IMPROVING PENSION FUNDS' PERFORMANCE USING DATA ENVELOPMENT ANALYSIS CONSIDERING GOVERNMENT REGULATIONS

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Abstract

Pension fund managers operate in an investment environment with strict government regulations and a unique taxation system. Also, low birth rates, together with a higher average age of the population and an increase in general life expectancy provide further motivation for investigating pension funds' performance. Adding to the study by Badrizadeh and Paradi (2020) in which a new model was presented for evaluating pension funds' performance considering the effects of invisible variables, this study introduces a new methodology based on data envelopment analysis (DEA) which evaluates the pension funds' performance by considering the importance of different variables based on an expert's judgements as well as borrowing useful information from the mutual funds' dataset. Similar variables between pension funds and mutual funds are included. The correlation between mutual fund variables is extracted and tested statistically. Then, these regressions are used to define trade-offs in the pension funds' model. When these trade-offs and expert's opinions are added, the results show that the discriminatory power of the DEA increases. Furthermore, three different target levels are defined for inefficient pension plans. This research is applied to Canadian pension funds and mutual funds but could be utilized in similar problems in industry and government.

Keywords: Data Envelopment Analysis (DEA), Performance Measurement, Pension Funds, Mutual Funds, Business-Government Interactions, Regulations

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1. INTRODUCTION

Private pension plans manage assets that are used to provide workers with retirement income. This study was carried out in a Canadian University using Canadian data sets. In Canada, as of March 31, 2014, approximately 7% of pension plans are federally regulated which cover over 639,000 employees with a total value of $171 billion. Pension plans under provincial regulation represent 18 million employees and total assets of $1.08 trillion (Office of Superintendent of Financial Institutions [OSFI], 2014). Pension fund managers operate in a different environment compared to other investment funds since they are subject to strict supervision as well as a different taxation system. In the typical North American pension plan, approximately 80% of ultimate benefit payments come from investment income versus only 20% from the original contributions (Ambachtsheer & Ezra, 1998). Therefore, the performance of pension fund managers is an important issue.

Also, low birth rates, together with a higher average age of the population and an increase in life expectancy provide further motivation for investigating private pension funds' performance. One of the key challenges facing Canada is the ageing population. In 2005, 13% of the population was older than 65. By 2031, this percentage is expected to exceed 25% (Canadian Bar Association, 2009). In light of the growing retiree population, ensuring that Canada's retirement income system is productive and efficient in enabling Canadians to achieve sufficient means in retirement, is a vital goal. Financial ratios, which have inherent limitations, have been used by governments, financial institutions, and managers to evaluate pension funds' performance for decades. However, financial ratio analysis does not consider the influence of different variables on each other simultaneously and it ignores any relationships, substitutions, or trade-offs among various performance measures. As a result, financial ratio analysis does not indicate whether the resources used to provide services are being managed efficiently. The objective of this research is to adapt operational research tools, specifically data envelopment analysis (DEA), to develop certain models which evaluate the efficiency in fund performance considering the main characteristics of this investment vehicle. From the findings, we suggest useful measures based on real data to better manage the investments in a private pension fund. To achieve this goal, this research investigates the performance of different pension plans by considering the effects of regulations on asset allocation and the managers' authority. As there are different types of pension funds, the effects of fully funded and underfunded active pension plans on DEA efficiency scores are examined from different perspectives. Then a new methodology is introduced to provide a framework in which pension plans' performance is evaluated by considering professional judgements and borrowing useful information from the mutual funds' dataset. The research evaluates the possibilities for pension fund managers to improve their performance under different rules. This research focuses on Canadian private pension funds that are regulated federally and Canadian mutual funds.

The rest of this article is structured as follows. Section 2 reviews the relevant literature. Section 3 explains the methodology that has been used to conduct empirical research on pension funds' data set. Section 4 provides the results. Section 5 analyses and discusses the results. Section 6 presents the conclusion and future perspectives.

2. LITERATURE REVIEW

The main categories for pension funds are defined benefit (DB) plans, defined contribution (DC) plans, and a combination of these two plans (Combo). In DB plans, an employee knows what to expect at retirement. In DC plans, employer and employee must contribute and the retirement is affected by how successfully contributions are invested. In Combo plans, the benefit payments are similar to DB plans but like DC plans there are contributions from time to time. The data in this article is based on the data set in Badrizadeh (2017).

According to Canadian federal regulations, all pension plans have to report their annual financial statements. Since employers for DB and Combo plans must evaluate the future benefit payments for their employees, the financial reporting for these two types of plans is different from the DC plan. Therefore, in this article, one part is focused on DB and Combo plans, and the second part is concentrated on DC plans.

One of the key challenges facing the world is an ageing and healthier population. In light of the growing retiree population, ensuring that the retirement income system is productive and enables people to achieve sufficient means in retirement is a vital goal. Governments, financial institutions, and managers use financial ratios to evaluate pension funds' performance for many years. To make this worse, typically, only profitability ratios are used. The problem is that financial ratio analysis does not consider the influence of different variables on each other simultaneously. DEA is a powerful operational research tool with specific characteristics that can calculate the efficiency score of a group of decision-making units (DMUs) by utilising multiple inputs and outputs at the same time. DEA indicates the efficient DMUs which can be the performance targets for inefficient DMUs (Charnes et al., 1978).

DEA has established itself as one of the most practical methods in finance industry DEA has established itself as one of the most practical methods in finance industry. Barrientos and Boussofiane (2005) studied the efficiency of pension fund managers in Chile by using DEA from 1982 to 1999. The results indicated that the Chilean pension fund management companies exhibited significant inefficiency. There were changes over time but no continuous trends towards efficiency improvement (Barrientos & Boussofiane, 2005). Barros and Garcia (2006) evaluated Portuguese pension funds' performance from 1994 to 2003 by using different DEA models. Three hypotheses were tested. The first hypothesis was as follows:

H1: Large pension funds management companies are more efficient than small pension funds management companies.

The results indicated that the majority of Portuguese pension funds management companies displayed relatively high managerial skills, being variable return to scale (VRS) efficient for the most part. However, there were some inefficient firms that could improve more.

The second hypothesis assumed:

H2: Private pension funds management companies are more efficient than public pension funds management companies.

The results supported this hypothesis. The third hypothesis the researchers tested was:

H3: Institutions involved in mergers and acquisitions during the period are more efficient than those that are not involved in these processes.

The results agreed with this hypothesis and small pension funds management companies which did not merge, had less efficient performance and their size acted as a restriction for them (Barros & Garcia, 2006). Barros and Garcia (2007) worked again on Portuguese pension funds' performance for the same period of time using stochastic frontier analysis (SFA). The authors concluded that some variables such as personnel fees, management fees, and benefit payments as well as the number of participants had major roles on pension funds' performance, and managerial skills had effects on improving this performance (Barros & Garcia, 2007). Garcia (2010) analyzed changes in the productivity of Portuguese pension funds management institutions from 1994 to 2007 by using DEA and the Malmquist index. Twelve (12) companies were investigated and the results indicated that increasing the governance and transparency of the pension funds management companies would increase their efficiency (Garcia, 2010). Sathye (2011) estimated the production efficiency of pension funds by DEA in Australia for the years 2005 to 2009. The results indicated that the efficiency scores of Australia's pension funds were too low. Also, the researcher carried out regression analysis on the variables and found that fund characteristics such as size and the proportion of funds invested in non-risk opportunities had a positive association while diversification and financial crises had a negative association with the efficiency of pension funds (Sathye, 2011). Galagedera and Watson (2015) assessed pension funds in Australia by using DEA for 2012. In the study, the funds were classified under four categories: industry, public sector, corporate, and retail. The results showed that retail funds were the best performers. However, each of these categories has its own specific characteristics and it might not be proper to consider all of them in one model (Galagedera & Watson, 2015). Zamuee (2015) evaluated Namibian pension funds by using the Charnes, Cooper, and Rhodes (CCR) model for the years 2010 to 2014. The results showed that the majority of Namibian pension funds were performing with low-efficiency scores and urgent management intervention was required to improve levels of efficiency (Zamuee, 2015). Paradi et al. (2018) compared pension funds and mutual funds by using DEA and the results show that after considering the effect of important variables for each type of funds the performances were increased. Badrizadeh and Paradi (2020) introduced a new mixed variable DEA for evaluating pension funds' performance and considered the effects of invisible variables for pension funds in the model. The results show that the new model prevents overestimation or underestimation of the performances and provides a more realistic estimation (Badrizadeh & Paradi, 2020). Demirtaş and Keçeci (2020) evaluated the efficiency of private pension companies for a time interval using dynamic DEA and compared it with traditional DEA. The results demonstrate that the efficiency can be improved by considering the effects of the inter-relations of the consecutive periods (Demirtaş & Keçeci, 2020). Xu et al. (2020) investigated the impact of public pension governance practices on the public-defined benefit pension fund performance by using DEA. The findings show that the public-defined benefit pension plans with a small board, appointed board trustees, and a separate investment council exhibits better performance (Xu et al., 2020). Krpan et al. (2022) assessed the sustainability of the pension system of new European Union (EU) member states using DEA. The results show how different techniques and indicators should be used to approach the concept of pension sustainability (Krpan et al., 2022). Badrizadeh and Paradi (2022) investigated the reasons for low efficiency scores in the pension funds industry. The results show that since both fully funded and underfunded pension funds should be considered in the models, very low minimum efficiency scores are often found in this industry (Badrizadeh & Paradi, 2022).

The aim of this research is to establish management parameters so that the work remains in the real world. In doing so, this article considers those variables which highlight the characteristics of pension funds when evaluating their performance. The effects of regulations, one of the main characteristics of pension funds has been included. Also, for some of the variables in pension funds, managers do not have complete control and must be treated appropriately. Moreover, certain experts' thoughts are sometimes valuable outside input. To increase the discrimination of the analysis, additional weight restrictions based on managerial perspectives can be included in the multiplier form of the DEA models (Dyson & Thanassoulis, 1988). Furthermore, in the approach taken here, pertinent and useful facts are extracted from the mutual funds' dataset and incorporated into the envelopment form of the DEA model. Extending to multiplier weight restrictions based on managerial judgements, the dual terms in the constraints of the envelopment model could be taken as production trade-offs that represent feasible simultaneous changes to the inputs and/or outputs of the technology (Podinovsky, 2004). This study focuses on Canadian private pension funds and Canadian mutual funds. The importance of retirement income to people is clear and the results of this work will be of interest to regulators and financial managers at all levels.

3. RESEARCH METHODOLOGY

Pension regulations shape the legal investment environment in which pension funds must perform. It is important to know, from the fund managers' point of view, how to effectively shape their portfolios while complying with the various regulations. In this work, we used the standard deviation of returns based on their asset allocation. On some of the variables such as benefit payments and contribution amounts, there are some government restrictions. This means that based on a pension plan's type and administration category, a governmental funding threshold is determined by regulators. In order to have a clear insight into this type of portfolio, the funding conditions (fully funded or underfunded) are considered. Hence, to indicate such funds' status categorical variables are used. Prior works in these investment vehicles using DEA were lacking as, unfortunately, they did not consider the special nature of this segment of the investment industry. They did not extend their work to include government regulations, nor their funding status, both major flaws.

Also, because of the uniqueness of regulations, funds' status (fully funded or underfunded), and contributions in pension funds compared to other investment vehicles another advantage of our work is the inclusion of managerial insights into the evaluation of the investment management process. We used an expert who had more than two decades of experience, to give weight to different variables in this model for pension funds compared to other funds and we included his insights in the pension funds' dataset. Another objective of this paper is to establish that by using some of the mutual funds' operating measures, pension funds would perform better. Based on available data, similar variables are examined for both fund types. Then, the correlations between the mutual funds' variables are extracted from the dataset. Now, the reliability of the regressions is tested statistically. If the regression is statistically significant, then it will be used as a trade-off from the mutual funds' dataset in the pension funds' model based on the trade-off approach in DEA. With this approach, pension plans run under their own rules while using facts from mutual funds. And in this way, new target levels for inefficient pension plans are defined.

Figure 1 and Table 1 provide an overview of the theoretical research objective with simple one input and two outputs (Badrizadeh, 2017).

The non-discretionary VRS (non-dis-VRS) model is used for pension funds as the base model and its frontier is shown in green. Then, the pension fund expert's perspectives are incorporated into the multiplier form of the non-dis-VRS model as the assurance region (AR) model and its frontier is named Leadership and shown in black. Finally, some trade-offs (TO) can be extracted from the mutual funds' dataset and added to the envelopment form of the AR model; this has been shown in red and the frontier is named Outstanding. The trade-off in this study is defined as the relationship between two variables from the mutual funds' dataset. Similar variables between pension funds and mutual funds' datasets are considered. The relationship between these variables is extracted from the mutual funds' dataset. Then, the reliability of the regressions is tested statistically. If the regression is statistically significant, then it will be used as a trade-off from the mutual funds' dataset in the pension funds' model. In Figure 1, we see clearly that pension plans (DMUs) A, B, C, D, and E are efficient and become targets for the inefficient units in the non-dis-VRS model. When we added expert opinions and used the AR approach to the non-dis-VRS model, only DMUs B, C, and D are efficient hence they become targets even for efficient DMUs in the non-dis-VRS model. When we introduced the trade-offs from mutual funds, the discriminatory power of the DEA model increases again and only DMUs C and D are efficient. These DMUs can be considered as targets for the originally inefficient units and the formerly efficient ones in the non-dis-VRS model and the AR model. Hence, DMUs C and D form the outstanding plans. Because DMU B is efficient in the non-dis-VRS and the AR models but inefficient for the AR with the trade-offs model. DMU B becomes a leading plan. DMUs A and E are efficient only in the non-dis-VRS model which means they are efficient plans. These give us three different target levels and improvement schemes for inefficient units. The first improvement is based on the Basic frontier to remove the DMU's pure inefficiency. The second improvement is based on the Leadership frontier while the third improvement is calculated based on results from the Outstanding frontier. On the one hand, we see that for DMU F there are three improvement opportunities. On the other hand, for DMU E there are only two improvement possibilities.

The classification of pension plans is presented in Table 1.

Figure 1. Snapshot of theoretical methodology

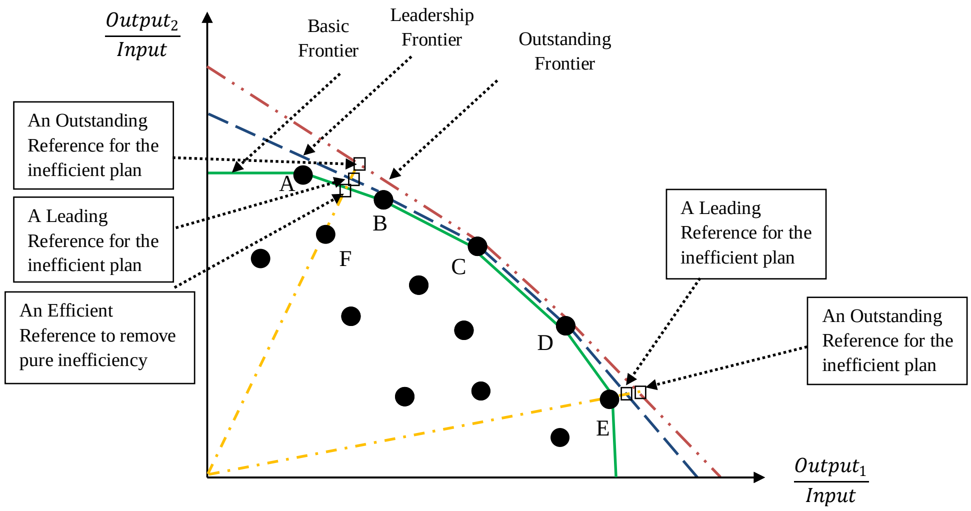

Table 1. Theoretical classification of pension plans

Pension plans (DMUs)	*Basic frontier: Non-Dis-VRS*	*Leadership frontier: Non-Dis-VRS + AR*	*Outstanding frontier: Non-Dis-VRS + AR + TO*
Outstanding plans (DMUs C & D)	Efficient	Efficient	Efficient
Leading plans (DMU B)	Efficient	Efficient	Inefficient
Efficient plans (DMUs A & E)	Efficient	Inefficient	Inefficient
Inefficient plans (one improvement scheme is needed)	Efficient	Efficient	Inefficient (its reference set is constructed based on Outstanding plans)
Inefficient plans (two improvement schemes are needed)	Efficient	Inefficient (its first reference set is constructed based on Leading plans)	Inefficient
Inefficient plans (all three improvement schemes are needed)	Inefficient (its first reference set is constructed based on Efficient plans to remove pure inefficiency)	Inefficient	Inefficient

In this study, the non-dis-VRS model, AR model, and TO are used. VRS model was proposed by Banker et al. (1984). The VRS frontier does not cross through the origin as the CCR model did and has a piecewise linear frontier that is concave in shape. Up until now, all the measures are varied at the discretion of the investment managers. However, under some circumstances, there are non-discretionary variables that cannot be fully controlled by management (Banker & Morey, 1986). The general formulation of the output-oriented non-dis-VRS model is provided below. Let us consider that we have DMUs ($i = 1, 2, \dots, n$), inputs ($j = 1, \dots, m$), and outputs ($r = 1, \dots, s$). The discretionary and non-discretionary variables are shown as D and ND:

Multiplier form of non-dis-VRS output-oriented model

$$Minimize: z = \sum_{j \in D} v_j x_{jo} - \sum_{r \in ND} u_r y_{ro} - v_o$$

Subject to:

$$\sum_{j \in D} v_j x_{ji} + \sum_{j \in ND} v_j x_{ji} - \sum_{r \in ND} u_r y_{ri} - v_o \geq 0$$

$$\sum_{r \in D} u_r y_{ro} = 1 \tag{1}$$

$$v_j \geq \varepsilon, \; j \in D$$

$$v_j \geq 0, \; j \in ND$$

$$u_r \geq \varepsilon, \; r \in D$$

$$u_r \geq 0, \; r \in ND$$

Envelopment form of non-dis-VRS output-oriented model

$$Maximize: \varphi + \varepsilon = \left(\sum_{j \in D} s_j + \sum_{r \in D} t_r \right)$$

Subject to:

$$\sum_{i=1}^{n} \lambda_i y_{ri} = t_r + \varphi y_{rio}, \; r \in D$$

$$\sum_{i=1}^{n} \lambda_i y_{ri} = t_r + y_{rio}, \; r \in ND \tag{2}$$

$$\sum_{i=1}^{n} \lambda_i x_{ji} = -s_j + x_{jio}, \; j = 1, \dots, m$$

$$\sum_{i=1}^{n} \lambda_i = 1$$

In DEA, the weights are not pre-assigned and the scores are calculated such that these weights are optimized for each DMU. However, sometimes the valuable facts about how the factors of production used by the DMUs behave or the opinions on the relative worth of inputs or outputs should be included in the models (Thanassoulis, 2001). In order to take into account an expert's opinions, the AR model is used to provide deeper insight into how pension funds work.

The AR model imposes constraints on the relative magnitude of the weights for inputs and outputs (Cooper et al., 2007). These constraints are shown mathematically as below:

$$L_{1,2} \leq \frac{v_2}{v_1} \leq U_{1,2} \quad (3)$$

where, $L_{1,2}$ and $U_{1,2}$ are lower and upper bounds, respectively.

For the trade-off method in DEA, consider $\bar{x}$ to be the $m \times n$ matrix with the columns x_i and $\bar{y}$ the $s \times n$ matrix with the columns y_i. If there are K technological values specifying production trade-offs, the trade-offs are represented in the following form (Podinovski, 2004):

$$(P_t, Q_t) \quad (4)$$

where, $t = 1, 2,..., K$. The vectors $P_t \in R^m$ and $Q_t \in R^s$ modify the inputs and outputs of production units, respectively.

For the trade-off for the envelopment VRS model, the output-oriented efficiency of DMU_o is the optimal value of θ in the following program:

$$\begin{aligned} & Maximize\ \theta \\ & \text{Subject to:} \\ & \theta y_o \leq \sum_{t=1}^{k} \pi_t Q + \bar{y}\lambda \\ & x_o \geq \sum_{t=1}^{k} \pi_t P_t + \bar{x}\lambda \\ & \sum_{i=1}^{n} \lambda_i = 1 \\ & \lambda, \pi \geq 0 \end{aligned} \quad (5)$$

The trade-off approach can be formulated for the construction of weight restrictions in the following multiplier program:

$$\begin{aligned} & Maximize\ v^T x_0 - v_o \\ & \text{Subject to:} \\ & u^T y_0 = 1 \\ & u^T \bar{y} - v^T \bar{x} \leq 0 \\ & u, v \geq 0\ and\ v_o sign\ free \end{aligned} \quad (6)$$

with the additional weight restrictions:

$$u^T Q_t - v^T P_t \leq 0, \qquad t = 1, 2, \dots, K \quad (7)$$

This dual relationship suggests that the incorporation of trade-offs (Eq. (4)) into the envelopment model (Eq. (5)) is equivalent to the incorporation of weight restrictions (Eq. (7)) in the multiplier model (Eq. (6)). The technological restrictions can be extracted from the data (Podinovski, 2004). For additional material about the trade-off method, the reader is encouraged to see (Podinovski, 2004, 2007; Alirezaee & Boloori, 2012; Podinovski & Bouzdine-Chameeva, 2013; Atici & Podinovski, 2015).

The experimental results are presented in the next section.

4. RESULTS

Among the various tests performed while developing the methods and gathering the results, the Wilcoxon rank sum test was run to statistically assure that DB plans and Combo plans belong to the same population of DMUs and can be considered in one group. Variables for DB and Combo plans are investment expenses, managerial fees, standard deviation of return, and contributions. These are the inputs, and the outputs are net investment income and benefit payments. For DC plans the inputs are investment expenses, standard deviation of return, and contributions. The output is net investment income. There are 173 pension plans which contain 90 DB plans, 37 DC plans, 46 Combo plans, and 61 open-ended mutual funds. The rule of thumb is that the number of DMUs should be at least three times the total number of inputs plus outputs which are used in the model. Another similar rule is: $n \geq max\{m \times s, 3 \times (m + s)\}$, where n is the number of DMUs, m is the number of inputs and s is the number of outputs (Cooper et al., 2011). Therefore, the number of pension plans and mutual funds is sufficient for this study.

First, the output-oriented non-dis-VRS model is used to evaluate the pension funds' performance. Then, an experienced manager provided pension fund managerial perspectives and thoughts in order to establish the actual decision-making parameters for managers as presented in Eq. (9). Moreover, the same variables between mutual funds and pension funds, such as investment expenses, the standard deviation of returns and net investment income for the year of study are examined. The regression between these variables is extracted from the mutual funds' dataset. Then the reliability of these regressions is tested and, if it is statistically significant, then we could accept it as a trade-off constraint in the model. The Durbin-Watson test is used to test the statistical correlation between the mutual funds' variables and the result of this test for net investment income and standard deviation of returns and net investment income and investment, expenses are meaningful (Field, 2009). After scaling the mutual funds' data to have a better interpretation of the regressions and restricting value between zero and one, the equivalent weight restrictions for the correlation between net investment income and standard deviation of returns as well as the correlation between net investment income and investment expenses are presented in Eq. (10).

This allowed us to have different target levels and improvement schemes which are defined as "Efficient funds" based on the first frontier for the non-dis-VRS model, "Leading funds" based on the AR model adding to the base non-dis-VRS model, and "Outstanding funds" based on the trade-off model for the inefficient pension funds. For each target level based on Efficient, Leading, and Outstanding funds, the values of the variables for the virtual references should be calculated to find the improvement schemes for inefficient units in each level. The virtual references for the non-dis-VRS model are determined by Eq. (8) below:

$$Maximize: \varphi$$

Subject to:

$$\sum_{i=1}^{n} \lambda_i y_{ri} \geq \varphi\, y_{rio}, \quad r \in D$$

$$\sum_{i=1}^{n} \lambda_i y_{ri} \geq y_{rio}, \quad r \in ND \qquad (8)$$

$$\sum_{i=1}^{n} \lambda_i x_{ji} \leq x_{jio}, \quad j = 1, \ldots, m$$

$$\lambda_i \geq 0$$

The virtual references for the AR model in this approach are calculated by Eq. (9) as below.

As represented in Eq. (10), the virtual references for the AR with mutual funds' trade-offs are evaluated as below:

$$Maximize: \varphi$$

Subject to:

$$\sum_{i=1}^{n} \lambda_i y_{ri} + \pi_9 \begin{pmatrix} 1 \\ -3 \end{pmatrix} + \pi_{10} \begin{pmatrix} -1 \\ 1 \end{pmatrix} \geq \varphi\, y_{rio}, \quad r \in D$$

$$\sum_{i=1}^{n} \lambda_i y_{ri} + \pi_9 \begin{pmatrix} 1 \\ -3 \end{pmatrix} + \pi_{10} \begin{pmatrix} -1 \\ 1 \end{pmatrix} \geq y_{rio}, \quad r \in ND \qquad (9)$$

$$\sum_{i=1}^{n} \lambda_i x_{ji} + \pi_3 \begin{pmatrix} -1 \\ 5 \\ 0 \\ 0 \end{pmatrix} + \pi_4 \begin{pmatrix} 1 \\ -1 \\ 0 \\ 0 \end{pmatrix} + \pi_5 \begin{pmatrix} -1 \\ 0 \\ 2 \\ 0 \end{pmatrix} + \pi_6 \begin{pmatrix} 1 \\ 0 \\ -1 \\ 0 \end{pmatrix} + \pi_7 \begin{pmatrix} -1 \\ 0 \\ 0 \\ 3 \end{pmatrix} + \pi_8 \begin{pmatrix} 1 \\ 0 \\ 0 \\ -1 \end{pmatrix} \leq x_{jio}$$

AR constraint 4 (terms π_9, π_{10}); AR constraint 1 (terms π_3, π_4); AR constraint 2 (terms π_5, π_6); AR constraint 3 (terms π_7, π_8)

$$\lambda_i, \pi_i \geq 0$$

$$Maximize: \varphi$$

Subject to:

$$\sum_{i=1}^{n} \lambda_i y_{ri} + \pi_1 \begin{pmatrix} 0.49 \\ 0 \end{pmatrix} + \pi_2 \begin{pmatrix} 0.30 \\ 0 \end{pmatrix} + \pi_9 \begin{pmatrix} 1 \\ -3 \end{pmatrix} + \pi_{10} \begin{pmatrix} -1 \\ 1 \end{pmatrix} \geq \varphi\, y_{rio}, \quad r \in D$$

$$\sum_{i=1}^{n} \lambda_i y_{ri} + \pi_1 \begin{pmatrix} 0.49 \\ 0 \end{pmatrix} + \pi_2 \begin{pmatrix} 0.30 \\ 0 \end{pmatrix} + \pi_9 \begin{pmatrix} 1 \\ -3 \end{pmatrix} + \pi_{10} \begin{pmatrix} -1 \\ 1 \end{pmatrix} \geq y_{rio}, \quad r \in ND \qquad (10)$$

$$\sum_{i=1}^{n} \lambda_i x_{ji} + \pi_1 \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \end{pmatrix} + \pi_2 \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} + \pi_3 \begin{pmatrix} -1 \\ 5 \\ 0 \\ 0 \end{pmatrix} + \pi_4 \begin{pmatrix} 1 \\ -1 \\ 0 \\ 0 \end{pmatrix} + \pi_5 \begin{pmatrix} -1 \\ 0 \\ 2 \\ 0 \end{pmatrix} + \pi_6 \begin{pmatrix} 1 \\ 0 \\ -1 \\ 0 \end{pmatrix} + \pi_7 \begin{pmatrix} -1 \\ 0 \\ 0 \\ 3 \end{pmatrix} + \pi_8 \begin{pmatrix} 1 \\ 0 \\ 0 \\ -1 \end{pmatrix} \leq x_{jio}$$

Trade-off constraint 1 (terms π_1); Trade-off constraint 2 (terms π_2); AR constraint 4 (terms π_9, π_{10}); AR constraint 1 (terms π_3, π_4); AR constraint 2 (terms π_5, π_6); AR constraint 3 (terms π_7, π_8)

$$\lambda_i, \pi_i \geq 0$$

5. DISCUSSION

For DB plans the results show that out of 90 plans, for the non-dis-VRS model, there are 33 efficient plans, and the average efficiency score is 0.576, then after adding AR constraints, there are 9 efficient plans, and the average efficiency score decreases to 0.303. After including trade-off constraints, there are 8 efficient plans and the average shrinkage to 0.302.

For DB and Combo plans the results display that out of 136 plans for the base non-dis-VRS model, there are 39 efficient units, and the average efficiency score is 0.508. By adding the AR constraints to the base model, there are 10 efficient units and the average drops to 0.257. Then, by adding the trade-off constraints, there are 9 efficient DMUs and the average is 0.256.

For DC plans the results demonstrate that out of 37 plans for the non-dis-VRS, there are 13 efficient plans, and the average efficiency score is 0.696. After adding AR constraints, the number of efficient plans drops to 6 and the average is 0.521. Afterwards, by inserting trade-off constraints the number of efficient plans is 6 and the average decreases to 0.517.

These results show that the discriminatory power of DEA for DB, Combo, and DC plans increases by adding the AR constraints and then the trade-off constraints from mutual funds to the non-dis-VRS model. Adding the new constraints from the mutual funds' dataset and the expert's judgement prohibits extreme weighting divergences which result, as expected, in a reduction in efficiency scores. This allowed us to have different target levels and improvement schemes based on Efficient, Leading, and Outstanding funds for the inefficient pension plans. The improvement schemes for some of the DB inefficient plans are presented here. For instance, DMU 22, a DB plan, is efficient for the non-dis-VRS model and the AR model but its efficiency score decreases to 0.92 in the AR with trade-off constraints model. This DMU needs only one improvement scheme, and its reference set is constructed based on Outstanding funds. The percentage change of the virtual output 1 based on Outstanding funds to the original output 1 is 8.2%. The percentage changes of the virtual output 2, inputs 1 to 4 based on Outstanding funds to the original variables are zero. Also, DMU 53, a DB plan, is efficient for the non-dis-VRS model, and its efficiency score decreases to 0.992 in the AR model and the AR with trade-off constraints model. DMU 53 has two improvement schemes based on Leading funds and Outstanding funds. The percentage changes of the virtual output 1 based on Leading funds and Outstanding funds to the original output are 0.73%. For DMU 65, the efficiency score for the non-dis-VRS model is 0.736, for the AR model is 0.374 and for the AR with trade-off constraints model is 0.371. Therefore, for this DMU all three improvement schemes are needed and its first reference set is built based on the Basic frontier to remove the DMU's pure inefficiency. The percentage changes of the virtual output 1 to the original output based on the Efficient, Leading, and Outstanding target levels are 36%, 169%, and 170%, respectively. Also, the percentage change of the virtual output 2 to the original output 2 for the efficient level is 99% and for the Leading and Outstanding levels, the percentage changes are close to zero. For this DMU, the virtual input 3 based on the Efficient funds' reference set should be decreased by 23%. The results can be interpreted in the same manner for the other DMUs in DB, Combo, and DC plans.

6. CONCLUSION

In this article, the differences in regulations for different pension plans are considered in the model. Also, an industry expert's judgement is applied to the pension funds' model to provide further insight into the available data. Then the same variables between mutual funds and pension funds are selected and the correlation between those variables is extracted from the mutual funds' dataset and added to the pension funds' model. After considering the expert's thoughts and facts from the mutual funds' dataset to the pension funds' DEA model, the results demonstrate that the discriminatory power of the model is increased, and the model can identify the efficient pension funds and provide different improvement schemes for inefficient funds. Therefore, based on the efficiency score for inefficient plans, instead of one big jump in improvement, there would be step-by-step target levels that makes the improvement more feasible and realistic for fund managers. One of the limitations in this area is data gathering. Data collection is a crucial task for pension funds. Extensive efforts were carried out in order to gather the data for this study. If data can be collected, for further research in this domain, the researchers are recommended to apply the model for multiple time periods in order to examine the changes in efficiency with time specifically in recent years with the COVID-19 pandemic, the recession, and the inflation after that. The comparison between pension funds and mutual funds can change with time and its effects on best performers in these types of funds would be interesting to examine.

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