

Does relative efficiency matter? An analysis of market uncertainty

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Does relative efficiency matter? A comparative analysis of high risk, high return firms versus low risk, low return firms

Abstract

In this paper we examine whether relative efficiency provides useful information with respect to uncertainty levels (news sensitivity), proxied by stock price volatility. We infer that investors have a preference for 'potential stock return opportunities' in firms that are lowly valued due to lower levels of efficiency. Investors are news sensitive; they are likely to invest in inefficient firms in periods of good news and disinvest in periods of bad news. On the other hand, investors in efficient firms may be less sensitive to good news because efficient firms are highly valued, suggesting low return opportunities. Further, investors should also be less sensitive in periods of bad news because efficient firms offer 'stable economic returns'. Thus, investors are more likely to invest/disinvest in firms with lower relative efficiency because of the potential for high-risk, high rewards compared to efficient firms with low-risk, low-reward. Using a sample of Korean listed firms, we find that a firm's stock price volatility is significantly negatively associated with relative efficiency, suggesting relative efficiency truly matters and that relative efficiency plays an important role for news sensitive market participants when making investment /disinvestment decisions.

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

I. Introduction

In this paper, we empirically test whether relative efficiency provides useful information for news sensitive investors when making investment and disinvestment decisions. Specifically, we examine whether levels of uncertainty (news sensitivity), proxied by stock price volatility is significantly associated with relative efficiency. 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). Thus, how market participants view these investments is likely to have an incremental effect on stock price volatility. First, investors

are likely to seek 'potential stock return opportunities' in firms with lower levels of efficiency. Investors are news sensitive 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 be relatively highly priced, suggesting low return opportunities. Therefore, if market participants are able to capture and utilize relative efficiency, the stock price volatility of news sensitive riskier inefficient firms is expected to be higher compared to more efficient firms.

Our study is motivated by two questions 1) whether relative efficiency matters in capital market and 2) whether it plays an important role for news sensitive market participants. If relative efficiency provides useful information about levels of uncertainty (news sensitivity), 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 undervalued and relatively riskier inefficient firms compared to stable efficient firms is an empirical question left unanswered.

To measure the high risk (low risk)-high return (low return) status of firms, we use stock price volatility as a felicitous proxy for uncertainty (news sensitivity). Volatility is a statistical measure of the dispersion of returns for a given security, and refers to the amount of uncertainty or risk 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 can potentially be 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 (high risk-high

return). Low volatility means that a security's value does not fluctuate dramatically (low risk-low return).

Low risk-low return stocks are safe but not attractive whereas high risk-high return stocks are risky but may be more attractive. We conjecture firms with high relative efficiency are low risk-low return, their value is less likely to fluctuate, offering 'stable economic return (lower stock price volatility). Further, they should be more highly priced compared to their inefficient peers, suggesting less stock return opportunities. Therefore, we conjecture that high relative efficiency is positively/negatively associated with low/high volatility. On the other hand, we consider relatively inefficient firms to be high risk-high return because they have the potential to be undervalued compared to their efficient peers. Hence, news sensitive investors may invest more aggressively in inefficient firms in periods of good news but disinvest more in periods of bad news because of 'potential stock return opportunities' (fluctuating stock prices) which increases stock price volatility and overall firm risk. Therefore, we believe relative inefficiency is positively/negatively correlated with high/low volatility.

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 (news sensitivity) of relatively efficient firms is lower compared to relatively inefficient firms. We interpret that relatively efficient firms are low risk, low return, and hence are safe but with low stock return opportunities. On the other hand, relatively inefficient firms are high risk, high return, and hence are risky but with high potential stock return opportunities. This is important because different investors have different investment preferences/strategies depending on whether they are risk averse or takers. Our results suggest that relative efficiency is a useful tool to predict levels of uncertainty or news sensitivity and thus, it helps market participants to make rational investment/disinvestment decisions based on their risk preferences.

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. Next, we compare safe and risky firms based on credit risk and market size. Overall, our results suggest

that the negative relation between efficiency and volatility is larger for risky firms and smaller for safe firms, suggesting that the risky group has more investment opportunities in periods of good news, and becomes even riskier in periods of bad news, consistent with our hypothesis. 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; stock price volatility is the basis of firm level risk. Thus, we demonstrate that a firm's risk level in the market 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. A firm with high (low) relative efficiency has low (high) volatility, and can be considered a low (high) risk, low (high) return investment. We find 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. If market participants can use relative efficiency as an additional tool to predict levels of uncertainty, they are likely able to implement optimum investment/disinvestment strategies depending on their risky-return preferences and thus are able to seek optimum investment opportunities. To the best of our knowledge, we are the very first to examine the relation between relative efficiency and stock price volatility. 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

Classic finance theory demonstrates a positive relation between risk and return. 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). Overall the literature establishes that regardless of risk averse/ neutral/ taking strategies, investors require the highest returns possible for holding stocks dependent on risk. In the estimation of CAPM, risk is determined by the beta, a mathematical estimation derived from stock price volatility. However, research into the precise factors that influence stock price volatility is ongoing. In this paper, we address this issue by empirically testing whether relative efficiency has the potential to influence stock price volatility.

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 ($Sales_t - Sales_{t-1}$) divided by changes in input

$(Costs_t - Costs_{t-1})$. 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 process. 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 optimal 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).

We are the first to examine the relation between relative efficiency and stock price volatility; therefore, we borrow from efficiency and stock pricing literatures. Efficiency related 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 and market prices 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 riskier firms because more efficient firms 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. Thus, we consider relative firm efficiency directly influences stock price volatility because of what relative efficiency signals as a potential opportunity to investors. First, efficient firms are less risky and are required to pay a lower rate of return to investors because high efficiency decreases uncertainty. We consider that efficient firms provide investors with a stable economic return because of the perception of high future economic potential depending on how 1) highly/ 2) lowly they are currently valued in the market. Second, firms with lower efficiency are required to pay higher returns to investors, and because of uncertainty, they are highly likely to have a lower current value on the market. Therefore, these firms should be highly news sensitive because both greater return (with good news) and greater loss (with bad news) are possible. Thus, due to the potential high risk-high return opportunity associated with inefficient firms compared to the stable economic return, but potential low return of efficient firms, news sensitive investors are likely to invest and disinvest more frequently in inefficient firms compared to efficient firms.

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 risk 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. 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 these firms are risky, but provide investors with 'higher potential return opportunities'. In periods of good news, investment in inefficient firm offers a large return on investment. In periods of bad news, investment in a less efficient firm leads to divestment. Thus, we believe that news sensitive investors are more likely to invest and disinvest in inefficient firms which cause the prices of these stocks to rise and fall; thus, the stock volatility of these firms is likely to be higher as a direct result of relative efficiency. Thus, we believe relative inefficiency will increase the uncertainty of less efficient stocks.

<Insert Figure 1 about here>

We conjecture that market participants are less sensitive to good / bad news when investing in efficient firms. Because efficient firms are safe (stable), there is likely lower speculation in these stocks; hence, lower levels of investment and disinvestment. Therefore, the volatility of these stocks should be lower compared to less efficient stocks because there are no significant opportunities for greater returns and hence

investors are less news sensitive in firms with relatively high efficiency levels. In periods of good news, investment in efficient stock is unlikely to be considered an investment with high potential stock return opportunities because whilst increases in returns and market value is possible, the stock price of an efficient firm is likely to already be relatively higher than its peers. Thus the potential price increase may be relatively low compared to the inefficient group. In periods of bad news, it is unlikely that market participants will sell shares in efficient firms since they are highly likely to have stable economic returns; therefore, efficient firms are likely to demonstrate less stock volatility compared to riskier firms.

It is likely that market participants consider relative efficiency as a signal for risk. Given that efficient firms have relatively 'stable economic returns' but offer 'lower potential return opportunities', news sensitive investors are likely to use relative efficiency to seek 'higher stock return opportunities' in firms with lower levels of efficiency. This type of behavior will increase the investment and disinvestment in less efficient firms and raise uncertainty. Thus, this market phenomenon will be expressed as a different relationship between the stock price volatility of firms with lower/higher relative efficiency. Based on the arguments above, we develop the following hypothesis.

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

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 are unknown. In different industries, the amount of inputs required to achieve the highest output is not similar because the values of inputs such as labour are obviously less valuable to a mining company compared to a clothing firm. 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

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

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

Where,

<i>Sales (Output)</i>	: Gross Sales
<i>Given Resources</i>	: PPE + Operating Lease + Goodwill + Other Intangibles
<i>Costs</i>	: 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

$$\text{Step1: } DR = (TP - YP) / YP * 100 \quad (3)$$

$$\text{Step2: } DSPV = SD \text{ of a stock's } DR \text{ for the trading days} \quad (4)$$

$$\text{Step3: } ASPV = DV * AF \quad (5)$$

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). As we explain in our hypothesis, news sensitive investors are likely to believe efficient firms provide relatively stable economic returns and future economic potential, and inefficient firms are likely to have higher return opportunities. Therefore, less efficient firms will have higher levels of investment which raises uncertainty. This uncertainty will be modeled empirically using stock price volatility. Therefore, we believe that market risk will be decreasing with market efficiency; and we expect to find a negative relation between relative market efficiency and stock price volatility.

$$\begin{aligned}
 ASPV_{i,t} = & \\
 & \beta_1 Relative_Eff_{i,t} + \beta_2 Size_{i,t} + \beta_3 Firm_Performance_{i,t} + \beta_4 TobinQ_{i,t} + \beta_5 Foreign_Operation_{i,t} + \\
 & \beta_6 BigOwn_{i,t} + \beta_7 Foreign_{i,t} + \beta_8 Indebtedness_{i,t} + \beta_9 Loss_{i,t} + \beta_{10} AEM_{i,t} + \beta_{11} REM_{i,t} + ID + YD + \varepsilon_{i,t}
 \end{aligned}
 \tag{6}$$

There are numerous factors that will 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 be decreasing with stock volatility due to the reduction of risk associated with 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 are calculated as size of gain/loss on foreign operation. We expect a negative relation between market risk and foreign operations because international operations reduce interest exchange risk and interest risk.

<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 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 market risk. Next, we control for earnings management, a proxy for a manager's opportunistic behavior. AEM, absolute value of discretionary accruals suggested by Dechow et al. (1995) and REM, real earnings management is proxied by $AbCFO^{*}(-1) + AbProd + AbSGA^{*}(-1)$ suggested by Roychowdhury (2006). Both are expected to be increasing with market risk because earnings management is considered a form of managerial opportunism. Finally, we control for governance structure to address the influence of stock ownership, due to different ownership structures having 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 risk 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. When we compare the relative efficiency of the top and bottom 50% percentile, we find that less volatile firms are statistically significantly more efficient compared to riskier firms (t value 1.83, z value 3.02). When we compare the relative efficiency of the top and bottom 25% percentile, we find that the safest firms (top 25%) are more efficient than the riskiest firm (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 risk.

<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 being news sensitive and seeking investments in firms with lower efficiency compared to more efficient firms because of potential high risk-high return opportunities and higher return premiums. All the control variables show the expected sign. There is a negative relation between stock price volatility and size (t value -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>

V. Additional Analysis

5.1 Further verification test

The purpose of our study is to test whether operational efficiency provides useful information with respect to the magnitude of uncertainty. However, we define 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 with relative efficiency and stock price volatility as our dependent variable of interest equations below (see equation 7).

$$\begin{aligned}
 &Return_{i,t} = \\
 &\beta_1 ASPV/Relative_Effi_{i,t} + \beta_2 Size_{i,t} + \beta_3 Risk_{i,t} + \beta_4 Firm_Performance_{i,t} + \\
 &\beta_5 Foreign_Operation_{i,t} + \beta_6 AEM_{i,t} + \beta_7 REM_{i,t} + ID + YD + \varepsilon_{i,t} \quad (7)
 \end{aligned}$$

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 operation, earnings management (AEM, REM). In Table 6, we overall find a positive relationship between annualized stock price volatility and stock return, suggesting that high volatility firms are likely to achieve higher returns. Therefore, we consider such firms with higher levels of uncertainty as being high risk, high return firms. 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 firms with high relative efficiency firms demonstrate lower level of stock returns, consistent with our assumptions.

5.2 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%). Further, 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 market risk 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.

$$\begin{aligned}
 ASPV_{i,t} = & \beta_1 Relative_{Effl}_{i,t} + \beta_2 Size_{i,t} + \beta_3 Firm_{Performance}_{i,t} + \beta_4 TobinQ_{i,t} + \beta_5 Foreign_{Operation}_{i,t} + \beta_6 BigOwn_{i,t} + \\
 & \beta_7 Foreign_{i,t} + \beta_8 Indebtedness_{i,t} + \beta_9 Loss_{i,t} + \beta_{10} AEM_{i,t} + \beta_{11} REM_{i,t} + ID + YD + \varepsilon_{i,t}
 \end{aligned}
 \tag{8}$$

$$\begin{aligned}
ASPV_{i,t} = & \beta_1 Relative_Effi_{i,t} + \beta_2 D_TOP25_{i,t} + \beta_3 Top25_Effi_{i,t} + \beta_4 Size_{i,t} + \beta_5 Firm_Performance_{i,t} + \beta_6 Tobin_Q_{i,t} + \\
& \beta_7 Foreign_Operation_{i,t} + \beta_8 BigOwn_{i,t} + \beta_9 Foreign_{i,t} + \beta_{10} Indebtedness_{i,t} + \beta_{11} Loss_{i,t} + \beta_{12} AEM_{i,t} + \beta_{13} REM_{i,t} + ID + \\
& YD + \varepsilon_{i,t}
\end{aligned}
\tag{9}$$

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 of 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>

5.3 High risk-High return group vs Low risk- Low return group analysis

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 for the most news sensitive group and the least new sensitive group. 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 the 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>

5.4 Safe vs Risky group analysis based on credit risk

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 $IG_Eff_{i,t}$ (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 riskier group has more investment opportunities in periods of good news, and then becomes even riskier in periods of bad news, consistent with our hypothesis.

<Insert Table 9 about here>

5.5 Safe vs Risky group analysis based on market size

Next, we establish the influence of firm efficiency on stock price volatility based on market size. As a rule, larger firms are less risky 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 be safer and the relatively riskier than 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 safe vs risky 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 being news sensitive and 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 (KOSPI_Effi, see Table 9) 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). Again, the results consistently suggest that the negative relation is larger for risky firms and weaker for safer firms.

<Insert Table 10 about here>

5.6 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. These results are consistent with all previous findings.

<Insert Table 11 about here>

5.7 Other additional analysis

For further robustness, we perform three more 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 only show 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 cross-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 found consistent with our previous findings.

VI. Conclusions

Classic finance theory states that investors require the highest possible rate of return for bearing additional risk. However, prior to this study, the relationship between relative efficiency and risk has been unknown. In this paper, we perform empirical tests to discover whether a firm's relative efficiency has the potential to influence a firm's risk,

proxied by stock price volatility. DEA provides additional explanatory power to measure efficiency because absolute efficiency measures can lead to bias compared to relative efficiency because the DEA procedure measures the relative efficiency of firms compared to industry peers. Relative efficiency represents a firm's overall operational performance based on superior (inferior) decision making that leads to efficiency (inefficiency). There is a logical relationship between risk and efficiency. Efficient firms can be classified as low risk, hence low return investments and inefficient firms can be classified as high-risk high return investments. A different relation between relative efficiency and stock price volatility for both inefficient/efficient firms would suggest that market participants have different investment strategies for both groups, which influences investment and disinvestment strategies causing stock price volatility.

Efficient firms have inherently less risk due to sound operational performance; however, these firms are also expected to provide investors with lower returns because of the positive relationship between risk and reward. Hence, investors are less likely to invest efficient firms in periods of good news because efficient firms do not provide high stock return opportunities as they are likely to be highly priced. Investors are also less likely to disinvest in periods of bad news because they are likely to believe efficient firms demonstrate 'stable economic returns. On the other hand, news sensitive investors are more likely to invest in risky firms because of 'potential stock return opportunities'; however, they are more likely to disinvest in periods of bad news due to their risk status. If investors utilize information about relative efficiency, there would be a differing relationship between the stock price volatility of efficient and inefficient firms.

Our results show that market participants use information about a firm's relative efficiency as the basis for investment / disinvestment decisions and that market participants have different investment strategies for high-risk, high-return (inefficient) firms and low-risk, low return (efficient) firms. Inefficient, high-risk, high-return firms are considered as having higher potential stock return opportunities. News sensitive

investors are likely to invest (disinvest) in inefficient firms in periods of good (bad news), which has an incrementally higher effect on the stock price volatility of these relatively inefficient firms compared to efficient firms. The negative relation between relative efficiency and stock price volatility demonstrates that market participants capture and utilize relative efficiency for investment and disinvestment decisions which in turn has an incrementally larger influence on the stock price volatility of news sensitive riskier inefficient firms compared to more 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 news 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 investors.

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