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Vishal Bhagia

Colleen Monica K. Chiu

Paulynne Castillo

Roberto Raymundo

Joel Q. Tanchuco

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## Policy Insights

There has been a growing interest in applying data envelopment analysis (DEA) as a non-parametric approach in portfolio optimization due to its flexibility in overcoming the limitations of the conventional mean-variance portfolio (MVP) model. Therefore, this study highlights the use of DEA as a portfolio selection tool that may encourage individuals to invest in the Philippine stock market for its ability to integrate any technical and fundamental factors. This study shows that the DEA model outperforms the MVP model in terms of risk-adjusted returns. However, the investor may need to change the model used to generate the highest returns because the investor may either hold a short-term or long-term investment. This study recommends that the investor does the following: (a) formulate short-term portfolios using the DEA model as it outperforms the MVP in the short-run and can provide for a versatile set of inputs and outputs that determine the optimal portfolio, and (b) formulate long-term portfolios using the MVP model as returns are mean-reverting in the long-run.

Written by:

Vishal Bhagia[1]
Colleen Monica K. Chiu[2]
Paulynne J. Castillo[3]
Roberto B. Raymundo[4]
Joel Q. Tanchuco[5]

[1]vishal_bhagia@dlsu.edu.ph
[2]colleen_chiu@dlsu.edu.ph
[3]paulynne.castillo@dlsu.edu.ph
[4]roberto.raymundo@dlsu.edu.ph
[5]joel.tanchuco@dlsu.edu.ph

*School of Economics, De La Salle University*

## Introduction

Investments in stocks can provide individuals with passive income. However, because stocks provide risk due to continuously changing markets, uncertain market events, and other uncontrollable factors, individuals may stray away from investing in stocks within the Philippines. Hence, this study was formed to aid investors in forming allocatively efficient portfolios that can integrate fundamental factors such as profitability ratios.

## Model Specification and Results

This study uses stock price data, return on assets (ROA), and earnings per share (EPS) of 25 blue-chip stocks that form part of the Philippine Stock Exchange Composite Index (PSEi) provided by Thomson Reuters Eikon from 2010 to 2019. The portfolios formed will consist of 10 equally-weighted stocks and have a holding period of 1 year and 10 years.

The utilization of the DEA model requires the investor to choose input factors it wants to minimize and output factors it wants to maximize to form the efficiency score of the stock. As summarized in Table 1, this study uses the variance and excess kurtosis of daily returns as inputs, and annual returns, skewness of daily returns, EPS, and ROA as outputs because an investor prefers odd moments over even moments (Essid et al., 2018).

To generate the DEA cross-efficiency portfolios, this study utilizes the maverick index given by Equation (4) to define the riskiness of a stock. It is given by the deviation of the stock's self-appraisal score, given by Equation (1), from the cross-efficiency score, given by Equation (3), which is the average of Equation (2). This approach uniquely distinguishes each individual stock from its peers—the other stocks in the sample (Doyle & Green, 1994; Essid et al., 2018).

$$
\begin{aligned}
&Max\ CCR_d = \textstyle\sum_{r=1}^{s} \mu_r y_{rd} \\
&s.t.\ \textstyle\sum_{r=1}^{s} \mu_r y_{rj} - \sum_{i=1}^{m} \omega_i x_{ij} \leq 0, j = 1, 2, \ldots n \\
&\textstyle\sum_{i=1}^{m} \omega_i x_{id} = 1 \\
&\omega_i, \mu_r \geq 0
\end{aligned} \tag{1}
$$

$$E_{dj} = \frac{\sum_{r=1}^{s} \mu_{rd}^{*} y_{rj}}{\sum_{i=1}^{m} \omega_{id}^{*} x_{ij}} \quad d, j = 1,2, \ldots, n \tag{2}$$

$$E_j = \frac{1}{n} \sum_{d=1}^{n} E_{dj} \quad d = 1,2, \ldots, n \tag{3}$$

$$M_j = \frac{CCR_j - E_j}{E_j} \tag{4}$$

where $\omega_i$ and $\mu_r$ are the set of input and output weights of for $m$ inputs and $s$ outputs while $\omega_{1d}{}^{*}, \ldots, \omega_{md}{}^{*}$ and $\mu_{1d}{}^{*}$, $\ldots, \mu_{sd}{}^{*}$ are the set of optimal weights for each stock $DMU_d$.

Equation (5) defines the optimization problem of the DEA cross-efficiency model that provides the 10 best-performing stocks according to their maverick index for the holding period.

$$
\begin{aligned}
&\min_{w_j} I_\Omega = \frac{1}{K} \textstyle\sum_{j=1}^{n} w_j M_j \\
&s.t.\ \textstyle\sum_{j=1}^{n} w_j = K = 10 \\
&w_j \in \{0,1\}\ j = 1, 2, \ldots, n
\end{aligned} \tag{5}
$$

where $I_\Omega$ is the risk degree indicator of the formed portfolio.

Upon forming the DEA portfolios, these are compared to the MVP portfolio, as defined by Equation (6).

$$
\begin{aligned}
&Min\ \sigma_\Omega^2 = Var(\Omega) = \textstyle\sum_{i=1}^{n} \sum_{j=1}^{n} w_i w_j \sigma_{ij} \\
&s.t.\ \textstyle\sum_{i=1}^{n} w_i = K = 10 \\
&w_i \in \{0,1\}\ i = 1, 2, \ldots, n
\end{aligned} \tag{6}
$$

To compare the portfolios, the modified Sharpe ratio, as defined by Equation (7), is used to assess the reward-to-variability ratio of any given portfolio where a greater value indicates better performance (Israelsen, 2005).

$$S_\Omega = \frac{R_\Omega - R_f}{\sigma_\Omega^{\frac{R_\Omega - R_f}{|R_\Omega - R_f|}}} \tag{7}$$

where $R_\Omega$ is the return of the portfolio, $R_f$ is the risk-free rate proxied by the yearly interest rates of the BSP 364-day Treasury Bills, and $\sigma_\Omega$ is the standard deviation of the portfolio.

Finally, to improve comparability with the MVP model, another iteration of the DEA cross-efficiency model is tested against the MVP model, where the inputs and outputs are given by the variance and returns.

**Table 1**
*Summary of Portfolio Performance*

| | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2010-2019 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Risk-free rate** | 0.0523 | 0.0482 | 0.0288 | 0.0176 | 0.0208 | 0.0179 | 0.0072 | 0.0198 | 0.0226 | 0.0426 | 0.0512 |
| **DEA Model (Variation 1)** | | | | | | | | | | | |
| Return | 0.0004 | -0.0001 | 0.0010 | 0.0003 | 0.0000 | 0.0011 | 0.0006 | 0.0016 | 0.0003 | 0.0031 | 0.0006 |
| Standard Deviation | 0.0093 | 0.0108 | 0.0066 | 0.0100 | 0.0091 | 0.0071 | 0.0122 | 0.0077 | 0.0103 | 0.0103 | 0.0103 |
| Modified Sharpe Ratio | -0.0005 | -0.0005 | -0.0002 | -0.0002 | -0.0002 | -0.0001 | -0.0001 | -0.0001 | -0.0002 | -0.0004 | -0.0005 |
| **MVP Model** | | | | | | | | | | | |
| Return | 0.0001 | -0.0007 | 0.0006 | 0.0004 | 0.0000 | 0.0008 | -0.0001 | 0.0198 | 0.0003 | 0.0019 | 0.0004 |
| Standard Deviation | 0.0096 | 0.0110 | 0.0074 | 0.0103 | 0.0089 | 0.0070 | 0.0115 | 0.0011 | 0.0098 | 0.0101 | 0.0094 |
| Modified Sharpe Ratio | -0.0005 | -0.0005 | -0.0002 | -0.0002 | -0.0002 | -0.0001 | -0.0001 | -0.0001 | -0.0002 | -0.0004 | -0.0005 |
| **DEA Model (Variation 2)** | | | | | | | | | | | |
| Return | 0.0003 | -0.0004 | 0.0007 | 0.0001 | -0.0003 | 0.0009 | 0.0001 | 0.0014 | 0.0002 | 0.0026 | 0.0006 |
| Standard Deviation | 0.0102 | 0.0107 | 0.0075 | 0.0087 | 0.0085 | 0.0179 | 0.072 | 0.0198 | 0.0226 | 0.0094 | 0.0111 |
| Modified Sharpe Ratio | -0.0005 | -0.0005 | -0.0002 | -0.0002 | -0.0002 | -0.0001 | -0.0001 | -0.0002 | -0.0003 | -0.0004 | -0.0006 |
| **Comparative Tests** | | | | | | | | | | | |
| Test 1 | DEA (Var. 1) | DEA (Var. 1) | DEA (Var. 1) | DEA (Var. 1) | DEA (Var. 1) | DEA (Var. 1) | DEA (Var. 1) | MVP | MVP | DEA (Var. 1) | MVP |
| Test 2 | MVP | DEA (Var. 2) | MVP | MVP | DEA (Var. 2) | MVP | MVP | MVP | MVP | DEA (Var. 2) | MVP |
| Best Model | DEA (Var. 1) | DEA (Var. 2) | DEA (Var. 1) | DEA (Var. 1) | DEA (Var. 2) | DEA (Var. 1) | DEA (Var. 1) | MVP | MVP | DEA (Var. 2) | MVP |

The results of the comparative tests for all portfolios are given in Table 1. It is observed that the DEA portfolios outperformed the MVP 8 out of 11 times during the period of 2010 to 2019. Therefore, the DEA cross-efficiency model provides investors with a more consistent portfolio selection tool that provides a superior risk-adjusted rate of return. This is mainly because it incorporates the use of both fundamental and technical analysis.

### Strategy 1: Formulate the Short-Term Portfolio Using DEA Model

The investor may hinge on the information provided by the monetary policies initiated by the Central Bank because it impacts the returns of the stocks. In fact, the sudden implementation of contractionary monetary policies during periods of fast expansion and growth of an economy leads to an immediate decrease in stock prices because an increase in interest rates leads to a lower capacity for individuals to borrow funds to invest in stocks; thus, the effects of contractionary monetary policy are more evident in the short-run (Kearney, 1996). This was reflected when the stock returns were at their lowest during 2018, and the BSP had initiated a contractionary monetary policy in 2018 to combat the high inflation in previous periods (Rivas, 2018). Therefore, when considering the possible impacts of monetary policy on the portfolio selection process of the investor, additional factors may include leverage and coverage ratios as inputs to the DEA cross-efficiency model when a contractionary monetary policy is initiated in the holding period because its effect on interest paid on outstanding debt is felt in the same period (Kearney, 1996). On the other hand, the investor may focus on profitability ratios as outputs to be maximized during periods where an expansionary monetary policy has been initiated in the prior periods because its positive effects on the finance costs of the firm are gradually observed. The investor may also include a firm's dividend-yield ratio in the outputs because stock prices are affected by the short-run demand runs.

**Strategy 2: Formulate the Long-Term Portfolio Using the MVP model**

Assuming that all available information is reflected in the stock prices in the long run, the MVP model can already sufficiently provide for a higher risk-adjusted return based on the results of the generated portfolios (Poterba & Summers, 1988). However, it should be noted that the DEA model provided higher returns at the expense of higher risk. Thus, depending on the risk appetite of the investor, the DEA model likewise remains useful in identifying superior stocks that provide higher overall returns for the portfolio. Similar to the short-term strategy, the impact of monetary policy must also be considered in the formulation of the investor's long-term strategy. The investor can hedge on the announcements of an expansionary monetary policy upon its announcement because it will lead to an increase in stock prices from an eventual and sustained decrease in interest rates in the medium- and long- run (Kearney, 1996). Furthermore, the effects of the monetary policy, in the long run, may also impact long-run dividends and capital gains. For example, if an expansionary monetary policy is implemented, the capacity for a firm to earn higher profit and release dividends will increase gradually in the long run. Finally, it is important to note that MVP assumes that the risk associated with the portfolio is measured completely by the variance of the stock returns and the covariance between the stocks in the portfolio. Thus, in the context of boom-bust cycles whereby forecast errors accumulate to sizable errors over time, the DEA model may provide a more effective portfolio selection tool by incorporating relevant factors, such as leverage and coverage ratios.

## Conclusion

The results of this study show that the DEA cross-efficiency model was more consistent in providing for superior risk-adjusted returns in the short run. The results, therefore, support this study's purpose of providing investors with optimal portfolios that are more allocatively efficient than those of the MVP approach. In the instances that the MVP model was observed to have a greater Sharpe ratio, the use of the DEA model may, nevertheless, be justified because it has the unique capacity to allow the investor to utilize any sets of inputs and outputs, regardless of the unit of measure that determine the eligibility of stock to enter the optimal portfolio. Therefore, the use of the DEA model can include the use of other factors such as fundamental factors that reflect the impact of monetary policy or short-run demand runs. In fact, if the investor intends to calibrate the DEA cross-efficiency model to differentiate the criteria to determine an efficient portfolio, the investor can simply revise the inputs and outputs of the DEA cross-efficiency model to include specific measures that are believed to affect the portfolio's optimality. Provided that the statistical tools needed to implement this methodology (i.e., R and Microsoft Excel) are readily available online, more investors will be able to hold portfolios with optimal returns.

## References

Doyle, J., & Green, R. (1994). Efficiency and cross-efficiency in DEA: Derivations, meanings and the uses. *Journal of the Operational Research Society, 45*(5). 567–578.

Essid, H., Ganouati, J., & Vigeant, S. (2018). A mean-maverick game cross-efficiency approach to portfolio selection: An application to Paris Stock Exchange. *Expert Systems with Applications, 113*, 161–185. https://doi.org/10.1016/j.eswa.2018.06.040

Israelsen, C. L. (2005). A refinement to the Sharpe ratio and information ratio. *Journal of Asset Management, 5*(6), 423-427.

Kearney, A. A. (1996). The effect of changing monetary policy regimes on stock prices. *Journal of Macroeconomics, 18*(3), 429–447. https://doi.org/10.1016/s0164-0704(96)80030-9

Poterba, J. M., & Summers, L. H. (1988). Mean reversion in stock prices. *Journal of Financial Economics, 22*(1), 27–59. https://doi.org/10.1016/0304-405x(88)90021-9

Rivas, R. (2018, November 15). *Bangko Sentral hikes interest rates for 5th time to curb inflation*. Rappler. https://www.rappler.com/business/bangko-sentral-increases-interest-rates-5th-time-2018

**CONTACT INFORMATION**

**DLSU - Angelo King Institute for Economic and Business Studies (DLSU-AKI)**
Room 223, St. La Salle Hall
2401 Taft Avenue
1004 Manila

Angelo King International Center
Corner of Arellano Avenue and Estrada Street
1004 Manila

+63-2-8524-4611 loc. 287,
+63-2-8524-5333, +63-2-85245347 (Fax)
https://www.dlsu-aki.com

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