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**Abstract**

The SRI funds performances remain inconclusive. Hence, more studies need to be conducted to determine if SRI funds systematically underperform or outperform conventional funds. This paper has employed dynamic mean-variance model using shortage function approach to evaluate the performance of SRI and Environmentally friendly funds. Unlike the traditional methods, this approach estimate fund performance considering both the return and risk at the same time. The empirical results show that SRI funds outperformed conventional funds in EU and U.S. In addition, the results of EU are among the top-performing categories. Environmentally friendly funds do not perform as well as SRI, but perform in manners equal or superior to conventional funds. These results show statistically significant in some cases.

*JEL classification:* G11; G15; G14; Q56

*Keywords*: Socially responsible investment fund; Environmentally friendly fund; Fund performance; Mean-variance model

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## 1. Introduction

Socially responsible investment (SRI), an investment strategy intended to pursue both financial returns and social good, is gaining worldwide attention. The modern roots of the SRI phenomenon can be traced back to the institutional climate of the 1960s. The bullish stock market of the 1990s and institutional investors' increasing interests in SRI (such as pension funds) contributed to the expansion of SRI markets in the U.S. and EU. In recent years, the SRI market has broadened to encompass not only the U.S. and EU but also Asia-Pacific markets. The SRI market is expected to grow and experience worldwide proliferation in the coming years. Recently, environmentally friendly funds (EF) have gained similar attention because of surging interests on climate and other policy requirements.

The growth of the global economy has expanded corporate social responsibility (CSR) activities into a wider area, including some of the most critical current social issues, such as curbing global warming, promoting energy efficiency and renewable energy, stopping pollution, saving endangered wildlife, and promoting diversity (e.g., equal opportunities for the physically challenged and gay and lesbian people) in the workplace. This obligation extends beyond the statutory requirements to comply with legislation, as organizations voluntarily take further steps to improve the quality of life for employees and their stakeholders.

In this investment climate, firms need to pursue balanced economic, social, and environmental performances, the so-called triple bottom line strategy. From an investor's perspective, SRI requires social, environmental, and ethical screening of companies in addition to conventional financial analyses. Typical vehicles for SRI include investment trusts by which individual and institutional investors can invest their money in SRI funds, pension funds, and community investment, in which financial institutions offer favorable (lower) rates on loans for urban development projects.

Participants of SRI are research institutions that monitor and evaluate social

performances.[1] Funds are established based on research conducted by organizations (e.g., Calvert Social Equity, Domini Social Equity, and Green Century Equity in the U.S.), individuals, and investors. These SRI movements are compelling companies to become more socially responsible. For example, investment trusts provide company information to individual and institutional investors through their lists of recommended funds, pension funds follow socially responsible investment guidelines, and banks offer favorable loan rates to socially responsible, guideline-compliant companies.

These SRI behaviors of participants can be seen not only as constraints but also as new opportunities for companies to expand their businesses. Building socially responsible companies might result in higher efficiency for a company, thus providing higher financial returns.

Empirical SRI literature can be divided into three types of studies. The first type focuses on SRI market indices, which compare the performance of SRI indices such as the Dow Jones Sustainability Index (DJSI), the FTSE4Good Index, and the Morningstar Socially Responsible Investment Index (MS-SRI) with the performances of stock market indices such as the Standard & Poor's 500 (S&P500), the FTSE100, and the Tokyo Stock Price Index (Managi et al., 2010). The second type of literature is based on an event study, which examines whether an environmentally troubled company suffers from lower market valuation following news of such an event (Gunther and Laguna, 2010). The last type of study focuses on mutual fund performances, comparing individual SRI mutual funds and conventional funds by analyzing their financial returns and Sharpe Ratio and/or alpha (Renneboog et al., 2008a).

Our study belongs to the last group and we provide a robust comparison of mutual fund performances, employing a nonparametric estimation method called “dynamic mean-variance model for evaluating mutual funds” that can simultaneously address fund returns and risks. In addition, considering the recent interest to firm’s actions to the environmental problems such as

[1]Examples of such institutions in the U.S. are the Investor Responsibility Research Center (IRRC), KLD Research and Analytics Inc. (KLD), and Interfaith Center on Corporate Responsibility (ICCR).

climate change, we analyze the EF. This study analyzes the performance of socially responsible investments and environmentally friendly funds in the U.S., EU, and Japan using data over 2000 and 2009. SRI and EF funds were compared to conventional funds. We apply a shortage function approach developed by Briec and Kerstens (2009).

We contribute to the literature on SRI in three ways which are not considered in previous studies: 1) this methodology does not require a benchmark selection, avoiding the evaluation bias induced by an inappropriate benchmark, 2) we manage the tradeoff between fund returns and fund risk, 3) we define each fund's projection on the efficient production frontier to not only locate ill-performing funds but also to determine the degree and causes of their inefficiencies. We examine the reaction of SRI fund performances to the recent financial shock by dividing our sample period into two samples: the long period of 2000 to 2009 and the short period of 2006 to 2009.

The paper has the following structure. In section 2, we review the literature on SRI fund performances. In section 3, we describe the dynamic mean-variance model. In section 4, we provide data for the funds category and the results of our model. Finally, we conclude the paper in section 5.

## 2. Background

The literature on SRI expanded following the rapid growth of the SRI market (see Renneboog et al., 2008a, for an overview of the literature). Many previous studies focused on SRI fund performance in individual countries (mainly the U.S. and the U.K.). Summary of previous studies is provided in Table 1. The table provides list of papers to understand how SRI performance is better than benchmark group. Most of the findings are categorized into group of mixed finding, meaning SRI can be better or inferior, and group of no statistical results are provided, meaning both of the SRI and reference group are statistically similar.

(Table 1 about here)

Hamilton et al. (1993), Goldreyer and Diltz (1999), Statman (2000), and Bello (2005) showed that the performance of SRI funds in the U.S. was not significantly different from that of conventional funds. The U.K. evidence suggested that the difference in performances between SRI funds and conventional funds was not significantly different from zero (Luther et al., 1992; Mallin et al., 1995; Gregory et al., 1997). A similar conclusion was drawn by Bauer et al. (2006) and Bauer et al. (2007) for Australian and Canadian SRI funds.

Multi-country studies have been undertaken by Schroder (2004) for U.S., German, and Swiss SRI funds and by Kreander et al. (2005) for SRI funds in several European countries (Belgium, Germany, the Netherlands, Norway, Sweden, Switzerland, and the U.K.). These empirical studies have suggested that differences between SRI funds and conventional funds have been small and statistically insignificant for each country.

A few previous studies have shown that the difference in returns between SRI funds and conventional funds was statistically significant. These studies include Bauer et al. (2005), Kempf and Osthoff (2007), Renneborg et al. (2008b), and Galema et al. (2008). Bauer et al. (2005) showed that in the early 1990s, U.S. SRI funds underperformed and U.K. SRI funds outperformed conventional funds by applying a multi-factor Carhart (1997) model.[2] Kempf and Osthoff (2007) report positive and significant risk-adjusted returns during 1992–2004 for a US portfolio based on a sample of SRI stocks from the KLD database. Their portfolio is based on a long-short strategy by investing in the 10% best SRI stocks within each industry and shorting the 10% worst SRI stocks within each industry. Renneborg et al. (2008b) showed that the risk-adjusted returns of SRI funds in Japan, France, and Sweden underperformed their domestic benchmarks. Galema et al. (2008) found that SRI investments outperformed their conventional counterparts in the U.S. using the

[2] We are not claiming our model prefers to multi-factor model nor comparing, instead, we intend to compare the relative position of SRI and EF to other categories.

book-to-market ratio.

Thus, the results on SRI fund performances remain inconclusive. Hence, more studies need to be conducted to determine if SRI funds systematically underperform or outperform conventional funds given the recent changes in the financial market after the Leman shock. Furthermore, it is difficult to draw definitive conclusions on SRI fund performance because some of the performance evaluation methods are deficient because we need to control time dimension and risk adjusted measure.

In addition to the SRI fund analysis, this study also provides an analysis of EF funds. This study contributes to the literature by considering a dynamic mean-variance analysis to evaluate SRI and EF funds. We employed the method developed by Briec and Kerstens (2009) that considers financial aspects in a data envelopment analysis (DEA) to evaluate SRI and EF funds. Evaluating mutual fund performances using the Briec and Kerstens (2009) model has three advantages. First, it does not require a benchmark selection, avoiding the evaluation bias induced by an inappropriate benchmark. Second, we were able to control the tradeoff between fund returns and fund risk (e.g., volatility of fund returns). Third, it can define each fund's "projection" on the efficient production frontier to not only locate ill-performing (inefficient) funds but also to determine the degree and causes of their inefficiencies. These aspects have not been considered in previous studies.

## 3. Model

DEA is a well-established methodology to evaluate the relative efficiencies of a set of comparable entities using mathematical programming models. These entities, called decision-making units (DMUs), perform the same function by transforming multiple inputs into multiple outputs. A main advantage of DEA is that it does not require any prior assumptions about the underlying functional relationships between inputs and outputs (Seiford and Thrall, 1990). Therefore, this approach is a nonparametric approach. In addition, DEA is a data-driven frontier analysis technique that floats a piecewise linear surface to rest on top of empirical observations

(Cooper et al., 2004). DEA has grown rapidly into an exciting field with various applications (see Førsund and Sarafoglou, 2005 and Førsund et al., 2009).

### 3-1. Application of DEA to Fund Performances

Several studies have applied DEA models for mutual fund performance evaluations. Basso and Funari (2005) scrutinized the performances of mutual funds, extending the work of Basso and Funari (2001) by including financial performance indices as output measures. Gregoriou and McCarthy (2005) assessed the performance of Fund of Funds (FoFs) and their respective returns-to-scale (RTS) properties with an input-oriented model and a cross-efficiency model. Gregoriou (2006) presented a case study on the portfolio performance of Commodity Trading Advisors. Gregoriou and Chen (2006) extended previous studies by applying fixed and variable input-oriented benchmark models. Daraio and Simar (2006) developed a conditional performance index based on free disposal hull technology and compared their findings with other non-parametric and financial performance indices. Gregoriou and Zhu (2007) concentrated on performance and RTS identification when assessing the performance of FoFs using an input-oriented DEA model. Chang (2004) employed minimum convex input requirement set (MCIRS) approach to evaluate the performance of US mutual funds. Chen and Lin (2006) and Lin and Chen (2008) evaluated mutual fund performance by introducing VaR and CVaR into existing DEA indices for considering the asymmetry and fat tails of the fund return distribution and this research indicate that VaR, CVaR and its combination with traditional risk measures are very helpful for better evaluation of overall performance of mutual funds. Hsu and Lin (2007) used excess returns as output and transaction costs and standard deviation as inputs in the CCR model to evaluate stock mutual fund performance in Taiwan. Their results indicate that the estimated outcome and the Sharpe index have a significantly positive correlation but show a different outcome in the continuous analysis for fund performance. Chen et al. (2011) evaluated mutual fund performance employing system BCC model and compare the results between the BCC model and system BCC model. This result showed that there is a significant

difference between system BCC model and BCC model and it is proper to adopt the system BCC model to evaluate fund performance.

In this paper, we also applied DEA extended by Briec and Kerstens (2009) to evaluate SRI and EF funds performance, and this model usefully complement above studies employing DEA methods

（Figure 1 about here）

In this study, we described the frontier by replacing inputs with a fund's risk and expected return, resulting in a Markowitz-type of efficient frontier. Here the DMUs were funds. All funds on the frontier were considered efficient, and all funds inside the frontier were considered inefficient. By comparing two snapshot frontiers over two periods, the funds were considered to have improved efficiency if one fund was observed to operate closer to the frontier than in the previous study. Unlike previous studies analyzing SRI fund performances, we considered the trade-off between risks and returns. In other words, we considered the lowest risk that needed to be taken to attain a given level of return or the highest return attainable given a certain level of risk.

There are several ways of measuring efficiency. The most frequently used methodology is the input-oriented or output-oriented approach, which is built on the concept of minimizing the cost of input or maximizing production. Luenberger (1992) presented the more flexible approach of the shortage function, which allows joint efficiency in input and output to be achieved. In our study, we employed Luenberger's type of flexible function.

This study then used the dynamic mean-variance model by Briec and Kerstens (2009), which extends Luenberger's function adapted for finance considering time-dimension. Their model elaborated the approach of Morey and Morey (1999), which assessed mutual fund performances using a quadratic programming approach in a variable return to scale. This approach differs from other DEA-based approaches because it considers the diversification effect on portfolio risk. Morey

and Morey also investigated the ‘‘true maximum improvement potential’’ by including slack to identify overall improvement potential.

### 3-3. Dynamic Mean-Variance Analysis

Assuming that there are *n* securities in the investable universe from which portfolio securities are chosen, the expected return of each fund and covariance among each fund at time *t* are given as follows:

$$E\left[R_i^t\right], i \in \{1,...,n\} \text{ and } \Omega_{i,j}^t = Cov\left[R_i^t, R_j^t\right], i, j \in \{1,...,n\}.$$

In addition, we defined a weight on each fund by $x^t = (x_1^t,...,x_n^t)$. We assumed that all weights on the funds included in a portfolio add up to 1, that is: $\left(\sum_{i=1...n} x_i^t = 1\right)$.

We supposed that a fund *x* 's return could be expressed as $R^t(x^t) = \sum_{i=1...n} x^t R_i^t$, allowing us to define the expected return and variance of the fund as follows:

$$\boldsymbol{E}\left[\boldsymbol{R}^t(\boldsymbol{x}^t)\right] = \boldsymbol{\mu}^t(\boldsymbol{x}^t) = \sum_{i=1...n} x_i^t \boldsymbol{E}\left[\boldsymbol{R}_i^t\right] \tag{1}$$

$$Var\left[R^t(x^t)\right] = E\left[(R^t(x^t) - \mu^t(x^t))^2\right] = \sum_{i,j} x_i^t x_j^t Cov\left[R_i^t, R_j^t\right] \tag{2}$$

A Markowitz efficient frontier can be represented by

$$DR^t = \left\{(V,E) \in \mathbb{R}_+^2 : \exists x^t \quad \text{with } V \geq Var\left[R^t(x^t)\right], E \leq E\left[R^t(x^t)\right]\right\}. \tag{3}$$

The shortage function measured a fund's distance from the frontier（Luenberger, 1995). A vector at time *t* was given by $g^t = (-g_V^t, g_E^t) \in (-\mathbb{R}_+) \times \mathbb{R}_+$, where the actual fund was indicated by $x^t$. The vector $g^t$ was used to measure the efficiency score of $S_{g^t}^t$, and $S_{g^t}^t$ of a portfolio $x^t$ is indicated by the following equation:

$$S_{g^t}^t(x^t) = \sup\left\{\delta; \left(Var\left[R^t(x^t)\right] - \delta g_V^t, E\left[R^t(x^t)\right] + \delta g_E^t \in DR^t\right)\right\}. \tag{4}$$

In reality, more recent observations (performances) should better reflect current fund status and should carry more weight on recent times. Therefore, our model considered this point and applied decaying weights over time. The elapsed time for a portfolio was addressed in the following manner: $\mathcal{X} = \left(x^t\right)_{t=1}^T = \underset{t=1}{\overset{T}{\times}} x^t$. The time-dependent directional vector was represented as

$\mathscr{G} = \left(g^t\right)_{t=1}^{T} = \underset{t=1}{\overset{T}{\times}} g^t$.

We used the notation of $\Delta = \left(\delta^1, ..., \delta^T\right)$ and the convention $\Delta\mathscr{G} = \left(\delta_T g^1, ..., \delta_T g^T\right)$ later in this section. Returns and risks were represented as

$$\mathscr{T}\left(\mathscr{X}\right) = \underset{t=1}{\overset{T}{\times}} \left(Var\left[\boldsymbol{R}^t\left(x^t\right)\right], E\left[\boldsymbol{R}^t\left(x^t\right)\right]\right). \tag{5}$$

In a dynamic setting, DR can be written as $\mathscr{DR} = \underset{t=1}{\overset{T}{\times}} DR^t$. Given a discount factor $\xi$ ($0 < \xi < 1$), the discounted shortage function was expressed as follows.

$$\mathscr{S}_{\mathscr{G}}^{\xi}\left(\mathscr{X}\right) = \max_{\Delta \in \mathbb{R}_+^T} \left\{ \frac{1}{T} \sum_{t=1}^{T} \xi^{T-t} \delta_t : \mathscr{T}\left(\mathscr{X}\right) + \Delta\mathscr{G} \in \mathscr{DR} \right\}. \tag{6}$$

The above formulation allowed us to represent a shortage function of a portfolio $\mathscr{X}$ as

$$\mathscr{S}_{\mathscr{G}}^{\xi}\left(\mathscr{X}\right) = \frac{1}{T} \sum_{t=1}^{T} \xi^{T-t} S_{g^t}^t\left(x^t\right) \tag{7}$$

In this paper, we employed $\mathscr{S}_{\mathscr{G}}^{\xi}\left(\mathscr{X}\right)$ as a performance measure, following Briec and Kerstens (2009).[3] When the fund retained $\mathscr{S}_{\mathscr{G}}^{\xi}\left(\mathscr{X}\right) = 0$, it was considered to be efficient and must be on the Markowitz efficient frontier. When the fund retained $\mathscr{S}_{\mathscr{G}}^{\xi}\left(\mathscr{X}\right) > 0$, it was off the frontier. The score $\mathscr{S}_{\mathscr{G}}^{\xi}\left(\mathscr{X}\right) > 0$ indicated a percentage reduction in risk (and percentage increase in return) in line with other efficient funds.[4] In other words, when $\mathscr{S}_{\mathscr{G}}^{\xi}\left(\mathscr{X}\right)$ moves closer to zero, the fund is more efficient. Hereafter, we called $\mathscr{S}_{\mathscr{G}}^{\xi}\left(\mathscr{X}\right)$ the improvement score (IS).

## 4. Empirical Application

### 4-1. Data and Analysis

We obtained weekly funds data from Bloomberg. Our study examined two data sets from the nine-year period from 2000 to 2009 (called the long-term period) and the three-year period from 2006 to 2009 (called the short-term period). We apply then short-term period because more

[3] Detailed explanation of $\mathscr{DR}$ (a subset of $\mathscr{S}_{\mathscr{G}}^{\xi}\left(\mathscr{X}\right)$) can be found in Briec and Kerstens (2009).

[4] $\mathscr{S}_{\mathscr{G}}^{\xi}\left(\mathscr{X}\right)$ = 0.05 indicates that a portfolio will be on the Markowitz efficient frontier by increasing return and decreasing risk by 5%.

fund data are available, which does not exist before 2006. The risk and return of a given fund were calculated based on weekly returns. Data for each region of the U.S., EU, and Japan are provided in Tables 2 to 4 in different categories.[5] We used a discount rate of 0.95 (or an interest rate of 5%) for our calculations. Note that the data were adjusted for dividends, transaction costs, management fees, and other expenses in each firm's stock and were therefore ideal for our analyses.

(Tables 2 to 4 about here)

Most previous studies on SRI fund performance have not supported the hypothesis that risk-adjusted SRI fund returns differ significantly from the stock market index and/or conventional funds. Therefore, to investigate whether SRI and EF fund performances are higher or lower than conventional funds, we first examined SRI and EF fund performances using the Capital Asset Pricing Model (CAPM) for basic comparison. Next, we examined SRI and EF fund performances in the EU, U.S., and Japan using our model.

**4-2. Single Index Performance Evaluation**

The most widely employed benchmark model in mutual fund performance studies is a single-index model based on the capital asset pricing theory of Sharpe (1964), Lintner (1965), and Mossin (1966). In a one-factor world, a fund's outperformance is measured as the difference between the return on the mutual fund and a consensus return that is derived from an estimated pricing model (i.e., the CAPM). It is implicitly assumed that a single-index model is sufficiently capable of explaining mutual fund return variation. The index is usually represented by a broad market index:

$$r_t - r_{f,t} = \alpha_1 + \beta_{MKT}(r_t^m - r_{f,t}) + \varepsilon_t, \tag{8}$$

where $r_t$ is the return on the mutual fund in week $t$, $r_{f,t}$ is the return on a local risk-free deposit

[5] We examined Jensen's (1968) alpha in Tables 2, 3, and 4.

(i.e., the one-week treasury bill rate or the inter-bank interest rate), $r_t^m$ is the return of a local equity market index, $\alpha_1$ is Jensen's alpha as introduced by Jensen (1968), $\beta_{MKT}$ is the factor loading on the market portfolio, and $\varepsilon_t$ is the idiosyncratic return. The estimation results of the Jensen's alpha, based on the CAPM, are presented in Table 5. We used the Financial Times Stock Exchange 100 Index (FTSE100) in the EU, S&P 500 Stock Index (S&P500) in the U.S., and Nikkei 225 in Japan as a local equity market index as reference groups. The numbers with (+) or (-) signs in Table 5 indicate the number of SRI and EF funds that are significantly better (or worse) than the market index in each country.

（Table 5 about here）

A striking finding was that there are no SRI or EF funds shown (-) in Table 5. That is, when the results are in all statistically significantly difference, SRI and EF funds performed better than conventional funds. Specifically, 6 out of 80 EU SRI funds and 7 out of 29 U.S. SRI funds were statistically better during the period from 2000 to 2009. From 2006 to 2009, two EU SRI funds and four U.S. SRI funds were better in the stock market index. For the EF fund category, 1 out of 27 SRI funds was better in both the 2000-2009 and 2006-2009 periods. In Japan, there were no statistically significant SRI or EF funds.

These results are surprising because there was a possibility that SRI and EF fund performances were relatively lower than other funds in the EU and U.S. This may be because we analyzed more recent data; thus, the market structure may have changed. However, the numbers of significant funds were small, so we analyzed the dynamic mean-variance method to see how the results could be changed using more recent analytical techniques.

**4-3. Results of non-parametric analysis**

In this section, we provide the results of our model. Tables 6 to 8 show the average IS under different categories for the period from 2000 to 2009 (long term) and 2006 to 2009 (short term) in the EU, U.S., and Japan.[6] We used two different models by changing the orientations of inputs and outputs. The first model considered both return and risk orientations at the same time ("*Dual model*"), and the second model considered only the return orientation ("*Return model"*). It should be noted *Dual model* is preferred to *Return model* because *Dual model* consider both of input and output changes. We apply *Return model* to identify the source of differences between SRI/EF and reference provided in *Dual model*. However, in case return performance is preferred to risk measure, the *Return model* needs to be used to for evaluation.

(Tables 6 to 8 about here)

*a*). *Case in EU*

We examined the results for the EU. Estimated by the *Dual model*, the IS of SRI funds averaged 22% (long term) and 29% (short term). The *Return model* indicated an average of 23% (long term) and 32% (short term). These four scores were always lower than those of all funds on average (see Total in Table 6). Especially in the case of the long-term analysis, the IS of SRI funds indicated the lowest improvement potential out of 11 categories based on the *Dual model* (i.e., performance of SRI is the best among 11 categories). For the short-term analysis, the IS indicated the third-lowest score next to Equity, Growth & Income under the *Dual model* and the second-lowest score next to Growth & Income under the *Return model*. Therefore, we found that the SRI fund was one of the best-performing categories in the EU. In addition, when comparing long-term and short-term results, SRI funds were ranked lower in the short term than in the long term. This result suggests that SRI fund relative performances to reference group might decline after 2006 compared to periods over 2000-2006.

[6] As explained above, IS indicates the potential for improvement compared to the most efficient funds, i.e., the fund on the Markowitz efficient frontier. Lower the IS, the funds are better in current structure. Therefore, funds with lower IS are the best funds in the periods analyzed.

Estimated by the *Dual model*, the IS of EF funds had an average of 28% (long term) and 34% (short term). In the case of the *Return model*, the IS of EF funds had an average of 32% (long term) and 35% (short term). These scores were fairly close to that of the Total in Table 6 (i.e., average performance), with the exception of the *Return model* in the short term. In the case of the *Dual model,* the IS of EF funds had the sixth-lowest score out of 11 categories in both long- and short-term analyses. In the *Return model*, EF funds had the eighth and third lowest IS in the long term and short term, respectively. Therefore, we show that the EF fund performance rank was close to average in the EU.

Comparing the all categories' average results of the *Dual* and *Return model*s in the EU, the IS of the *Return model* was, on average, 0.04 higher than that of the *Dual model* for each time period analyzed (see Total category). These results imply that the distance from frontier to funds, which takes into account only the return dimension is longer than the distance considering both the risk and return dimensions at the same time. Hence, mutual funds in the EU are more efficient, on average, when they are evaluated not only for increasing return but also for reducing risk.

The difference between *Dual* and *Return model*s for all categories in the EU ranged from 0.01 to 0.06 points in the long term and 0.01 to 0.07 points in the short term. In the case of SRI funds, the difference between the *Return* and *Dual model*s was 0.01 and 0.03 points in the long term and short term, respectively, and it was the lowest and the fifth lowest among 11 categories. In the case of EF funds, it was 0.04 points and 0.01 points in the long term and short term, respectively. In the long term, it was the same as the total, and in the short term, it was the lowest among 11 categories. Therefore, the differences between considering only return and both return and risk had little influence on SRI and EF fund performances. As discussed above, SRI fund performances were relatively better than other categories in both the short and long terms. We found that SRI fund performances in the EU under both orientations were relatively better than other categories.

*b*). *Case in U.S.*

Table 7 shows the results for the U.S., estimated. The IS of SRI funds averaged 12% (long term) and 10% (short term) using the *Dual model*. From the results of the *Return model*, the IS of SRI funds was 13% (long term) and 10% (short term). Especially in the case of the long-term analysis, the IS of SRI funds was the sixth lowest out of 13 categories in both models. The short-term result showed that the IS of SRI funds was the second and third lowest score under the *Dual* and *Return model*s, respectively. In addition, these four scores were lower than those of all funds on average. Therefore, similar to the results for the EU, SRI fund performances in the U.S. were relatively higher than those of other categories.

Estimated under the *Dual model*, the average IS of EF funds was 9% (long term) and 22% (short term). In the *Return model*, the IS of EF funds was 9% (long term) and 21% (short term). In addition, EF funds showed the third-lowest IS out of 13 categories in both models in the long term. On the other hand, EF funds had the tenth and twelfth lowest scores under the *Dual model* and the *Return model*, respectively, for the short term. Comparing the long-term and short-term results, there was strong evidence that EF fund relative performance decreased in later years. This result might suggest that the influence of the 2007 financial crisis, caused by a liquidity problem in the U.S. banking system, was larger for EF fund performances than for other categories. We suggest that the financial crisis did not enable investors to evaluate the advantages of EF funds, which mainly invest in companies developing environmentally friendly products or environmentally efficient technologies because the development of such a product or technology cannot easily lead to short-term benefits for these companies.

Comparing the results of the *Dual model* and the *Return model* in the U.S., the IS of the *Return model* averaged 0.03 points higher than that of the *Dual model* in the long term and averaged 0.01 points lower than that of the *Dual model* in the short term. Hence, in the short term, the difference in distance from the frontier for the risk dimension and return dimension to funds in the U.S. was small on average. The difference between these models for all categories in the U.S.

ranged from zero (Equity, Geography, Market, and EF) to 0.09 points (Aggressive growth) in the long term and from −0.11 (Aggressive growth) to 0.11 (Contrarian) in the short term. Seven out of 13 categories in the *Return model* were lower than the *Dual model*, and five out of 13 categories were zero. Only Contrarian funds on the *Return model* were higher than the *Dual model* on average. These results show that the distance from frontier to funds considering the return dimension only is shorter than the distance considering both return and risk dimensions in the short term.

The IS of SRI funds under the *Return model* was 0.01 points higher than the *Dual model* in the long term. There was no difference in the short term. In the case of EF funds, the difference between the *Return* and *Dual models* was zero in the long term, and the *Return model* was 0.01 points lower than the *Dual model* in the short term. The difference of each model for both SRI and EF funds was lower than the Total category in the long term.

*c*). *Case in Japan*

We examined the results for Japan, listed in Table 8. In the *Dual model*, the IS of EF funds was 25% and 28% for the long term and short term, respectively. In the *Return model*, the IS of EF funds averaged 36% and 34% in the long and short term, respectively. Except for the short term in the *Return model*, EF funds had the lowest score for all categories. Therefore, the performances of EF funds were relatively higher than those of other categories.

Comparing the results of IS for the *Dual model* and the *Return model* in Japan, the *Return model* in the Total was 0.12 and 0.10 points larger than the *Dual model* in the long and short term, respectively. The difference between the *Return* and *Dual models* in Japan varied considerably across categories, from a maximum of 0.26 points (Blue Chip) to a minimum of zero (Emerging) in the long term and from a maximum of 0.19 points (Sector) to a minimum of 0.06 points (EF) in the short term. Therefore, these results show that the performances of many funds improved if they were evaluated not only by the return dimension but also by the risk dimension. These differences were much larger than those of the EU and U.S. for each term and were caused

by the shape of the frontier in Japan. The line of the frontier was sharply increased in each term. Therefore, the distance from frontier to funds when considering both the risk and return dimensions was shorter on average than when comparing only the return dimension in the results for the EU and U.S.

The IS of EF funds in the *Return model* was 0.11 and 0.06 points higher than that of the *Dual model* in the long term and short term, respectively. The differences in EF funds were lower than that of the Total. The performance of EF funds in Japan was relatively better than that of other categories. Hence, combined with those results, EF fund performances were better on average when estimated by either return or risk only.

### 4-4. Robustness tests

This sub-section provides the results of robustness tests. We compared the distributions using the two-sample Kolmogorov-Smirnov test (KS test).[7] This is a test of the null hypothesis that two independent samples have been drawn from the same population. Table 9 and 10 show the *p* values in tests for the average improvement scores between SRI and EF funds and conventional funds.

(Tables 9 and 10 about here)

The IS in both the long and short term showed that SRI and EF funds in the EU were significantly different from conventional funds in each model. Therefore, combined with Table 5, SRI fund performances statistically outperformed conventional funds, and EF fund performances were similar to all fund performances on average. In the case of U.S. funds, the IS of SRI funds was significantly different from that of conventional funds, based on the *Dual model* from 2000 to

[7] The Kolmogorov-Smirnov test is sensitive to differences in location and skewness as well as central tendency. It is a non-parametric test that is based on the observed deviations between the cumulative distribution functions for the two samples (Siegel and Castellan, 1988).

2009 and from 2006 to 2009. The IS of EF in the U.S., based on the *Return model* from 2000 to 2009 and the *Dual model* from 2006 to 2009, was significantly different from conventional funds. In Japan, the IS of EF funds was significantly different from conventional funds, based on the *Dual model*. From these results, we conclude that SRI funds statistically outperformed conventional funds on average in the EU and U.S. This finding is especially true for the EU, where SRI funds constituted one of the top-performing categories.

## 5. Conclusion

In this paper, socially responsible investments and environmentally friendly funds in the U.S., EU, and Japan were empirically analyzed using a nonparametric methodology. SRI and EF funds were compared to conventional funds. We apply dynamic mean-variance model using shortage function of Briec and Kerstens (2009). Previous studies such as Basso and Funari (2001, 2005), Bauer et al (2005), Daraio and Simar (2006), Gregoriou and Chen (2006), and Lin and Chen (2008) analyze mutual fund performance but there remain several problems to be solved. Comparing to previous studies, therefore, we contribute to the literature on the financial evaluation of funds in three ways: 1) our analysis considered performances in the risk-adjusted sense, 2) we measured efficiency using only applicable funds, not benchmarks, 3) it can define each fund's "projection" on the efficient production frontier to not only locate ill-performing (inefficient) funds but also to determine the degree and causes of their inefficiencies, and 4) application in SRI and EF funds.

In summary, we found that SRI funds outperformed conventional funds in EU and U.S. in contrast to the result of CAPM. Many previous studies have shown that SRI fund performances were statistically insignificant or that SRI funds underperformed conventional funds. Similarly, environmentally friendly funds have not performed as well as SRI, but have performed in manners equal or superior to conventional funds. We showed that the use of a dynamic mean-variance model for evaluating mutual funds might usefully complement the traditional method. Our methodology was able to provide clear implications for risk-adjustment, return-orientation, and

time dimensions.

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Table 1. Summary of Previous Studies

| Statistical differences of SRI and reference group | Author(s) | Country | Period | Findings for SRI funds | |
|---|---|---|---|---|---|
| Mixed findings | Schroder (2004) | U.S., Germany, Switzerland | 1990-2002 | The monthly alphas of ethical funds range from -2.06% to 0.87%. 38 out of the 46 funds are negative. | |
| | Bauer et al. (2005) | Germany, U.K., and U.S. | 1990-2001 | The average monthly alphas of SRI funds are 0.29%, 0.09% and 0.05% for Germany, UK domestic and US domestic funds, respectively. | |
| | | | | U.S. | The U.S. domestic ethical funds significantly underperform conventional domestic funds |
| | | | | U.K. | The U.K. ethical funds significantly outperform conventional funds. |
| | | | | German | The difference in average alphas between SRI and non-SRI funds is insignificant. |
| | Rennenboog et al. (2008b) | World-wide | 1991-2003 | SRI funds in many European and Asia-Pacific countries strongly underperform domestic benchmark portfolios. | |
| | | | | The risk-adjusted returns of the average SRI funds are less than -5% per annum. | |
| | Galema et al. (2008) | U.S | 1992-2006 | SRI impacts on stock returns by lowering the book-to-market ratio and not by generating positive alphas. | |
| Not significant | Hamilton et al.(1993) | U.S. | 1981-1985 | The average monthly alpha of SRI funds is -0.06% and non-SRI funds is -0.14% | |
| | | | 1986-1990 | The average monthly alpha of SRI funds is -0.28% and non-SRI funds is -0.04% | |
| | Mallin et al. (1995) | U.K. | 1986-1993 | The monthly alphas of ethical funds range from -0.28 to 1.21%. 22 out of the 29 funds are positive. | |

| | | | | |
|---|---|---|---|---|
| Not significant | Gregory et al.(1997) | U.K. | 1986-1994 | The monthly alphas of ethical funds range from -0.71 to 0.24%. |
| | Goldreyer et al.(1999) | U.S. | 1981-1997 | The average Jensen's alpha of 29 SRI equity funds is -0.49% and non-SRI equity funds is 2.78% |
| | Statman (2000) | U.S. | 1990-1998 | The average monthly alpha of SRI funds is -0.42% and non-SRI funds is -0.62%. |
| | Kreander et al. (2005) | 6 European countries. | 1996-1998 | The average Jensen's alphas of SRI and non-SRI funds are 0.20% and 0.12% per month, respectively |
| | Bauer et al. (2006) | Australia | 1992-2003 | Domestic ethical funds underperform domestic conventional funds by 1.56% per year. International ethical funds outperform their conventional peers by 3.31% per year. |
| | Bauer et al. (2007) | Canada | 1994-2002 | The difference in average alphas is insignificant between the SRI funds and non-SRI funds (0.21% vs. 0.18% per month) |
| Almost positive | Kempf and Osthoff (2007) | U.S | 1992-2004 | Their best-in-class screening approach has positive and significant risk-adjusted returns during 1992–2004 for a US portfolio based on a sample of SRI stocks from the KLD database. |

Note: "Positive" implies results of SRI are statistically better than those of reference group.
"Negative" implies results of SRI are statistically inferior to those of reference group.

Table 2. Average weekly returns of funds under different categories in EU

| **Long term (2000-2009)** | **Mean Weekly Returns (percent)** | **Standard deviation of Returns** | **α** | **Number of Funds** |
|---|---|---|---|---|
| Aggressive growth | -0.09 | 0.14 | -0.04 | 32 |
| Blue Chip | -0.09 | 0.08 | -0.06 | 105 |
| Contrarian | — | — | — | — |
| Emerging | 0.1 | 0.07 | 0.16 | 105 |
| Equity | 0 | 0.08 | 0.03 | 10 |
| Geography | — | — | — | — |
| Growth | -0.04 | 0.09 | -0.01 | 268 |
| Growth & Income | -0.04 | 0.08 | 0 | 188 |
| Index | -0.07 | 0.09 | -0.02 | 180 |
| Market | — | — | — | — |
| Sector | -0.08 | 0.15 | -0.03 | 267 |
| Value | -0.02 | 0.12 | 0.02 | 75 |
| EF | -0.08 | 0.07 | -0.04 | 27 |
| SRI | -0.05 | 0.07 | -0.02 | 80 |
| Total | -0.04 | 0.11 | 0 | 1337 |
| **Short term (2006-2009)** | **Mean Weekly Returns (percent)** | **Standard deviation of Returns** | **α** | **Number of Funds** |
| Aggressive growth | 0.06 | 0.09 | 0.11 | 32 |
| Blue Chip | 0.01 | 0.08 | 0.06 | 105 |
| Contrarian | — | — | — | — |
| Emerging | 0.23 | 0.09 | 0.31 | 105 |
| Equity | 0.06 | 0.06 | 0.09 | 10 |
| Geography | — | — | — | — |
| Growth | 0.05 | 0.08 | 0.09 | 268 |
| Growth & Income | 0.05 | 0.07 | 0.09 | 188 |
| Index | 0.04 | 0.07 | 0.09 | 180 |
| Market | — | — | — | — |
| Sector | 0.02 | 0.09 | 0.07 | 267 |
| Value | 0.02 | 0.08 | 0.07 | 75 |
| EF | 0.04 | 0.07 | 0.09 | 27 |
| SRI | 0.04 | 0.06 | 0.07 | 80 |
| Total | 0.05 | 0.1 | 0.1 | 1337 |

Table 3. Weekly Returns of funds under different categories in U.S.

| **Long term (2000-2009)** | **Mean Weekly Returns (percent)** | **Standard deviation of Returns** | **α** | **Number of Funds** |
|---|---|---|---|---|
| Aggressive growth | -0.1 | 0.08 | -0.04 | 25 |
| Blue Chip | -0.04 | 0.05 | 0 | 18 |
| Contrarian | -0.02 | 0.11 | 0.1 | 11 |
| Emerging | 0.16 | 0.05 | 0.22 | 49 |
| Equity | 0.03 | 0.06 | 0.06 | 44 |
| Geography | 0.03 | 0.08 | 0.07 | 294 |
| Growth | -0.05 | 0.09 | 0 | 412 |
| Growth & Income | -0.02 | 0.06 | 0.02 | 59 |
| Index | -0.03 | 0.05 | 0.01 | 44 |
| Market | 0.06 | 0.03 | 0.07 | 8 |
| Sector | 0.05 | 0.16 | 0.11 | 160 |
| Value | — | — | — | — |
| EF | -0.01 | 0.03 | 0.05 | 3 |
| SRI | -0.01 | 0.08 | 0.02 | 29 |
| Total | 0 | 0.11 | 0.05 | 1156 |
| **Short term (2006-2009)** | **Mean Weekly Returns (percent)** | **Standard deviation of Returns** | **α** | **Number of Funds** |
| Aggressive growth | 0.03 | 0.06 | 0.08 | 25 |
| Blue Chip | 0.02 | 0.04 | 0.06 | 18 |
| Contrarian | -0.09 | 0.15 | 0.01 | 11 |
| Emerging | 0.27 | 0.05 | 0.35 | 49 |
| Equity | 0.01 | 0.04 | 0.06 | 44 |
| Geography | 0.1 | 0.09 | 0.16 | 294 |
| Growth | 0.02 | 0.06 | 0.07 | 412 |
| Growth & Income | 0 | 0.04 | 0.05 | 59 |
| Index | 0.01 | 0.04 | 0.07 | 44 |
| Market | 0.03 | 0.06 | 0.04 | 8 |
| Sector | 0.05 | 0.13 | 0.13 | 160 |
| Value | — | — | — | — |
| EF | -0.03 | 0.03 | 0.03 | 3 |
| SRI | 0.02 | 0.05 | 0.05 | 29 |
| Total | 0.05 | 0.1 | 0.11 | 1156 |

Table 4. Weekly Returns of funds under different categories in Japan

| **Long term (2000-2009)** | **Mean Weekly Returns (percent)** | **Standard deviation of Returns** | **α** | **Number of Funds** |
|---|---|---|---|---|
| Aggressive Growth | -0.1 | 0.06 | -0.03 | 19 |
| Blue Chip | -0.14 | 0.06 | -0.07 | 8 |
| Contrarian | — | — | — | — |
| Emerging | 0.09 | 0.05 | 0.16 | 3 |
| Equity | -0.04 | 0.16 | 0.02 | 3 |
| Geography | -0.05 | 0.11 | 0.03 | 61 |
| Growth | -0.09 | 0.07 | -0.02 | 116 |
| Growth & Income | -0.11 | 0.08 | -0.04 | 6 |
| Index | -0.1 | 0.02 | -0.02 | 29 |
| Market | — | — | — | — |
| Sector | -0.09 | 0.14 | -0.01 | 67 |
| Value | -0.05 | 0.09 | 0.01 | 36 |
| EF | -0.07 | 0.07 | -0.01 | 3 |
| SRI | — | — | — | — |
| Total | -0.08 | 0.1 | -0.01 | 351 |
| **Short term (2006-2009)** | **Mean Weekly Returns (percent)** | **Standard deviation of Returns** | **α** | **Number of Funds** |
| Aggressive Growth | -0.13 | 0.07 | -0.1 | 19 |
| Blue Chip | -0.05 | 0.04 | -0.01 | 8 |
| Contrarian | — | — | — | — |
| Emerging | 0.24 | 0.07 | 0.29 | 3 |
| Equity | -0.07 | 0.06 | -0.05 | 3 |
| Geography | 0.03 | 0.13 | 0.07 | 61 |
| Growth | -0.07 | 0.09 | -0.04 | 116 |
| Growth & Income | -0.05 | 0.07 | -0.02 | 6 |
| Index | -0.04 | 0.02 | 0 | 29 |
| Market | — | — | — | — |
| Sector | -0.01 | 0.09 | 0.03 | 67 |
| Value | -0.04 | 0.09 | -0.01 | 36 |
| EF | 0 | 0.09 | 0.03 | 3 |
| SRI | — | — | — | — |
| Total | -0.04 | 0.1 | 0 | 351 |

Table 5. The number of funds that have statistically significant level

| **Long term(2000-2009)** | | SRI | | Environmentally Friendly | |
|---|---|---|---|---|---|
| | | + | — | + | — |
| EU | * | 0 | 0 | 0 | 0 |
| | ** | 3 | 0 | 0 | 0 |
| | *** | 3 | 0 | 1 | 0 |
| | Insignificant | 74 | | 26 | |
| U.S. | * | 0 | 0 | 0 | 0 |
| | ** | 2 | 0 | 0 | 0 |
| | *** | 5 | 0 | 0 | 0 |
| | Insignificant | 22 | | 3 | |
| Japan | * | - | - | 0 | 0 |
| | ** | - | - | 0 | 0 |
| | *** | - | - | 0 | 0 |
| | Insignificant | - | | 3 | |
| **Short term (2006-2009)** | | SRI | | Environmentally Friendly | |
| | | + | — | + | — |
| EU | * | 1 | 0 | 0 | 0 |
| | ** | 1 | 0 | 1 | 0 |
| | *** | 0 | 0 | 0 | 0 |
| | Insignificant | 78 | | 26 | |
| U.S. | * | 0 | 0 | 0 | 0 |
| | ** | 3 | 0 | 0 | 0 |
| | *** | 1 | 0 | 0 | 0 |
| | Insignificant | 25 | | 3 | |
| Japan | * | - | - | 0 | 0 |
| | ** | - | - | 0 | 0 |
| | *** | - | - | 0 | 0 |
| | Insignificant | - | | 3 | |

Note *, **, and *** stand for the significance levels at the 10%, 5%, and 1% thresholds, respectively.

Table 6. SRI Funds vs. Conventional Funds (EU)

| Category | Long term (2000-2009) | | Short term (2006-2009) | | Number of funds |
|---|---|---|---|---|---|
| | Dual | Return | Dual | Return | |
| Aggressive Growth | 0.32 | 0.33 | 0.38 | 0.45 | 32 |
| Blue Chip | 0.29 | 0.31 | 0.33 | 0.35 | 105 |
| Contrarian | — | — | — | — | — |
| Emerging | 0.27 | 0.29 | 0.31 | 0.38 | 105 |
| Equity | 0.26 | 0.28 | 0.21 | 0.43 | 10 |
| Geography | — | — | — | — | — |
| Growth | 0.24 | 0.27 | 0.37 | 0.40 | 268 |
| Growth & Income | 0.27 | 0.31 | 0.27 | 0.29 | 188 |
| Index | 0.27 | 0.29 | 0.34 | 0.36 | 180 |
| Market | — | — | — | — | — |
| Sector | 0.34 | 0.42 | 0.43 | 0.49 | 267 |
| Value | 0.30 | 0.36 | 0.41 | 0.45 | 75 |
| EF | 0.28 | 0.32 | 0.34 | 0.35 | 27 |
| SRI | 0.22 | 0.23 | 0.29 | 0.32 | 80 |
| Total | 0.28 | 0.32 | 0.35 | 0.39 | 1337 |

Table 7. SRI Funds vs. Conventional Funds (U.S.)

| Category | Long term (2000-2009) | | Short term (2006-2009) | | Number of funds |
|---|---|---|---|---|---|
| | Dual | Return | Dual | Return | |
| Aggressive Growth | 0.27 | 0.36 | 0.26 | 0.15 | 25 |
| Blue Chip | 0.21 | 0.25 | 0.23 | 0.19 | 18 |
| Contrarian | 0.20 | 0.23 | 0.24 | 0.33 | 11 |
| Emerging | 0.10 | 0.11 | 0.14 | 0.08 | 49 |
| Equity | 0.08 | 0.08 | 0.10 | 0.10 | 44 |
| Geography | 0.20 | 0.20 | 0.17 | 0.16 | 294 |
| Growth | 0.17 | 0.20 | 0.12 | 0.12 | 412 |
| Growth & Income | 0.11 | 0.12 | 0.10 | 0.10 | 59 |
| Index | 0.15 | 0.18 | 0.13 | 0.12 | 44 |
| Market | 0.05 | 0.05 | 0.06 | 0.06 | 8 |
| Sector | 0.13 | 0.17 | 0.17 | 0.13 | 160 |
| Value | — | — | — | — | — |
| EF | 0.09 | 0.09 | 0.22 | 0.21 | 3 |
| SRI | 0.12 | 0.13 | 0.10 | 0.10 | 29 |
| Total | 0.16 | 0.19 | 0.14 | 0.13 | 1156 |

Table 8. SRI Funds vs. Conventional Funds (Japan)

| Category | Long term (2000-2009) | | Short term (2006-2009) | | Number of funds |
|---|---|---|---|---|---|
| | Dual | Return | Dual | Return | |
| Aggressive Growth | 0.59 | 0.80 | 0.63 | 0.75 | 19 |
| Blue Chip | 0.42 | 0.68 | 0.45 | 0.54 | 8 |
| Contrarian | — | — | — | — | — |
| Emerging | 0.61 | 0.61 | 0.26 | 0.39 | 3 |
| Equity | 0.46 | 0.52 | 0.55 | 0.65 | 3 |
| Geography | 0.31 | 0.45 | 0.38 | 0.48 | 61 |
| Growth | 0.49 | 0.70 | 0.49 | 0.57 | 116 |
| Growth & Income | 0.52 | 0.59 | 0.56 | 0.63 | 6 |
| Index | 0.52 | 0.58 | 0.58 | 0.64 | 29 |
| Market | — | — | — | — | — |
| Sector | 0.60 | 0.61 | 0.45 | 0.64 | 67 |
| Value | 0.42 | 0.46 | 0.53 | 0.61 | 36 |
| EF | 0.25 | 0.36 | 0.28 | 0.34 | 3 |
| SRI | — | — | — | — | — |
| Total | 0.48 | 0.60 | 0.48 | 0.58 | 351 |

Table 9. Robustness test: P values of two sample Kolmogorov-Smirnov test

| SRI vs. Conventional fund | | | | |
|---|---|---|---|---|
| | Long term (2000-2009) | | Short term (2006-2009) | |
| | Dual | Return | Dual | Return |
| EU | 0.00 | 0.00 | 0.02 | 0.00 |
| U.S. | 0.04 | 0.39 | 0.04 | 0.30 |
| ENV vs. Conventional fund | | | | |
| | Long term (2000-2009) | | Short term (2006-2009) | |
| | Dual | Return | Dual | Return |
| EU | 0.00 | 0.00 | 0.00 | 0.00 |
| U.S. | 0.17 | 0.01 | 0.04 | 0.91 |
| Japan | 0.08 | 0.71 | 0.06 | 0.52 |

Table 10. The average of Improvement score and P-values of two sample Kolmogorov-Smirnov test

| | | | The average of Improvement score | | P-value | The average of Improvement score | | P-value |
|---|---|---|---|---|---|---|---|---|
| | | | SRI | Conventional | | EF | Conventional | |
| **EU** | Long term | **Dual** | 0.22 | 0.28 | 0.00 | 0.28 | 0.28 | 0.00 |
| | | **Return** | 0.23 | 0.33 | 0.00 | 0.32 | 0.32 | 0.00 |
| | Short term | **Dual** | 0.29 | 0.35 | 0.02 | 0.34 | 0.35 | 0.00 |
| | | **Return** | 0.32 | 0.40 | 0.00 | 0.35 | 0.39 | 0.00 |
| **U.S.** | Long term | **Dual** | 0.12 | 0.16 | 0.04 | 0.09 | 0.16 | 0.17 |
| | | **Return** | 0.13 | 0.19 | 0.39 | 0.09 | 0.19 | 0.01 |
| | Short term | **Dual** | 0.10 | 0.15 | 0.04 | 0.22 | 0.14 | 0.04 |
| | | **Return** | 0.10 | 0.13 | 0.30 | 0.21 | 0.13 | 0.91 |
| **Japan** | Long term | **Dual** | − | − | − | 0.25 | 0.48 | 0.08 |
| | | **Return** | − | − | − | 0.36 | 0.60 | 0.71 |
| | Short term | **Dual** | − | − | − | 0.28 | 0.48 | 0.06 |
| | | **Return** | − | − | − | 0.34 | 0.59 | 0.52 |

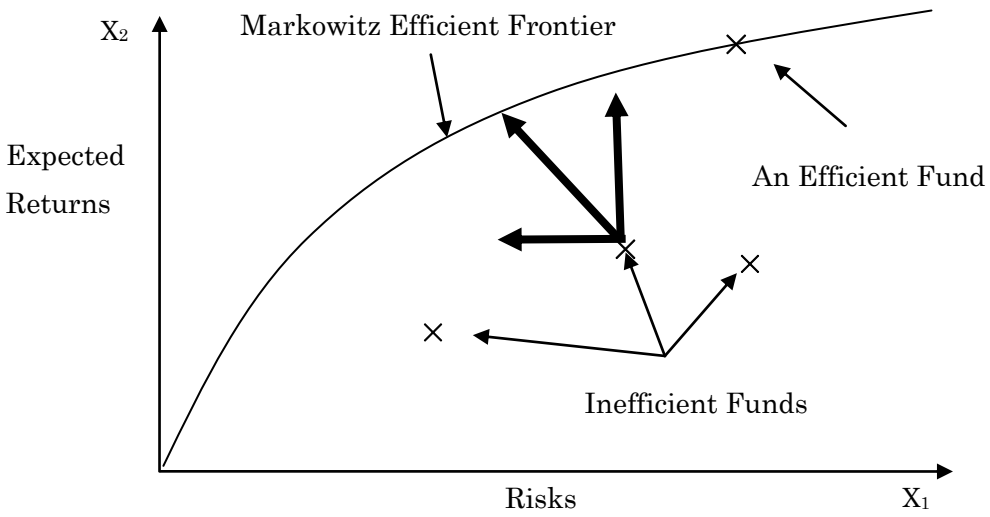


Figure 1. An Application of DEA to Measure Fund Performances