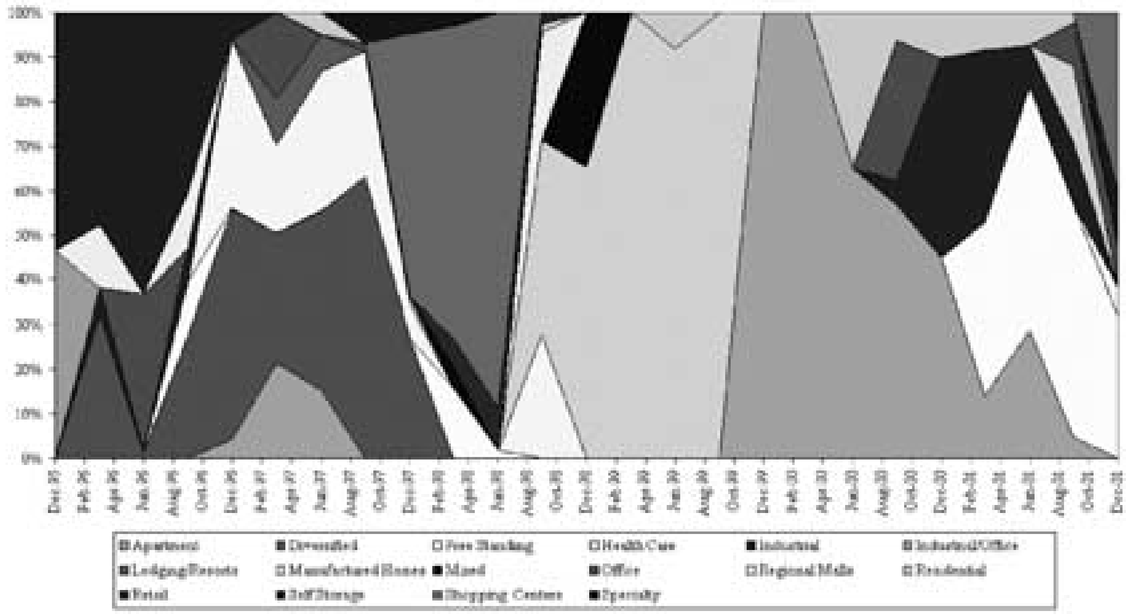
Exhibit 2

Rolling Tangency Portfolio Allocations



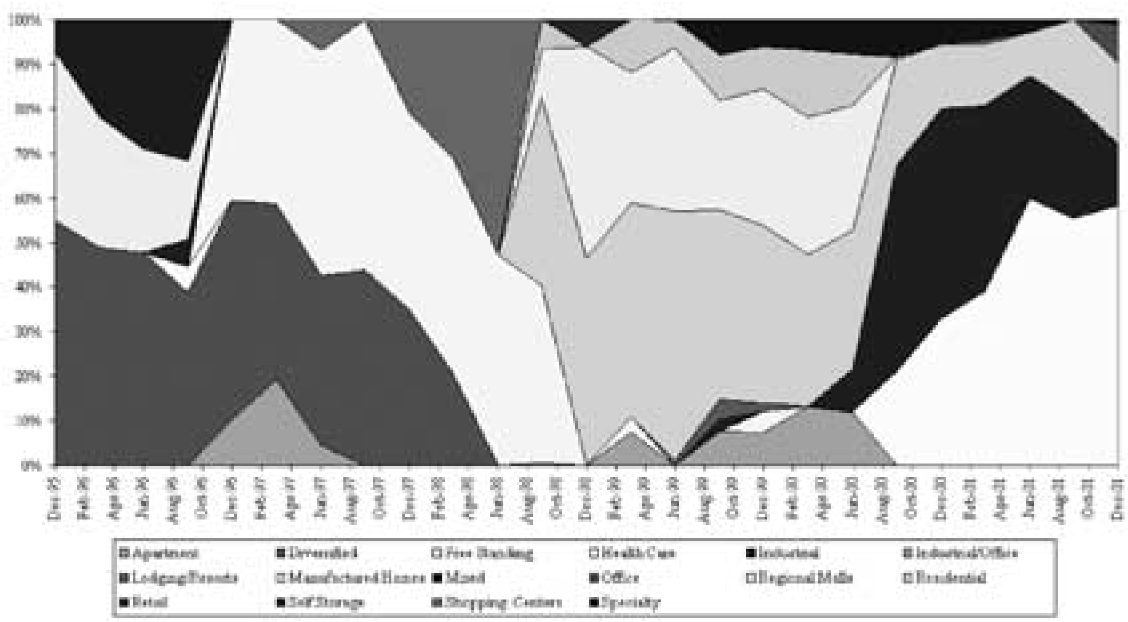
Notes: Exhibit 2 displays rolling allocations in the NAREIT sectors for the Classical Tangency Portfolio. The weights are estimated using the previous twenty-four months of data.

Exhibit 3
Rolling Bayes-Stein Tangency Portfolio Allocations



Notes: Exhibit 3 displays rolling allocations in the NAREIT sectors for the Tangency Portfolio using the Bayes-Stein adjusted returns. The weights are estimated using the previous twenty-four months of data.

Exhibit 4
Rolling Minimum Variance Portfolio Allocations



Notes: Exhibit 4 displays rolling allocations in the NAREIT sectors for the minimum-variance portfolio. The weights are estimated using the previous twenty-four months of data.

Exhibit 5
Out-of-Sample Performance of Optimal Portfolios

	Mean Return	Std. Dev.	Variance
NAREIT Equity Index	0.991	3.664	13.424
Equally-Weighted Portfolio	0.939	3.457	11.952
Minimum-Variance Portfolio	0.866	3.298	10.879
Tangency Portfolio	1.064	3.736	13.956
Bayes-Stein Tangency Portfolio	1.044	3.451	11.906
Winner Portfolio	1.099	3.542	12.545
Loser Portfolio	0.829	3.695	13.656

Notes: Exhibit 5 reports the out-of-sample performance of the alternative portfolios. Each portfolio is re-balanced each quarter using the rolling allocations.

Stevenson (2001b) and in studies of the general capital markets, but they are more in line with the analysis of the U.K. direct market analyzed by Lee and Stevenson (2000). The results would indicate a degree of performance persistence that was absent in the international data with one potential reason being the cyclical nature of the underlying asset. As the REIT data is divided by market sector, the results may well be reflecting the relative performance of the underlying sectors and the cyclical performance of each. Therefore, while the tangency portfolios are prone to estimation error and the allocations are often corner solutions and are therefore relatively undiversified, they do provide enhanced performance. However, it should be noted that the Bayes-Stein approach, which adjusts for differences in the means through the shrinkage approach, does provide better performance than the classical tangency portfolio. Therefore, while performance persistence does appear to dominate the performance on a quarterly basis, the reduction of estimation error through the Bayes-Stein method does still lead to improved performance.

In order to more formally compare ex-post performance the Jobson and Korkie (1981) pair-wise test of the equality of the Sharpe Ratio is used. This statistic can be formulated 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, contained in Exhibit 6, show that while the tangency portfolios do outperform, the degree of out-performance is generally not statistically significant at conventional levels. Only three significant t-Statistics are reported, and all are concerned with the ranked loser portfolio. This portfolio significantly underperforms the equally-weighed, Bayes-Stein tangency and ranked winner portfolios. Therefore, while a number of the portfolios do outperform the benchmark, the improvement in performance is

Exhibit 6
Jobson-Korkie Tests for Comparative Performance

	NAREIT Equity Index	Equally-Weighted Portfolio	Minimum-Variance Portfolio	Tangency Portfolio	Bayes-Stein Tangency Portfolio	Winner Portfolio
NAREIT Equity Index						
Equally-Weighted Portfolio	−0.050					
Minimum-Variance Portfolio	0.179	0.239				
Tangency Portfolio	−0.339	−0.324	−0.534			
Bayes-Stein Tangency Portfolio	−0.751	−0.771	−1.082	−0.821		
Winner Portfolio	−1.130	−1.098	−1.123	−0.800	−0.231	
Loser Portfolio	1.046	1.310*	0.774	0.983	1.316*	1.431*

Notes: Exhibit 6 reports the Jobson-Korkie t-Statistics to compare the out-of-sample performance of the alternative portfolios and the two benchmarks.

*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

Exhibit 7
Out-of-Sample Performance of Optimal Portfolios with Transaction Costs

	Mean Return	Std. Dev.	Variance
NAREIT Equity Index	0.991	3.664	13.424
Equally-Weighted Portfolio	0.874	3.421	11.701
Minimum-Variance Portfolio	0.720	3.370	11.358
Tangency Portfolio	0.827	3.855	14.861
Bayes-Stein Tangency Portfolio	0.824	3.650	13.319
Winner Portfolio	0.952	3.554	12.629
Loser Portfolio	0.194	4.563	20.824

Notes: Exhibit 7 reports the out-of-sample performance of the alternative portfolios after the inclusion of transaction costs. Each portfolio is re-balanced each quarter using the rolling allocations.

not statistically significant. However, it should be noted that Jobson and Korkie (1981) and Jorion (1985) show that the test has low power, therefore, relatively large degrees of improved performance need to be exhibited before significant findings are observed.

Due to the use of rolling portfolios, the tests are re-estimated after incorporating transaction costs into the analysis. This is particularly important in relation to the tangency portfolios due to the instability in the weights, the large shifts in weights between sectors and the presence of corner solutions. Transaction costs of 1% are incorporated each quarter when weights are altered. It should be noted that the change in weights does not just involve the change between the estimated weights used at the beginning of each quarter. During each quarter the weights will change due to the respective price movements in each sector. Therefore, the weights of the sectors can alter substantially during each individual three-month period. The transaction costs are therefore based on the change between the ending weight and the newly estimated weight using the previous twenty-four months of data. The equally-weighted portfolio also requires re-balancing due to shifts in the weights over each quarter. For example, while the portfolio will start each quarter equally weighted, if a sector falls in value its weight will drop relative to those sectors that have outperformed. This means that the equally-weighted portfolio effectively increases the weight in those sectors that have under-performed and reduces its exposure to those that have outperformed.

The results are contained in Exhibits 7 and 8, with the basic summary statistics displayed in Exhibit 7 and the Jobson-Korkie t-Statistics reported in Exhibit 8. The introduction of transaction costs results in the expected effect of worsening the performance of the tangency portfolios due to the instability in their weights and therefore increased the trading activity in these portfolios. When such costs are incorporated into the analysis, none of

Exhibit 8
Jobson-Korkie Tests for Comparative Performance with Transaction Costs

	NAREIT Equity Index	Equally-Weighted Portfolio	Minimum-Variance Portfolio	Tangency Portfolio	Bayes-Stein Tangency Portfolio	Winner Portfolio
NAREIT Equity Index						
Equally-Weighted Portfolio	0.634					
Minimum-Variance Portfolio	1.337*	1.125				
Tangency Portfolio	1.293*	0.918	−0.017			
Bayes-Stein Tangency Portfolio	1.019	0.686	−0.314	−0.564		
Winner Portfolio	0.073	−0.329	−1.247	−1.664*	−1.234	
Loser Portfolio	3.182***	3.186***	2.461***	2.137**	2.308**	2.940***

Notes: Exhibit 8 reports the Jobson-Korkie t-Statistics to compare the out-of-sample performance of the alternative portfolios after the inclusion of transaction costs.

*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

the estimated portfolios outperform the benchmark NAREIT index on a risk-adjusted basis, with the ranked loser, the minimum-variance portfolio and the classical tangency portfolio all underperforming at statistically significant levels. Indeed, the ranked loser portfolio significantly underperforms all of the alternative portfolio scenarios. The classical tangency portfolio also significantly underperforms the ranked winner portfolio. The Bayes-Stein portfolio continues to maintain advantages over the classical approach, and while it does not out-perform at significant levels, it does outperform all of the alternatives with the exception of ranked winner portfolio. Therefore, while predictability in REIT returns does not result in contrarian results and the strong performance of portfolios such as the minimum-variance, the addressing of estimation error can still lead to improvements in performance. The results do however also indicate that once transaction costs are included in the tests, the predictability of REITs and the resulting creation of portfolios do not reveal consistent means of outperforming the benchmark. These findings are also consistent with those reported by Nelling and Gyourko (1998).

Conclusion

This study examines the out-of-sample performance of Equity REIT portfolios based on market sectors, with the aim of examining the potential improvements in performance resulting from alternative methods designed to reduce estimation error. The results are in marked contrast to previous studies of the capital markets, however, they can be reconciled with the existing literature on REIT predictability. Unlike previous studies, the best performing portfolio is not the minimum-variance portfolio but alternative tangency portfolios. This is despite the instability in the estimated allocations, the presence of corner solutions and the frequent large shifts in the weights. The two tangency portfolios are only outperformed by simple ranked winner portfolios. These results all indicate a degree of performance persistence and therefore predictability in Equity REIT returns that could be potentially useful to real estate mutual fund managers. It is hypothesized that this predictability may be due to the use of sector data and the cyclical nature of the underlying real estate. However, the inclusion of transaction costs does lead to the two tangency portfolios seeing performance worsen due to the active trading required by such a strategy. The continuous outperformance of the Bayes-Stein tangency portfolio, which addresses some of the concerns with regard to estimation error, does however highlight the importance of addressing the issue and the potential gains that may be realized.

Endnote

1. Other studies to have found the MVP strategy to be attractive in terms of out-of-sample performance include Haugen and Baker (1991), Jobson, Korkie and Ratti (1979) and Jobson and Korkie (1981).

References

Chopra, V. K., C. R. Hensel and A. L. Turner, Massaging Mean Variance Inputs: Returns form Alternative Global Investment Strategies in the 1980's, *Management Science*, 1993, 39, 845–55.

Chopra, V. K. and W. T. Ziemba, The Effect of Errors in Means, Variances and Covariances on Optimal Portfolio Choice, *Journal of Portfolio Management*, 1993, Winter, 6–11.

Cooper, M., D. H. Downs and G. A. Patterson, Real Estate Securities and a Filter Based Short-Term Trading Strategy, *Journal of Real Estate Research*, 1999, 18, 313–34.

Gallo, J. G., L. J. Lockwood and R. C. Rutherford, Asset Allocation and the Performance of Real Estate Mutual Funds, *Real Estate Economics*, 2000, 28, 165–84.

Graff, R. A. and M. S. Young, Serial Persistence in Equity REIT Returns, *Journal of Real Estate Research*, 1997, 14, 183–214.

Jobson, J. D. and B. Korkie, Performance Hypothesis Testing with the Sharpe and Treynor Measures, *Journal of Finance*, 1981, 36, 888–908.

Jobson, J. D., B. Korkie and V. Ratti, Improved Estimation for Markowitz Portfolios using James-Stein Type Estimators, Proceedings of the American Statistical Association, Business and Economics Statistics Section, Washington: American Statistical Association, 1979.

Jorion, P., International Portfolio Diversification with Estimation Risk, *Journal of Business*, 1985, 58, 259–78.

——., Bayes-Stein Estimators for Portfolio Analysis, *Journal of Financial and Quantitative Analysis*, 1986, 21, 279–92.

Kalberg, J. G. and W. T. Ziemba, Mis-Specification in Portfolio Selection Problems, In G. Bamberg and A. Spremann (Eds.), *Risk and Capital*, New York, NY: Springer-Verlag, 1984.

Lee, S. and S. Stevenson, Real Estate Portfolio Construction and Estimation Risk, Paper presented at the European Real Estate Society annual conference, Bordeaux, June, 2000.

Liu, C. H. and J. P. Mei, The Predictability of Returns on Equity REITs and their co-movement with Other Assets, *Journal of Real Estate Finance & Economics*, 1992, 5, 401–18.

Mei, J. P. and Gao, Price Reversals, Transaction Costs and Arbitrage Profits in the Real Estate Securities Market, *Journal of Real Estate Finance & Economics*, 1995, 11, 153–65.

Mei, J. P. and H. H. Liao, Risk Characteristics of Real Estate Related Securities: An Extension of Liu & Mei (1992), *Journal of Real Estate Research*, 1998, 16, 279–90.

Nelling, E. and J. Gyourko, The Predictability of Equity REIT Returns, *Journal of Real Estate Research*, 1998, 16, 251–68.

Stevenson, S., Emerging Markets, Downside Risk and the Asset Allocation Decision, *Emerging Markets Review*, 2001a, 2, 50–66.

——., Bayes-Stein Estimators & International Real Estate Asset Allocation, *Journal of Real Estate Research*, 2001b, 21, 89–104.

——., Momentum Effects and Mean Reversion in Real Estate Securities, *Journal of Real Estate Research*, 2002, 23, 47–64.