A Comparison of New Factor Models in the Korean Stock Market

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JEL classification: G12

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Abstract

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1 Introduction

After the failure of the capital asset pricing model (CAPM) to explain the cross-section of stock returns, a host of previous literature has sought to uncover its behavior. Fama and French (1992) show that size and book-to-market equity do a major role in explaining the cross-section of average stock returns in the U.S. stock market. Continuing from this result, Fama and French (1993) (FF henceforth) build a three-factor model to capture the relation between average return and size, and the relation between average return and book-to-market. Although the FF three-factor model summarizes the cross-section of average stock returns better than the CAPM, it appears that the model fails to capture myriad market anomalies.[1]

In recent years, a number of factor models based on the q-theory of firm investment are introduced. Cooper, Gulen and Schill (2008) document that asset growth, which is a proxy for firm's investment, is closely related to the expected returns. Chen, Novy-Marx and Zhang (2011) suggest an alternative three-factor model from the q-theory with the market, investment-to-assets, and return-on equity as its factors. Hou, Xue and Zhang (2014) (HXZ henceforth) propose an empirical q-factor model consisting of the market factor, a size factor, an investment-to-assets factor, and a return-on-equity factor. They argue that the q-factor model performs better than the FF three-factor model and the Carhart (1997) four-factor model in explaining stock market anomalies in the U.S. market.

Motivated by Novy-Marx (2013) gross profitability premium and Miller and Modigliani (1961), Fama and French (2015) add a profitability factor and an investment factor to their three-factor model and propose the FF five-factor model. They show that the FF five-factor model outperforms the FF three-factor model. Hou, Xue and Zhang (2016), however, sustain their empirical q-factor model in the sense that the q-factor model outperforms the FF five-factor model in digesting a number of market anomalies.

Researchers try to examine whether the well-known cross-sectional patterns in the U.S. stock

[1]Examples include Ang, Hodrick, Xing and Zhang (2006); Cooper, Gulen and Schill (2008); Daniel and Titman (2006); Fama and French (1996).

market also exist in the Korean stock market, and they try to find an asset pricing model that best explains the cross-section of expected returns. Kim, Kim and Shin (2012) compare performance of various asset pricing models including variations of CAPM and CCAPM, the FF three-factor model, and the Chen-Novy-Marx-Zhang three-factor model. Kim (2014) tests empirical asset pricing models which work well in the Korean stock market based on FF (2015). Lee and Ohk (2015) compares the FF three-factor model and the Chen, Novy-Marx and Zhang (2011) three-factor model, focusing on the models' ability to explain the various anomalies in the Korean market. However, the empirical evidence of the cross-section of the stock returns in the Korean market is mixed across various sample periods and data management methodologies.

This paper aims to compare performances of the FF five-factor model and the HXZ q-factor model, and their variations using the Korean stock data. First, we test whether the size, book-to-market, profitability, or investment effect exists in the Korean market. Second, we discuss the performance of alternative asset pricing models in describing the cross-section of portfolio returns sorted on size, book-to-market, profitability, and investment. Third, we consider a variety of anomaly variables in the U.S. market, and test whether our candidate models well explains the significant anomalies in the Korean market.

Our empirical findings can be summarized as follows. First, we find that in our July 2002 to June 2014 sample, we observe the value, profitability, and investment effect in the Korean market. Especially for the profitability effect, we find that the profitability variable should be based on quarterly earnings data following Hou, Xue and Zhang (2014) instead of annual profitability measure in Fama and French (2015) to exhibit strong cross-sectional pattern. Second, the adjusted FF five-factor model with the quarterly profitability factor outperforms the FF three-factor model, the FF five-factor model, and the HXZ four-factor model in explaining the portfolio returns sorted on the size, book-to-market, profitability, or investment-sorted portfolios and significant anomaly portfolios.

This paper makes further contribution especially in the following three points. First, we examine whether the size, value, profitability, or investment effect exists in the Korean market. Second, we cover the FF five-factor model and its subordinate models as well as the HXZ q-factor model. Specifically, we suggest the adjusted five-factor model which shows better performance than the FF five-factor model and the HXZ model. We show that the quarterly-based profitability measure is closely related to the cross-section of returns and that the HML factor has strong explanatory power unlike the U.S. market. Third, we investigate which model performs well in digesting significant anomalies. By doing this, we also examine whether various stock market anomalies exist in the Korean market. Compared to Lee and Ohk (2015), we only use significant anomalies to our asset pricing tests.

This paper is organized as follows. Section 2 describes the dataset, the asset pricing models, and empirical methodology including measure construction, factor construction, and portfolio formation. In section 3, we report the results from our empirical analyses. Section 4 concludes.

2 Data and Empirical Methodology

2.1 Data Source and New Factor Models

Monthly stock returns and accounting information are from FN-DataGuide. We use all non-financial stocks in the KOSPI and KOSDAQ market. We exclude stocks with negative book equity and stocks with non-December fiscal year-ends. Our sample period is from July 2002 to June 2015 with the following two reasons. First, we need to include KOSDAQ stocks, which have been listed since 1996, to have enough number of firms in our portfolios. Second and more importantly, we use quarterly-based accounting information, which is available after 2000, to construct the quarterly profitability measure. We use the one-year monetary stabilization bond yields from the Economic Statistic System (ECOS) in the Bank of Korea as the risk-free rate.

2.1.1 The FF (2015) five-factor Model

Fama and French (2015) add a profitability factor (RMW) and an investment factor (CMA) to their three-factor model in Fama and French (1993) to capture the variation in average returns related to profitability and investment. This five-factor model is written as the following:

$$\mathrm{E}[r_i] - r_f = b_i E[MKT] + s_i E[SMB] + h_i E[HML] + r_i [RMW] + c_i [CMA] \qquad (1)$$

in which $\mathrm{E}[r_i] - r_f$ is the expected excess return, MKT is the market excess return, SMB (small-minus-big) is the difference between the returns on diversified portfolios of small and big stocks, HML (high-minus-low) is the difference between the returns on diversified portfolios of high and low book-to-market stocks, RMW (robust-minus-weak) is the difference between the returns on diversified portfolios of robust and weak profitability stocks, and CMA (conservative-minus-aggressive) is the difference between the returns on diversified portfolios of low and high investment stocks. The slopes b_i, s_i, h_i, r_i and c_i are the exposures to the five factors.

2.1.1 The HXZ (2014) q-factor Model

Hou, Xue and Zhang (2014) construct a new empirical model inspired by investment-based asset pricing, which is built on the q-theory of investment. They argue that the expected excess return is described by the market factor, the size factor, the investment factor, and the profitability factor. Their q-factor model is formally written as the following:

$$\mathrm{E}[r_i] - r_f = \beta^i_{MKT} \mathrm{E}[MKT] + \beta^i_{ME} \mathrm{E}[r_{ME}] + \beta^i_{I/A} \mathrm{E}[r_{I/A}] + \beta^i_{ROE} \mathrm{E}[r_{ROE}] \qquad (2)$$

In the equation, $\mathrm{E}[r_i] - r_f$ is the expected excess return. MKT is the market excess return, r_{ME} is the difference between the returns on diversified portfolios of small and big stocks, $r_{I/A}$ is the difference between the returns on diversified portfolios of low and high investment-to-assets stocks, and r_{ROE} is the difference between the returns on diversified portfolios of high and low ROE stocks. The factor loadings on MKT, r_{ME}, $r_{I/A}$, and r_{ROE} are denoted as β^i_{MKT}, β^i_{ME}, $\beta^i_{I/A}$, and β^i_{ROE}, respectively. In the subsequent paper, Hou, Xue and Zhang (2016) conclude that the four-factor q-factor model outperforms the Fama-French five factor model in digesting a number of anomalies in the U.S. stock market.

2.2 Measure Construction and Empirical Properties

We measure *Size* as the market capitalization. We measure *B/M* as book equity at the end of the fiscal year ending in $t-1$ divided by the market capitalization at the end of December of year $\mathrm{t}-1$. Investment, *Inv*, is measured as the annual change of total assets from the fiscal year ending in year $t-2$ to the year $t-1$ divided by total assets at the fiscal year ending in year $t-2$. We follow Fama and French (2015) to construct operating profitability (*OP*), which is measured as operating profit divided by book equity for the fiscal year ending in year $t-1$.[2]

Hou, Xue and Zhang (2016) argue that the most recent quarterly earnings announcement contains the latest information on future profitability. To incorporate their argument, we measure quarterly operating profitability (OP^q) in the same way we did to construct *OP*, except that we use operating profit and book equity of the last quarter, not the last year. To avoid possible problems due to the late announcement of quarterly earnings, we apply one more lag both on earnings and book equity.[3]

Before we construct factor portfolios, we first examine whether the average returns of our portfolios in the Korean market formed on size, book-to-market, investment, and profitability exhibit the known patterns in the U.S. stock market. The reported portfolio returns are in excess of the implied monthly returns of one-year monetary stabilization bond yields. Following Fama and French (1993), at the end of June each year, we sort stocks by *Size, B/M, Inv, OP,* and OP^q using the KOSPI breakpoints. We choose 4 by 4 double sorts instead of 5 by 5 sorts to have enough number of firms in each portfolio.

Table 1 depicts average monthly excess returns of value-weight portfolios formed on (1) *Size* and *B/M*, and (2) *Size* and *OP*, and (3) *Size* and OP^q, and (4) *Size* and *Inv*. In each Panel of Table 1, we

[2] Although HXZ (2014, 2016) use income before extraordinary items instead of operating profits to measure ROE, we mainly follow FF (2015) here for the numerator of the profitability measure.
[3] In Korea, for firms whose fiscal year-end is December, Q1, Q2, Q3 and Q4 earnings reports should be submitted to Financial Supervisory Service (FSS) before/on May 16, August 16, November 14, and March 30, respectively, and are announced few days later. For example, in April of year t, we use quarterly data reported for Q3 of year $t-1$ instead of those reported for Q4 of year $t-1$ to take account of possible delays in quarterly reports.

report monthly excess returns of 16 double-sorted portfolios, together with the small-minus-big and high-minus-low excess returns and their t-statistics.

Panel A of Table 1 shows the pattern of average excess returns of 16 *Size-B/M* portfolios. In each size quartile, average excess return increases from low *B/M* stocks to high *B/M* stocks, and high-minus-low excess returns are significantly positive. This clearly indicates that there exists the value effect in our sample. However, in the lowest *B/M* quartile, the average small-minus-big excess return is negative. In the other *B/M* quartiles, small-minus-big excess returns are positive but insignificant. This result is robust in Panels B, C, and D of Table 1. Out of 16 small-minus-big excess returns, three are negative, and only one excess return in Panel C is significantly positive with 1.15% of monthly average. Therefore, we see no size effect in our sample.

Panel B of Table 1 shows average monthly excess percent returns for 16 *Size-OP* portfolios. Except for the last row, high-minus-low excess returns are positive. However, only high-minus-low returns in the two smaller quartiles are significant. Moreover, for the biggest stocks, the pattern of returns is in reverse direction and high-minus-low excess return is significantly negative (-0.86% a month). Thus, it is in doubt that there is the profitability effect in the Korean stock market when the sorting variable is annual *OP*.

Panel C of Table 1 reports average monthly excess percent returns for 16 Size-OP^q portfolios. Compared to the *Size-OP* portfolios in Panel B, we see stronger evidence that the profitability effect exists in the *Size*-OP^q portfolios. High-minus-low returns are positive and significant with one exception, again the biggest stocks. Motivated by this observation, we measure the profitability as OP^q rather than *OP*, since quarterly profitability measure generates stronger expected return patterns in the Korean market.

Panel D of Table 1 shows average monthly excess percent returns for 16 *Size-Inv* portfolios. The investment effect appears in the Korean stock market, because high-minus-low excess return is significantly negative for each size row with values from -0.53% to -0.82%. This result implies that there is strong investment effect in the Korean market.

To summarize the performance of portfolios sorted on *Size*, *B/M*, *Inv*, *OP*, and OP^q in our sample, we observe strong return patterns sorted on *B/M*, OP^q, and *Inv*. However, we find weaker evidence that *Size* and *OP* are closely related to the cross-section of stock returns in the Korean market.

3.3 Factor Construction

FF (2015) construct the size, B/M, profitability and investment factors in three different ways: (1) 2×3 sorts on *Size* and *B/M*, or *Size* and *OP*, or *Size* and *Inv*, and (2) 2×2 sorts on *Size* and *B/M*, or *Size* and *OP*, or *Size* and *Inv*, and (3) $2 \times 2 \times 2 \times 2$ sorts on *Size*, *B/M*, *OP*, and *Inv*. We follow their approach to construct factors in the Korean stock market. However, as shown in the previous subsection, portfolios formed on *OP* have weak patterns of average returns, while portfolios formed on OP^q have stronger empirical patterns in our sample. Therefore, we substitute OP^q in place of *OP* in our factor construction.

The 2×3 sort is a familiar and usual way as Fama and French (1993) did. Taking the intersection of the two *Size* and three *B/M* groups, six portfolios are formed. The *Size* breakpoint is the KOSPI median and the *B/M* breakpoint is the 30^{th} and 70^{th} percentiles of the KOSPI stocks. We define $SMB_{B/M}$ as the average of three small size portfolios minus three big size portfolios and the value factor, HML, as the average of two high *B/M* portfolios minus two low *B/M* portfolios. Repeating the same procedure, $SMB_{OP}{}^q$ and the profitability factor RMW^q, SMB_{Inv} and the investment factor CMA can be similarly defined. Lastly, the size factor SMB is defined as the average of the size factors from each 2×3 sort: $SMB_{B/M}$, $SMB_{OP}{}^q$, and SMB_{Inv}. The 2×2 sort is not different from the 2×3 sort, except that the breakpoint of *B/M* (or OP^q, *Inv*) is the KOSPI median instead of the 30^{th} and 70^{th} percentiles (or OP^q, *Inv*, respectively).

In the $2 \times 2 \times 2 \times 2$ sort, *Size*, *B/M*, OP^q, and *Inv* are jointly controlled, taking intersection of the two *Size*, two *B/M*, two OP^q, and two *Inv* groups. For each variable, the breakpoint is the KOSPI median. SMB is defined as the average of 8 small portfolios minus 8 big portfolios. HML, RMW^q, and CMA are similarly defined. In the $2 \times 2 \times 2 \times 2$ sorts, each factor better isolates the premium in average returns related to the other three factors.

Table 2 reports summary statistics of average factor returns following FF (2015). Panel A of Table 2 shows means, standard deviations, and t-statistics for the five factors in each version of factor construction. Panel B of Table 2 shows the correlation matrices across the five factors in each version of factor construction. Panel C of Table 2 shows the correlation matrices between different versions of each factor.

In Panel A of Table 2, we report the averages, standard deviations, and the corresponding t-statistics of the FF factors. The average SMB return is 0.16% in the 2×3 sort, which is not statistically significant. Consistent with the results in Table 1, we observe no significant size premium in our sample, which is robust across the sorting method. HML earns more than monthly 1% returns, which is highly significant and robust to the sorting method. In the 2×3 sort, RMW^q and CMA earn about 0.65% monthly and highly significant. However, the mean returns of RMW^q and CMA vary significantly with their sorting method. Specifically, RMW^q earns 0.39% and 0.72% in the 2×2 and $2 \times 2 \times 2 \times 2$ sorts, and CMA earns 0.37% and 0.25% in the 2×2 and $2 \times 2 \times 2 \times 2$ sorts.

In Panel B of Table 2, we show correlations of the FF factors. Notably, we find high correlation of CMA and RMW^q to the other factors in the double sorts. CMA is positively correlated with HML and negatively correlated with RMW^q, and RMW^q is negatively correlated with SMB. Given that correlations, we understand the results that RMW^q and CMA returns are quite different in the $2 \times 2 \times 2 \times 2$ sorts because they are highly correlated with the others. In addition, we report correlations between different versions of the same factor in Panel C of Table 2. As shown in Panel A, SMB and HML seem quite robust across the sorting method. RMW^q is less robust with its lowest correlation of 0.73, and CMA is the least robust with its lowest correlation of 0.61.

To summarize, the mean excess returns of the factors are highest in the 2×3 sort with an exception of RMW^q. Especially, CMA earns much higher return in the 2×3 sort. Therefore, we use the factors from the classical 2×3 sort in our subsequent analyses. We use this 2×3 sorted measure not only to follow FF (2015), but also to reflect the empirical properties in the Korean market.

Although not reported in Table 2, RMW from the annual OP measure earns insignificant average returns.

HXZ (2014) construct the q-factors from an independent $2 \times 3 \times 3$ sort on *Size*, OP^q, and *Inv* in order to control for size when constructing the investment and the profitability factors. Taking the intersection of the two *Size*, the three *Inv*, and the three OP^q groups, total 18 portfolios are formed. The *Size* breakpoint is the KOSPI median. The OP^q and *Inv* breakpoints are the 30th and 70th percentiles of KOSPI stocks, respectively. The size factor, r_{ME}, is the difference between the average return of 9 small size portfolios and the average return of 9 big size portfolios. The investment factor, $r_{I/A}$, is the difference between the average return of 6 low *Inv* portfolios and the average return of 6 high *Inv* portfolios. Lastly, the profitability factor, r_{ROE}, is the difference between the average return of 6 high OP^q portfolios and the average return of 6 low OP^q portfolios.

According to Hou, Xue and Zhang (2016), the empirical difference between the HXZ factors and the FF factors is twofold. First, the quarterly ROE measure is different from the annual *OP* measure. Second, HXZ use triple sort, whereas FF use 2×3 double sort. In this paper, we use the same sorting variable in constructing FF and HXZ profitability factors. Therefore, we do not have the first difference, and the only difference between SMB, HML, and RMW^q and $r_{ME}, r_{I/A}$ and r_{ROE} in this paper is in the sorting method.

Table 3 reports the summary statistics of the q-factors in the Korean market. In Panel A, the overall average returns are quite similar to those in Table 2. Although r_{ME} earns 0.25% monthly, which is greater than 0.16% of SMB from the 2×3 sort, it is still statistically insignificant. In Panel B, except for the -0.20 correlation between r_{ME} and r_{ROE}, we find modest correlations among the factors, with their absolute values less than 0.1.

3 Empirical Evidence

3.1 Performance of the Alternative Models

In this subsection, we report the performance of alternative asset pricing models to explain the cross section of portfolios in the Korean market. If an asset pricing model describes the expected returns well, the intercept from a time-series regression of excess asset returns on the factors should be indistinguishable from zero. To test whether the intercepts are not jointly different from zero for all portfolios, we employ the GRS tests developed by Gibbons, Ross and Shanken (1989). The GRS statistic is computed as follows:

$$\text{GRS} = \frac{T-N-K}{N}\left[\frac{\hat{\alpha}'\hat{\Sigma}^{-1}\hat{\alpha}}{1+\bar{\mu}'\hat{\Omega}^{-1}\bar{\mu}}\right] \tag{3}$$

In the GRS statistic, N and K represent the number of test portfolios and factors, respectively. $\hat{\alpha}$ is an $N \times 1$ vector of estimated intercepts, $\hat{\Sigma}$ is an unbiased estimate of the residual covariance matrix, $\bar{\mu}$ is an $L \times 1$ vector of the factor portfolios' sample means where L is the number of factors, and $\hat{\Omega}$ is an unbiased estimate of the factor portfolios' covariance matrix. Under the null hypothesis that all intercepts of the N assets are jointly zero, the GRS statistics have the F-distribution with degree of freedom N and $T-N-K$. In this paper, the GRS statistic and the corresponding p-value are used to measure model performances.

As documented in the previous section, the annual profitability factor, RMW, earns insignificant average returns in our sample. Therefore, we focus on the FF five-factor model with the quarterly profitability factor, RMW^q. We call this five factor model as the adjusted FF five-factor model throughout this paper.

Table 4 reports the model performance summary of (1) the FF three-factor model, (2) three four-factor models with MKT, SMB, and two factors of HML, RMW^q, and CMA, (3) the adjusted FF five-factor model with MKT, SMB, HML, RMW^q, and CMA. The test assets in Panel A, B, C, and D are 16 value-weight portfolios sorted on *Size-B/M*, *Size-OP*, *Size-OP*^{q}, and *Size-Inv*, respectively. We report the GRS statistic with its corresponding p-value, together with the average absolute value of the intercept. In each column, we use the factors with different sorting methods, namely, the 2×3, 2×2, and $2 \times 2 \times 2 \times 2$ sorts. The regression equations are as follows:

$$r_{it} - r_{ft} = a_i + b' \boldsymbol{f_t} + \epsilon_t \qquad (4)$$

where $\boldsymbol{f_t}$ denotes the vector of factors. For example, for the FF three-factor model, $\boldsymbol{f_t} = [MKT_t \ \ SMB_t \ HML_t]$. In every regression in this paper, we use Newey and West (1987) standard errors with four lags to adjust for possible heteroscedasticity and autocorrelations to calculate the t-statistics and the GRS statistics.

We summarize the results in Table 4 in the following three observations. First, the adjusted FF five-factor model outperforms the FF three-factor model and the four-factor models. The GRS statistic tends to attain its minimum value when the five factors are used. Especially, we cannot reject the five-factor model in Panel A and D in 5% level of significance. This implies that the profitability and investment factors help explaining the cross-section of returns in the Korean market. Second, unlike Fama and French (2015) in the U.S. market, the HML factor is not redundant in the Korean market. Comparing the fourth and fifth rows of each Panel, we observe the GRS statistic and the average absolute intercept decrease when HML is introduced. Third, the quarterly profitability factor, RMW^q, has an important role in explaining the *Size-B/M*, *Size-OP*, and *Size-OP*^{q} portfolios. We find large decreases of the GRS statistic and the average absolute intercept in the fifth rows of Panel A, B, and C, compared the third rows where RMW^q is missing. This confirms that our use of the quarterly profitability factor is important in capturing the expected returns in the Korean market, compared to the results in Kim (2014) who uses annual profitability factor and finds weak evidence for its explanatory power.

Hou, Xue and Zhang (2016) argue that the empirical performance of their four-factor model is better than that of the FF five-factor model. Lee and Ohk (2015) show that the three-factor Chen, Novy-Marx and Zhang (2011) model with the market, investment, and profitability factors outperforms the FF three-factor model in the Korean market. Hence, we compare the FF three-factor model, the original and adjusted FF five-factor model, and the HXZ four-factor model in Table 5. We introduce one more variation of the HXZ model, which is the augmented HXZ model. The augmented HXZ model uses MKT, r_{ME}, r_{ROE}, $r_{I/A}$, and HML as its factors. We compare this model and the adjusted FF five-factor model to see the effect of different sorting method in factor construction. As noted in the last section, the only difference between the HXZ factors and the FF factors in this paper is in sorting method. Since Hou, Xue and Zhang (2016) argue that the joint control in sorting stocks is important and affects the empirical performance, we test whether the triple sort is better in the Korean market.

In Panel A, B, C, and D of Table 5, we use *Size-B/M*, *Size-OP*, *Size-OP*^{q}, and *Size-Inv* portfolios as test assets, respectively. We use five competing asset pricing models: the FF three-factor model (FF3), the FF five-factor model which uses annual RMW as its profitability factor (FF5), the FF five-factor model with quarterly RMW^{q} factor (AdjFF5), the HXZ four-factor model (HXZ), and the augmented HXZ model which uses MKT, HML, r_{ME}, $r_{I/A}$, and r_{ROE} as its factors (AugHXZ). Similar to Table 4, we report the GRS statistic with its p-value, and the average absolute intercept for each model. All factors used in the FF models are 2×3 sorted.

In Table 5, we first observe that the adjusted FF five-factor model always performs better than the original FF five-factor model. The adjusted model generates lower GRS statistics and average absolute intercepts. Therefore, the use of quarterly profitability factor instead of the annual one is crucial in explaining the cross-section of stock returns in the Korean market. This result is consistent with one of the critiques in Hou, Xue and Zhang (2016) that more recent profitability data have more correct information about the firm's profitability. Second, the adjusted FF five-factor model and augmented HXZ five-factor model always perform better than the HXZ four-factor model. Specifically, in Panel A and D, the adjusted FF five-factor model and augmented HXZ model are not rejected in the GRS test, whereas the original HXZ model is rejected in every Panel. This verifies that unlike the U.S. market, the HML factor is not redundant and helps explaining the cross-section of expected returns even in the existence of the other factors. Third, the adjusted FF five-factor model is better than the augmented HXZ five-factor model in Panels A, B, and C. The only difference between the two models is in the sorting method to construct the size, profitability, and investment factors. Although Hou, Xue and Zhang (2016) argue that their triple sort does a better job in empirical tests, that is not the case in our sample.

The results from the asset pricing tests in Table 5 indicate that HML, RMW^q, and CMA have their own roles in pricing the cross-section of returns. We take a further step to test this argument. In Table 6, we regress one of the adjusted FF five factors (MKT, SMB, HML, RMW^q, and CMA) on the other four factors. We focus on the intercepts, which are the factor returns unexplained by the remaining four. If the intercept of one dependent variable is insignificant, it means that the other four factors span the factor, which also implies that the factor is redundant in explaining the cross-section of returns in existence of the others.

The intercepts of HML, RMW^q, and CMA in Table 6 are positive and significant. The estimated intercepts are 0.73%, 0.79%, 0.61% per month, respectively. Compared to their time-series averages in Table 2, which are 1.05%, 0.65%, 0.66%, the unexplained parts of the factors are still substantial. In the RMW^q case, the intercept is even greater than its time-series average. In contrast, the intercepts from the regressions of MKT and SMB are 0.27% and 0.48%. The SMB intercept is three times greater than its original time-series mean (0.16%). However, it is still statistically insignificant. The overall level of the R^2s is quite low, with the maximum value of 0.14. In sum, the unexplained portion of the factors is quite large and it is only significantly positive in HML, RMW^q, and CMA cases. Therefore, we assure that those three factors are not subsumed by the others, so that each of them has its own role in explaining the cross-section of expected returns.

To summarize our horse-racing results in this subsection, we find that the adjusted FF five-factor model best explains the cross-section of portfolios sorted in *Size*, *B/M*, *OP* (OP^q), or *Inv*. Especially, it is not rejected when the test assets are sorted by *Size-B/M* or *Size-Inv*. In addition, the HML, RMW^q, and CMA are not redundant in the Korean market in presence of the other factors. In the next subsection, we further investigate the performance of the asset pricing models in this paper to explain a broad collection of anomalies in the Korean stock market.

3.2 Digesting Anomalies

In this subsection, we perform empirical horse races with the FF3, FF5, adjusted FF5, and HXZ models in capturing various anomalies in the Korean market. We consider a subset of anomalies discussed in Hou, Xue and Zhang (2014). The list of 34 anomalies and their definitions are in Appendix. The selected anomalies are categorized into five groups: value, investment, profitability, intangibles, and momentum. For each anomaly, we construct value-weight decile portfolios with KOSPI breakpoints, and examine whether the tenth-minus-first excess returns are significantly positive.

Table 7 reports the results of digesting 10 anomalies which are significant in our sample. In the first and second rows, we report the mean of the tenth-minus-first excess returns for each anomaly and its t-statistics. We report the average absolute alphas from 10 portfolios, the GRS statistics and their p-values for each asset pricing model.

The monthly anomaly excess returns exhibit 1.05% to 2.23%. In momentum portfolio returns, Ri_j stands for the one-month returns calculated from the portfolios sorted on the holding period returns from $t-1-i$ to $t-1-j$. We observe strong momentum returns in our sample with various specifications of formation periods (R6_1, R11_1, and R11_6). The significant R11_6 excess return is called the intermediate term momentum, which is documented in Novy-Marx (2012).

The average absolute alphas from the FF three-factor model range in 0.23% ~ 0.62% with the mean of 0.4%, and the GRS statistic cannot reject the model in three anomalies. Although the FF three-factor model helps explaining some anomalies, it is not enough to digest the anomalies. The FF five-factor model shows some improvement from the FF three-factor model. The mean of average absolute alphas is 0.37%, and we cannot reject the FF five-factor model with 5% level of significance in 7 out of 10 anomalies. The adjusted FF five-factor model shows the best performance among the tested models. Its mean of average absolute alphas is 0.32%, and it cannot be rejected in 8 out of 10 anomalies. The performance of the HXZ model is comparable to that of the FF five-factor model. The mean of average absolute intercepts is 0.37%, and it is not rejected in 8 anomalies.

Comparing the adjusted FF five-factor model and the HXZ model, the adjusted FF five-factor model dominates the HXZ model in six anomalies in the sense that it generates lower average absolute intercepts and lower GRS statistics, whereas the HXZ model dominates only in one anomaly. The two anomaly portfolios that are not explained by the tested models are those sorted on cash flow-to-price (CF/P) and R11_6. Although the adjusted five-factor model cannot digest the intermediate term momentum, it helps explaining various anomaly portfolio returns which are related to size, value, investment, profitability, and momentum. Also, its ability to digest anomalies is stronger than that of the FF three-factor model, the FF five-factor model, and the HXZ four-factor model. The results from the analysis in this section confirm the superiority of the adjusted FF five-factor model in capturing the cross-section of expected returns in the Korean stock market.

4 Conclusion

This paper compares newly introduced asset pricing models in the Korean stock market. The asset pricing models tested are the FF three-factor model, the FF five-factor model, the HXZ q-factor model and their variations. To evaluate asset pricing models, we mainly perform time-series regressions of test portfolios sorted on size, book-to-market, profitability, investment, and other anomaly variables. We use the average absolute intercepts the GRS F-statistics as our criteria to compare the pricing performance.

The overall results show that the adjusted FF five-factor model with the quarterly-based profitability factor best describes the cross-section of stock returns in Korea. The results indicate that the value factor, HML, is an important factor under the existence of the investment and profitability factors, and that the use of RMW^q, the quarterly-based profitability factor is crucial in improving the asset pricing performance. In addition, we find strong evidence that the adjusted five-factor model shows best performance in digesting various anomaly returns in the Korean market including momentum.

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Table 1. Summary statistics of double sorted portfolios

This table reports average monthly excess return for value-weight portfolios formed on *Size* and *B/M*, *Size* and *OP*, *Size* and OP^q, *Size* and *Inv*; July 2002 – June 2015, 156 months. *Size* is measured as market capitalization at June of year t. *B/M* is measured as book value at the fiscal year ending in year $t-1$ divided by market value at the end of December of year $t-1$. Operating profitability, *OP*, is measured as operating profit divided by book value in the fiscal year ending in year $t-1$. Quarterly-based profitability, OP^q, is measured as operating profit in the most recent public quarterly earnings announcement divided by one-quarter-lagged book equity. Investment, *Inv*, is the growth rate in total assets from the fiscal year ending in year $t-2$ to the fiscal year ending in year $t-1$. At the end of June of year t, Stocks are allocated to four *Size* and *B/M* groups to form 16 *Size-B/M* portfolios, using KOSPI breakpoints. 16 *Size-OP*, *Size-*OP^q, and 16 *Size-Inv* portfolios are constructed in the same way as 16 *Size-B/M* portfolios, except that the second sorting variable is *OP*, OP^q, and *Inv*, respectively.

	Low	2	3	High	HML	t(HML)
Panel A: *Size-B/M* portfolios						
Small	0.09	1.13	1.44	1.79	1.69	3.69
2	-0.02	0.62	1.35	1.60	1.62	3.60
3	-0.02	0.91	1.49	1.70	1.72	3.93
Big	0.40	0.98	1.35	1.69	1.29	2.24
SMB	-0.31	0.15	0.09	0.10		
t(SMB)	-0.54	0.29	0.18	0.16		
Panel B: *Size-OP* portfolios						
Small	0.48	1.63	1.31	1.17	0.69	2.10
2	0.06	1.20	1.00	0.64	0.59	1.98
3	0.23	1.00	0.89	0.60	0.37	1.23
Big	1.30	0.99	0.57	0.44	-0.86	-2.00
SMB	-0.82	0.63	0.74	0.72		
t(SMB)	-1.43	1.33	1.61	1.44		
Panel C: *Size-*OP^q portfolios						
Small	0.11	1.49	1.53	1.57	1.47	4.50
2	-0.07	0.68	1.10	1.11	1.18	3.74
3	0.00	0.90	1.06	0.78	0.77	2.53
Big	0.13	0.97	0.80	0.43	0.29	0.71
SMB	-0.03	0.52	0.73	1.15		
t(SMB)	-0.05	1.07	1.51	2.45		
Panel D: *Size-Inv* portfolios						
Small	1.11	1.30	1.17	0.58	-0.53	-2.11
2	0.63	1.19	1.13	0.05	-0.58	-2.17
3	0.96	1.20	0.73	0.21	-0.75	-2.58
Big	1.09	0.58	0.69	0.27	-0.82	-2.31
SMB	0.03	0.72	0.48	0.32		
t(SMB)	0.05	1.54	0.96	0.65		

Table 2. Summary statistics of the FF five factors

This table displays summary statistics for monthly FF five factor returns from July 2002 to June 2015, 156 months. MKT is the market excess return. SMB (Small-minus-big), HML (High-minus-low), RMW^q (Robust-minus-weak), and CMA (Conservative-minus-aggressive) are the size, value, quarterly profitability, and investment factor, respectively. Panel A shows means, standard deviations, and t-statistics of the five factors in each version of factor construction. Panel B shows the correlation matrices with the corresponding p-values across the five factors in each version of factor construction. Panel C shows the correlation matrices between different versions of each factor.

Panel A: Averages, standard deviations, and t-statistics for monthly returns

	2 x 3 Factors					2 x 2 Factors					2 x 2 x 2 x 2 Factors				
	MKT	SMB	HML	RMW^q	CMA	MKT	SMB	HML	RMW^q	CMA	MKT	SMB	HML	RMW^q	CMA
Mean	0.52	0.16	1.05	0.65	0.66	0.52	0.13	1.00	0.39	0.37	0.52	0.07	1.03	0.72	0.25
Std dev.	5.81	4.43	3.85	2.95	2.32	5.81	4.57	2.69	2.21	1.82	5.81	4.22	2.79	2.26	1.76
t-Statistic	1.12	0.45	3.41	2.75	3.57	1.12	0.37	4.65	2.20	2.55	1.12	0.20	4.60	3.96	1.78

Panel B: Correlations and their corresponding p-values between different factors

	2 x 3 Factors					2 x 2 Factors					2 x 2 x 2 x 2 Factors				
	MKT	SMB	HML	RMW^q	CMA	r_m-r_f	SMB	HML	RMW^q	CMA	MKT	SMB	HML	RMW^q	CMA
MKT	1.00	-0.04	-0.03	0.14	-0.03	1.00	-0.03	-0.01	0.08	-0.07	1.00	-0.11	0.09	0.15	-0.07
		0.58	0.75	0.07	0.72		0.71	0.89	0.30	0.40		0.19	0.26	0.06	0.36
SMB	-0.04	1.00	-0.08	-0.18	-0.01	-0.03	1.00	-0.12	-0.20	0.04	-0.11	1.00	-0.22	-0.19	-0.05
	0.58		0.33	0.02	0.87	0.71		0.15	0.01	0.66	0.19		0.01	0.02	0.57
HML	-0.03	-0.08	1.00	-0.04	0.29	-0.01	-0.12	1.00	-0.03	0.42	0.09	-0.22	1.00	0.43	0.00
	0.75	0.33		0.64	0.00	0.89	0.15		0.72	<.0001	0.26	0.01		<.0001	1.00
RMW^q	0.14	-0.18	-0.04	1.00	-0.27	0.08	-0.20	-0.03	1.00	-0.37	0.15	-0.19	0.43	1.00	-0.13
	0.07	0.02	0.64		0.00	0.30	0.01	0.72		<.0001	0.06	0.02	<.0001		0.10
CMA	-0.03	-0.01	0.29	-0.27	1.00	-0.07	0.04	0.42	-0.37	1.00	-0.07	-0.05	0.00	-0.13	1.00
	0.72	0.87	0.00	0.00		0.40	0.66	<.0001	<.0001		0.36	0.57	1.00	0.10	

Panel C: Correlations between different versions of the same factor

	SMB			HML			RMW^q			CMA		
	2 x 3	2 x 2	2 x 2 x 2 x 2	2 x 3	2 x 2	2 x 2 x 2 x 2	2 x 3	2 x 2	2 x 2 x 2 x 2	2 x 3	2 x 2	2 x 2 x 2 x 2
2 x 3	1.00	0.99	0.96	1.00	0.84	0.81	1.00	0.85	0.73	1.00	0.80	0.61
2 x 2	0.99	1.00	0.96	0.84	1.00	0.92	0.85	1.00	0.82	0.80	1.00	0.72
2 x 2 x 2 x 2	0.96	0.96	1.00	0.81	0.92	1.00	0.73	0.82	1.00	0.61	0.72	1.00

Table 3. Summary statistics of the HXZ four factors

This table shows summary statistics of monthly HXZ factor returns from July 2002 to June 2015, 156 months. MKT is the value-weight return on the market portfolio in excess of the one-year monetary stabilization bond yield. r_{ME}, r_{ROE}, and $r_{I/A}$ are the size, profitability, and investment factor, generated from the $2 \times 3 \times 3$ sort of Size, OP^q, and Inv, respectively. The breakpoints are KOSPI median, and 30^{th} and 70^{th} percentiles. Panel A shows means, standard deviations, and t-statistics. Panel B shows the correlation matrix across the four HXZ factors and their p-values.

Panel A: Averages, standard deviations, and t-statistics for monthly returns

	$2 \times 3 \times 3$ Factors			
	MKT	r_{ME}	r_{ROE}	$r_{I/A}$
Mean	0.52	0.25	0.68	0.64
Std dev.	5.81	4.29	2.53	2.15
t-Statistic	1.12	0.72	3.34	3.71

Panel B: Correlations and their corresponding p-values between different factors

	$2 \times 3 \times 3$ Factors			
	MKT	r_{ME}	r_{ROE}	$r_{I/A}$
MKT	1.00	-0.09	0.05	-0.08
		0.25	0.51	0.31
r_{ME}	-0.09	1.00	-0.20	-0.08
	0.25		0.01	0.33
r_{ROE}	0.05	-0.20	1.00	0.02
	0.51	0.01		0.78
$r_{I/A}$	-0.08	-0.08	0.02	1.00
	0.31	0.33	0.78	

Table 4. Model performance summary: the FF models and their variations

This table displays summary statistics for tests of three-, four-, and five-factor models inherited from the adjusted FF five-factor model; July 2002 - June 2015, 156 months. In each column, $|a_i|$ denotes the average absolute value of the intercepts, and GRS and p-val denote the GRS statistic and the corresponding p-value under the null hypothesis that all 16 intercepts are jointly zero.

	Adjusted FF five-factor model								
	2×3 Factors			2×2 Factors			$2 \times 2 \times 2 \times 2$ Factors		
	GRS	p-val	$\|a_i\|$	GRS	p-val	$\|a_i\|$	GRS	p-val	$\|a_i\|$
Panel A: 16 *Size-B/M* portfolios									
HML	2.232	0.007	0.334	1.458	0.124	0.245	1.515	0.102	0.226
HML RMW^q	1.886	0.027	0.278	1.278	0.220	0.221	1.598	0.077	0.225
HML CMA	2.111	0.011	0.307	1.486	0.114	0.247	1.432	0.136	0.212
RMW^q CMA	1.805	0.036	0.439	1.962	0.020	0.505	1.959	0.020	0.517
HML RMW^q CMA	1.540	0.095	0.235	1.230	0.254	0.224	1.438	0.133	0.218
Panel B: 16 *Size-OP* portfolios									
HML	3.197	0.000	0.331	3.084	0.000	0.330	2.959	0.000	0.316
HML RMW^q	2.737	0.001	0.313	2.911	0.000	0.320	3.061	0.000	0.317
HML CMA	3.502	0.000	0.359	3.101	0.000	0.334	3.224	0.000	0.340
RMW^q CMA	3.150	0.000	0.343	3.323	0.000	0.361	3.826	0.000	0.404
HML RMW^q CMA	2.803	0.001	0.334	2.850	0.001	0.323	3.228	0.000	0.343
Panel C: 16 *Size-OP^q* portfolios									
HML	3.220	0.000	0.397	2.751	0.001	0.382	2.762	0.001	0.351
HML RMW^q	2.636	0.001	0.344	2.383	0.004	0.320	2.442	0.003	0.003
HML CMA	3.105	0.000	0.415	2.793	0.001	0.390	3.034	0.000	0.378
RMW^q CMA	2.477	0.002	0.369	2.924	0.000	0.392	3.022	0.000	0.412
HML RMW^q CMA	2.214	0.007	0.349	2.291	0.005	0.329	2.619	0.001	0.339
Panel D: 16 *Size-Inv* portfolios									
HML	2.031	0.015	0.266	1.570	0.085	0.241	1.621	0.071	0.238
HML RMW^q	2.233	0.007	0.303	1.780	0.040	0.271	1.748	0.045	0.258
HML CMA	1.578	0.083	0.243	1.606	0.075	0.244	1.451	0.128	0.232
RMW^q CMA	1.811	0.035	0.270	2.285	0.005	0.331	2.076	0.013	0.356
HML RMW^q CMA	1.478	0.116	0.248	1.622	0.071	0.263	1.498	0.109	0.242

Table 5. Model performance summary: the FF and HXZ models

This table reports the summary statistics for tests of the FF and HXZ models and their variations. The models are the FF three-factor model (FF3), the FF five-factor model (FF5), the adjusted FF five-factor model (AdjFF5), the HXZ model (HXZ), and the augmented HXZ model (AugHXZ). In Panel A, B, C, and D, the test assets are 16 *Size-B/M* portfolios, 16 *Size-OP* portfolios, 16 *Size-OP^q^* portfolios, and 16 *Size-Inv* portfolios, respectively. $A|a_i|$ is the average absolute intercept, GRS is the GRS F-statistic, and p-val is the p-value for the GRS statistic.

	Panel A: 16 Size-B/M portfolios					Panel B: 16 Size-OP portfolios				
	FF3	FF5	AdjFF5	HXZ	AugHXZ	FF3	FF5	AdjFF5	HXZ	AugHXZ
$A|a_i|$	0.310	0.258	0.235	0.471	0.276	0.334	0.357	0.334	0.360	0.336
GRS	2.158	1.761	1.540	1.938	1.659	3.137	3.133	2.803	3.155	3.024
p-value	0.009	0.043	0.095	0.022	0.062	0.000	0.000	0.001	0.000	0.000
	Panel C: 16 Size-OP^q portfolios					Panel D: 16 Size-Inv portfolios				
	FF3	FF5	AdjFF5	HXZ	AugHXZ	FF3	FF5	AdjFF5	HXZ	AugHXZ
$A|a_i|$	0.390	0.390	0.349	0.389	0.383	0.260	0.268	0.248	0.279	0.246
GRS	3.123	2.762	2.214	2.644	2.600	1.974	1.654	1.478	1.791	1.394
p-value	0.000	0.001	0.007	0.001	0.001	0.019	0.063	0.116	0.038	0.154

Table 6. Using four factors in regressions to explain returns on the fifth

This table shows the regression results from the regressions to explain the fifth factor using four factors from the adjusted FF five-factor model. The intercept and slope coefficients are displayed with their Newey-West t-statistics with four lags.

	Int	MKT	SMB	HML	RMW^q	CMA	R^2
MKT							
coeff	0.27		-0.01	-0.04	0.40	0.07	0.04
t-stat	0.53		-0.09	-0.30	2.39	0.31	
SMB							
coeff	0.48	-0.01		-0.09	-0.28	-0.07	0.04
t-stat	1.23	-0.09		-0.93	-2.21	-0.41	
HML							
coeff	0.73	-0.02	-0.06		0.02	0.48	0.09
t-stat	2.27	-0.30	-0.93		0.19	3.62	
RMW^q							
coeff	0.79	0.09	-0.11	0.01		-0.31	0.12
t-stat	3.35	2.39	-2.21	0.19		-3.09	
CMA							
coeff	0.61	0.01	-0.02	0.17	-0.19		0.14
t-stat	3.25	0.31	-0.41	3.62	-3.09		

Table 7. Digesting Anomalies

This table reports the summary statistics of the anomaly excess returns and the tests to digest anomalies. In the first and second rows, the means (m) and their t-statistics (t(m)) of the excess returns of tenth-minus-first value-weight decile portfolios are displayed. For each model, the average absolute values of intercepts across a given set of deciles and the GRS statistics with the corresponding p-values are reported. In the last column, the simple average of the estimated average absolute intercepts is reported. The definition of the anomaly variables is in Appendix.

		Value-versus-Growth				Investment	Profitability	Intangibles	Momentum			Average
		A/ME	E/P	CF/P	OCF/P	NOA	ROA^q	Ad/M	R6_1	R11_1	R11_6	
	m	1.428	1.089	2.005	1.150	1.050	1.094	1.123	2.224	2.096	1.325	
	t(m)	2.53	2.12	3.88	2.26	2.10	2.22	2.59	3.44	3.13	2.12	
FF3	$\|a_{FF3}\|$	0.235	0.303	0.448	0.414	0.299	0.334	0.321	0.488	0.624	0.562	0.403
	GRS	0.891	1.090	3.141	2.143	1.607	1.462	1.752	2.132	2.307	3.306	
	p-value	0.543	0.374	0.001	0.025	0.110	0.160	0.075	0.026	0.015	0.001	
FF5	$\|a_{FF5}\|$	0.255	0.292	0.419	0.431	0.295	0.271	0.299	0.405	0.478	0.536	0.368
	GRS	0.985	0.924	2.803	1.923	1.429	1.006	1.473	1.613	1.860	2.752	
	p-value	0.459	0.513	0.003	0.047	0.173	0.442	0.156	0.109	0.056	0.004	
$FF5^q$	$\|a_{FF5q}\|$	0.206	0.271	0.371	0.413	0.317	0.258	0.292	0.288	0.346	0.502	0.326
	GRS	0.664	0.893	2.219	1.713	1.558	0.632	1.285	1.294	1.739	2.438	
	p-value	0.756	0.541	0.020	0.083	0.125	0.785	0.245	0.239	0.078	0.010	
HXZ	$\|a_{HXZ}\|$	0.406	0.387	0.450	0.370	0.321	0.313	0.260	0.352	0.349	0.498	0.371
	GRS	0.832	1.474	2.961	1.754	1.435	0.892	1.174	1.305	1.807	2.897	
	p-value	0.599	0.155	0.002	0.074	0.171	0.543	0.313	0.233	0.064	0.003	

Appendix. Definition of Anomalies

1. List of Anomalies

A. Value-versus-growth

E/P	Earning-to-price	A/ME	Market Leverage
OCF/P	Cash flow from operations-to-price	CF/P	Cash flow-to-price
D/P	Dividend yield		

B. Investment

IvC	Inventory changes	NOA	Net operating assets
dPI/A	Changes in property, plant, and equipment plus changes in inventory scaled by assets	IvG	Inventory growth
OACC	Operating accruals	POACC	Percent operating accruals

C. Profitability

ROA	Yearly-based return on assets	ROA^q	Quarterly-based return on assets
CTO	Capital turnover	GP/A	Gross profits-to-assets

D. Intangibles

Ad/M	Advertisement expense-to-market	RD/S	R&D-to-sales
RD/M	R&D-to-market	OL	Operating leverage

E. Momentum

Ri_j	Prior returns from $t-i-1$ to $t-j$, skipping $t-1$. Holding period is fixed to one-month at t.

2. Definition of Anomaly Variables

A. Value-versus-growth

E/P At the end of June of year t, E/P is measured with operating income at the end of the fiscal year t-1 divided by market capitalization excluding preferred stocks at the end of June of year t.

A/ME At the end of June of year t, A/ME is measured with total assets at the end of the fiscal year t-1 divided by market capitalization excluding preferred stocks at the end of June of year t.

OCF/P At the end of June of year t, OCF/P is measured with cash flow from operations at the end of the fiscal year t-1 divided by market capitalization excluding preferred stocks at the end of June of year t.

CF/P At the end of June of year t, CF/P is measured with cash flow at the end of the fiscal year t-1 divided by market capitalization excluding preferred stocks at the end of June of year t.

D/P At the end of June of year t, D/P is measured with dividends at the end of the fiscal year t-1 divided by market capitalization excluding preferred stocks at the end of June of year t, if paying dividends.

B. Investment

IvC At the end of June of year t, IvC is measure with changes in inventory from the fiscal year t-2 to t-1.

NOA At the end of June of year t, NOA is measured with operating assets minus operating liabilities where operating assets are total assets minis cash and short-term investment and operating liabilities are total assets minus debt included in current liabilities, minus long-term debt, minus preferred stocks, and minus common equity.

dPI/A At the end of June of year t, dPI/A is measured with changes in property, plant, and equipment plus changes in inventory in the fiscal year of t-1 scaled by total assets in the fiscal year of t-2.

IvG At the end of June of year t, IvG is measured with inventory at the end of the fiscal year of t-

1 divided by inventory at the end of the fiscal year of t-1, minus one. In other word, it is the growth rate of inventory from the fiscal year t-2 to t-1.

OACC At the end of June of year t, OACC is measured with net incomes minus cash flow from operation at the end of the fiscal year of t-1 divided by one-year-lagged total assets.

POACC At the end of June of year t, POACC is measured with net incomes minus cash flow from operations at the end of the fiscal year of t-1 divided by net incomes at the end of the fiscal year of t-1.

C. Profitability

ROA At the end of June of year t, ROA is measured with operating profit at the end of the fiscal year of t-1 divided by total assets at the end of the fiscal year of t-1.

ROA^q In each month, ROA^q is measured with operating profit in the most recent public quarterly earnings announcement divided by one-quarter-lagged total assets.

CTO At the end of June of year t, CTO is measured with sales at the end of the fiscal year of t-1 divided by one-year-lagged total assets.

GP/A At the end of June of year t, GP/A is measured with sales minus cost of good sold scaled by total assets at the end of the fiscal year of t-1.

D. Intangibles

Ad/M At the end of June of year t, Ad/M is measured with advertisement expenses at the end of the fiscal year of t-1 divided by market capitalization at the end of June of year t.

RD/S At the end of June of year t, RD/S is measured with R&D expenses divided by sales at the end of the fiscal year of t-1, if R&D expenses are positive.

RD/M At the end of June of year t, RD/M is measured with R&D expenses at the end of the fiscal year of t-1 divided by market capitalization at the end of June of year t.

OL At the end of June of year t, OL is measured with cost of goods sold plus selling, general, and administrative expenses, all divided by total assets at the end of the fiscal year of t-1.