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On the information content of new asset pricing factors in the UK

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1. Introduction

Asset pricing models have been widely employed in the academic literature to capture variations of stock returns. Due to their influence in the finance literature, numerous researchers have investigated the properties of three factor models mainly using US and international data. However, the performance of the most widely used models such as the Fama-French (FF) three factor model were subject to criticism. When the FF three factor model is employed as the baseline model, many papers have shown relation between additional factors and the cross-section of stock returns (Harvey, Liu and Zhu, 2015). Empirical asset pricing researchers therefore have proposed new factor models aimed to improve the three-factor model. Fama and French (2015a) propose a new five factor model which extends the FF three factor model, using profitability and investment factors. Hou, Xue and Zhang (2015), by contrast, use a four factor model with a different formation of profitability factors and making value factor redundant. Both Fama and French (2015a) and Hou, Xue and Zhang (2015) show the performance of their new factor models by using various sorted portfolios on the left hand side. Although both new papers justify the economic interpretation of their factor models, the new factor models are believed to be empirically motivated. They use US data and show that the new factor models outperform the Fama-French three factor model and that the majority of capital market anomalies are subsumed by the new models.

For newly proposed US factor models, out-sample testing is desirable from a practical perspective. Fama and French (2012) test and find inconsistent performance of their three-factor model in describing international stock return cross-sections. Fama and French (2015c), as a follow up, examine the power of their five factor model using international regional data. Interestingly, significant differences in model performance are reported between North America, Europe, Asia Pacific and Japan. For instance, the value factors are found redundant in the North America while in Europe, investment factors and size factors merely provide any information. These regional differences therefore suggest that researchers need to keep abreast for the use of new factor models outside the US markets. Moreover, Fama and French (2012, 2015c) both suggest that regional constructed factor models out-perform global models. Griffin (2002) compares the performance of FF three factor model between regional level and country level and concludes that country-level factor models have better performance. In the UK, past literature has followed Griffin (2002) and focused on local FF three factor model performance. Discernible differences from the US results have also been reported (Michou, Sulaiman and Stark, 2014; Grogery, Tharyan and Christidis, 2013). However, there is limited evidence on the performance of new factor models in the UK. The first contribution of this study is to fill this gap by testing the performance of new factor models using a UK sample during the period between June 1990 to December 2013.

Another crucial issue for new empirical asset pricing models is the choice of factors. Evidence suggests that the information content of new asset pricing factors is sensitive to factor variable defintion and construction methods (Fama and French, 2015b). Different choices of factor variable definition have been proposed for five factor models, especially with respect to profitability factors. For instance, Fama and French (2015a) follow Norwy-Marx (2013) and construct their profitability factor using operating profitability scaled by

book value. Hou, Xue and Zhang (2015) instead use income before extraordinary items as the numerator of their profitability measure. Fama and French (2015b) compare alternative factor forms such as cash profitability (Ball et al, 2015) and quality minus junk (Asness et al, 2013). Their results suggest that using cash profitability measures and the small end constructing method improve the five factor model performance. The arbitrary nature of factor construction is more pervasive outside the US market. For instance, Michou, Sulaiman and Stark (2014) find that researchers using UK data construct SMB and HML in nine different ways. It is therefore reasonable, in the early stage of new model development, to test the sensitivity of new factor model performance to the choices of factor construction. The second object of this paper is to provide insight on the choice of factor construction method in the UK.

Given the above discussion, the main aim of the paper is to cast light on the efficiency of new asset pricing factors in the UK as a way of controlling for risk in UK asset pricing research. Our paper has the following contributions: we are the first to illustrate how profitability and investment influence stock return patterns in the UK stock market. Secondly, our paper provides evidence for the information content of new asset pricing factors in the UK as there is very limited evidence on how new factor models perform on UK data specifically. In addition, our paper contributes to the stream of literature related to the sensitivity of factor choices. We employ alternative profitability measures seeking to find the most effective profitability factors in the UK market.

We attempt a number of tasks within the overall objective of evaluating the performance of five factor models in the UK. First, we ask whether there are profitability and investment patterns across UK stock returns. Secondly, we construct various versions of new asset pricing factors and test whether they are statistically different from zero. Third, we use factor spanning tests to examine the relative informativeness of all versions of the asset pricing factors, especially the profitability factors. Finally, we employ time series asset pricing tests to compare the performance of new asset pricing models, seeking to find effective forms of new factors models in the UK.

Our sorted portfolio returns suggest that the size effect does not exist, while value effect is significant in the UK market, which is consistent with previous academic evidence (Michou, Sulaiman and Stark, 2014; Grogery, Tharyan and Christidis, 2013). For our new profitability factor and investment factor, distinguishable stock return effects are evident in the UK market.

Spanning tests produce initial results for the choice of new factor models. Firstly, we find consistent results that SMB does not provide additional information uncaptured by the other factors, which suggest that SMB is a redundant factor in the UK. Secondly, we find that the value factor HML is spanned by the new factors, using small end does not save the value factor. This result is consistent with the findings in the US market (Fama and French, 2015a). Thirdly, the investment factor provides information uncaptured by the other factors. The use of small end factor construction method further improve its information content. For profitability factors, our evidence suggests that using total asset as the denominator does provide extra information compared with those scaled by book equity. Amongs the three versions of profitability measures used, operating income and income before extraordinary

items outperform gross profit. However, the interaction between choices of construction methods and scaler makes it difficult to decide the best profitability factor.

GRS tests results are in general consistent with factor spanning tests. We use sorting combinations of size-Book- to –Market (B/M), size-profitability and size-Investment (I/A). We compare more than 20 versions of factor models in terms of their asset pricing test performance. GRS tests confirm that SMB and HML are redundant factors in the UK. The results further show that using operating profit or income before extraordinary items produce best profitability factors. However, the choice of scaler and small/normal end factor is sensitive to portfolio sorting methods. Instead of a five factor model, athree factor model including a market factor (RM-RF), an investment factor (CMA_S) and a profitability factor (RMW) explain most of the variations across sorted portfolio returns in the UK. The structure of the papers has as follows: section 2 explains the model, section 3 describes the variables definition and the methodology used, section 4 presents the results and section 5 concludes.

2. New asset pricing model

Following Fama and French (2015a) and Hou, Xue and Zhang (2015), the general time-series regression model for the five-factor model is given in the equation below:

$$R_{it} - R_{ft} = \alpha_p + \beta_1(R_{mt} - R_{ft})_t + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 RMW_t + \beta_5 CMA_t + e_{it}$$

where:

R_{it} is the return of asset *i* in month *t*;

R_{ft} is the three-month T-bill rate from the UK in month *t*;

R_{mt} is the return on the market in the UK in month *t*;

SMB_t is size factor small minus big;

HML_t is value factors high minus low of Book to market equity;

RMW_t is robust minus weak factor for profitability;

CMA_t is conservative minus aggressive for investment factor

Both Fama and French (2015a) and Hou, Xue and Zhang (2015) augment the FF three factor model with investment factor, and profitability factor. Hou, Xue and Zhang (2015) make the value factor HML redundant and use a different definition for profitability factor variable. Fama and French (2015a) also find empirical evidence of the redundancy of HML using the US data. They suggest it could be specific to their sample selection. Fama and French (2015c) confirm this point of view, but further differences in the information content of new factors are reported across different regions. Under the general form of the five factor model, we test various versions of the model above with respect to factor redundancy, variable formation, and construction methods with our UK sample.

3. Data and Method

3.1 Data and variables

Our resource data for monthly stock returns is the London Business School Share Price Database (LSPD) and accounting information have been extracted from Datastream, covering the period from January 1990 to December 2013. Consistent with the literature (Michou, Sulaiman and Stark, 2014; Gregery, Tharyan and Christidis, 2013), we exclude stocks from the financial sector, companies with negative/missing book values and companies with more than one class of share. However we include companies that have been de-listed from the UK stock exchange due to merger or bankruptcy. The distribution of firms available across our sample period is illustrated in table 1 .Our sample is used to construct time series asset pricing factors and left hand side portfolios for asset pricing tests.

[Table 1]

3.2 Factor variable definition

For the original FF three factor model, we follow the standard definition. $(R_{mt} - R_{ft})$ is the market factor. R_{mt} is the return of FT All Share Index; R_{ft} is the monthly return of one month UK Treasury Bill rate. The size factor (SMB) is the difference between small minus big firms based on market capitalization. The HML factor is the difference between high minus low book to market firms (B/M) .

The investment factor variable is defined following Hou, Xue and Zhang (2015), which is measured using change in total assets from year *t-2* to Year *t-1*, divided by total asset (TA) at Year t-2. We use Datastream total asset (WC02999) to calculate the investment measure, denoted by I/A.

We use three different measures for the profitability variable: firstly, we follow Fama and French (2015a) and Norwy-Marx (2013) using $(operating\ income/BE)_{t-1}$. The second profitability measure is $(income\ before\ extraordinary\ items/BE)_{t-1}$ following Hou, Xue and Zhang, 2015. We also follow Norwy-Marx (2013) to use $(gross\ profit/BE)_{t-1}$ as the third measure. Finally, we follow Ball et al (2015) to replace the denominator of the three profitability measures with Datastream total asset (WC02999). Altogether, we test six profitability formations.

3.3 Factor construction

Our asset pricing factors are constructed in line with the Fama and French style factors. We construct six independently sorted portfolios using size and the corresponding factor variable. Following Gregory, Tharyan and Christidis (2013), we use the break points from the UK largest 350 stocks each year simulating NYSE break points in the US market to sort factor construction portfolios. At the end of June each year from 1990 to 2013, stocks are allocated to two size groups based on the median size of the largest 350 stocks at the end of year *t-1*.

Stocks are sorted independently into three groups of other variables such as Book-to-Market (B/M), Investment (I/A) and six forms of profitability using 30th and 70th percentiles from the largest 350 stocks as breakpoints based on data at the end of year *t-1*. The intersections of size sorting and the other variable sorting leads to six portfolios, which are used to produce corresponding factor return time-series.

These independently sorted portfolios are labelled using letters: for size group, small (S) or big (B); B/M group, high (H), neutral (N), or low (L); profitability group, robust (R), neutral (N), or weak (W); I/A group, conservative (C), neutral (N), or aggressive (A). Intersected portfolios are obtained to build the factors. Value-weighted (VW) returns are calculated for each portfolio. For example, SL stands for the monthly value weighted return of intercepted portfolio with small size and low B/M.

The factors are obtained using the formula stated in the table 2. For instance, each month the normal value factor HML is defined as the difference between the simple average of the VW returns on two high-B/M-stock portfolios (SH and BH) and the simple average of the VW returns on two losing-stock portfolios (SL and BL). In order to differentiate the profitability factors (RMW), we name its different versions as follows:

OP_B for factors obtained using $(\boldsymbol{operating\ income/BE})_{t-1}$;
OP_A for factors obtained using$(\boldsymbol{operating\ income/TA})_{t-1}$;
ROE_B for factors obtained using$(\boldsymbol{income\ before\ extraordinary\ items/BE})_{t-1}$;
ROE_A for factors obtained using $(\boldsymbol{income\ before\ extraordinary\ items/TA})_{t-1}$;
GRO_B for factors obtained using $(\boldsymbol{gross\ profit/BE})_{t-1}$;
GRO_A for factors obtained using $(\boldsymbol{gross\ profit/TA})_{t-1}$;

In addition to the normal factor construction, we follow the Fama and French (2015b) and calculate alternative value, profitability and investment factors using the small end of sorted portfolios to test whether they outperform their normal peers. For instance, the six portfolios used to produce investment factors are SC (small and conservative), SN (small and neutral), SA (small and aggressive), BC (big and conservative), BN (big and neutral) and BA (big and aggressive). The standard investment factor (CMA) is calculated using value weighted returns (SC + BC – SA –BA)/2. The small end of the factor (CMA_S) is calculated by SC – SA. We use "_S" at the end of the corresponding factor name to denote its small end version.

[Table 2]

3.4 Factor spanning tests

We run a number of factor spanning tests (Fama and French, 2015a) to compare the relative informativeness of the asset pricing factors. Each factor candidate is regressed against all the other factors in the five factor model. A factor might be seen redundant if the spanning test intercept is not significantly different from zero. For instance, the following regression is used to test whether information provided by HML is fully captured by other factors in the asset pricing model:

$$HML_t = \alpha_p + \beta_1(R_{mt} - R_{ft}) + \beta_3 SMB_t + \beta_4 RMW_t + \beta_5 CMA_t + e_{it}$$

The statistical significance of the regression intercepts indicate whether or not the HML factor provides additional information uncaptured by the right hand side factors. Factor spanning test results provide initial implication for the information content of asset pricing factor candidates. Along with the Gibbons, Ross and Shanken (GRS) (1989) test, we provide guidance on the choice of factors in new factor models in the UK.

3.5 GRS tests

The GRS tests are based on the time-series regression model. Firstly, we construct different test portfolios on the left hand side (LHS) and compare the performance of alternatives of factor models based on GRS statistics. The investment and profitability based portfolios are also used to illustrate investment-related and profitability-related patterns of UK stock returns.

The left hand side (LHS) portfolios are mainly constructed using asset pricing factor measures. We construct various groups of independently sorted portfolios based on intersections of different pairs of factor measures. At the end of June each year we use accounting data from the end of previous year and construct 25 Size-B/M; 25 size-profitability and 25 size-I/A portfolios. Fama and French (2012) suggest that appropriate break points need to be employed for both factors and test portfolios for regional studies. We therefore follow Gregory, Tharyan and Christidis (2013) to use break points based on the largest 350 stocks in the UK market. The larger four size groups are constructed using the quartiles of the largest 350 stocks and smallest size group is formed from the rest of the sample. The five groups of other variables are sorted using quintile break points of the largest 350 stocks. (In addition to the 25 annually rebalancing portfolios, we also follow Lewellen, Nagel and Shanken (2010)'s suggestion to construct industry based portfolios for robustness test.)

The Gibbons, Ross and Shanken (1989) test, or GRS test, is used in the following steps. Each group of the LHS portfolios is regressed on the time series asset pricing factor returns:

$$R_{it} - R_{ft} = \alpha_i + \beta_i F_t + e_{it}$$

R_{it} is the return of asset *i* in month *t*;

R_{ft} is the three-month T-bill rate from the UK in month *t*;

F_t is the vector of factor returns of the corresponding asset pricing model tested in month t.

GRS test examine the overall performance of the asset pricing models by asking if the alphas across LHS portfolios are jointly equal to zero, in which case the return variations across LHS portfolios are fully captured by asset pricing factors.

4. Results

4.1 LHS portfolio excess returns

Firstly, we focus on the pattern of UK stock returns by looking at the average 25 intersected portfolios' excess returns. Table 3 shows the average excess returns with their statistical significance for the 25 size-B/M; size-profitability and size-I/A portfolios. The table allows us to have an overview of the UK stock return patterns that are relevant to B/M, profitability and investment variable respectively.

The size-B/M sorts show a clear value effect in the UK. Across every size group, average excess returns increase with higher B/M ratio. This result is consistent with previous finding in the UK (Michou, Sulaiman and Stark, 2014; Grogery, Tharyan and Christidis, 2013) and Europe (Fama and French, 2012; 2015c). The average value premiums are equal to 1.04%, 0.98%, 0.50%, 0.72% and 0.39% respectively from smallest to largest size groups. There is, however, no clear relation between size and excess return, which also confirms previous results of insignificant size effect in the UK (Michou, Sulaiman and Stark, 2014; Grogery, Tharyan and Christidis, 2013).

The second sort, size-profitability, employs ($income\ before\ extraordinary\ items/TA$) as profitability formation. There is a discernible negative relation between average excess returns and profitability for every size group except for the largest. The profitability premiums mainly come from the difference between the lowest profitability quintile and the second lowest quintile. From the smallest size to the second largest quintile group, the difference between the two lowest quintiles of profitability portfolios are equal to 0.65%, 0.43%, 0.53% and 0.52% respectively. The UK profitability effect is in general consistent with the Europe pattern (Fama and French, 2015c), with the only difference in largest size quintile portfolios, where there is no profitability effect in UK but significant trend in European sample.

The size-I/A sorts indicate that future return is also negatively correlated with past investment in the UK. For each size group, future excess returns are higher for lower investment quintile. The low-minus-high investment premiums are amount to 0.41%, 0.97%, 0.44%, 0.88% and 0.14% from the smallest to largest size group. Similar to the profitability effect, the investment pattern fades out in the largest size group in the UK. Fama and French (2015c) report similar results in their European sample where investment provides trivial information in the biggest size group.

In short, there is observable investment and profitability-related stock return pattern in the UK. The negative relation between investment and future excess returns and positive relation between profitability and future excess returns are generally in line with the results from US and Europe market. Whether or not those patterns are captured by existing versions of factor models will be examined.

[Table 3]

4.2 Factor summary statistics

Before we move on to the information content of the time series asset pricing factors, we focus on their statistical significance and correlations. Table 4 provides summary statistics for our factor. The size factor SMB has a negative mean with no statistical significance. The result is not surprising since past evidence has documented the absence of the size effect in the UK market (Michou, Sulaiman and Stark, 2014; Grogery, Tharyan and Christidis, 2013).The HML factor is significantly different from zero with 0.42% premium per month. The small end of HML provides 0.19% higher monthly premiums with higher statistical significance. For the investment factor CMA, both normal and small end are significantly different from zero at the 1% level. The average premium for CMA and CMA_S are 0.55% and 0.66% respectively. Among the 12 differently constructed profitability factors, all but ROE_B exhibit average means that are statistically different from zero. The small end of ROE_A provide the highest mean among all the time series factors (0.68% per month). The small end of OP_A provides the second highest mean of 0.67% per month. In general, every small end of the factor has a higher mean compared with the normal version in our sample.

[Table 4]

Table 5 illustrates the time series correlations between asset pricing factors. The correlations between normal factors and their corresponding small end versions are generally high. For example, 0.80 between HML and HML_S and 0.72 between CMA and CMA_S. Among the specifications of profitability factors, there are highly positive correlations between ROEs and OPs: 0.69 between ROE_B and OP_B; 0.91 between ROE_A and OP_A. The correlations between GROs and ROEs/OPs are relatively lower: 0.50 between GRO_B and TOE_B; 0.42 between GRO_B_S and ROE_B_S, but the correlations are still higher than those with other factors. The correlations between Book value scaled and Total asset scaled profitability factors are also high: 0.76 between ROE_A and ROE_B; 0.87 for OP; and 0.82 for GRO. The combination of different factor variable formation and construction method has the potential to dramatically influence the information content of profitability factor. For instance, OP_B and GRO_A_S has 0.29 correlation; ROE_B and GRO_A_S has correlation of 0.26.

[Table 5]

4.3 Factor spanning tests

We now turn our attention to the relative informativeness of asset pricing factors using factor spanning tests. Table 6 illustrates the test results.

Panel A shows that the market factor (RM-RF) is informative in UK. The explanatory power of the market factor is not spanned by the other factors as the regression intercepts are statistically different from zero for all asset pricing factor combinations tested. This result is similar to the Europe sample evidence in Fama and French (2015c). Panel B suggests that the intercepts for regressions of SMB on other factors are statistically indifferent from zero. The

results are consistent with our previous evidence that size effect does not exist in the UK market. SMB is therefore a redundant factor for UK asset pricing models.

Panels C and D illustrate factor spanning test results for HML and HML_S. Both versions of value factor is spanned by the remaining factors in factor models, leaving the intercepts indifferent from zero. The results suggest that value factor is redundant in the UK market. The redundancy of value factor is also found in the US (Fama and French, 2015a), but not in Asian Pacific, Japan, North America and Europe (2015c). This further confirms the argument of Fama and French (2015a, 2015c) that the factor information may be sample specific. Moreover, the factor informativeness is likely to be country-specific as we observe noticeable difference between the US and North America (Fama and French, 2015c) as well as between the UK and Europe.

Panels E and F focus on information content of the investment factor CMA and CMA_S. In contrast to the results in Europe (Fama and French, 2015c) where CMA is fully captured by the other factors, our spanning tests suggest that investment factor is an important component of the UK factor model. All the spanning regression intercepts are highly significantly different from zero for both versions of CMA: after controlling for other factors, the intercepts range from 0.29% to 0.49% for CMA and 0.32% to 0.52% for CMA_S. Our UK specific results for CMA also suggest that the information content of asset pricing factors are likely to be heterogeneous among the European countries.

Starting from Panel G, we concentrate on the relative information content of profitability factors RMW. In Panels G and H, we test the impact of profitability variable definition on information content. Panel G shows that when scaled by book value, ROE provide information uncaptured by OP and GRO since regressions on ROE_Bs generate significant intercepts. When scaled by total assets, results from Panel H suggest that variable ROE and OP outperform GRO: OP_A_S regressed on GRO_A_S and other factors generates an intercept of 0.36% with statistical significance; ROE_A has significant 0.27%, 0.22% and 0.52% intercepts after controlling for other factors plus GRO_A, OP_A_S, GRO_A_S respectively; in contrast, the intercepts for GRO_A and GRO_A_S regressions are indifferent from zero. This evidence confirms Ball et al (2015)'s finding that scaler of RWM matters to its information content. To further illustrate the relative information difference, we employ RMWs based on profitability variables scaled by total assets to regress on those based on book value scaler together with other factors for spanning tests and vice versa, with results presented in Panel I and J. The significant intercepts across the regressions in panel I and insignificant intercepts under panel J regressions confirm Ball et al (2015)'s argument that total asset scaler provides superior information for profitability factor is held in the UK as well. In short, the dominant choices are ROE and OP for UK profitability factor variable numerator; while using total asset as scaler outperforms book value.

However, the above results have not taken into account small end factor construction methods. Panel K of Table 6 presents the additional information from small end factor construction method. When using CMA_S as a regressor in the spanning tests, some of the intercepts are significantly different from zero. Together with the results from Panel E and F, it seems that small end of investment factor CMA_S should be included in the factor model to provide better explanatory power. For profitability factors based on OP and ROE,

information content of small end factors are also not fully captured by their normal versions plus other factors. Though ROE and OP dominate GRO as the denominator of variable definition, the choice of profitability factor can not be made with certainty. There are more possibilities based on the interaction of variable scaler choices and small end construction methods. We leave this task to our GRS tests.

[Table 6]

4.4 GRS tests

Based on our spanning test results, we further consider 21 different factor models in the UK, in order to compare the information content from different versions of the profitability factor. We do not include SMB in the new models as robust results have been provided of its redundancy in the UK market. Tables 7, 8 and 9 uses 25 Size-B/M, 25 size-profitability and 25 size-I/A portfolio as LHS portfolio sets respectively. GRS test statistics are used to compare relative performance among the factor models.

The GRS tests results are in general consistent with our findings from factor spanning tests. Firstly, HML is found redundant in the UK factor model since it does not improve model performance with the existence of new factor RMWs and CMAs. Secondly, there is prominent evidence from GRS statistics that using the small end of CMA factor improves model performance. For every portfolio set, models with CMA_S outperform their peer models with CMA factors. Moreover, with respect to the information content of new asset pricing factors, all models with new factors CMA_S and RMW outperform the CAPM model and FF three factor model consistently across all portfolio sets. Therefore we can conclude that the information content of new asset pricing factors improve factor model performance in the UK.

[Table 7]

[Table 8]

[Table 9]

Among the improved factor models, we try to identify the best in describing portfolio returns. However, it seems that there is no dominant profitability factor in the UK market. For the 25 Size-B/M portfolios, the dominant factor model is composed of RM-RF, CMA_S and ROE_B_S; for the size-investment portfolios, the best performing model uses OP_A as profitability factor; the optimal profitability factor choice that explains 25 size-profitability portfolios return variation is ROE_A_S. The mixed results have also been discovered by Fama and French (2015b) in their US sample, which suggest that our version of new factor models remain to be incomplete.

In general, the ROE_B_S might so far be our best choice for UK asset pricing models. Together with RM-RF and CMA_S, the new factor model fully captures the variation of size-B/M and size-investment portfolios. For cross sections among size-profitability portfolios, the new model also provides a solid improvement in descriptive power compared with the CAPM and FF three factor model. Our results therefore suggest that future UK researchers

should use an updated version of three factor model to capture systematic cross-section of stock returns:

$$R_{it} - R_{ft} = \alpha_p + \beta_1(R_{mt} - R_{ft})_t + \beta_5 CMA\_S_t + \beta_4 ROE\_B\_S_t + e_{it}$$

5. Conclusion

To summarise, our paper provides out of sample evidence for the effectiveness of profitability factor and investment factor from the new Fama-French five factor model. We firstly provide evidence that investment and profitability influence UK stock market patterns. We also employ both factor spanning tests and the GRS tests to shed light on the empirical performance of potential new factor models in the UK market.

Our results using the UK data imply the following*: Firstly,* the performance of the new factor model, from a local perspective, is not entirely consistent with the US or the European results. The discrepancy suggests that optimal factor models choice is sensitive to market sample, which also confirms Griffin (2002)'s conclusion that factor models should be constructed within country-level. Secondly, our results suggest that the UK factor models' performance are improved using the two new factors: Investment factor and profitability factor. On the other hand, Size factor and Value factor are proven redundant. From a parsimonious perspective, we do not need to include SMB or HML in the UK factor model. Thirdly, information content of the new investment factor is improved by constructing using the small end. Furthermore, we confirm the findings from the US market that choice of profitability factor matters to a factor performance. Among the factor candidates, operating profit or income before extraordinary items outperform gross profit for profitability factor. However, the optimal choice becomes a tougher question when we take into account different scalers and small end construction methods. The ambiguous results may suggest that our factor models remain incomplete.

Despite the inconclusive results for the best profitability factor, our new three factor models significantly outperform the FF three factor model in the UK. Therefore, we suggest that future UK research should employ a new three factor model by replacing size and value factor with profitability factor and investment factor to control for time series variations among stock returns.

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Table 1

Year	No. of stocks
1990	1218
1991	1047
1992	1051
1993	1008
1994	1013
1995	1047
1996	1122
1997	1147
1998	1165
1999	1143
2000	1141
2001	1079
2002	1080
2003	1138
2004	1111
2005	1075
2006	1181
2007	1326
2008	1300
2009	1251
2010	1196
2011	1153
2012	1123
2013	1093

Table 2

Factor	variable Definition	Factors and their components
Mkt	FT all share index return; One month Treasury Bill return	$(R_m - R_f)$
Size	Market Capitalization	$\mathrm{SMB} = (\mathrm{SL} + \mathrm{SM} + \mathrm{SH})/3 - (\mathrm{BL} + \mathrm{BM} + \mathrm{BH})/3$
Value	Book-To-Market ratio	$\mathrm{HML} = (\mathrm{SH} + \mathrm{BH})/2 - (\mathrm{SL} + \mathrm{BL})/2$ $\mathrm{HML\_S} = (\mathrm{SH} - \mathrm{SL})$
Profitability	$operating\ income/BE$ $operating\ income/TA$ $income\ before\ extraordinary\ items/BE$ $income\ before\ extraordinary\ items/TA$ $gross\ profit/BE$ $gross\ profit/TA$	$\mathrm{RMW} = (\mathrm{SR} + \mathrm{BR})/2 - (\mathrm{SW} + \mathrm{BW})/2$ $\mathrm{RMW\_S} = (\mathrm{SR} - \mathrm{SW})$
Investment	Investment/TA	$\mathrm{CMA} = (\mathrm{SC} + \mathrm{BC})/2 - (\mathrm{SA} + \mathrm{BA})/2$ $\mathrm{CMA\_S} = (\mathrm{SC} - \mathrm{SA})$

Table 3

Average monthly excess returns on portfolios from July 1990—December 2013											
Excess return						**T value**					
variable	**B/M**						**B/M**				
	high	4	3	2	low	level	high	4	3	2	low
size	0.63	0.53	0.32	-0.02	-0.41	small	1.97	1.67	0.98	-0.05	-1.06
	1.08	0.47	0.29	0.15	0.10	2	2.32	1.15	0.70	0.41	0.19
	0.78	0.70	0.58	0.19	0.28	3	1.88	1.67	1.64	0.55	0.72
	1.03	0.57	0.50	0.38	0.31	4	2.46	1.54	1.37	1.08	0.74
	0.73	0.57	0.53	0.43	0.34	big	2.20	1.97	1.81	1.57	1.41
	Profitability						**Profitability**				
	high	4	3	2	low	level	high	4	3	2	low
size	0.67	0.75	0.54	0.53	-0.12	small	2.35	2.53	1.68	1.69	-0.30
	0.77	0.43	0.85	0.50	0.07	2	2.29	1.30	1.93	1.31	0.13
	0.86	0.85	0.36	0.50	-0.03	3	2.68	2.53	0.97	1.27	-0.06
	0.80	0.56	0.91	0.58	0.06	4	2.17	1.63	2.79	1.56	0.13
	0.54	0.42	0.54	0.43	0.51	big	2.16	1.52	2.04	1.51	1.50
	Investment						**Investment**				
	high	4	3	2	low	level	high	4	3	2	low
size	0.03	0.38	0.60	0.60	0.44	small	0.09	1.24	2.07	1.95	1.19
	-0.14	0.15	0.58	0.67	0.83	2	-0.34	0.37	1.68	1.75	1.83
	0.49	0.42	0.64	0.91	0.93	3	1.20	1.11	1.95	2.61	2.22
	0.19	0.63	0.47	0.49	1.07	4	0.43	1.75	1.45	1.38	2.60
	0.48	0.16	0.47	0.66	0.62	big	1.51	0.50	1.96	2.66	2.12

Note: This table reports the average excess returns of 25 Size-B/M; Size-profitability; size-investment portfolios. At the end of June each year we use accounting data from the end of previous year to construct portfolios. We use quartiles of the largest 350 stocks to form size groups and combine the rest of the sample stocks into the smallest size group. Independently, we construct five groups of B/M, Profitability or Investment portfolios using quintile break points of the largest 350 stocks. Profitability is defined as income before extraordinary items/TA and investment is defined as investment/TA.

Table 4

Summary Statistics for asset pricing factors, June 1990 to December 2013							
Variable	mean	s.d.	skewness	kurtosis	max	p50	min
RMRF	0.402	4.17	-0.56	3.61	10.48	0.85	-13.61
SMB	-0.08	3.59	0.17	5.85	17.43	-0.20	-14.54
HML	0.42**	2.85	-0.23	8.48	11.62	0.31	-13.53
HML_S	0.61***	3.60	-0.09	9.66	17.25	0.48	-19.61
CMA	0.55***	2.51	0.83	5.94	12.35	0.13	-8.76
CMA_S	0.66***	2.59	0.91	7.58	15.91	0.39	-8.59
ROE_B	0.11	2.27	0.12	4.46	10.51	0.21	-7.32
ROE_B_S	0.28*	2.45	-0.45	4.70	7.36	0.40	-10.17
ROE_A	0.42**	2.77	0.24	4.76	10.99	0.36	-8.41
ROE_A_S	0.68***	2.93	-0.70	6.93	10.12	0.73	-14.66
OP_B	0.30*	2.67	0.76	6.90	12.58	0.13	-8.29
OP_B_S	0.43**	2.86	0.06	5.43	10.85	0.43	-12.33
OP_A	0.46***	2.75	0.45	5.95	12.06	0.25	-9.05
OP_A_S	0.67***	3.07	-0.51	7.33	12.83	0.62	-15.89
GRO_B	0.29**	2.14	0.70	4.98	9.15	0.12	-5.95
GRO_B_S	0.40***	2.41	0.10	3.41	8.01	0.30	-7.04
GRO_A	0.37***	2.33	0.32	3.61	7.77	0.16	-6.80
GRO_A_S	0.47***	2.88	0.00	4.64	12.74	0.46	-8.96

Note:
This table reports the summary statistics of asset pricing factors with alternative definitions. (Rm-Rf) is the market risk premium (value weighted market return minus T-bill rate), SMB is the size factor (small minus big); HML is the value factor(high minus low B/M), CMA is the investment factor(conservative minus aggressive), and there are three specifications used to construct profitability factors: ROE represents profitability factor based on income before extraordinary items; OP represents profitability factor based on operating income and GRO represents profitability factor based on gross profit. On the basis of different profitability specification, book value and total asset value are used respectively as denominator to construct the profitability factors, _B and _A are used to label the difference. Small ends of the factors are constructed and labelled with _S.

Table 5

Correlations																
	RM-RF	SMB	HML	HML_S	CMA	CMA_S	ROE_B	ROE_B_S	ROE_A	ROE_A_S	OP_B	OP_B_S	OP_A	OP_A_S	GRO_B	GRO_B_S	GRO_A
SMB	0.12																
HML	0.09	-0.14															
HML_S	-0.06	-0.11	0.80														
CMA	-0.15	-0.09	0.38	0.39													
CMA_S	-0.02	0.09	0.43	0.48	0.72												
ROE_B	-0.30	-0.35	-0.30	-0.04	-0.23	-0.22											
ROE_B_S	-0.33	-0.44	-0.09	-0.06	-0.07	-0.22	0.66										
ROE_A	-0.40	-0.39	-0.22	0.09	0.09	-0.06	0.76	0.56									
ROE_A_S	-0.43	-0.53	0.00	0.10	0.13	-0.07	0.57	0.78	0.73								
OP_B	-0.32	-0.30	-0.10	0.25	0.16	0.11	0.69	0.45	0.81	0.58							
OP_B_S	-0.34	-0.45	0.10	0.18	0.17	0.11	0.54	0.69	0.63	0.76	0.74						
OP_A	-0.37	-0.37	-0.12	0.19	0.16	0.04	0.68	0.51	0.91	0.69	0.87	0.67					
OP_A_S	-0.39	-0.53	0.08	0.16	0.20	0.02	0.51	0.71	0.68	0.93	0.59	0.81	0.71				
GRO_B	-0.33	-0.15	-0.22	0.09	0.34	0.22	0.50	0.33	0.68	0.49	0.77	0.58	0.70	0.51			
GRO_B_S	-0.26	-0.12	-0.02	0.05	0.22	0.26	0.30	0.42	0.37	0.45	0.40	0.62	0.39	0.50	0.69		
GRO_A	-0.32	-0.13	-0.37	-0.10	0.22	0.11	0.43	0.32	0.63	0.50	0.57	0.48	0.66	0.52	0.82	0.63	
GRO_A_S	-0.27	-0.16	-0.22	-0.18	0.14	0.08	0.26	0.40	0.36	0.56	0.29	0.52	0.36	0.62	0.57	0.78	0.74

Note: This table reports the correlations between alternative versions of asset pricing factors. (Rm-Rf) is the market risk premium (value weighted market return minus T-bill rate), SMB is the size factor (small minus big); HML is the value factor(high minus low B/M), CMA is the investment factor(conservative minus aggressive), and there are three specifications used to construct profitability factors: ROE represents profitability factor based on income before extraordinary items; OP represents profitability factor based on operating income and GRO represents profitability factor based on gross profit. On the basis of different profitability specification, book value and total asset value are used respectively as denominator to construct the profitability factors, _B and _A are used to label the difference. Small ends of the factors are constructed and labelled with _S.

Table 6 Spanning tests on asset pricing factors:

(Rm-Rf) is the market risk premium (value weighted market return minus T-bill rate), SMB is the size factor (small minus big); HML is the value factor(high minus low B/M), CMA is the investment factor(conservative minus aggressive), and there are three specifications used to construct profitability factors: ROE represents profitability factor based on income before extraordinary items; OP represents profitability factor based on operating income and GRO represents profitability factor based on gross profit. On the basis of different profitability specification, book value and total asset value are used respectively as denominator to construct the profitability factors, _B and _A are used to label the difference. Small ends of the factors are constructed and labelled with _S.

Panel A Market factor RM-RF

VARIABLES	RM-RF	RM-RF	RM-RF	RM-RF	RM-RF	RM-RF	RM-RF	RM-RF	RM-RF	RM-RF	RM-RF	RM-RF	RM-RF
SMB	0.13*	0.01	-0.06	-0.05	-0.18**	0.03	-0.07	-0.02	-0.14*	0.06	0.08	0.06	0.05
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.08)	(0.07)	(0.07)	(0.07)	(0.07)
HML_S	-0.05	-0.05	-0.06	-0.01	-0.01	0.02	-0.02	0.01	-0.01	-0.07	-0.09	-0.14*	-0.17**
	(0.08)	(0.08)	(0.08)	(0.07)	(0.07)	(0.08)	(0.08)	(0.08)	(0.07)	(0.08)	(0.08)	(0.08)	(0.08)
CMA_S	-0.01	-0.11	-0.11	-0.05	-0.06	0.01	0.05	-0.01	0.01	0.13	0.14	0.12	0.12
	(0.11)	(0.11)	(0.11)	(0.10)	(0.10)	(0.11)	(0.11)	(0.10)	(0.10)	(0.11)	(0.11)	(0.11)	(0.11)
RMW		ROE _B	ROE _B_S	ROE _A	ROE _A_S	OP _B	OP _B_S	OP _A	OP _A_S	GRO _B	GRO _B_S	GRO _A	GRO _A_S
		-0.58***	-0.64***	-0.62***	-0.74***	-0.50***	-0.54***	-0.57***	-0.61***	-0.65***	-0.47***	-0.59***	-0.43***
		(0.11)	(0.11)	(0.09)	(0.09)	(0.10)	(0.09)	(0.09)	(0.09)	(0.11)	(0.10)	(0.11)	(0.09)
Constant	0.45*	0.57**	0.69***	0.70***	0.94***	0.54**	0.61**	0.66***	0.80***	0.56**	0.57**	0.64***	0.64**
	(0.26)	(0.25)	(0.25)	(0.24)	(0.24)	(0.25)	(0.24)	(0.24)	(0.24)	(0.24)	(0.25)	(0.25)	(0.25)
R-squared	0.02	0.10	0.12	0.16	0.21	0.10	0.12	0.14	0.16	0.12	0.08	0.12	0.10

Panel B size factor SMB													
VARIABLES	SMB	SMB	SMB	SMB	SMB	SMB	SMB	SMB	SMB	SMB	SMB	SMB	SMB
RM-RF	0.09*	0.01	-0.04	-0.04	-0.12**	0.02	-0.04	-0.02	-0.09*	0.05	0.06	0.05	0.04
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
HML_S	-0.19***	-0.17***	-0.17***	-0.14**	-0.10*	-0.12*	-0.12*	-0.11*	-0.09	-0.19***	-0.20***	-0.22***	-0.25***
	(0.07)	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)	(0.06)	(0.06)	(0.06)	(0.07)	(0.07)	(0.07)	(0.07)
CMA_S	0.25***	0.13	0.10	0.18**	0.13	0.25***	0.27***	0.22**	0.20**	0.30***	0.32***	0.30***	0.32***
	(0.09)	(0.09)	(0.09)	(0.09)	(0.08)	(0.09)	(0.08)	(0.09)	(0.08)	(0.09)	(0.10)	(0.09)	(0.09)
RMW		ROE_B	ROE_B_S	ROE_A	ROE_A_S	OP_B	OP_B_S	OP_A	OP_A_S	GRO_B	GRO_B_S	GRO_A	GRO_A_S
		-0.53***	-0.67***	-0.50***	-0.71***	-0.37***	-0.59***	-0.47***	-0.65***	-0.27**	-0.22**	-0.25**	-0.27***
		(0.10)	(0.09)	(0.08)	(0.07)	(0.08)	(0.07)	(0.08)	(0.06)	(0.11)	(0.09)	(0.10)	(0.08)
Constant	-0.17	-0.01	0.16	0.10	0.42**	-0.07	0.08	0.06	0.31	-0.10	-0.10	-0.07	-0.03
	(0.22)	(0.21)	(0.20)	(0.21)	(0.19)	(0.21)	(0.20)	(0.21)	(0.19)	(0.22)	(0.22)	(0.22)	(0.22)
R-squared	0.05	0.14	0.22	0.17	0.31	0.11	0.24	0.16	0.30	0.07	0.07	0.07	0.09

Table 6 Panel C value factor HML													
VARIABLES	HML	HML	HML	HML	HML	HML	HML	HML	HML	HML	HML	HML	HML
RM-RF	0.08**	0.02	0.07*	0.01	0.07*	0.04	0.08**	0.03	0.09**	-0.00	0.05	-0.02	0.03
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)
SMB	-0.15***	-0.22***	-0.17***	-0.23***	-0.16***	-0.20***	-0.15***	-0.21***	-0.14***	-0.19***	-0.16***	-0.19***	-0.18***
	(0.04)	(0.04)	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)
CMA_S	0.50***	0.43***	0.49***	0.49***	0.50***	0.52***	0.50***	0.51***	0.49***	0.59***	0.54***	0.55***	0.52***
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.05)	(0.06)
RMW		ROE_B	ROE_B_S	ROE_A	ROE_A_S	OP_B	OP_B_S	OP_A	OP_A_S	GRO_B	GRO_B_S	GRO_A	GRO_A_S

		-0.38***	-0.06	-0.31***	-0.03	-0.22***	0.01	-0.23***	0.03	-0.50***	-0.17***	-0.57***	-0.28***
		(0.07)	(0.07)	(0.06)	(0.07)	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)	(0.07)	(0.06)	(0.05)
Constant	0.05	0.16	0.08	0.21	0.08	0.11	0.05	0.16	0.03	0.17	0.10	0.26*	0.18
	(0.16)	(0.15)	(0.16)	(0.15)	(0.16)	(0.15)	(0.16)	(0.16)	(0.16)	(0.14)	(0.16)	(0.14)	(0.15)
R-squared	0.23	0.30	0.23	0.29	0.23	0.26	0.23	0.27	0.23	0.35	0.25	0.42	0.30

Table 6 Panel D small end of value factor HML_S

VARIABLES	HML_S	HML_S	HML_S	HML_S	HML_S	HML_S	HML_S	HML_S	HML_S	HML_S	HML_S	HML_S	HML_S
RM-RF	-0.03	-0.03	-0.04	-0.01	-0.01	0.01	-0.01	0.01	-0.00	-0.05	-0.06	-0.08*	-0.09**
	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)
SMB	-0.15***	-0.14***	-0.16***	-0.12**	-0.11*	-0.10*	-0.11*	-0.10*	-0.10	-0.15***	-0.16***	-0.17***	-0.19***
	(0.05)	(0.06)	(0.06)	(0.06)	(0.06)	(0.05)	(0.06)	(0.06)	(0.06)	(0.05)	(0.05)	(0.05)	(0.05)
CMA_S	0.69***	0.69***	0.68***	0.69***	0.69***	0.66***	0.67***	0.68***	0.68***	0.71***	0.73***	0.72***	0.72***
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
RMW		ROE_B	ROE_B_S	ROE_A	ROE_A_S	OP_B	OP_B_S	OP_A	OP_A_S	GRO_B	GRO_B_S	GRO_A	GRO_A_S
		0.01	-0.06	0.09	0.09	0.23***	0.10	0.18**	0.11	-0.10	-0.18**	-0.32***	-0.35***
		(0.09)	(0.09)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.10)	(0.08)	(0.08)	(0.06)
Constant	0.16	0.15	0.18	0.11	0.08	0.09	0.12	0.07	0.08	0.18	0.21	0.27	0.32*
	(0.19)	(0.19)	(0.20)	(0.20)	(0.20)	(0.19)	(0.20)	(0.19)	(0.20)	(0.19)	(0.19)	(0.19)	(0.19)
R-squared	0.26	0.26	0.26	0.26	0.26	0.28	0.26	0.27	0.26	0.26	0.27	0.29	0.33

Table 6 Panel E investment factor CMA

VARIABLES	CMA	CMA	CMA	CMA	CMA	CMA	CMA	CMA	CMA	CMA	CMA	CMA	CMA
RM-RF	-0.07**	-0.13***	-0.10***	-0.08**	-0.06*	-0.07*	-0.06*	-0.06*	-0.05	-0.02	-0.05	-0.03	-0.04
	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)
SMB	-0.03	-0.10***	-0.07	-0.03	-0.01	-0.02	-0.01	-0.02	0.02	-0.00	-0.01	-0.01	-0.00
	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)
HML_S	0.26***	0.24***	0.25***	0.26***	0.26***	0.26***	0.26***	0.26***	0.26***	0.25***	0.26***	0.29***	0.29***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
RMW		ROE_B	ROE_B_S	ROE_A	ROE_A_S	OP_B	OP_B_S	OP_A	OP_A_S	GRO_B	GRO_B_S	GRO_A	GRO_A_S
		-0.37***	-0.14**	-0.01	0.03	0.03	0.06	0.04	0.10*	0.35***	0.18***	0.27***	0.17***
		(0.06)	(0.07)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)	(0.06)	(0.06)	(0.05)
Constant	0.42***	0.49***	0.48***	0.43***	0.40***	0.41***	0.40***	0.40***	0.35**	0.31**	0.34**	0.29**	0.31**
	(0.14)	(0.13)	(0.14)	(0.14)	(0.15)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)
R-squared	0.17	0.26	0.18	0.17	0.17	0.17	0.17	0.17	0.18	0.24	0.20	0.22	0.20

Table 6 Panel F small end of investment factor CMA_S

VARIABLES	CMA _S	CMA _S	CMA _S	CMA _S	CMA _S	CMA _S	CMA _S	CMA _S	CMA _S	CMA _S	CMA _S	CMA _S	CMA _S
RM-RF	-0.00	-0.03	-0.04	-0.02	-0.02	0.00	0.02	-0.00	0.00	0.04	0.04	0.04	0.03
	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)
SMB	0.10***	0.06	0.05	0.09**	0.07	0.11***	0.13***	0.10**	0.11**	0.12***	0.12***	0.12***	0.13***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
HML_S	0.36***	0.34***	0.34***	0.36***	0.36***	0.35***	0.35***	0.36***	0.36***	0.35***	0.35***	0.38***	0.39***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
RMW		ROE_B	ROE_B_S	ROE_A	ROE_A_S	OP_B	OP_B_S	OP_A	OP_A_S	GRO_B	GRO_B_S	GRO_A	GRO_A_S

		-0.22***	-0.19***	-0.07	-0.07	0.03	0.10*	-0.00	0.02	0.26***	0.29***	0.22***	0.20***
		(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)	(0.06)	(0.06)	(0.05)
Constant	0.45***	0.49***	0.52***	0.48***	0.50***	0.44***	0.40***	0.45***	0.43***	0.36***	0.32**	0.34**	0.32**
	(0.14)	(0.13)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.13)	(0.13)	(0.14)	(0.14)
R-squared	0.25	0.28	0.28	0.26	0.26	0.25	0.26	0.25	0.25	0.29	0.32	0.29	0.30

Table 6 Panel G—profitability factor using book value as denominator

VARIABLES	OP_B	OP_B	OP_B_S	OP_B_S	ROE_B	ROE_B	ROE_B_S	ROE_B_S	GRO_B	GRO_B	GRO_B_S	GRO_B_S
RM-RF	-0.03	-0.05*	-0.07**	-0.10***	-0.06***	-0.08***	-0.07***	-0.11***	-0.02	-0.03	-0.03	-0.06*
	(0.03)	(0.02)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)	(0.03)
SMB	0.00	-0.12***	-0.13***	-0.28***	-0.12***	-0.18***	-0.09***	-0.24***	0.03	0.04	0.10***	0.04
	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.04)
HML	0.01	0.14***			-0.11***	-0.02			-0.21***	-0.19***		
	(0.04)	(0.04)			(0.03)	(0.04)			(0.03)	(0.03)		
HML_S			0.08**	0.12***			-0.06*	0.01			-0.13***	-0.08**
			(0.04)	(0.04)			(0.03)	(0.04)			(0.03)	(0.04)
CMA	0.35***	-0.21***			-0.29***	-0.42***			0.28***	0.48***		
	(0.05)	(0.05)			(0.04)	(0.05)			(0.03)	(0.04)		
CMA_S			0.24***	-0.09*			-0.23***	-0.29***			0.25***	0.39***
			(0.05)	(0.05)			(0.04)	(0.05)			(0.05)	(0.05)
RMW	ROE_B	GRO_B	ROE_B_S	GRO_B_S	OP_B	GRO_B	OP_B_S	GRO_B_S	OP_B	ROE_B	OP_B_S	ROE_B_S
	0.89***	1.02***	0.74***	0.66***	0.54***	0.60***	-0.23***	0.41***	0.55***	0.53***	0.58***	0.49***
	(0.06)	(0.05)	(0.05)	(0.05)	(0.03)	(0.05)	(0.04)	(0.05)	(0.03)	(0.05)	(0.04)	(0.06)
Constant	0.01	0.07	0.04	0.17	0.17**	0.20**	0.25**	0.32***	0.07	0.06	0.10	0.09
	(0.11)	(0.10)	(0.12)	(0.12)	(0.08)	(0.10)	(0.10)	(0.11)	(0.07)	(0.09)	(0.11)	(0.13)
R-squared	0.59	0.65	0.59	0.57	0.65	0.55	0.59	0.45	0.71	0.55	0.48	0.33

Table 6 Panel H—profitability factor using total asset as denominator

VARIABLES	OP_A	OP_A	OP_A_S	OP_A_S	ROE_A	ROE_A	ROE_A_S	ROE_A_S	GRO_A	GRO_A	GRO_A_S	GRO_A_S
RM-RF	-0.00	-0.10***	0.01	-0.13***	-0.05***	-0.13***	-0.07***	-0.17***	-0.02	-0.02	-0.01	-0.01
	(0.02)	(0.03)	(0.02)	(0.03)	(0.02)	(0.03)	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)	(0.03)
SMB	-0.00	-0.19***	-0.04*	-0.32***	-0.07***	-0.23***	-0.05**	-0.31***	0.03	0.04	0.14***	0.11**
	(0.02)	(0.03)	(0.02)	(0.03)	(0.02)	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)
HML	0.05*	0.12**			-0.11***	0.00			-0.33***	-0.30***		
	(0.03)	(0.05)			(0.03)	(0.05)			(0.04)	(0.04)		
HML_S			0.02	0.23***			-0.01	0.18***			-0.32***	-0.31***
			(0.02)	(0.04)			(0.02)	(0.04)			(0.04)	(0.04)
CMA	0.07**	-0.08			-0.03	-0.10*			0.26***	0.29***		
	(0.03)	(0.05)			(0.03)	(0.05)			(0.04)	(0.04)		
CMA_S			0.09***	-0.15***			-0.09***	-0.21***			0.27***	0.34***
			(0.03)	(0.05)			(0.03)	(0.05)			(0.05)	(0.06)
RWM	ROE_A	GRO_A	ROE_A_S	GRO_A_S	OP_A	GRO_A	OP_A_S	GRO_A_S	OP_A	ROE_A	OP_A_S	ROE_A_S
	0.91***	0.76***	0.96***	0.61***	0.85***	0.66***	-0.09***	0.49***	0.48***	0.45***	0.72***	0.67***
	(0.03)	(0.06)	(0.03)	(0.04)	(0.03)	(0.06)	(0.03)	(0.04)	(0.04)	(0.04)	(0.05)	(0.06)
Constant	0.01	0.19*	-0.07	0.36***	0.11	0.27**	0.22***	0.52***	0.15	0.15	0.03	-0.01
	(0.07)	(0.12)	(0.07)	(0.11)	(0.07)	(0.12)	(0.07)	(0.12)	(0.09)	(0.10)	(0.13)	(0.14)
R-squared	0.83	0.55	0.87	0.66	0.85	0.54	0.88	0.62	0.59	0.55	0.54	0.46

Table 6 Panel I—profitability factor using total asset as denominator while the profitability factor regressors use book value as denominator												
VARIABLES	OP_A	OP_A	OP_A_S	OP_A_S	ROE_A	ROE_A	ROE_A_S	ROE_A_S	GRO_A	GRO_A	GRO_A_S	GRO_A_S
RM-RF	-0.07**	-0.09***	-0.12***	-0.16***	-0.09***	-0.12***	-0.14***	-0.20***	-0.05**	-0.06**	-0.08**	-0.11***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.04)
SMB	-0.07**	-0.19***	-0.22***	-0.37***	-0.14***	-0.22***	-0.18***	-0.35***	-0.01	-0.00	0.03	-0.03
	(0.03)	(0.03)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.05)
HML	-0.04	0.06			-0.15***	-0.03			-0.36***	-0.35***		
	(0.04)	(0.04)			(0.03)	(0.04)			(0.04)	(0.04)		
HML_S			0.08**	0.12***			0.01	0.09**			-0.31***	-0.26***
			(0.04)	(0.04)			(0.03)	(0.04)			(0.04)	(0.05)
CMA	0.34***	-0.15***			-0.01	-0.18***			0.28***	0.42***		
	(0.05)	(0.05)			(0.04)	(0.05)			(0.04)	(0.05)		
CMA_S			0.14***	-0.14**			-0.14***	-0.21***			0.22***	0.36***
			(0.05)	(0.06)			(0.05)	(0.06)			(0.06)	(0.07)
RWM	ROE_B	GRO_B	ROE_B_S	GRO_B_S	OP_B	GRO_B	OP_B_S	GRO_B_S	OP_B	ROE_B	OP_B_S	ROE_B_S
	0.82***	0.87***	0.72***	0.53***	0.72***	0.81***	-0.14***	0.45***	0.39***	0.38***	0.56***	0.45***
	(0.06)	(0.06)	(0.06)	(0.06)	(0.04)	(0.06)	(0.05)	(0.05)	(0.04)	(0.06)	(0.06)	(0.07)
Constant	0.21*	0.28**	0.35***	0.51***	0.30***	0.33***	0.54***	0.63***	0.27***	0.26**	0.30**	0.31**
	(0.11)	(0.11)	(0.12)	(0.13)	(0.09)	(0.11)	(0.11)	(0.12)	(0.10)	(0.11)	(0.14)	(0.16)
R-squared	0.59	0.59	0.62	0.54	0.72	0.60	0.67	0.54	0.52	0.45	0.40	0.29

Table 6 Panel J—profitability factor using book value as denominator while the profitability factor regressors use total asset as denominator												
VARIABLES	OP_B	OP_B	OP_B_S	OP_B_S	ROE_B	ROE_B	ROE_B_S	ROE_B_S	GRO_B	GRO_B	GRO_B_S	GRO_B_S
RM-RF	0.01	-0.09***	-0.01	-0.11***	-0.05**	-0.10***	-0.05*	-0.12***	-0.02	-0.01	-0.04	-0.03
	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)	(0.03)	(0.03)
SMB	0.03	-0.15***	-0.06*	-0.26***	-0.10***	-0.20***	-0.06*	-0.23***	0.05*	0.06**	0.10**	0.09**
	(0.03)	(0.04)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.04)	(0.04)
HML	0.05	0.10*			-0.09***	-0.04			-0.20***	-0.16***		
	(0.04)	(0.06)			(0.03)	(0.05)			(0.03)	(0.03)		
HML_S			0.02	0.18***			-0.06*	0.05			-0.12***	-0.12***
			(0.03)	(0.04)			(0.03)	(0.04)			(0.04)	(0.04)
CMA	0.08*	-0.04			-0.29***	-0.32***			0.29***	0.32***		
	(0.04)	(0.06)			(0.04)	(0.05)			(0.04)	(0.04)		
CMA_S			0.16***	-0.02			-0.18***	-0.24***			0.30***	0.34***
			(0.05)	(0.06)			(0.04)	(0.05)			(0.05)	(0.05)
profit factor	ROE_A	GRO_A	ROE_A_S	GRO_A_S	OP_A	GRO_A	OP_A_S	GRO_A_S	OP_A	ROE_A	OP_A_S	ROE_A_S
	0.81***	0.63***	0.70***	0.46***	0.52***	0.38***	-0.18***	0.27***	0.49***	0.49***	0.45***	0.45***
	(0.04)	(0.07)	(0.05)	(0.05)	(0.04)	(0.06)	(0.04)	(0.04)	(0.03)	(0.04)	(0.05)	(0.05)
Constant	-0.11	0.07	-0.17	0.14	0.09	0.20*	0.10	0.31**	0.00	-0.01	0.01	-0.03
	(0.10)	(0.13)	(0.12)	(0.13)	(0.09)	(0.11)	(0.10)	(0.12)	(0.08)	(0.09)	(0.12)	(0.13)
R-squared	0.67	0.40	0.61	0.49	0.62	0.43	0.57	0.40	0.62	0.60	0.36	0.33

Table 6 Panel K—influence of the small end of factors

VARIABLES	CMA_S	CMA_S	CMA_S	CMA_S	CMA_S	CMA_S	CMA_S	CMA_S	OP_B_S	ROE_B_S	OP_A_S	ROE_A_S
RM-RF	0.05**	0.03	0.03	0.02	0.05*	0.06**	0.04	0.03	-0.08***	-0.09***	-0.11***	-0.13***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
SMB	0.13***	0.09***	0.10***	0.08**	0.12***	0.14***	0.11***	0.10***	-0.21***	-0.17***	-0.27***	-0.24***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
HML_S	0.18***	0.18***	0.18***	0.18***	0.18***	0.18***	0.18***	0.18***	-0.04	-0.03	0.00	0.02
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)
CMA	0.68***	0.66***	0.67***	0.67***	0.67***	0.66***	0.67***	0.67***				
	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)				
CMA_S									0.09*	-0.07	0.03	-0.03
									(0.05)	(0.05)	(0.05)	(0.05)
profit factor	ROE_B	ROE_B_S	ROE_A	ROE_A_S	OP_B	OP_B_S	OP_A	OP_A_S	OP_B	ROE_B	OP_A	ROE_A
	0.03	-0.10**	-0.06	-0.09**	0.01	0.06	-0.03	-0.05	0.67***	0.54***	0.60***	0.58***
	(0.05)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)	(0.04)
Constant	0.16	0.21**	0.19*	0.23**	0.16	0.14	0.18*	0.20*	0.20*	0.30***	0.40***	0.48***
	(0.10)	(0.10)	(0.10)	(0.11)	(0.10)	(0.10)	(0.10)	(0.10)	(0.11)	(0.11)	(0.12)	(0.11)
R-squared	0.60	0.61	0.61	0.61	0.60	0.61	0.60	0.61	0.62	0.51	0.61	0.64

Table 7

model factors	Mean alpha	GRS statistic	P-value	Mean adj R2	Mean SE	Mean abs alpha
RM-RF	0.02	1.87	0.01	0.53	0.25	0.23
RM-RF SMB HML	0.05	1.79	0.01	0.74	0.19	0.15
RM-RF SMB HML umd	0.13	1.86	0.01	0.75	0.19	0.18
RM-RF SMB HML CMA	0.10	1.61	0.04	0.74	0.19	0.17
RM-RF SMB HML_S CMA	0.09	1.55	0.05	0.75	0.19	0.17
RM-RF SMB HML CMA_S	0.05	1.42	0.09	0.74	0.19	0.14
RM-RF SMB HML_S CMA_S	0.05	1.39	0.11	0.75	0.19	0.14
RM-RF HML CMA_S ROE_B	0.10	1.44	0.08	0.60	0.24	0.15
RM-RF HML CMA_S ROE_B_S	0.16	1.34	0.13	0.60	0.25	0.19
RM-RF HML CMA_S OP_A	0.17	1.61	0.04	0.61	0.24	0.21
RM-RF HML CMA_S OP_A_S	0.31	1.52	0.06	0.63	0.24	0.31
RM-RF HML CMA_S ROE_A	0.22	1.65	0.03	0.62	0.24	0.25
RM-RF HML CMA_S ROE_A_S	0.40	1.58	0.04	0.63	0.24	0.40
RM-RF HML CMA_S GRO_A	0.12	1.43	0.09	0.59	0.25	0.17
RM-RF HML CMA_S GRO_A_S	0.06	1.33	0.14	0.58	0.25	0.15
RM-RF CMA_S ROE_B	0.07	1.43	0.09	0.57	0.25	0.15
RM-RF CMA_S ROE_B_S	0.16	1.26	0.19	0.58	0.25	0.19
RM-RF CMA_S OP_A	0.15	1.65	0.03	0.58	0.25	0.19
RM-RF CMA_S OP_A_S	0.31	1.49	0.07	0.61	0.25	0.31
RM-RF CMA_S ROE_A	0.19	1.71	0.02	0.59	0.25	0.21
RM-RF CMA_S ROE_A_S	0.40	1.58	0.04	0.61	0.25	0.40
RM-RF CMA_S GRO_A	0.05	1.60	0.04	0.56	0.26	0.16
RM-RF CMA_S GRO_A_S	0.03	1.37	0.12	0.55	0.26	0.16

Note: This table reports GRS test results for various asset pricing factor models using 25 size-B/M portfolios. (Rm-Rf) is the market risk premium (value weighted market return minus T-bill rate), SMB is the size factor (small minus big); HML is the value factor(high minus low B/M), CMA is the investment factor(conservative minus aggressive), and there are three specifications used to construct profitability factors: ROE represents profitability factor based on income before extraordinary items; OP represents profitability factor based on operating income and GRO represents profitability factor based on gross profit. On the basis of different profitability specification, book value and total asset value are used respectively as denominator to construct the profitability factors, _B and _A are used to label the difference. Small ends of the factors are constructed and labelled with _S.

Table 8

model factors	Mean alpha	GRS statistic	P-value	Mean adj R2	Mean SE	Mean abs alpha
RM-RF	0.10	1.62	0.03	0.54	0.24	0.25
RM-RF SMB HML	0.11	1.55	0.05	0.74	0.18	0.21
RM-RF SMB HML umd	0.17	1.70	0.02	0.75	0.18	0.25
RM-RF SMB HML CMA	0.15	1.50	0.06	0.76	0.18	0.19
RM-RF SMB HML_S CMA	0.13	1.37	0.12	0.76	0.18	0.17
RM-RF SMB HML CMA_S	0.10	1.18	0.26	0.76	0.18	0.15
RM-RF SMB HML_S CMA_S	0.09	1.12	0.31	0.76	0.18	0.14
RM-RF HML CMA_S ROE_B	0.13	1.07	0.38	0.60	0.23	0.16
RM-RF HML CMA_S ROE_B_S	0.20	1.09	0.35	0.60	0.24	0.22
RM-RF HML CMA_S OP_A	0.19	0.99	0.49	0.60	0.24	0.21
RM-RF HML CMA_S OP_A_S	0.33	1.31	0.15	0.63	0.23	0.34
RM-RF HML CMA_S ROE_A	0.24	1.06	0.40	0.61	0.23	0.26
RM-RF HML CMA_S ROE_A_S	0.42	1.57	0.05	0.63	0.23	0.43
RM-RF HML CMA_S GRO_A	0.15	1.33	0.14	0.59	0.24	0.18
RM-RF HML CMA_S GRO_A_S	0.10	1.13	0.31	0.58	0.24	0.14
RM-RF CMA_S ROE_B	0.11	1.10	0.35	0.59	0.24	0.16
RM-RF CMA_S ROE_B_S	0.20	1.10	0.35	0.60	0.24	0.22
RM-RF CMA_S OP_A	0.17	0.99	0.48	0.60	0.24	0.19
RM-RF CMA_S OP_A_S	0.33	1.31	0.15	0.62	0.23	0.34
RM-RF CMA_S ROE_A	0.22	1.05	0.40	0.60	0.24	0.23
RM-RF CMA_S ROE_A_S	0.42	1.56	0.05	0.63	0.23	0.43
RM-RF CMA_S GRO_A	0.09	1.29	0.17	0.58	0.24	0.15
RM-RF CMA_S GRO_A_S	0.08	1.15	0.29	0.57	0.24	0.14

Note: This table reports GRS test results for various asset pricing factor models using 25 size-investment portfolios. (Rm-Rf) is the market risk premium (value weighted market return minus T-bill rate), SMB is the size factor (small minus big); HML is the value factor(high minus low B/M), CMA is the investment factor(conservative minus aggressive), and there are three specifications used to construct profitability factors: ROE represents profitability factor based on income before extraordinary items; OP represents profitability factor based on operating income and GRO represents profitability factor based on gross profit. On the basis of different profitability specification, book value and total asset value are used respectively as denominator to construct the profitability factors, _B and _A are used to label the difference. Small ends of the factors are constructed and labelled with _S.

Table 9

model factors	Mean alpha	GRS statistic	P-value	Mean adj R2	Mean SE	Mean abs alpha
RM-RF	0.09	3.25	0.00	0.55	0.24	0.27
RM-RF SMB HML	0.12	3.33	0.00	0.74	0.18	0.27
RM-RF SMB HML umd	0.19	3.22	0.00	0.75	0.18	0.27
RM-RF SMB HML CMA	0.16	3.80	0.00	0.75	0.18	0.28
RM-RF SMB HML_S CMA	0.15	3.81	0.00	0.75	0.18	0.27
RM-RF SMB HML CMA_S	0.12	3.60	0.00	0.75	0.19	0.28
RM-RF SMB HML_S CMA_S	0.11	3.63	0.00	0.74	0.19	0.28
RM-RF HML CMA_S ROE_B	0.16	3.30	0.00	0.60	0.24	0.25
RM-RF HML CMA_S ROE_B_S	0.21	3.04	0.00	0.60	0.24	0.25
RM-RF HML CMA_S OP_A	0.22	3.12	0.00	0.61	0.24	0.26
RM-RF HML CMA_S OP_A_S	0.34	2.76	0.00	0.62	0.23	0.36
RM-RF HML CMA_S ROE_A	0.27	3.02	0.00	0.62	0.23	0.30
RM-RF HML CMA_S ROE_A_S	0.43	2.42	0.00	0.63	0.24	0.44
RM-RF HML CMA_S GRO_A	0.17	3.11	0.00	0.58	0.24	0.25
RM-RF HML CMA_S GRO_A_S	0.12	3.16	0.00	0.57	0.25	0.25
RM-RF CMA_S ROE_B	0.13	3.31	0.00	0.59	0.24	0.25
RM-RF CMA_S ROE_B_S	0.21	3.01	0.00	0.59	0.24	0.25
RM-RF CMA_S OP_A	0.20	3.12	0.00	0.60	0.24	0.25
RM-RF CMA_S OP_A_S	0.34	2.72	0.00	0.62	0.23	0.36
RM-RF CMA_S ROE_A	0.25	3.04	0.00	0.61	0.24	0.28
RM-RF CMA_S ROE_A_S	0.43	2.38	0.00	0.62	0.24	0.44
RM-RF CMA_S GRO_A	0.11	3.23	0.00	0.57	0.24	0.25
RM-RF CMA_S GRO_A_S	0.09	3.22	0.00	0.57	0.25	0.25

Note: This table reports GRS test results for various asset pricing factor models using 25 size-profitability portfolios. (Rm-Rf) is the market risk premium (value weighted market return minus T-bill rate), SMB is the size factor (small minus big); HML is the value factor(high minus low B/M), CMA is the investment factor(conservative minus aggressive), and there are three specifications used to construct profitability factors: ROE represents profitability factor based on income before extraordinary items; OP represents profitability factor based on operating income and GRO represents profitability factor based on gross profit. On the basis of different profitability specification, book value and total asset value are used respectively as denominator to construct the profitability factors, _B and _A are used to label the difference. Small ends of the factors are constructed and labelled with _S.