# Analyzing Risks And Returns In Emerging Equity Markets

Peter Went, (E-mail: pwent@bucknell.edu), Bucknell University

**ABSTRACT**

*This study applies an operations research technique, Data Envelopment Analysis (DEA) on emerging equity market returns. Sharpe and Treynor measures focus only one risk aspect of portfolio return and in reality investors consider several alternative risk measures outside the traditional mean-variance framework. DEA is a multivariate approach that can incorporate multiple risk characteristics that may be equally important for the investor's decision to allocate assets to emerging markets, the risk and performance relationships are explored in a multivariate framework.*

Conventional univariate risk-adjusted portfolio and financial asset performance metrics, such as the Sharpe, Treynor or Information Ratios, fail to contemporaneously capture multiple aspects of the risk and return relationship. An alternative non-parametric, multi-factor linear programming technique, Data Envelopment Analysis, DEA, allows for the joint and simultaneous analysis of multiple risk, return, and performance criteria. Its application to financial market and asset performance is nascent and promising: it not only relates multiple risk variables to multiple performance variables, but also evaluates the most efficient combination of all existing risk and performance combinations. This technical efficiency, different from classical market efficiency, quantifies the efficient contribution of inputs to outputs. Since this efficiency measure ranks relative performance and quantifies inefficiencies, it offers a comprehensive metric of performance. [1]

(1) $$Efficiency = \frac{Output}{Input}$$

In analyzing risks, DEA offers several benefits compared to the traditional regression based factor analysis:

1. DEA allows for the simultaneous evaluation of multiple risk and performance variables. Regression based models are limited because they relate one performance variable to multiple risk variables, or vice versa.
2. DEA evaluates all feasible combinations determined by the data and measures relative performance and not average performance. It arrives to an efficiency score that evaluates and scores results relative to all possible combinations. Regression based models relate individual risk to the average risk in the sample.
3. DEA is a non-parametric method, which does not require any specification, assumption or prior knowledge of the statistical or distributional properties of the underlying time-series data. Apart from these advantages over regression based models, DEA is capable of analyzing smaller samples without further skewing the statistical properties of the data.
4. DEA can concurrently use as input or output variables that are each others' linear transformations. Multicollinearity is not a problem in DEA. In panel data models, controlling for the bias due to multicollinearity becomes a frequent consideration.

For various portfolio management and financial asset performance evaluation applications, the nascent financial and investment literature using DEA considers various risk measures as suitable input variables and selects return or performance measures as suitable output variables. Previous studies have applied the flexibility and ease of

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[1] For a detailed derivation of the relationship, please see the Appendix.

DEA to analyze the risk and performance of major stock markets (Meric and Meric 2001), the performance of mutual funds (e.g., McMullen and Strong 1998; Basso and Funari, 2003; Galagadera and Silvapulle, 2002), portfolio performance (Brockman et al, 2006), hedge funds and Commodities Trading Advisors (Gregorhiou and Zhu, 2005). The present study applies DEA to analyze the risk and performance characteristics of 23 emerging markets.

I complement commonly used measures of risk, variance of returns, beta and idiosyncratic risk, with measures of downside risk or semi-deviation and semi-mean. These serve as input variables. As output variables, I use absolute performance variables such as excess returns and measures of positive performance persistence. The output variables are the arithmetic average monthly excess return, the average geometric monthly excess return, the proportion of positive excess returns to total returns, and the maximum number of months with consecutive monthly excess returns (c.f., Gregorhiou and Zhu, 2005).

The results indicate that certain emerging markets exhibit consistent efficiencies, irrespective of distinctly different specifications, mixtures of input variables, and combinations of performance measures. One practical implication of these results is that certain risk characteristics, particularly various measures of shortfall risk, are not fully reflected in the performance of several emerging markets. Capitalizing on shortfall risk in emerging markets could discover yet underutilized investment opportunities for quantitatively focused investors. For a U.S. domiciled non-taxable investor with return requirements in USD, the equity markets of Czech Republic, China, Israel and Argentina have offered untapped opportunities.

The remainder of the study unfolds as follows. First, I describe the emerging equity market data and providing descriptive statistics on the markets, risk, and performance variables. The empirical results follow this discussion; conclusions conclude.

## DATA AND RISK CHARACTERISTICS WITH SUMMARY STATISTICS

Total return indexes from Morgan Stanley Capital International for emerging markets, denominated USD serve as data.[2] As several countries included in the dataset periodically suffered from galloping inflation, the use of USD denominated returns adjusts for high nominal, non-inflation adjusted returns. [3] Four selected benchmarks proxy four distinct investment objectives.

1. MSCI Emerging Market Index proxies the investment opportunities in emerging markets
2. MSCI World Index ex USA proxies international investment opportunities outside the United States in both developed and emerging markets
3. The S&P 500 Index proxies a return requirement imposed by a US domiciled investor
4. MSCI World Index proxies global investment opportunities

Table 1 offers descriptive statistics for the excess returns and benchmark series, and the descriptive statistics corroborate previous findings on emerging equity market: return volatilities are high with skewed and leptokurtic distributions.[4]

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[2] The data is freely downloadable from the Morgan Stanley Capital International website http://www.msci.com. Jordan, Egypt, Pakistan, and Morocco are excluded. The overall market capitalization in these markets is concentrated to a few closely-held major companies. Trading is comparatively infrequent. There are structural problems within the exchanges. Results including these markets are available upon request.

[3] Selecting MSCI World Index ex USA as a proxy excludes for the considerable weight of the US markets' capitalization and captures the broader international markets, while MSCI World Index captures global investment opportunities.

[4] The Jaques-Berra test rejects the (log)normality of distributions. Additionally, Ljung-Box statistics, with 12 lagged lengths, suggest the presence of autocorrelation and heteroskedasticity in most returns.

**Table 1 – Descriptive statistics**

Univariate descriptive statistics of the USD denominated excess returns for emerging markets and benchmarks used in the study between January 1995 and December 2005. Average is the arithmetic average of monthly excess return, standard deviation is calculated the same return series. For the higher moments, skewness is centered at 0. Ljung-Box is the Ljung-Box statistics with 12 lagged correlations. The Jarque-Berra is the test for normality. The geometric average is the geometric average of monthly excess return. Runs is the longest consecutively positive monthly excess return during the period.

| | Average | Standard dev | Skewness | Kurtosis | Ljung-Box | p-value | Jarque-Berra | p-value | Geometric average | Runs |
|---|---|---|---|---|---|---|---|---|---|---|
| Argentina | -0.0005 | 0.05 | -0.31 | 4.92 | 10.95 | 0.5336 | 22.41 | 0 | 0.015544 | 7 |
| Brazil | 0.001 | 0.052 | -0.96 | 5.27 | 5.57 | 0.9361 | 48.77 | 0 | 0.01621 | 10 |
| Chile | -0.0013 | 0.0304 | -0.95 | 6.76 | 9.74 | 0.6391 | 97.49 | 0 | 0.015289 | 9 |
| China | -0.0051 | 0.0477 | 0.24 | 4.71 | 22.07 | 0.0367 | 17.33 | 0.0002 | -0.0035 | 9 |
| Colombia | 0.0024 | 0.0428 | -0.22 | 3.44 | 22.52 | 0.0321 | 2.16 | 0.3401 | 0.012216 | 8 |
| Czech Republic | 0.0026 | 0.0369 | -0.56 | 4.6 | 16.38 | 0.1746 | 21.07 | 0 | 0.013998 | 9 |
| Hungary | 0.0042 | 0.0456 | -0.74 | 7.18 | 13.37 | 0.3426 | 108.25 | 0 | 0.017483 | 10 |
| India | -0.0005 | 0.0364 | -0.14 | 2.37 | 15.37 | 0.2217 | 2.63 | 0.2688 | 0.006579 | 8 |
| Indonesia | -0.004 | 0.0662 | -0.38 | 4.63 | 23.55 | 0.0234 | 17.83 | 0.0001 | 0.006852 | 6 |
| Israel | 0.0009 | 0.0329 | -0.45 | 3.66 | 8.93 | 0.7088 | 6.84 | 0.0328 | 0.009211 | 8 |
| Korea | -0.0008 | 0.055 | 0.28 | 5.41 | 7.16 | 0.8469 | 33.62 | 0 | 0.006465 | 7 |
| Malaysia | -0.0038 | 0.0437 | -0.09 | 6.55 | 28.6 | 0.0045 | 69.41 | 0 | 0.005358 | 7 |
| Mexico | 0.0016 | 0.0402 | -1.24 | 6.08 | 7.64 | 0.8124 | 85.97 | 0 | 0.018767 | 7 |
| Peru | 0.0009 | 0.0361 | -0.87 | 7.94 | 9.56 | 0.6541 | 150.99 | 0 | 0.010991 | 6 |
| Philippines | -0.0068 | 0.0427 | 0.01 | 5.02 | 16.3 | 0.1777 | 22.34 | 0 | 0.003626 | 6 |
| Poland | 0.0004 | 0.0463 | -0.3 | 4.8 | 13.56 | 0.3299 | 19.86 | 0 | 0.009541 | 5 |
| Russia | 0.0043 | 0.0813 | -1.08 | 7.49 | 12.09 | 0.4383 | 136.55 | 0 | 0.018455 | 6 |
| South Africa | -0.0001 | 0.0354 | -1.13 | 5.88 | 9.87 | 0.6274 | 73.81 | 0 | 0.008082 | 9 |
| Sri Lanka | -0.0026 | 0.0451 | 0.44 | 5.28 | 18.99 | 0.0888 | 33.01 | 0 | 0.001432 | 5 |
| Taiwan | -0.0035 | 0.039 | 0.09 | 3.24 | 16.98 | 0.1504 | 0.5 | 0.7775 | 0.005154 | 6 |
| Thailand | -0.006 | 0.0576 | -0.29 | 4.29 | 26.26 | 0.0099 | 11.02 | 0.0041 | 0.004975 | 10 |
| Turkey | 0.0027 | 0.073 | -0.24 | 4.26 | 10.05 | 0.6117 | 9.99 | 0.0068 | 0.010844 | 9 |
| Venezuela | -0.0012 | 0.0617 | -0.82 | 7.92 | 7.14 | 0.848 | 148.13 | 0 | 0.004687 | 7 |
| MSCI EM | 0.0047 | 0.0688 | -1.29 | 6.9 | 6.79 | 0.8709 | 120.31 | 0 | | |
| MSCI WORLD | 0.0069 | 0.0408 | -0.79 | 4.01 | 7.79 | 0.8014 | 19.14 | 0.0001 | | |
| MSCI WORLD ExUS | 0.0057 | 0.0425 | -0.65 | 3.61 | 7.2 | 0.8444 | 11.27 | 0.0036 | | |
| S&P 500 | 0.0086 | 0.0433 | -0.61 | 3.56 | 8.48 | 0.7463 | 9.94 | 0.0069 | | |

**Input Variables - Risk Variables**

DEA provides certain flexibility in selecting input and output variables and the empirical DEA literature in finance has generally agreed that risk variables should be used as input variables and performance variables as output variables (cf. Andersen and Springer, 2003). I employ several different risk variables as input variables, including total risk, correlations, and beta as well as lower partial moments. Since shortfall risk is a serious consideration in emerging markets, following the empirical findings of Estrada (2002) and Harvey (2003), I use lower moment risk variables as well. Table 2 lists the risk variables and Table 3 provides correlation coefficients for the individual input and output variables.

**Table 2 – Risk variables used as input factors in the DEA model**

| **Variable** | **Definition** |
|---|---|
| σj2 | Total risk or the variance of monthly excess returns |
| ρ(j, EM), | Correlation with MSCI Emerging Market Index |
| ρ(j, WORLD), | Correlation with MSCI World Market Index |
| ρ(j, SP), | Correlation with S&P 500 Index |
| ρ(j, World ex US) | Correlation with MSCI World ex US Index |
| β(j, EM), | Market risk, beta using MSCI Emerging Market Index as market proxy |
| β(j, WORLD), | Market risk, beta using MSCI World Market Index as market proxy |
| β(j, SP), | Market risk, beta using S&P 500 Index as market proxy |
| β(j, World ex US) | Market risk, beta using MSCI World ex US Index as market proxy |
| ε(j, EM), | Idiosyncratic risk, standard deviation of residuals using MSCI Emerging Market Index as the market proxy |
| ε(j, WORLD), | Idiosyncratic risk, standard deviation of residuals using MSCI World Market Index as the market proxy |
| ε(j, SP), | Idiosyncratic risk, standard deviation of residuals using S&P 500 Index as the market proxy |
| ε(j, World ex US) | Idiosyncratic risk, standard deviation of residuals using MSCI World ex US Index as the market proxy |
| SEMI-Dev | Semi-deviation of excess returns less than zero (negative returns) |
| MEAN-Down | Average return when monthly excess return is less than zero |
| MEAN-Up | Average return when monthly excess return is greater than zero |
| VAR 95% | Monthly excess return Value-at-risk below the 5th percentile |

**Variance Or Total Risk**

In the mean-variance framework, the total risk of a financial asset is measured by the variance of returns and is calculated on the average monthly return for each period, $\sigma_j^2$, with subscript $j$ identifying the individual country returns.

**Correlation**

As correlation assesses the individual contribution of one financial asset to the overall risk of the portfolio, I calculate correlations relative the benchmarks, to yield $\rho_{(j,\ EM)}$, $\rho_{(j,\ World\ ex\ US)}$, $\rho_{(j,\ SP500)}$ and $\rho_{(j,\ WORLD)}$.[5] The correlation cluster between the US market index and Global market indexes suggest that the US equity markets due to their large capitalization contribute significantly to the global equity market capitalization.

[5] Subscript EM refers to the USD denominated MSCI Emerging Market Index, World ex US refers to the USD denominated MSCI World Index ex USA, and SP500 refers to the S&P 500 index, and WORLD refers to the USD denominated MSCI World Index, respectively.

**Table 3 – Correlation coefficients for input and risk variables**

Negative values for input and output variables are adjusted according to the translation invariance property of the variables. Input variables are risk variables found in table 2, and the output variables are the arithmetic average monthly excess return, the geometric average excess return, the longest consecutively positive monthly excess return, and positive to total is the proportion of positive excess returns to the total number of returns.

| | σj2 | ρ(j, EM), | ρ(j, World) | ρ(j, SP), | ρ(j, World ex US) | β(j, EM), | β(j, World) | β(j, SP), | β(j, World ex US) | VAR 95% | ε(j, EM), | ε(j, WORLD), | ε(j, SP), | ε(j, World ex US) | SEMI-DevZero | MEAN-DownZero | MEAN-UpZero | Average return | Geometric return | Longest run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ρ(j, EM), | 0.96 | 1.00 | | | | | | | | | | | | | | | | | | |
| ρ(j, WORLD), | 0.99 | 0.99 | 1.00 | | | | | | | | | | | | | | | | | |
| ρ(j, SP), | 0.92 | 0.91 | 0.93 | 1.00 | | | | | | | | | | | | | | | | |
| ρ(j, World ex US) | 0.55 | 0.54 | 0.54 | 0.65 | 1.00 | | | | | | | | | | | | | | | |
| β(j, EM), | 0.58 | 0.55 | 0.56 | 0.67 | 1.00 | 1.00 | | | | | | | | | | | | | | |
| β(j, WORLD), | 0.53 | 0.51 | 0.52 | 0.64 | 1.00 | 1.00 | 1.00 | | | | | | | | | | | | | |
| β(j, SP), | 0.47 | 0.45 | 0.46 | 0.51 | 0.98 | 0.97 | 0.98 | 1.00 | | | | | | | | | | | | |
| β(j, World ex US) | 0.46 | 0.48 | 0.48 | 0.48 | -0.32 | -0.30 | -0.34 | -0.48 | 1.00 | | | | | | | | | | | |
| VAR 95% | 0.65 | 0.68 | 0.68 | 0.49 | -0.22 | -0.21 | -0.25 | -0.31 | 0.83 | 1.00 | | | | | | | | | | |
| ε(j, EM), | 0.63 | 0.73 | 0.69 | 0.51 | -0.15 | -0.15 | -0.18 | -0.24 | 0.79 | 0.98 | 1.00 | | | | | | | | | |
| ε(j, WORLD), | 0.63 | 0.61 | 0.63 | 0.45 | -0.29 | -0.25 | -0.30 | -0.36 | 0.85 | 0.97 | 0.91 | 1.00 | | | | | | | | |
| ε(j, SP), | -0.09 | -0.12 | -0.11 | 0.04 | -0.14 | -0.13 | -0.13 | -0.22 | 0.22 | -0.03 | -0.06 | 0.01 | 1.00 | | | | | | | |
| ε(j, World ex US) | 0.78 | 0.76 | 0.77 | 0.86 | 0.92 | 0.93 | 0.92 | 0.85 | 0.00 | 0.10 | 0.15 | 0.05 | -0.06 | 1.00 | | | | | | |
| SEMI-DevZero | -0.11 | -0.08 | -0.10 | 0.01 | -0.20 | -0.21 | -0.21 | -0.28 | 0.23 | 0.03 | 0.03 | 0.04 | 0.64 | -0.10 | 1.00 | | | | | |
| MEAN-DownZero | 0.66 | 0.64 | 0.66 | 0.69 | 0.95 | 0.96 | 0.95 | 0.94 | -0.24 | -0.07 | -0.02 | -0.12 | -0.21 | 0.91 | -0.23 | 1.00 | | | | |
| MEAN-UpZero | 0.04 | 0.07 | 0.06 | -0.04 | 0.15 | 0.14 | 0.14 | 0.20 | -0.22 | -0.06 | -0.02 | -0.10 | -0.30 | 0.06 | -0.47 | 0.20 | 1.00 | | | |
| Average return | 0.24 | 0.18 | 0.22 | 0.14 | 0.04 | 0.06 | 0.04 | 0.05 | 0.04 | 0.16 | 0.10 | 0.20 | -0.20 | 0.18 | 0.25 | 0.18 | 0.07 | 1.00 | | |
| Geometric return | 0.30 | 0.27 | 0.29 | 0.30 | -0.02 | -0.01 | -0.03 | -0.09 | 0.36 | 0.31 | 0.26 | 0.34 | -0.01 | 0.20 | 0.20 | 0.06 | 0.20 | 0.78 | 1.00 | |
| Longest run | 0.19 | 0.23 | 0.21 | 0.09 | -0.18 | -0.18 | -0.19 | -0.19 | 0.28 | 0.36 | 0.37 | 0.35 | 0.01 | -0.05 | 0.17 | -0.09 | 0.05 | 0.19 | 0.26 | 1.00 |
| Positive to total | 0.31 | 0.24 | 0.28 | 0.23 | -0.12 | -0.09 | -0.12 | -0.15 | 0.32 | 0.38 | 0.31 | 0.44 | 0.04 | 0.15 | 0.38 | -0.06 | -0.17 | 0.81 | 0.77 | 0.26 |

**Systematic And Idiosyncratic Risk**

Using the empirical specification of CAPM, I calculate the systematic risk of each emerging market relative the chosen benchmarks. In calculating the excess return for the four betas $\beta_{EM}$, $\beta_{World\ ex\ US}$, $\beta_{SP500}$, $\beta_{WORLD}$, I use the 3-month U.S. Treasury bill yield as the risk-free rate. The correlation cluster between US and Global market indexes continues in this risk measure as well. The idiosyncratic risk is the standard deviation of the residual of the empirical model, $\varepsilon_{jt}$.

(2) $$r_{jt} - R_{ft} = \alpha_j + \beta_j (R_{mt} - R_{ft}) + \varepsilon_{jt}$$

**Value-At-Risk**

I use the average of monthly returns below the 5th percentile level, a variable used both by Estrada (2000) and Campbell (2003).

**Semi-Deviation And Lower Partial Moments**

Although portfolio theory uses variance of returns as its principal measure of total risk, its appropriateness remains arguable. For instance, variance is only appropriate when the distributions are symmetric; evidence from descriptive statistics in Table 1 as well as from other studies suggest that equity market returns are non-symmetric. Moreover, kurtosis and skewness is reported to be considerably higher in emerging markets than in developed markets due to the excess volatility and persistence of runs. For most investors downside risk is the major concern; therefore, I use semi-deviation which only considers deviations below the zero. As semi-deviation combines into one measure the information provided by two statistics: variance and skewness, it is useful in explaining market returns (e.g., Harvey 2000). This measure is non-symmetric as only negative returns increase the semi-deviation, but positive returns do not influence semi-deviation:

(3) $$SEMI = \sqrt{\frac{1}{N}\sum_{t=1}^{T} \min\left(0, r_{jt}\right)^2}$$

N is the number of negative return months and not the total number of return months. Since investors generally prefer upside volatility and shun, when possible, downside volatility, semi-deviation reflects these preferences.[6] To complement semi-deviation, I also calculate MEAN-Down; the average return when monthly returns are negative.

(4) $$MEAN_{D} = \frac{1}{N}\sum_{t=1}^{T} \min\left(0, r_{jt}\right)$$

For completeness, I also include UP-months, the proportion of excess monthly returns exceeding zero. P is the number of positive return months and not the total number of return months. Setting $\mu_{jt}$ to equal zero, (5) yields the average excess positive monthly returns, or MEAN-Up.

(5) $$MEAN_{U} = \frac{1}{P}\sum_{t=1}^{T} \max\left(0, r_{jt} - \mu_{jt}\right)$$

**Performance Variables**

Performance variables serve as output variable, and I use four measures of performance. The first variable, the arithmetic average monthly excess returns, is the traditional measure of performance. The last three performance variables capture positive performance persistence: the magnitude, consistency and sustainability of positive, long-term positive excess returns generated by each market.

6 While I performed the analysis with additional upper partial moments as risk variables, I do not present these results here; if requested, I will make them available.

1. the arithmetic average of monthly excess returns for each country
2. the geometric average of monthly excess returns over the period measures consistency of long-term returns in each market over the period studied
3. the longest number of consecutive months of positive returns or runs within each period, measures the overall persistence of positive returns
4. the proportion of positive excess returns to total returns within each period identifies markets with the ability to sustain the greatest number of monthly positive excess returns

## FINDINGS

Empirically, DEA offers two different approaches. The *input oriented DEA models* measure how efficiently inputs generate the existent output; to improve performance, inputs should be reduced. Inefficiencies quantify a slack, the needed reduction of inputs to maintain the existing level of outputs. When the inefficiently used inputs are reduced, the unit in question becomes efficient. In other words, an input oriented and conventionally specified financial DEA model measures the required reduction in risk to motivate or satisfy the performance. The *output oriented DEA models* measure the potential increase in outputs given the existent levels of inputs. Here inefficiencies quantify a slack as well: the needed increase in outputs to effectively use the existing levels of inputs to generate outputs. With inputs held constant, the output increases to an efficient level, because currently they do not generate efficient performance relative to the levels of inputs used. To state it differently, DEA measures the loss of performance at a given level of risk. [7]

Previous DEA studies in finance employ input oriented models exclusively, partly due to the interpretation of the efficiency score: the calculated efficiency score quantifies the performance shortfall at a given risk level. Moreover, as outlined in the Appendix, the Markowitz model can be seen as a special case of input oriented DEA. This relationship establishes a connection between this approach of performance evaluation and the principles underlying portfolio construction. Thus both Mecir and Mecir (2001) and Andersen and Springer (2003) use a univariate approach. McMullen and Strong (1998), Basso and Funari (2003) and Drew et al (2002) follow a multivariate approach by selecting several risk variables as input variables and using return and other performance related variables as output variables. Furthermore, in both Galgadera and Silvapulle (2002) and Gregorhiou and Zhu (2005) uni- and multivariate approaches assess the efficiency of alternative assets. It is generally accepted that the sample should be twice as large as the number of input and output variables used in the analysis: here I use 23 emerging markets with a maximum of six total input and output variables Gregorhiou and Zhu (2005). For consistency, I will keep the number of output variables constant (one or four) and only change the input variables or the combination of input variables. This approach ensures uniformly determined efficiency scores (Zhu, 2003). Efficiency scores identify the best risk adjusted performance and rank markets relative to the best risk-adjusted performance or how much higher relative risk is compared to the risk of the most efficient market (Brockman et. al., 2006). The highest efficiency score of 1.00 indicates a market that offers the highest performance relative to risks.[8] Since this is the most efficient combination of risk and performance, risk is transferred into performance and not one part of risk is wasted. When the efficiency score is below 1.00, then the actual risk-adjusted performance is lower and shows inefficiencies. The distance from 1.00 measures the relative inefficiencies, and in this case, is a risk slack. Risk slack is the proportion of the risk that disappears and does not contribute to the returns. For instance, an efficiency score of 0.75 indicates 25% inefficiency; to achieve efficiency at the existing performance, risk should have been 25% less. Alternatively, performance does not reflect 25% of the risk at the given risk level or the risk adjusted performance is only 75% of the best risk adjusted performance.

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7 In mutual fund parlance – and most research in finance using DEA has been done on mutual funds – the input efficiency measure assesses whether the fund has had excessive loads, expenses, and risk for the returns earned. The output efficiency measure assesses whether the returns have been adequate in terms of loads, expenses and risks.

8 When needed, variables are linearly transformed, Zhu (2001).

**Table 4 – DEA efficiency scores for risk variables using average monthly return as output variable**
Input variables are defined in Table 2, above. The efficiency scores are calculated using a VRS input-oriented DEA model.

| **Average return as output variable 1995 – 2003** | **σj2** | **ρ(j, EM),** | **ρ(j, WORLD),** | **ρ(j, SP),** | **ρ(j, World ex US)** | **β(j, EM),** | **β(j, WORLD),** | **β(j, SP),** | **β(j, World ex US)** | **VAR 95%** | **ε(j, EM),** | **ε(j, WORLD),** | **ε(j, SP),** | **ε(j, World ex US)** | **SEMI-DevZero** | **MEAN-DownZero** | **MEAN-UpZero** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Argentina | 0.38 | 0.35 | 0.32 | 0.34 | 0.44 | 0.53 | 0.51 | 0.51 | 0.49 | 0.02 | 0.50 | 0.38 | 0.35 | 0.39 | 0.07 | 0.04 | 0.62 |
| Brazil | 0.40 | 0.25 | 0.22 | 0.24 | 0.37 | 0.71 | 0.65 | 0.69 | 0.71 | 0.04 | 0.44 | 0.28 | 0.26 | 0.29 | 0.08 | 0.04 | 0.66 |
| Chile | 0.93 | 0.37 | 0.32 | 0.35 | 0.48 | 0.90 | 0.85 | 0.87 | 0.99 | 0.01 | 0.34 | 0.24 | 0.21 | 0.26 | 0.09 | 0.05 | 0.81 |
| China | 0.22 | 0.22 | 0.14 | 0.18 | 0.23 | 0.28 | 0.29 | 0.28 | 0.27 | 0.05 | 0.25 | 0.20 | 0.15 | 0.24 | 0.08 | 0.01 | 0.32 |
| Colombia | 0.67 | **1.00** | **1.00** | **1.00** | **1.00** | 0.76 | 0.74 | 0.73 | 0.66 | 0.02 | **1.00** | **1.00** | 0.99 | **1.00** | 0.10 | 0.05 | 0.77 |
| Czech Republic | 0.92 | 0.71 | 0.87 | 0.79 | 0.86 | 0.94 | 0.88 | 0.89 | 0.84 | 0.02 | 0.74 | 0.67 | 0.73 | 0.60 | **1.00** | 0.20 | 0.96 |
| Hungary | 0.68 | 0.47 | 0.39 | 0.43 | 0.65 | 0.92 | 0.89 | 0.90 | 0.85 | 0.05 | 0.68 | 0.45 | 0.39 | 0.48 | 0.13 | 0.05 | 0.89 |
| India | 0.72 | 0.55 | 0.69 | 0.60 | 0.66 | 0.72 | 0.68 | 0.68 | 0.65 | **1.00** | 0.56 | 0.50 | 0.57 | 0.45 | 0.06 | 0.03 | 0.67 |
| Indonesia | 0.14 | 0.18 | 0.17 | 0.18 | 0.22 | 0.25 | 0.24 | 0.24 | 0.22 | 0.08 | 0.34 | 0.27 | 0.25 | 0.27 | 0.05 | 0.05 | 0.29 |
| Israel | **1.00** | 0.48 | 0.37 | 0.42 | 0.88 | **1.00** | **1.00** | **1.00** | 0.80 | 0.03 | 0.66 | 0.31 | 0.26 | 0.35 | 0.21 | 0.09 | **1.00** |
| Korea | 0.30 | 0.25 | 0.24 | 0.25 | 0.39 | 0.50 | 0.46 | 0.48 | 0.43 | 0.02 | 0.50 | 0.30 | 0.29 | 0.30 | 0.65 | 0.33 | 0.47 |
| Malaysia | 0.32 | 0.28 | 0.27 | 0.28 | 0.32 | 0.40 | 0.38 | 0.38 | 0.38 | 0.01 | 0.32 | 0.28 | 0.26 | 0.28 | 0.05 | 0.04 | 0.48 |
| Mexico | 0.71 | 0.36 | 0.30 | 0.33 | 0.49 | 0.93 | 0.90 | 0.93 | **1.00** | 0.05 | 0.45 | 0.30 | 0.26 | 0.33 | 0.13 | 0.07 | 0.88 |
| Peru | 0.83 | 0.59 | 0.72 | 0.63 | 0.65 | 0.84 | 0.79 | 0.80 | 0.81 | 0.30 | 0.54 | 0.52 | 0.58 | 0.48 | 0.16 | 0.07 | 0.89 |
| Philippines | 0.17 | 0.14 | 0.11 | 0.13 | 0.17 | 0.21 | 0.21 | 0.21 | 0.20 | 0.01 | 0.17 | 0.12 | 0.11 | 0.13 | 0.03 | 0.05 | 0.22 |
| Poland | 0.48 | 0.31 | 0.29 | 0.31 | 0.47 | 0.68 | 0.64 | 0.65 | 0.61 | 0.04 | 0.50 | 0.32 | 0.30 | 0.33 | 0.17 | 0.09 | 0.64 |
| Russia | 0.21 | 0.30 | 0.24 | 0.27 | 0.35 | 0.50 | 0.49 | 0.49 | 0.49 | 0.04 | 0.66 | 0.50 | 0.43 | 0.54 | 0.12 | 0.05 | 0.54 |
| South Africa | 0.78 | 0.35 | 0.35 | 0.36 | 0.49 | 0.90 | 0.80 | 0.84 | 0.90 | 0.09 | 0.40 | 0.28 | 0.28 | 0.28 | 0.06 | 0.03 | 0.88 |
| Sri Lanka | 0.36 | 0.57 | 0.93 | 0.72 | 0.65 | 0.43 | 0.42 | 0.41 | 0.36 | 0.02 | 0.68 | 0.76 | **1.00** | 0.60 | 0.05 | 0.04 | 0.47 |
| Taiwan | 0.42 | 0.27 | 0.22 | 0.24 | 0.32 | 0.48 | 0.47 | 0.47 | 0.49 | 0.02 | 0.28 | 0.21 | 0.19 | 0.24 | 0.05 | 0.03 | 0.45 |
| Thailand | 0.12 | 0.11 | 0.09 | 0.10 | 0.14 | 0.20 | 0.20 | 0.20 | 0.19 | 0.01 | 0.19 | 0.13 | 0.12 | 0.14 | 0.03 | **1.00** | 0.22 |
| Turkey | 0.24 | 0.26 | 0.22 | 0.24 | 0.42 | 0.52 | 0.50 | 0.51 | 0.44 | 0.02 | 0.71 | 0.39 | 0.35 | 0.42 | 0.22 | 0.11 | 0.48 |
| Venezuela | 0.23 | 0.38 | 0.32 | 0.36 | 0.49 | 0.38 | 0.37 | 0.37 | 0.32 | 0.02 | 0.69 | 0.49 | 0.43 | 0.53 | 0.35 | 0.77 | 0.40 |

Efficiency scores in Table 4 provide efficiency scores for individual risk measures to the average monthly return of the market. Here, in the input oriented analysis I only use one input and output variable; the analysis yields one efficiency score.

**Performance And Performance Persistence**

In the case of total risk, $\sigma_j^2$, Israel offers the best performance, and the Chilean market, with an efficiency score of 0.93, is nearest in efficiency. The 0.93 score indicates that the Chilean market's input inefficiency relative the Israeli market is 7%. Were the Chilean total market risk decline by 7%, the performance of the Chilean market would become efficient as well. The Thai market offers the lowest relative return for total risk, 0.12. In efficiency terms, for the total risk investors assumed in the Thai market, their reward was 88% worse than investors in the Israeli equity market and 81% worse than the Chilean market. In other words, the Thai equity market should have had an 88% lower variance to be considered efficient or their risk adjusted performance is 88% less than the Chilean market.[9] The Colombian market's correlation relative to its performance is the highest, with all other combinations inferior; the worst existing combination is Thailand. If investors consider high correlation as a positive risk attribute, the Colombian market offers the best relationship. However, if low correlations to returns are preferable, then investing in the Thai market is most beneficial. An investor focusing on diversifiable risk with $\beta_{World\ ex.\ US}$ as the benchmark would have received the best compensation for this risk in the Mexican market. Israel provided the highest performance efficiency for most diversifiable risk or β measures. In terms of idiosyncratic risk, Colombia is the most efficient for all specifications, except for $\varepsilon_{i,\ SP}$, where the Sri Lankan market is the most efficient. For this measure, the Colombian market is near efficiency (0.99). Out of the shortfall oriented alternative risk measures, India is the most efficient market in terms of VAR 95%, the Czech Republic offered the highest efficiency in terms semi-deviation, and Thailand demonstrated the best efficiency in MEAN-Down. For a US domiciled and USD denominated investor, investment in these markets would have provided the best opportunity in terms of the shortfall risks and total excess returns.

One of the advantages of DEA is the concurrent use of multiple input and output variables to calculate efficiencies. By adding three additional performance variables to average monthly returns, I attempt to capture the persistence of positive performance. With multiple input and output variables, the number of possible efficient combinations increases and multiple markets can provide efficiencies. In this multivariate case, the efficiency score maximizes the investor's utility (e.g., McMullen and Strong 1998). [10] The efficiency scores then distinguish between those markets that are efficient and the relative degree of inefficiencies between the remaining markets relative risk and performance. [11] Table 5 contains the efficiency score for individual risk measures to positive performance persistence.

After introducing positive performance persistence as the output variable, the Israeli market lost its highest efficiency. Both Brazil and India are efficient in terms of total risk, $\sigma_j^2$. Investors looking at performance persistence would reap the best benefits if investing in either of these two markets; investing in other markets might not be as beneficial. The inefficiency of the Israeli market is 14% relative to either of these markets. Other risk variables indicate similar changes in their efficiencies; Venezuela is the only market efficient in semi-deviations and Taiwan is the only market efficient relative MEAN-Down. This finding is unusual: multiple input and output variables often lead to multiple efficiencies. While neither of these two markets demonstrates any additional efficiency, they have several uni-and multivariate efficiencies. Brazil, India, Philippines and Venezuela are all efficient in MEAN-Up. Investors seeking emerging market exposure and demanding positive performance persistence and low relative risk, could shift part of their emerging market exposure towards Venezuela; its equity market has a higher combined proportion of positive return months and average positive returns than other markets and demonstrates efficiencies and near efficiencies in several alternative specification...

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9 The model examines the relationship between average return and variance of returns, and ranking by the variance to mean ratio would yield qualitatively similar results. Using the highest inverted variance-to-mean ratio as a base and then dividing each inverted variance-to-mean ratio with the base, would generate the same efficiency scores.

10 Efficiency scores of multiplicative DEA models could quantify the relative or preferential weight each output variable has.

11 Theoretically with sufficiently large number of input and output variables, it is possible to achieve efficiencies in all markets.

**Table 5 – DEA efficiency scores for risk variables using performance variables as output variable**

Input variables are defined in Table 2, above. The efficiency scores are calculated using a VRS input-oriented DEA model. The output variable are the arithmetic average monthly excess return, the geometric average excess return, the longest consecutively positive monthly excess return, and positive to total is the proportion of positive excess returns to the total number of returns.

| **All performance variables as output variables 1995 – 2003** | **σj2** | **ρ(j, EM),** | **ρ(j, WORLD),** | **ρ(j, SP),** | **ρ(j, World ex US)** | **β(j, EM),** | **β(j, WORLD),** | **β(j, SP),** | **β(j, World ex US)** | **VAR 95%** | **ε(j, EM),** | **ε(j, WORLD),** | **ε(j, SP),** | **ε(j, World ex US)** | **SEMI-DevZero** | **MEAN-DownZero** | **MEAN-UpZero** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Argentina | 0.43 | 0.35 | 0.31 | 0.34 | 0.51 | 0.77 | 0.73 | 0.75 | 0.71 | 0.07 | 0.62 | 0.39 | 0.36 | 0.41 | 0.10 | 0.04 | 0.75 |
| Brazil | **1.00** | 0.60 | 0.51 | 0.56 | 0.77 | **1.00** | **1.00** | **1.00** | **1.00** | 0.03 | 0.54 | 0.39 | 0.35 | 0.41 | 0.13 | 0.05 | **1.00** |
| Chile | 0.22 | 0.36 | 0.28 | 0.35 | 0.43 | 0.42 | 0.40 | 0.40 | 0.34 | 0.14 | 0.69 | 0.50 | 0.39 | 0.54 | 0.10 | 0.05 | 0.49 |
| China | 0.69 | **1.00** | **1.00** | **1.00** | **1.00** | 0.79 | 0.78 | 0.76 | 0.66 | 0.03 | **1.00** | **1.00** | **1.00** | **1.00** | 0.10 | 0.05 | 0.80 |
| Colombia | 0.73 | 0.71 | 0.90 | 0.78 | 0.86 | 0.75 | 0.72 | 0.72 | 0.65 | **1.00** | 0.73 | 0.65 | 0.70 | 0.59 | 0.07 | 0.03 | 0.73 |
| Czech Republic | 0.70 | 0.52 | 0.42 | 0.48 | 0.71 | 0.96 | 0.95 | 0.94 | 0.85 | 0.07 | 0.75 | 0.49 | 0.43 | 0.53 | 0.13 | 0.05 | 0.93 |
| Hungary | 0.22 | 0.31 | 0.25 | 0.28 | 0.37 | 0.53 | 0.53 | 0.51 | 0.49 | 0.06 | 0.69 | 0.51 | 0.45 | 0.56 | 0.12 | 0.05 | 0.56 |
| India | **1.00** | 0.57 | 0.42 | 0.50 | **1.00** | **1.00** | **1.00** | **1.00** | 0.81 | 0.03 | 0.80 | 0.36 | 0.29 | 0.42 | 0.24 | 0.09 | **1.00** |
| Indonesia | 0.30 | 0.30 | 0.29 | 0.30 | 0.46 | 0.51 | 0.47 | 0.48 | 0.43 | 0.02 | 0.61 | 0.37 | 0.33 | 0.37 | 0.76 | 0.33 | 0.48 |
| Israel | 0.86 | 0.66 | 0.80 | 0.70 | 0.72 | 0.88 | 0.85 | 0.84 | 0.81 | 0.49 | 0.61 | 0.58 | 0.65 | 0.54 | 0.17 | 0.07 | 0.96 |
| Korea | 0.48 | 0.51 | 0.48 | 0.51 | 0.55 | 0.60 | 0.57 | 0.57 | 0.52 | 0.02 | 0.58 | 0.50 | 0.44 | 0.51 | 0.08 | 0.04 | 0.73 |
| Malaysia | 0.75 | 0.47 | 0.38 | 0.42 | 0.63 | **1.00** | **1.00** | **1.00** | **1.00** | 0.09 | 0.58 | 0.38 | 0.34 | 0.42 | 0.16 | 0.07 | 0.99 |
| Mexico | 0.43 | 0.42 | 0.33 | 0.39 | 0.49 | 0.53 | 0.52 | 0.52 | 0.45 | 0.01 | 0.50 | 0.37 | 0.30 | 0.41 | 0.08 | 0.06 | 0.56 |
| Peru | 0.48 | 0.37 | 0.30 | 0.36 | 0.52 | 0.69 | 0.64 | 0.66 | 0.61 | 0.05 | 0.59 | 0.36 | 0.30 | 0.39 | 0.20 | 0.09 | 0.64 |
| Philippines | 0.57 | 0.45 | 0.31 | 0.40 | 0.50 | 0.67 | 0.66 | 0.66 | 0.62 | 0.02 | 0.47 | 0.34 | 0.26 | 0.40 | 0.08 | 0.03 | 0.62 |
| Poland | 0.84 | 0.49 | 0.50 | 0.50 | 0.69 | **1.00** | 0.91 | 0.94 | 0.91 | 0.10 | 0.57 | 0.40 | 0.37 | 0.39 | 0.07 | 0.03 | **1.00** |
| Russia | 0.43 | 0.35 | 0.31 | 0.34 | 0.51 | 0.77 | 0.73 | 0.75 | 0.71 | 0.07 | 0.62 | 0.39 | 0.36 | 0.41 | 0.10 | 0.04 | 0.75 |
| South Africa | 0.42 | 0.82 | **1.00** | **1.00** | 0.88 | 0.51 | 0.50 | 0.49 | 0.40 | 0.02 | 0.98 | **1.00** | **1.00** | 0.86 | 0.07 | 0.04 | 0.56 |
| Sri Lanka | 0.23 | 0.47 | 0.39 | 0.44 | 0.60 | 0.39 | 0.39 | 0.38 | 0.32 | 0.02 | 0.85 | 0.61 | 0.51 | 0.66 | 0.39 | 0.77 | 0.42 |
| Taiwan | 0.31 | 0.42 | 0.35 | 0.39 | 0.55 | 0.55 | 0.56 | 0.54 | 0.47 | 0.04 | 0.74 | 0.51 | 0.43 | 0.55 | 0.12 | **1.00** | 0.64 |
| Thailand | 0.24 | 0.28 | 0.24 | 0.26 | 0.46 | 0.53 | 0.52 | 0.52 | 0.44 | 0.03 | 0.78 | 0.43 | 0.38 | 0.47 | 0.22 | 0.11 | 0.50 |
| Turkey | 0.41 | 0.63 | 0.41 | 0.52 | 0.65 | 0.55 | 0.60 | 0.56 | 0.48 | 0.11 | 0.72 | 0.56 | 0.41 | 0.68 | 0.20 | 0.01 | 0.69 |
| Venezuela | 0.95 | 0.79 | 0.96 | 0.87 | 0.95 | 0.98 | 0.94 | 0.93 | 0.84 | 0.03 | 0.82 | 0.74 | 0.81 | 0.67 | **1.00** | 0.20 | **1.00** |

**Table 6 – DEA efficiency scores for benchmarks**

The efficiency scores are calculated using a VRS input-oriented DEA model. The input variables are correlation, beta, and idiosyncratic risk for each of the four respective benchmarks, i.e., MSCI Emerging Market Index, MSCI World ex US Index, Standard and Poor's 500 Index and MSCI World Index. Beta and idiosyncratic risk are calculated using all four benchmarks. The output variable(s) are either the arithmetic average monthly excess return, or performance variables. The performance variables are the arithmetic average monthly excess return, the geometric average excess return, the longest consecutively positive monthly excess return and positive to total is the proportion of positive excess returns to the total number of returns.

| | **Average return** | | | | **Average return with performance variables** | | | |
|---|---|---|---|---|---|---|---|---|
| | Emerging Market Index | World ex U.S. Index | S&P 500 Index | World Index | Emerging Market Index | World ex U.S. Index | S&P 500 Index | World Index |
| Argentina | 0.62 | 0.61 | 0.57 | 0.58 | 0.87 | 0.85 | 0.77 | 0.80 |
| Brazil | 0.71 | 0.75 | 0.72 | 0.69 | 0.87 | 0.82 | 0.80 | 0.79 |
| Chile | 0.90 | 0.99 | 0.87 | 0.86 | **1.00** | **1.00** | **1.00** | **1.00** |
| China | 0.32 | 0.35 | 0.31 | 0.32 | 0.84 | 0.92 | 0.74 | 0.81 |
| Colombia | **1.00** | **1.00** | **1.00** | **1.00** | **1.00** | **1.00** | **1.00** | **1.00** |
| Czech Republic | **1.00** | **1.00** | **1.00** | **1.00** | **1.00** | **1.00** | **1.00** | **1.00** |
| Hungary | 0.96 | 0.97 | 0.96 | 0.97 | 0.97 | 0.97 | 0.98 | 0.99 |
| India | 0.77 | 0.77 | 0.77 | 0.78 | 0.91 | 0.90 | 0.91 | 0.93 |
| Indonesia | 0.34 | 0.32 | 0.30 | 0.31 | 0.69 | 0.64 | 0.59 | 0.61 |
| Israel | **1.00** | 0.99 | **1.00** | **1.00** | **1.00** | **1.00** | **1.00** | **1.00** |
| Korea | 0.59 | 0.51 | 0.53 | 0.52 | 0.67 | 0.59 | 0.60 | 0.59 |
| Malaysia | 0.43 | 0.45 | 0.42 | 0.43 | 0.73 | 0.79 | 0.73 | 0.74 |
| Mexico | 0.93 | **1.00** | 0.94 | 0.91 | **1.00** | **1.00** | **1.00** | **1.00** |
| Peru | 0.89 | 0.93 | 0.89 | 0.89 | 0.94 | 0.98 | 0.95 | 0.94 |
| Philippines | 0.22 | 0.23 | 0.22 | 0.23 | 0.63 | 0.67 | 0.62 | 0.65 |
| Poland | 0.71 | 0.69 | 0.70 | 0.69 | 0.72 | 0.75 | 0.75 | 0.74 |
| Russia | 0.66 | 0.69 | 0.57 | 0.62 | 0.69 | 0.70 | 0.57 | 0.63 |
| South Africa | 0.90 | 0.93 | 0.87 | 0.83 | **1.00** | 0.99 | **1.00** | 0.96 |
| Sri Lanka | 0.68 | 0.65 | **1.00** | 0.93 | 0.98 | 0.93 | **1.00** | **1.00** |
| Taiwan | 0.49 | 0.54 | 0.50 | 0.50 | 0.72 | 0.82 | 0.74 | 0.75 |
| Thailand | 0.24 | 0.23 | 0.22 | 0.22 | 0.85 | 0.81 | 0.73 | 0.76 |
| Turkey | 0.71 | 0.58 | 0.56 | 0.57 | 0.78 | 0.60 | 0.56 | 0.57 |
| Venezuela | 0.69 | 0.53 | 0.48 | 0.50 | 0.85 | 0.66 | 0.57 | 0.62 |

**Table 7 – DEA efficiency scores for total and downside risk variables**

The efficiency scores are calculated using a VRS input-oriented DEA model. The input variables are total risk with a short-fall measure. The three shortfall measures are: SEMI-DevZero, the semi-deviation of excess returns less than zero (negative returns); SEMI-DevMean, the semi-deviation of excess returns less than the average return, and VAR 95%, the monthly excess return Value-at-risk below the 5th percentile. The output variable(s) are either the arithmetic average monthly excess return, or performance variables. The performance variables are the arithmetic average monthly excess return, the geometric average excess return, the longest consecutively positive monthly excess return and positive to total is the proportion of positive excess returns to the total number of returns.

| | **Average return** | | | **Average return and performance variables** | | |
|---|---|---|---|---|---|---|
| | σj2 with SEMI-DevZero | σj2 with DOWN | σj2 with VAR 95% | σj2 with SEMI-DevZero | σj2 with DOWN | σj2 with VAR 95% |
| Argentina | 0.53 | 0.55 | 0.41 | 0.67 | 0.66 | 0.52 |
| Brazil | 0.58 | 0.59 | 0.46 | 0.65 | 0.64 | 0.62 |
| Chile | 0.93 | 0.93 | 0.93 | **1.00** | **1.00** | **1.00** |
| China | 0.32 | 0.34 | 0.26 | 0.69 | 0.68 | 0.60 |
| Colombia | 0.91 | 0.90 | 0.68 | 0.91 | 0.90 | 0.72 |
| Czech Republic | **1.00** | **1.00** | 0.92 | **1.00** | **1.00** | 0.96 |
| Hungary | 0.91 | 0.91 | 0.75 | 0.91 | 0.91 | 0.79 |
| India | 0.81 | 0.85 | **1.00** | 0.90 | 0.91 | **1.00** |
| Indonesia | 0.26 | 0.27 | 0.18 | 0.46 | 0.47 | 0.30 |
| Israel | **1.00** | **1.00** | **1.00** | **1.00** | **1.00** | **1.00** |
| Korea | 0.55 | 0.58 | 0.33 | 0.60 | 0.61 | 0.34 |
| Malaysia | 0.43 | 0.45 | 0.34 | 0.68 | 0.70 | 0.51 |
| Mexico | 0.77 | 0.77 | 0.80 | 0.84 | 0.82 | 0.91 |
| Peru | 0.90 | 0.92 | **1.00** | 0.93 | 0.95 | **1.00** |
| Philippines | 0.23 | 0.25 | 0.18 | 0.62 | 0.64 | 0.44 |
| Poland | 0.68 | 0.70 | 0.55 | 0.72 | 0.72 | 0.56 |
| Russia | 0.49 | 0.50 | 0.25 | 0.49 | 0.50 | 0.25 |
| South Africa | 0.79 | 0.79 | 0.90 | 0.88 | 0.88 | **1.00** |
| Sri Lanka | 0.55 | 0.57 | 0.40 | 0.69 | 0.71 | 0.47 |
| Taiwan | 0.52 | 0.56 | 0.45 | 0.77 | 0.80 | 0.62 |
| Thailand | 0.21 | 0.21 | 0.14 | 0.60 | 0.59 | 0.42 |
| Turkey | 0.53 | 0.54 | 0.27 | 0.53 | 0.54 | 0.28 |
| Venezuela | 0.45 | 0.46 | 0.26 | 0.48 | 0.49 | 0.27 |

**Multiple Risk And Performance Measures**

Creating composite input and output variables offers an additional benefit over regression models that are limited by relating one single or one pre-defined combination of weighted inputs to one single output. In DEA, input and output weights do not need to be specified initially.[12]

The results in Table 6 use total risk, correlation, beta, and idiosyncratic risk, as input variables with performance as the output variable. Colombia, Israel, and the Czech Republic offer the highest efficiency from the MSCI Emerging Market Index based risk variables. When including the additional variables for performance persistence, these three markets remain efficient and two new markets become efficient: Chile and South Africa. Of the 23 markets, these 5 markets provide the best combination of risk and positive performance persistence. Using the MSCI World ex US Index as benchmark, Mexico, Colombia and the Czech Republic are efficient in performance terms. After including positive performance persistence variables, Chile and South Africa, two previously near-efficient markets in the single output variable specification, become efficient in the multiple input specifications. Comparing the results for these two benchmarks suggest Colombia, Czech Republic, Chile and South Africa all offer risk and performance persistence combinations that appeal to investors seeking exposure to both emerging markets and developed markets outside the US. Using the Standard and Poor's 500 Index as benchmark, Colombia, Israel, Sri Lanka, and the Czech Republic are efficient in the single output specification. Further considering the persistence of positive performance Chile, Mexico and South Africa become efficient. Using the MSCI World Index as benchmark for the risk variables, Colombia, Israel and the Czech Republic are efficient in average performance terms. Augmenting this multiple output specification with performance persistence, Chile and Mexico become efficient as well. Overall, the Czech Republic has provided multiple efficiencies across various benchmarks and specifications. An investor seeking exposure to these multiple investment objectives would have benefited from investing in Czech market compared to another market such as Hungary or Argentina.

An advantage of DEA is the simultaneous evaluation of multiple risk and performance variables, while regression based models are limited and can relate multiple risk variables to one performance variable. Table 7 contains several combinations of risk variables, where both total risk and other downside risk variables are inputs. Israel and the Czech Republic are efficient in total risk and semi-deviation specification of input variables relative to average return. Including the variables for positive performance persistence, Chile becomes efficient as well. Including total risk and VAR 95%, India, Israel and Peru are efficient in the average return case and South Africa and Chile are efficient in the positive performance persistence.

**CONCLUSIONS**

Data Envelopment Analysis, a non-parametric, multi-criteria linear programming method offers distinct advantages over traditional regression based performance analysis. DEA simultaneously quantifies the relationship among multiple investment risk and performance variables. It evaluates relative performance by ranking the strength of the relationships. The findings indicate that several emerging equity markets exhibit multiple efficiencies across different specifications, while other markets do not exhibit any efficiency at all. DEA can provide additional insights to the portfolio construction and selection process as well as to the evaluation of performance relative to various investment risks. DEA allows investors to pinpoint combinations that for a given level or combination input variables offer the best possible combination of outputs. For a U.S. domiciled non-taxable investor with return requirements in USD, the equity markets of Czech Republic, China, Israel and Argentina have offered untapped opportunities.

[12] Certain specifications of DEA can select the combination of output variables that offers the highest efficiency relative to input variables.

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**Appendix – Data Envelopment Analysis**

I use an input-oriented, variable-returns-to-scale specification in calculating the efficiency score of risk variables. In this specification, DEA captures the relationship between the risk variables as inputs and performance variables as outputs to yield an efficiency score. This score captures the efficiency is which the market is able to generate performance. For a general DEA model, $y_{rj}$ is the known positive output level of country *j*, r = 1,2,…,s where s is the number of outputs, $x_{rj}$ is known positive input level of country *j*, r = 1,2,…,s where s is the number of inputs, and n is total number of countries. Thus, the relative efficiency of a country "A" is

(A1)
$$Max\left\{\frac{\sum_{r=1}^{s}u_r y_{rA}}{\sum_{i=1}^{m}u_i y_{iA}}\right\}$$

subject to

(A2)
$$\frac{\sum_{r=1}^{s}u_r y_{rj}}{\sum_{i=1}^{m}u_i y_{ij}} \leq 1$$

for j=1, 2, …, n; r = 1, 2, …, s; and i= 1 ,2 …, m.

In the above model, the variables are input and output weights of $u_r$ and $v_i$, respectively. The objective function (A1) defines the ratio of weighted sum of outputs to weighted sum of inputs. Here the weights are the optimal values of the variables $u_r$ and vi to be determined. The model can be transformed into an equivalent linear programming model. This linear program determines the relative efficiency score, θ, of fund of a country A by

(A3) $Max\theta$

subject to

(A4) $\sum_{j=1}^{n} \lambda_j y_{rj} \leq y_{rA,}$ , r = 1, 2, …, s;

(A6) $\theta x_{iA} \leq \sum_{j=1}^{n} \lambda_j x_{ij}$ , i = 1, 2, …, m;

(A7) $\lambda_j \geq 0$, j=1, 2, …, n;

(A8) $\sum_{j=1}^{n} \lambda_j = 1$

The variables of the model are $\theta$ and $\lambda$ which both are non-negative. $\theta$ is the proportional reduction required in each input of the specific country fund to achieve efficiency. The model contains constraints; their function is to ensure that relative efficiency of the fund cannot exceed one. The sufficient condition for efficiency is that the optimum value of $\theta$ equals one. If that is not the case, the country is inefficient compared to the other countries in the sample. Consequently, a DEA produces relative efficiency scores and a set of $\lambda j$, j=1, 2, …, n; values for each country. The set of $\lambda j$ values defines a point on the envelopment surface. For an inefficient country, $\lambda j$ values establish a benchmark. Introducing the convexity requirement, (A8) in the linear programming model outlined in (A4-A7), distinguishes the variable return-to-scale approach.

## NOTES

**NOTES**