Does relative efficiency matter? An analysis of uncertainty

Abstract

In this paper, we examine whether relative efficiency provides useful information for investment decisions. We find that efficient firms have lower levels of stock price volatility compared to inefficient firms. The results suggest that market participants consider relative efficiency when making investment decisions. This finding is consistent with investors speculating in inefficient firms due to potential stock return opportunities that increase the uncertainty levels of inefficient firms. Next, we test whether higher levels of investment and disinvestment in inefficient firms are due to potential investment opportunities. We find a positive relation between stock price volatility and market returns. Moreover, we find a negative relation between stock returns and relative efficiency. These findings show that inefficient firms provide high-risk, high-return potential investment opportunities; and efficient firms can be considered low-risk, low return investment opportunities.

Keywords: relative efficiency, stock price volatility, market risk, news sensitivity

I. Introduction

Whether or not investors use a firm's relative efficiency to make investment decisions is of interest to market participants. Market factors dictate that investments in low–risk firms provide investors with low-returns; on the other hand, high-risk investments provide investors with high-returns (Sharpe, 1964; Black, 1972). In this paper, we empirically test whether relative efficiency provides useful information for investors when making investment and disinvestment decisions. Specifically, we examine whether levels of uncertainty, proxied by stock price volatility is significantly associated with relative efficiency. Moreover, we test the relationship between relative efficiency and stock returns.

If relative efficiency provides useful information about levels of uncertainty, market participants have the potential to utilize relative efficiency as an additional tool for making rational investment/disinvestment decisions. Recent studies report that relative efficiency calculated using frontier analysis (DEA) is informative in predicting firm performance (e.g. Baik et al., 2013); the results demonstrate that firms with high efficiency are likely to achieve higher financial performance compared to inefficient peers. Moreover, there is evidence suggesting that efficient firms have higher market value compared to inefficient firms (Frijns et al., 2012), suggesting there is a greater opportunity for gains in investment in firms with lower market value. Given that investors require additional compensation for bearing additional risk, whether market participants prefer to speculate in relatively inefficient firms compared to stable efficient firms is an empirical question left unanswered. Furthermore, whether or not there is a relationship between stock returns and stock price volatility/relative efficiency is another empirical question left unanswered.

To answer our first empirical question, whether investors are more likely to speculate in firms that are relatively inefficient compared to their peers, we test the relation between stock price volatility and relative efficiency. Volatility is a statistical measure of the dispersion of returns for a given security, and refers to the amount of uncertainty about the size of changes in a security's value. Stock price volatility is governed by the supply and demand of stocks, which is determined by market sentiment. Higher volatility means that a security's value is spread over a large range of values meaning that the price of the security can change dramatically over a short time period in either direction (potentially high risk-high return). Low volatility means that a security's value does not fluctuate dramatically (potentially low risk-low return). We believe investors are profit maximizing and are likely to invest in inefficient firms in periods of good news and disinvest in periods of bad news. On the other hand, it is likely that investors are less sensitive to bad news in efficient firms because they are less likely to disinvest because investors value the stable economic returns of efficient firms. Investors should also be less sensitive in periods of good news, because efficient firms are likely to have a higher value, suggesting low return opportunities. Therefore, if market participants are able to capture and utilize relative efficiency, the stock price volatility of inefficient firms is expected to be higher compared to more efficient firms.

Next, we formally establish whether inefficient (efficient) firms can be considered as high (low) risk high (low) return investments. Inefficient firms can be considered as being investments with inherently higher risk-return compared to efficient firms and thus could be considered low-risk low return stocks. Efficient firms are likely to have inherently less risk compared to inefficient firms because they are able to maximize output from given inputs through robust operational decision making processes. A positive relation between stock returns and market uncertainty proxied by market volatility would suggest that stock returns increase with the level of investment/disinvestment in the firm stocks. Next, we test the relationship between stock returns and relative efficiency to establish whether market participants can use relative efficiency for investment decisions. A negative relation between stock returns and relative efficiency would suggest that investors are likely to acquire higher stock returns from firms with lower levels of relative efficiency.

Using a sample of Korean listed firms over a period spanning 2000 to 2015, we find that relative efficiency has a negative association with stock price volatility, suggesting the uncertainty levels of relatively efficient firms is lower compared to relatively inefficient firms. Next, we perform tests to find that inefficient firms are high risk, high return investment compared with efficient firms. We find a positive relation between stock returns and stock price volatility and a negative relation between relative efficiency and stock returns. The results demonstrate that stock price volatility is potentially due to the high (low) risk high (low) reward status of inefficient (efficient) firms. Our results suggest that relative efficiency helps market participants to make rational investment/disinvestment decisions.

Second, we compare the most efficient group (top25%) with the most inefficient group (bottom 25%), and find that the negative relationship between stock price volatility and relative efficiency is larger for top 25% group, suggesting the most efficient group has the lowest level of uncertainty whereas the most inefficient group has the highest level of uncertainty. Then, we compare firms based on credit risk and market size. Overall, our results suggest that the negative relation between efficiency and volatility is larger for firms based on 'risk status', suggesting that the risk status of a group has the potential to provide incremental evidence for investment decisions. For further robustness, we conduct sensitivity analysis based on 1) efficiency and 2) volatility decile rank. Finally, we repeat our analyses using 1) Fama and MacBeth (1973) yearly regression analysis, 2) relative stock price volatility, 3) relative efficiency calculated from stochastic frontier analysis. Overall, we find consistent results.

Our study makes several contributions to existing literature. First, we provide evidence that relative firm efficiency has an incremental influence on stock price volatility. Thus, we demonstrate that market uncertainty is dependent on market sentiment based on a firm's relative efficiency levels. Second, we provide evidence that relative efficiency is important for investment /disinvestment decisions. We find a positive relation between stock returns and stock volatility; and a negative relationship between relative efficiency and stock returns. The results suggests that firm with high (low) relative efficiency has low (high) volatility, and can be considered a (high) returns on investment. We conjecture risk averse investors would prefer the stocks of firms with high relative efficiency and hold these stocks for a long period of time as those efficient firms are likely to gradually increase their value with no dramatic changes. Risk takers, however, may prefer relatively inefficient firms in periods of good news for higher stock return opportunities.

Our results overall suggest that market participants may use relative efficiency values based on financial statements when making investment and disinvestment decisions. The results are consistent with investors seeking investments in firms with lower operational efficiency compared to more efficient firms because of potentially higher premiums. We interpret that the idiosyncratic volatility might show firm-specific uncertainty beyond the CAPM, which can be related with the firms' operational efficiency. Thus, market participants are likely able to implement optimum investment strategies depending on their risky-return preferences. To the best of our knowledge, we are the very first to examine the relation between relative efficiency and stock price volatility and stock returns. Our results are likely to be of interest to investors, government legislators, policy makers and firm management who consider that relative efficiency has the potential to influence the future economic potential of market participants due to investment and disinvestment behavior.

The remainder of the paper proceeds as follows; in section II, we review relevant literature and develop our hypothesis. In section III, we explain our research design and provide details about our sample selection process. In section IV, we discuss our empirical results. In section V we provide the results of additional analysis, and section VI concludes.

II. Literature review & Hypotheses

2.1 Literature review

Based the positive linear relationship between risk and reward in Capital Asset Pricing Model (CAPM). Markowitz (1952) defines two types of risk, 1) market risk that is common to all firms within the market and 2) idiosyncratic risk that can be reduced through market diversification. In modern finance theory, the Capital Asset Pricing Model (CAPM) shows a positive linear relation between risk and return (Sharpe, 1964; Black, 1972). More recent studies expand the CAPM. Fama and French (1992, 1993) add explanatory power by developing the three factor model, expanding CAPM by adding book-to-market ratio and size to control for risk. Whilst the improved three-factor model adds additional explanatory power to explain the cross sectional relation of risk and stock return, there is evidence the model is not complete (Pastor and Stambaugh, 2003; Easley et al., 2002). Given the conflicting views regarding CAPM in academic literature, we question whether relative firm efficiency can be used as a tool to improve investment strategies, and provide additional explanatory power with regards to firm level risk.

Technological advancements have increased market competition and firm efficiency. Superior (inferior) decision making leads to higher (lower) efficiency. A firm's efficiency level is determined by changes in output $(\mathrm{Sales}_t - \mathrm{Sales}_{t-1})$ divided by changes in input $(\mathrm{Costs}_t - \mathrm{Costs}_{t-1})$. The most efficient firms are able to achieve maximum output with minimum input. Firms with lower efficiency can be considered as those with inferior decision making processes. Obtaining maximum output from a given input relative to market peers is a comparative advantage because it influences growth (Majumdar et al., 1998). Efficiency can be decomposed into two components, technical efficiency (1) output maximization and allocative efficiency (2) input minimization (Farrell, 1957). Technical efficiency reflects a firm's ability to achieve the optimum level of output from a given set of physical inputs based on operational activities, understanding of their market, effective pricing strategies and the utilization of resources. Allocative efficiency reflects a firm's decision to minimize costs. Both technical and allocative efficiency are functions of operational performance based on the decisions of management; and therefore influence market performance as they both are measures of firm profitability determined by how firms utilize resources and technologies (Alam & Sickles, 1998). Therefore, there is a logical link between firm level risk and operational efficiency.

We are the first to examine the relation between relative efficiency and stock price volatility and stock returns; therefore, we borrow from efficiency and stock pricing literatures. Stock pricing literature extend the risk-return relationship established in CAPM (Fama & French, 1993; Vassalou & Xing, 2004). However, very few academic studies directly examine the relation between firm efficiency, market uncertainty and market returns. Risk and stock returns are linked as a result of effective/ineffective operational activities that are, in theory, manifested in the efficiency ratio. Efficiency's effect on stock prices is determined by maximizing output and minimizing input. Thus, the efficiency to generate cash flows directly influence stock values (Peltzman, 1977; Fama & French, 1995) because efficient firms are more profitable and face lower distress risks. Using U.S. data Nguyen and Swanson (2009) find highly efficient firms pay lower premiums compared to inefficient firms. Frijns et al. (2012) find evidence that efficient firms have higher market value compared to inefficient firms. The literature suggests that more efficient firms are able to increase their market value. However, inefficient firms pay higher compensation to investors for bearing additional risk (Demsetz, 1973; Nguyen and Swanson, 2009).

Efficient firms are able to improve their market share and increase earnings (Hay and Liu, 1997). Investors will seek investment opportunities based on short term efficiency, day-to-day operational activities and long term operational decisions that include corporate governance, size and performance, and ownership structure (Dilling–Hansen et al., 2003). Investors would obviously favor high returns from efficient firms with higher stock prices. However, they are more likely to seek investment opportunities in risker firms because firms with lower levels of risk pay lower returns and can retain earnings in their equity structure compared to less efficient riskier firms that will have to pay additional compensation to investors for bearing additional risk. We consider relative firm efficiency directly influences uncertainty (stock price volatility) because of what relative efficiency signals as a potential opportunity to investors. Moreover, we conjecture that relatively inefficient firms are required to pay higher stock returns to market participants.

2.2 Hypotheses

Firms with high relative efficiency are deemed to have developed more robust operational systems and be able to achieve larger profits compared to firms with low efficiency. Given an equal rate of return, market participants would value relatively highly efficient firms compared to inefficient firms; however, due to the negative relation between uncertainty and efficiency, more efficient firms pay lower returns to investors (see CAPM literature including Sharpe, 1964; Black, 1972). Higher risk firms offer higher returns, but also have inherently higher uncertainty. Whilst financial markets dislike uncertainty, markets are efficient and investors are news sensitive. Thus, we conjecture investors understand the benefits of the relative efficiency of a firm within a market.

Investors will seek investments opportunities in relatively inefficient firms because they are likely to have higher potential stock return opportunities. In periods of good news, investment in inefficient firms may offer a large return on investment. In periods of bad news, investment in a less efficient firm leads to divestment. Thus, we believe that investors are more likely to invest and disinvest in inefficient firms which causes market uncertainty; thus, the stock volatility of these firms is likely to be higher as a direct result of relative efficiency. Therefore, we believe relative inefficiency will increase the stock price of less efficient stocks. Based on the arguments above, we develop the following hypothesis:

Hypothesis 1: The stock price volatility of firms with high levels of relative efficiency firms is lower compared to firms with low levels of relative efficiency.

<Insert Figure 1 about here>

In our first hypothesis, we suggest that speculation in inefficient firms increases uncertainty because inefficient firms are required to pay investors for bearing additional risk. Efficiency can be considered as the operational process of generating maximum output from given resources. Efficient managers have the ability to optimize output by effectively allocating physical inputs, maximizing labour productivity, implementing effective pricing strategies, understanding their market and minimizing costs. Therefore, due to the association between risk and return established in CAPM, we hypothesize that efficient firms are likely to present investors with potential low risk-low return investment opportunities. On the other hand, inefficient firms are likely to present investors with potential high risk-high return investment opportunities. Thus, we believe that we will find a negative relation between relative efficiency and stock returns. Moreover, we expect to find a positive relation between SPV and stock return. Overall we suggest that investors may consider relative efficiency as an additional tool making investment decisions. The results would demonstrate that relative efficiency could be considered as an alternate measure of risk for market participants. Based on the arguments above, we develop the following hypothesis.

Hypothesis 2: Relatively inefficient (efficient) firms are high (low risk)-high return (low return) investments

III. Research Design

3.1 Research model

There are two methods to calculate efficiency. Absolute efficiency is a measure that uses simple accounting ratios such as return on assets (for example earnings divided by assets). In this study, we examine the relation between market risk (stock price volatility) and relative efficiency because of its analytic advantages. Relative efficiency is considered a more robust measure because the efficiency of each decision making unit (DMU) can be measured independently as a part of the entire sample. Moreover, the effectiveness of each DMU can be estimated within each industry because each DEA vector is industry specific. The advantage of relative efficiency using DEA compared to absolute efficiency is that whilst output (sales) can be considered a single measure, how it is achieved using different levels of inputs is unknown. In different industries, the amount of input required to achieve the highest output level can be considered different because the requirement of inputs such as labor are obviously less for a merchandising firm compared to a clothing manufacturer. DEA is a measure of efficiency where a different weighting is given to different inputs. However, if two firms produce the same output from a given number of inputs, both are considered efficient regardless of which inputs are used. An additional advantage of relative efficiency is that each efficiency score is ranked ordinally which has practical advantages for data interpretation compared to OLS regression. For further details about the advantages of frontier analysis, refer to Demerjian et al. (2012) and Frijns et al. (2012).

We consider each firm to be a DMU and estimate the relative efficiency of each firm against all firms listed on the Korean stock exchange and all firms that belong to the same industry independently. For this decomposition, we divide output, a firm's revenue (sales) with all relevant inputs required to generate outputs, given resources and costs. A firm's costs are different types of expenditure, incurred to generate revenue including advertising expenses, expenditure on R&D, admin expenses and the cost of goods sold. A firm's given resources are the equity a firm holds to make sales including property, plants, and equipment, operating lease, goodwill and other intangibles. In equation (1), *s* represents sales and *c* represents given resources and costs of each DMU. Because different industries have different levels of inputs to generate outputs, we add additional weightings for our output and input values denoted by *u* and *v*. We express the total quantities of the output and inputs using *x* and *y*.

Relative Efficiency

$$\frac{\sum_{i=1}^{s} u_i y_{ik}}{\sum_{j=1}^{c} v_j x_{jk}} \; k = 1, \dots, n. \quad (1)$$

$$max_u \theta = \frac{u_1 Sales}{u_1 GivenResources + u_2 Costs} \quad (2)$$

Where,

Sales (Output): Gross Sales

Given Resources	: PPE + Operating Lease + Goodwill + Other Intangibles
Costs	: Cost of goods sold + SG&A
PPE	: net property, plant, and equipment
Operating least	: net operating lease
Goodwill	: purchased goodwill

Next, we optimize our DEA values and to discover the most efficient frontier, from which we develop our ordinal efficiency ranking listed in equation (2). First, we group all DMUs based on industry classification because the amount of inputs required to maximize efficiency for each group is almost certainly expected to be different. Next, we vary the weightings for *u* and *v* in equation one to maximize each DMU's efficiency score based on an efficiency frontier. Finally, all efficiency scores are scaled by the highest efficiency value within the industry group. The most efficient value for example could have an efficiency value of 6/6 which is considered 1 and the optimum level of efficiency for this group. An efficiency score of 1.5/6 would then have an ordinal rank of 0.25. This careful decomposition allows us to measure the relative efficiency within the market with a high degree of accuracy. After establishing this ordinal rank, we rank the efficiency of all firms within the market as well as within each industry.

Stock price volatility

Step1: *DR = (TP – YP) / YP * 100* (3)

Step2: *DSPV = SD of a stock's DR for the trading days* (4)

Step3: *ASPV = DV * AF* (5)

Where,

DR : Daily return

TP : Today's Price

YP : Yesterday's Price

DSPV : Daily volatility

SD : Standard deviation

ASPV : Annualized stock price volatility

AF : Annualized factor, calculated by square root of trading days for the year

The dependent variable for all our empirical models is annualized stock price volatility (ASPV). To calculate ASPV of a given security, we go through a three step procedure. First, daily stock price returns are calculated in equation (3). The percentage change in closing price is calculated by subtracting the prior day's price from the current price, then dividing by the prior day's price. Next, we compute daily stock price volatility as the standard deviation of a stock's daily return for trading days. Finally, we multiply daily stock price volatility by its annualized factor (square root of trading days for the year) to calculate our dependent variable, ASPV. For example, if a standard deviation of a firm A's daily return for 252 trading days is 2.78, ASPV is 44.13 (=2.78 * $252^{0.5}$). We conjecture higher volatility suggests high risk-high return (news sensitive), and lower volatility suggests lower risk-lower return (non-news sensitive)

Our main relation of interest is the relation between stock price volatility and our relative efficiency score estimated in equation (6). Therefore, we believe that uncertainty will be decreasing with relative efficiency; and we expect to find a negative relation between relative market efficiency and stock price volatility because of the potential stock return opportunities associated with inefficient firms.

$$ASPV_{i,t} = \beta_1 Relative\_Effi_{i,t} + \beta_2 Size_{i,t} + \beta_3 Firm\_Performance_{i,t} + \beta_4 Tobin_{Q_{i,t}} + \beta_5 Foreign\_Operation_{i,t} + \beta_6 BigOwn_{i,t} + \beta_7 Foreign_{i,t} + \beta_8 Indebtedness_{i,t} + \beta_9 Loss_{i,t} + \beta_{10} AEM_{i,t} + \beta_{11} REM_{i,t} + ID + YD + \varepsilon_{i,t} \quad (6)$$

There are numerous factors that influence stock price volatility. Therefore, to develop the model with the highest explanatory power, we identify the key determinants of stock price volatility in Table 1. Performance (Hay & Liu, 1997), and financial resources (Nickell, Nicolitsas & Dryden, 1997) influence stock price volatility. To control for size and firm performance, we include the following control variables. *Size*, the natural logarithm of total assets is expected decrease with stock volatility due economies of scale. Firm performance is estimated using abnormal levels of ROA (=ROA – industry median). We expect firm performance to have a negative influence on volatility because firms with higher performance are likely efficient. Firm value, estimated as Tobin's Q calculated using Chung and Pruitt (1994) is expected to have a negative relation with uncertainty. *Foreign operations* is calculated as the size of gain/loss on foreign operations. We expect a negative relation between market risk and foreign operations because international operations reduce interest exchange risk and interest risk, hence uncertainty.

<Insert Table 1 about here>

To control for business risk, we include a firm's debt and financial loss. Loss is estimated using a dummy variable that takes the value of 1 if a firm's net income is negative, 0 otherwise. Indebtedness is estimated as debt ratio (=total liabilities / total assets). We expect both indebtedness and loss to have a positive relation with uncertainty. Next, we control for earnings management, a proxy for a manager's opportunistic behavior. AEM, is the absolute value of discretionary accruals proxy suggested by Dechow et al. (1995); REM, real earnings management is proxied by AbCFO*(-1) + AbProd + AbSGA*(-1), as suggested by Roychowdhury (2006). Both proxies are expected to be increasing with uncertainty because earnings management is considered a form of managerial opportunism. Finally, we control for governance structure to address the influence of stock ownership on uncertainty. Different ownership structures have different influences on market risk (Jensen & Meckling, 1976). Bigown, the biggest shareholder's share holdings (%) has the potential to be positive or negative depending on the market. Given South Korea is a developed market, we expect a negative relation because of investor vetting. *Foreign*, foreign investors' share holdings (%) are likely to decrease with market unceirtenty because foreign investors are likely to demand increased governance and CSR (El Ghoul et al., 2011). We include yearly and industry dummy variables to control for year and industry fixed effects.

3.2 Sample Selection

We collect our dataset by combining data from DataGuide, TS-2000, and KISVALUE databases. Table 2 Panel A details our sample selection process. Initially, we download financial information for all firms registered on the KOSDAQ and KOSPI from 2000-2015. We exclude 8,928 observations due to insufficient data to complete DEA analysis, and exclude all financial firms. We exclude an additional 929 observations due to data unavailability. Panel B illustrates the relative efficiency of Korean firms in each year from 2000-2015. With few exceptions, the efficiency of Korean firms has been increasing almost every year since 2000. Given the rapid technological advances in recent history, an increase in relative efficiency is expected.

<Insert Table 2 about here>

IV. Empirical Results

4.1 Univariate Analysis

Table 3 illustrates the results of our univariate analysis and mean/median difference tests. The two columns of interest are the rightmost columns that compare the mean of the top 50% volatility percentile and the bottom 50% volatility percentile of our sample labeled Diff (2)-(3) and the top 25% volatility percentile and the bottom 25% volatility percentile labeled Diff (6)-(4). Due to the sample partitioning, the highly statistically significant difference in firm efficiency is expected (row 1). When we compare the relative efficiency of the top and bottom 50% percentile (in row 2), we find that less volatile firms are statistically significantly more efficient (t value 1.83, z value 3.02). When we compare the relative efficiency of the top and bottom 25% percentile, we find that firms with the lowest level of stock price volatility (top 25%) are more efficient than firms with the highest volatility levels (bottom 25%) (t value, 1.96, z value 2.63).

<Insert Table 3 about here>

Table 4 provides the results of Person correlations. We are primarily interested in the statistical relation between stock price volatility in column 1 with other variables. The relation between stock price volatility and our main variable of interest, relative efficiency is negative and statistically significant at the 1% significance level, consistent with our hypothesis. This evidence demonstrates more efficient firms have lower levels of stock price volatility. The results suggest that investment and divestment in efficient firms is lower compared to inefficient firms. Overall, the majority of our control variables show the predicted results. Our proxies for size and performance and governance structure are decreasing with market risk. The opportunistic behavior of management and business risk are increasing with market uncertainty.

<Insert Table 4 about here>

4.2 Multivariate Analysis

Table 5 provides the results of our main analysis. The relationship of interest for our OLS regression is the relation between $ASPV$ stock price volatility and $Relative\_Effi.$ Consistent with our hypothesis, we find a negative relation between stock price volatility and relative efficiency (t value -12.87). The results, at a 1% significance level show that as efficiency increases, the propensity to invest and disinvest in stocks decreases. This evidence is consistent with investors seeking investments in firms with lower operational efficiency compared to more efficient firms because of potential high-risk high return opportunities and higher return premiums. We interpret that the idiosyncratic volatility might show firm-specific uncertainty beyond the CAPM, which can be related with the firms' operational efficiency. All the control variables show the expected sign. There is a negative relation between stock price volatility and size (t vale –35.25), firm performance (t value -6.15), Tobin's Q (t value -4.35), foreign operation (t value -9.52), big ownership (t value -12.50) and foreign ownership (t value -6.13). Moreover, we find a positive relation between stock price volatility and indebtedness (t value 14.69), loss (t value 5.90), accruals earnings management (t value 20.58) and real earnings management (t value 10.57). We expected to find a 1% significance level for all our control variables because of our robust variable selection process.

<Insert Table 5 about here>

The purpose of our study is to test whether operational efficiency provides useful information with respect to the magnitude of uncertainty. However, we consider high volatility firms as high-risk, high return firms without directly testing the link between returns and volatilities (related to efficiency). This view may be different from the classical view of the CAPM, because volatility is different from risk (beta), therefore, it might be questionable to say that firms with higher volatility are high risk, high return firms. Furthermore, whether firms with low levels of efficiency are required to issue high/low stock return is question left unanswered. Therefore, we conduct additional tests to establish the relationship between stock return and ASPV/Relative efficiency with the following two equations where we use relative efficiency and stock price volatility as our main variables of interest as seen in the equations below (see equation 7).

$$Return_{i,t} = \beta_1 ASPV/Relative\_Effii_{i,t} + \beta_2 Size_{i,t} + \beta_3 Risk_{i,t} + \beta_4 Firm\_Performance_{i,t} + \beta_5 Foreign\_Operation_{i,t} + \beta_6 AEM_{i,t} + \beta_7 REM_{i,t} + ID + YD + \varepsilon_{i,t} \quad (7)$$

We use 12 months cumulative stock return as our dependent variable and examine its' association with ASPV/relative efficiency. We include well known key determinants of stock return such as size, business risk(leverage), firm performance(Abnormal ROA), foreign operations, earnings management (AEM, REM). In Table 6, we overall find a positive relationship between annualized stock price volatility and stock return in all four of our models, suggesting that high volatility firms are likely to achieve higher returns. In Panel B, we replace ASPV with relative efficiency, and repeat the analysis. Overall, we find a negative relationship between operational efficiency and stock return, suggesting that firms with high relative efficiency demonstrate lower level of stock returns, consistent with our assumptions. These results allow us to accept our second hypothesis that efficient firms present investors with potential low-risk low return investment opportunities; and inefficient firms present investors with potential high-risk high return investment opportunities.

<Insert Table 6 about here>

V. Additional Analysis

5.1 Most efficient group vs Most inefficient group analysis

In Table 7 we perform additional analysis where we perform 3 individual regressions for the top 1 quartile (top 25%), the two middle quartiles (middle 50% efficiency levels) and the bottom quartile (bottom 25%). Furthermore, we compare the most efficient group (top 25%) and the most inefficient group (bottom 25%). First, in equation (7), after partitioning our sample into 3 individual groups, we find the consistent results that there is a significant negative relation between relative efficiency and stock price volatility regardless of the groups partitioned based on the level of efficiency. Next, the individual regressions for each sample show that the incremental effect of relative efficiency on stock price volatility is lower for the top 25 efficiency sample (coefficient -4.91) when compared to the middle efficiency group (coefficient -7.27) and the firms with the lowest efficiency (coefficient -7.93). All results are statistically significant at the 1% level.

$$ASPV_{i,t} = \beta_1 Relative_{Effi_{i,t}} + \beta_2 Size_{i,t} + \beta_3 Firm_{Performance_{i,t}} + \beta_4 Tobin_{Q_{i,t}} + \beta_5 Foreign_{Operation_{i,t}} + \beta_6 BigOwn_{i,t} + \beta_7 Foreign_{i,t} + \beta_8 Indebtedness_{i,t} + \beta_9 Loss_{i,t} + \beta_{10} AEM_{i,t} + \beta_{11} REM_{i,t} + ID + YD + \varepsilon_{i,t} \quad (8)$$

$$ASPV_{i,t} = \beta_1 Relative\_Effi_{i,t} + \beta_2 D\_TOP25_{i,t} + \beta_3 Top25\_Effi_{i,t} + \beta_4 Size_{i,t} + \beta_5 Firm\_Performance_{i,t} + \beta_6 Tobin\_Q_{i,t} + \beta_7 Foreign\_Operation_{i,t} + \beta_8 BigOwn_{i,t} + \beta_9 Foreign_{i,t} + \beta_{10} Indebtedness_{i,t} + \beta_{11} Loss_{i,t} + \beta_{12} AEM_{i,t} + \beta_{13} REM_{i,t} + ID + YD + \varepsilon_{i,t} \quad (9)$$

Where,

D_TOP25: A dummy variable that takes a value of 1 if the most efficient group (top25 efficiency), 0 if most inefficient group (bottom 25% efficiency)

Top25_Effi: Interaction term between relative efficiency score and *D_TOP25* dummy.

Next, in equation (8), we perform a formal test to compare the incremental effect of the efficiency on stock price volatility for the top and the bottom 25% group. First, we use a dummy to compare the top 25% and the bottom 25% samples. *D_TOP25* is a dummy variable that takes a value of 1 if the most efficient group (top25 efficiency), 0 for the most inefficient group (bottom 25% efficiency). We find that the most efficient group (top 25 efficiency) has lower levels of stock price volatility compared to the most inefficient group (t value -1.98), consistent with our main findings. Furthermore, we interact our dummy variable *D_TOP25* and $Relative\_Effi$ (using the interaction term $Top25\_Effi$) to demonstrate that the negative relation between relative efficiency and stock price volatility is larger for the most efficient group compared to the most inefficient group (t -2.27). The result shows the most efficient group has the lowest level of uncertainty (stock price volatility), consistent with our hypothesis.

<Insert Table 7 about here>

5.2 Risk status - news sensitivity

In the previous additional analysis, we directly compare the incremental effect of the most efficient firms with the most inefficient firms based on relative efficiency levels. In this section, we compare the relation between the two key dimensions based on news sensitivity. First, we divide our sample into 3 groups based on levels of news sensitivity; 1) the most news sensitive group (top 25% volatility), 2) the two middle quartiles of news sensitive groups (middle 50% volatility, 3) the least news sensitive (bottom 25% volatility) group. As expected, we consistently find a negative relation between relative efficiency and stock volatility for all the three groups. Next, more importantly, we directly compare the most sensitive group with the least sensitive group using the interaction term $TopVola\_Effi$ (see table 8). We find that the negative relationship between efficiency and volatility is larger for the most news sensitive group, suggesting that relative firm efficiency has an incrementally higher influence on stock price volatility for news sensitive risky firms compared to the least news sensitive firms (t -3.41).

<Insert Table 8 about here>

5.3 Risk status – credit ratings

Next, we directly examine the stability and riskiness of firms based on credit ratings. Previous studies consider a relation between uncertainty and credit ratings because market risk influences credit risk (Lim and Mali, 2017). Credit ratings provide meaningful information to market participants about a firm's financial performance and corporate governance structures (Kraft 2014, 2015). Firms with similar credit ratings are expected to have similar quality (Kisgen 2006). Therefore, comparing investment and non-investment grade firms adds robustness to our findings because the levels of risk and uncertainty of investment grade firms and non-investment grade firms are fundamentally different (Kisgen 2006, 2009; Alissa et al., 2013). IG is a dummy variable that takes a value of 1 if a firm is investment grade, 0 if non-investment grade. To decompose firms into investment grade and non-investment grade firms, we use KISS value guidelines that are based on S&P and Moody's criteria in the U.S. that consider a credit rating of 6 to 10 to be investment grade firms; 5 and below are non-investment grade firms.

Table 9 consistently shows that relative efficiency is negatively associated with stock price volatility for both IG group (t -8.70) and NIG group (t -9.55). When we directly compare safe vs risky firms, we find that firms with lower risk proxied by investment grade credit ratings have lower levels of uncertainty (-8.30 t value) compared to non-investment grade firms, again consistent with our main findings. However, when we use the interaction term $IG\_Effi_{i,t}$ (see table 8), the interaction term between relative efficiency score and D_IG dummy, we find relative efficiency has an incrementally lower effect on the stock price volatility for investment grade firms (t value 2.90). The results suggest that the negative relation is larger for the risky group and weaker for the safe group suggesting that the risker group has more investment opportunities, consistent with our hypotheses.

<Insert Table 9 about here>

5.4 Risk status – market size

Next, we establish the influence of firm efficiency on stock price volatility based on market size. As a rule, larger firms have inherently lower levels of risk compared to smaller firms because of economies of scale and the ability to access resources compared to smaller firms. Therefore, for robustness we compare the relation between firm efficiency and stock volatility for larger KOSPI listed firms, that are considered to safer compared to the KOSDAQ listed sample that is made up of smaller firms. First, in table 9, we consistently find that there is a significant negative relation between relative efficiency and stock price volatility for both KOSPI group (t -9.95) and KOSDAQ group (-8.86). Next, we directly compare firms based on market size. In our regression, we use D_KOSPI as a dummy variable that takes a value of 1 if a firm is listed on KOSPI market, 0 if a firm is listed on KOSDAQ market. Overall, we find that the levels of uncertainty (stock price volatility) is lower for the larger KOSPI sample compared to the smaller KOSDAQ sample (t value -6.25). The results suggest that firms are relatively less likely to invest and disinvest in larger firms. However, there is more investment and divestment in smaller firms consistent with investors seeking opportunities for future economic potential. In this model, we also perform a test using the interaction term between relative efficiency score and the D_KOSPI dummy ($\mathrm{KOSPI\_Effi}$, see Table 10) to capture the incremental effect of the influence of efficiency on stock price volatility comparing the larger KOSPI index compared to the smaller KOSDAQ. We find that relative efficiency has an incrementally lower influence on stock price volatility on the larger KOSPI market (t value 2.08).

<Insert Table 10 about here>

5.5 Sensitivity analysis based on 1) efficiency, and 2) volatility decile rank

Next we examine the relation between relative efficiency and stock price volatility based on the decile rank of 1) relative efficiency and 2) stock price volatility. For brevity, we only show the results for our main variable of interest, efficiency by decile rank and volatility by decile rank. The purpose of this section is to give a complete overview of the negative relationship between relative efficiency and stock price volatility. To perform our tests, we partition firms into deciles and analyze the incremental value of relative efficiency on stock price volatility for each decile. In Panel A, overall, we find that as efficiency increases, stock price volatility decreases. In Panel B, we find that as stock price volatility decreases, firm efficiency increases. Overall, we conclude that high(low) relative efficiency leads to low(high) volatility; which also means low(high) risk, low(high) return based on our analysis as a whole. These results are consistent with all previous findings.

<Insert Table 11 about here>

5.6 Other additional analysis

For further robustness, we perform three additional analyses; 1) Fama and MacBeth (1973) yearly regression analysis, 2) a different definition of market risk, 3) a different definition of firm efficiency. For brevity, we provide untabulated results. First, relative efficiency may not be consistent over time due to various reasons such as technological advancements. Because we use pooled data and thus our coefficient may not be constant over time, our results may be affected by potential time series dependence in the error terms. Therefore, we corss-sectionally estimate the relation between relative efficiency and stock price volatility for each year using technique suggested by Fama and MacBeth (1973). Untabulated results show the consistent negative relation as our previous findings.

Second, we use absolute stock price volatility as our dependent variable in our main analysis. However, we use relative efficiency (Not absolute efficiency, such as asset turnover) as our main variable of interest. For robustness, we additionally calculate relative stock price volatility by ASPV of firm *j* minus ASPV median of its industry peer and repeat all the above analyses. Our untabulated results remain qualitatively unchanged. Finally, we re-perform our analyses using relative efficiency, calculated from stochastic frontier analysis (SFA). To estimate our SFA models, we borrow from the Malmquist efficiency index calculation technique (Coelli et al., 2005). The conceptual basis of how efficiency is estimated for SFA and DEA are inherently similar, output / input. Untabulated results are consistent with our previous findings.

VI. Conclusions

In this paper, we perform empirical tests to discover whether a firm's relative efficiency has the potential to influence investment and disinvestment proxied by stock price volatility. Moreover, we test whether efficient firms can be considered as low-risk low return investment opportunities compared to firms that are more inefficient, that can be considered as being high-risk high reward investment opportunities.

Relative efficiency represents a firm's overall operational performance based on superior (inferior) decision making that leads to efficiency (inefficiency). Therefore, there is a logical relationship between market uncertainty, risk and efficiency; however, until now, it has not been captured empirically. We find that the stock price volatility of efficient firms is statistically significantly lower compared to inefficient firms. The results suggest that market participants use information about a firm's relative efficiency as the basis for investment / disinvestment decisions and that market participants are more likely to speculate in inefficient firms because of potential stock return opportunities.

Next, we find a positive relation between stock price volatility and market returns. Moreover, we find a negative relation between stock returns and relative efficiency. These findings allow us to accept that the market uncertainty is likely caused by the high-risk, high-return potential investment opportunities in inefficient firms. The findings also provide evidence that efficient firms can be considered low-risk, low return investment opportunities. This behavior has an incrementally higher effect on the stock price volatility of relatively inefficient firms compared to efficient firms. The results are robust to additional tests using alternative samples partitioning based on higher/lower firm efficiency/risk that includes large/small firm size, higher/lower new sensitivity, IG/NIG credit ratings and a test where we partition our sample into decile ranks.

A limitation of this paper is that our sample is exclusively made up of Korean listed firms. Further studies may replicate our findings using an international sample comparing the relative efficiency and stock price volatility of firms in an international context. Whilst there is a slim possibility the behavior of Korean market is significantly different to markets in other geographical areas, we posit the results will be indifferent to samples taken from other international markets. Since the purpose of this study is to examine whether relative operational efficiency provides useful information with respect to uncertainty levels, and because we use a large dataset to conduct our analyses, we do not consider corporate events when good or bad information could be important to investors. We hope that future studies extend our research by focusing on the effect of relative efficiency on positive/negative volatilities by considering good/bad corporate events that are important to investors.

References

Alam, I. M. S., & Sickles, R. C. (1998). The relationship between stock market returns and technical efficiency innovations: evidence from the US airline industry. *Journal of Productivity Analysis*, 9(1), 35-51.

Alissa, W., Bonsall, S. B., Koharki, K., & Penn, M. W. (2013). Firms' use of accounting discretion to influence their credit ratings. *Journal of Accounting and Economics*, 55(2), 129-147.

Baik, B., Chae, J., Choi, S., & Farber, D. B. (2013). Changes in operational efficiency and firm performance: a frontier analysis approach. *Contemporary Accounting Research*, *30*(3), 996-1026.

Black, F. (1972). Capital market equilibrium with restricted borrowing. *The journal of business*, 45(3), 444-455.

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis*. Springer Science & Business Media.

Chung, K. H., & Pruitt, S. W. (1994). A simple approximation of Tobin's q. *Financial management*, 70-74.

Dechow, P. M., Sloan, R. G., & Sweeney, A. P. (1995). Detecting earnings management. *Accounting review*, 193-225.

Demsetz, H. (1973). Industry structure, market rivalry, and public policy. *The Journal of Law and Economics*, 16(1), 1-9.

Demerjian, P. R., Lev, B., Lewis, M. F., & McVay, S. E. (2012). Managerial ability and earnings quality. *The Accounting Review*, *88*(2), 463-498.

Easley, D., Hvidkjaer, S., & O'hara, M. (2002). Is information risk a determinant of asset returns? *The journal of finance*, 57(5), 2185-2221.

Dilling-Hansen, M., Madsen, E. S., & Smith, V. (2003). Efficiency, R&D and ownership–some empirical evidence. *International Journal of Production Economics*, 83(1), 85-94.

El Ghoul, S., Guedhami, O., Kwok, C. C., & Mishra, D. R. (2011). Does corporate social responsibility affect the cost of capital? *Journal of Banking & Finance*, 35(9), 2388-2406.

Fama, E. F., & French, K. R. (1992). The cross-section of expected stock returns. *The Journal of Finance*, 47(2), 427-465.

Fama, E. F., & French, K. R. (1993). Common risk factors in the returns on stocks and bonds. *Journal of financial economics*, 33(1), 3-56.

Fama, E. F., & French, K. R. (1995). Size and book-to-market factors in earnings and returns. *The Journal of Finance*, 50(1), 131-155.

Fama, E. F., & MacBeth, J. D. (1973). Risk, return, and equilibrium: Empirical tests. *Journal of political economy*, *81*(3), 607-636.

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society*. Series A (General), 120(3), 253-290.

Frijns, Bart, Dimitris Margaritis, and Maria Psillaki. "Firm efficiency and stock returns." *Journal of Productivity Analysis* 37.3 (2012): 295-306.

Hay, D. A., & Liu, G. S. (1997). The efficiency of firms: what difference does competition make? *The Economic Journal*, 107(442), 597-617.

Jensen, M. C., & Meckling, W. H. (1976). Theory of the firm: Managerial behavior, agency costs and ownership structure. *Journal of financial economics*, 3(4), 305-360.

Kisgen, D. J. (2006). Credit ratings and capital structure. *The Journal of Finance*, 61(3), 1035-1072.

Kisgen, D. J. (2009). Do firms target credit ratings or leverage levels? *Journal of Financial and Quantitative Analysis*, 44(6), 1323-1344.

Kraft, P. (2014). Rating agency adjustments to GAAP financial statements and their effect on ratings and credit spreads. *The Accounting Review*, 90(2), 641-674.

Kraft, P. (2015). Do rating agencies cater? Evidence from rating-based contracts. *Journal of Accounting and Economics*, 59(2), 264-283.

Lim, H. J., & Mali, D. (2016). Does market risk predict credit risk? An analysis of firm risk sensitivity, evidence from South Korea. *Asia-Pacific Journal of Accounting & Economics*, 1-18.

Majumdar, M. K., Thiede, M. A., Mosca, J. D., Moorman, M., & Gerson, S. L. (1998). Phenotypic and functional comparison of cultures of marrow-derived mesenchymal stem cells (MSCs) and stromal cells. *Journal of cellular physiology*, 176(1), 57-66.

Markowitz, H. (1952). Portfolio selection. *The Journal of Finance*, 7(1), 77-91.

Nguyen, G. X., & Swanson, P. E. (2009). Firm characteristics, relative efficiency, and equity returns. *Journal of Financial and Quantitative Analysis*, 44(1), 213-236.

Nickell, S., Nicolitsas, D., & Dryden, N. (1997). What makes firms perform well? *European economic review*, 41(3), 783-796.

Pástor, Ľ., & Stambaugh, R. F. (2003). Liquidity risk and expected stock returns. *Journal of Political economy*, 111(3), 642-685.

Peltzman, S. (1977). The gains and losses from industrial concentration. *The Journal of Law and Economics*, 20(2), 229-263.

Roychowdhury, S. (2006). Earnings management through real activities manipulation. *Journal of accounting and economics*, 42(3), 335-370.

Sharpe, W. F. (1964). Capital asset prices: A theory of market equilibrium under conditions of risk. *The Journal of Finance*, 19(3), 425-442.

Vassalou, M., & Xing, Y. (2004). Default risk in equity returns. *The Journal of Finance*, 59(2), 831-868.