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ORIGINAL ARTICLE

# Testing alternative versions of the Fama–French five-factor model in the UK

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**Abstract** This paper evaluates whether the new Fama–French five-factor model is able to offer an improved method for pricing investment risk in UK equity returns. The paper extends previous studies by testing alternative specifications of the profitability factor. The initial tests indicate that a respecified five-factor model—using gross profit rather than operating profit—provides an improved description of UK equity returns. However, the factors tested perform inconsistently when evaluated against different test portfolios and neither the value nor investment premiums are consistently priced. As well as highlighting the importance of testing factor models using an array of different test portfolios, the results show that both the three- and five-factor models are unable to offer a convincing description of UK equity returns and therefore cannot be considered a reliable measure of financial risk.

**Keywords** Asset pricing · Multi factor models · CAPM · Fama–French three-factor model · Fama–French five-factor model · UK

## Introduction

Multifactor models have become the mainstay of modeling equity returns for investment and risk management purposes. Recently, Fama and French (2015) have proposed a five-factor model (FF15) that adds two additional factors to their seminal three-factor model (FF93) (Fama and French 1993).

While FF93 is used pervasively in both industry and academia, recent evidence suggests the model may be incomplete. Firstly, Novy-Marx (2013) documents

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that controlling for profitability enhances the performance of value-based investment strategies. Secondly, Aharoni et al. (2013) identify a relationship between investment and equity returns. Furthermore, average returns from the profitability and investment strategies cannot be explained by FF93. These findings motivated the creation of FF15, which adds profitability and investment factors to the market, size, and value factors of FF93. Fama and French (2015) first tested FF15 in the US market and found that the model offers a better explanation of average returns than FF93. Fama and French (2017) extend their earlier work by testing the models using an international sample and find that FF15 is able to absorb the profitability and investment patterns left unexplained by FF93 when the factors and the test portfolios are both formed regionally. However, versions of FF93 and FF15 constructed from global factors perform poorly when tested on regional portfolios.

Although authors such as Sevillano and Jareño (2018) show that increasing globalization is an important determinant of national stock market returns, previous research generally suggests that tests of factor models are best conducted on a local basis. Most recently, Fama and French (2017) find that FF93 and FF15 perform better when tested using regional rather than global factors. In an earlier study, Fama and French (2012) show that regional versions of FF93 are better at explaining equity returns than global versions of the model. Also, Griffin (2002) reports that country-specific versions of FF93 provide better descriptions of equity returns than both world and international versions of the model. However, despite the evidence supporting using local versions of FF93, results from UK tests suggest that the model has only limited applicability. In one of the earliest tests of FF93 in the UK, Miles and Timmermann (1996) report that a two-factor model consisting of just the HML and SMB factors has greater explanatory power than both CAPM and FF93—supporting the existence of the size and value premiums but not the market risk premium component of FF93. Hussain et al. (2002) report that although FF93 has more explanatory power than CAPM, substantial mispricing is present for a number of portfolios. Gregory et al. (2001) test a UK sample between 1975 and 1998 and strongly reject FF93. Otten and Bams (2002) show that UK small-cap funds substantially outperform Carhart's (1997) four-factor model—i.e., the size premium is not entirely explained by the SMB factor. Gregory et al. (2013) find that although FF93 and Carhart's (1997) four-factor model are able to explain returns from portfolios formed using large stocks, the factors are not consistently or reliably priced. Mouselli (2010) examines FF93 in the UK from a risk management perspective and shows that value stocks do not seem riskier than growth stocks when compared to their betas.

The primary motivations for this research are threefold. Firstly, the paper addresses Lo and MacKinlay's (1990) concern that empirically motivated asset pricing models are subject to data mining and this necessitates out-of-sample tests. In addition to alleviating concerns about data snooping, different accounting standards, as well as Hope's (2003) finding that legal origin and culture are important determinants of firm disclosure, may impact the performance of the profitability and investment factors outside the US. While FF93 has been extensively tested in the prior literature, far fewer studies have tested FF15. This has created a need for tests of FF15 outside the US: The large and liquid stock market of the UK offers an ideal sample for testing the model.

Secondly, the research outlined above has identified a particular need for an alternative model to FF93 for explaining UK cross-sectional equity returns. Although the evidence from the UK tends to be supportive of the existence of the size and value premiums, studies generally find that FF93 does not adequately describe returns. This suggests that augmenting FF93 with additional factors has the potential to offer a better description of UK equity returns. However, as FF15 is a recent development, there have been few tests of the model in the UK. One exception is Nichol and Dowling (2014) who test FF15 using FTSE 350 constituents between 2002 and 2013 and find that the five-factor model performs better than the three-factor model when used to explain returns on test portfolios formed from size and book-to-price (BP). In addition to testing a much longer sample period (27 years, rather than 11 years) and the whole of the UK Main Market (not just the FTSE 350), this paper extends Nichol and Dowling's (2014) work by testing the factor models against test portfolios formed from a range of different variables—if FF15 truly offers an improved description of equity returns, the factors should be consistently priced across different test assets.

The third motivation of the paper is to address the previously overlooked requirement to test FF15 using alternative measures of profitability to form the RMW factor (a detailed explanation of the construction of the factors is provided in "Data and method" section). Novy-Marx (2013) finds that profitability (as measured by gross-profit-to-assets) has an explanatory power similar to BP. Furthermore, controlling for profitability substantially improves the performance of value strategies. Fama and French (2015) cite this paper as the motivation for including a profitability term in their five-factor model. However, while Novy-Marx (2013) measures profitability using gross profit, Fama and French (2015) use operating profitability to form RMW. Fama and French (2015) are silent as to why they do not use the same measure of profitability as Novy-Marx (2013). This has created the need to reconcile the works by Novy-Marx (2013) and Fama and French (2015) by testing FF15 using RMW formed from different measures of profitability. Furthermore, Nichol and Dowling (2014) report that the profitability factor was particularly promising in their UK test of FF15 and suggest that future research tests alternative specifications of profitability—a gap in the literature that this paper fills.

The paper tests FF93 and FF15 in the UK and extends previous research by constructing the RMW factor using four different measures of profitability. As in Fama and French (2015), factor models are tested against portfolios constructed from the following intersecting sorts: size-BP, size-profitability, size-investment, size-profitability-investment, and size-BP-investment. The primary concern of this paper is to determine whether the factors are consistently priced across the various test portfolio sorts. The tests using portfolios formed from size-BP and size-profitability sorts show that forming the RMW factor using gross profit (the measure of profitability favored by Novy-Marx 2013) rather than operating profit (the measure of profitability used by Fama and French 2015) seems to provide an improved description of UK equity returns. Firstly, the five-factor model using a gross profitability factor has the highest *r*-squared from the size-BP sorts. Secondly and more importantly, the five-factor model using the gross profitability factor is the only one of the four five-factor models in which the CMA factor is statistically significant. These initial tests seem to favor constructing RMW using gross profit rather than operating profit in the UK. However, when testing the factor models against portfolios sorted on size-investment, size-profitability-investment, and size-BP-investment, the investment and value premiums are not consistently priced, regardless of the measure of profitability used to form the RMW factor. These findings call into serious question Nichol and Dowling's (2014) approach of only testing factor models against size-BP-sorted portfolios and lead to the conclusion that neither the three- nor five-factor models are able to offer an acceptable description of UK equity returns.

The paper proceeds as follows. Outline of the factor models tested is provided in "The empirical models" section. "Data and method" section describes the formations of factor and test portfolio along with the methods adopted for their construction. Statistical parameters based on the findings of this study are summarized and the results of regression for the factor models against various test portfolios are detailed in "Results" section. The main conclusions based on findings of the study are drawn outlining the limitations of this and previous research in "Conclusion" section.

## The empirical models

This section outlines the factor models tested. A more detailed explanation of the construction of the factors is provided in a separate section below.

FF93 extends CAPM with additional factors to mimic size and value:

$$R_{\mathrm{it}} = \mathrm{RF}_{\mathrm{t}} + \beta_{\mathrm{i}}\left(\mathrm{RM}_{\mathrm{t}} - \mathrm{RF}_{\mathrm{t}}\right) + s_{\mathrm{i}}\mathrm{SMB}_{\mathrm{t}} + h_{\mathrm{i}}\mathrm{HML}_{\mathrm{t}} + \varepsilon_{\mathrm{it}}, \tag{1}$$

where $R_i$ is the return on portfolio i; RF is the risk free rate; $\beta_i$ is portfolio $i$'s CAPM beta, RM is the return on the market; SMB (small minus big) is the size factor, formed using market value of equity; and HML (high minus low) is the value factor, formed using BP.

FF15 adds profitability and investment factors to FF93:

$$R_{\mathrm{it}} = \mathrm{RF}_{\mathrm{t}} + \beta_{\mathrm{i}}\left(\mathrm{RM}_{\mathrm{t}} - \mathrm{RF}_{\mathrm{t}}\right) + s_{\mathrm{i}}\mathrm{SMB}_{\mathrm{t}} + h_{\mathrm{i}}\mathrm{HML}_{\mathrm{t}} + r_{\mathrm{i}}\mathrm{RMW}_{\mathrm{t}} + c_{\mathrm{i}}\mathrm{CMA}_{\mathrm{t}} + \varepsilon_{\mathrm{it}}, \tag{2}$$

where RMW (robust minus weak) is the profitability factor, which this paper constructs and tests using four different specifications of profitability, and CMA (conservative minus aggressive) is the investment factor, formed using year-on-year change in total assets.

## Data and method

The data come from Datastream and cover the period from October 1989 to September 2016. The Datastream sample includes both active and dead firms, ensuring that the results are not affected by the survivorship bias. Following previous UK research (e.g., Gregory et al. 2013; Dimson et al. 2003), the sample only includes stocks listed on the Main Market and excludes AIM stocks, financials, and foreign companies. Companies with negative or missing book values are also excluded.

## Factor formation

In models (1) and (2), RM is the total return on the FTSE All Share Index. RF is the monthly return on three month UK Treasury Bills. RM − RF is the market risk premium. Following Gregory et al. (2013), the portfolios are formed at the beginning of October in year *t*, the median market capitalization of the 350 largest firms is used as the size breakpoint, and the 70th and 30th percentiles of the BP sorts of the largest 350 firms as the value breakpoint. Two size groups Small (S) and Big (B) are formed. Three value groups are formed: High (H), Medium (M), and Low (L). The following six intersecting portfolios are then constructed from the size and value groups: SH, SM, SL, BH, BM, and BL. The SMB and HML factors are formed from these portfolios. SMB is calculated as (SL + SM + SH)/3 − (BL + BM + BH)/3. HML is calculated as (SH + BH)/2 − (SL + BL)/2.

In model (2), the RMW factor is the difference between returns on firms with robust profitability and weak profitability. Three profitability groups are formed: Robust (R), Medium (M), and Weak (W). RMW is calculated as (SR + BR)/2 − (SW + BW)/2. Fama and French (2015) only construct RMW using operating profitability (OP), which they calculate as annual revenue minus cost of goods sold, interest expense, and selling, general, and administrative expenses, all divided by book value of equity. In addition to testing the five-factor model using $RMW_{OP}$, this paper also tests the effect of forming the RMW factor using the three alternative specifications of profitability used by Novy-Marx (2013). Gross profitability (GP), used to form $RMW_{GP}$, is calculated as gross profit (revenue minus cost of goods sold) divided by book value of assets. Net income (NI), used to form $RMW_{NI}$, is calculated as income before extraordinary items scaled by book value of equity. Free cash flow (FCF), used to form $RMW_{FCF}$, is calculated as net income plus amortization and depreciation minus changes in working capital and capital expenditures all divided by book value of equity.

The CMA factor is the difference between the returns from portfolios of stocks of low and high investment firms. Following Fama and French (2015), investment is defined as the change in total assets from the fiscal year ending $t-2$ to the fiscal year ending $t-1$ divided by $t-2$ total assets.

## Test portfolio formation

Following the approach used to construct the factors, the test portfolios are formed at the beginning of October for each year *t*. All firms in the sample are used to form the test portfolios. The 25 (5 × 5) intersecting size-BP portfolios are formed using the approach of Gregory et al. (2013). Five size portfolios are constructed: four from quartiles of the largest 350 firms and one from the rest of the sample. The BP quintiles of the largest 350 firms are used as breakpoints to create five BP groups.

**Table 1** Factor summary statistics, October 1989 to September 2016

| | RM – RF | SMB | HML | $RMW_{OP}$ | CMA | $RMW_{GP}$ | $RMW_{FCF}$ | $RMW_{NI}$ |
|---|---|---|---|---|---|---|---|---|
| Mean (%) | 0.12 | 0.31** | 0.27 | 1.22*** | 0.26 | 0.51*** | 1.05*** | 1.24*** |
| SD (%) | 4.35 | 2.50 | 3.89 | 3.27 | 3.30 | 2.37 | 2.38 | 3.38 |
| Skewness | – 0.54 | 0.24 | 0.80 | 1.03 | 2.00 | 0.10 | 0.51 | 0.87 |
| Max (%) | 11.40 | 11.24 | 21.80 | 15.40 | 19.70 | 11.23 | 11.02 | 15.11 |
| Min (%) | – 15.29 | – 6.97 | – 13.03 | – 7.18 | – 9.53 | – 9.02 | – 6.12 | – 8.53 |
| p50 (%) | 0.79 | 0.24 | 0.28 | 1.00 | 0.04 | 0.38 | 0.86 | 0.94 |
| Kurtosis | 0.93 | 1.01 | 5.31 | 3.34 | 9.15 | 1.88 | 1.49 | 2.77 |

The table reports the summary statistics for the Fama–French five factors, including four alternative definitions of the profitability factor. RM – RF is the market risk premium. SMB, HML, CMA, $RMW_{OP}$, $RMW_{GP}$, $RMW_{FCF}$, and $RMW_{NI}$ are all formed from six intersecting portfolios. The construction of SMB, HML, CMA, and $RMW_{OP}$ follows Fama and French (2015). The construction of the $RMW_{GP}$, $RMW_{FCF}$, and $RMW_{NI}$ factors follows $RMW_{OP}$, except the factors that are formed using gross profit, free cash flow, and net income, respectively, rather than operating profit. A detailed explanation of the construction of the factors is provided in the text. The table reports statistics for the mean, standard deviation (sd), skewness, maximum (max), minimum (min), median (p50), and kurtosis. ***, **, and *represent statistical significance at the 1, 5, and 10% levels, respectively

The profitability and investment portfolios are formed using the same approach as the BP groups—the profitability and investment quintiles of the largest 350 firms are used as breakpoints to create profitability and investment groups. Following the approach used when constructing the factors, the profitability portfolios are formed using OP, GP, FCF, and NI.

To get a clearer picture of the drivers of UK equity returns, it would be useful to sort jointly on size, BP, profitability, and investment. However, echoing the findings of Fama and French (2015), this results in 81 very poorly diversified portfolios. Thus, following the approach of Fama and French (2015), two size groups are formed using the median market capitalization from the sample as the breakpoint. Quintiles from the largest 350 firms are used as breakpoints for BP, profitability, and investment. This leaves 32 (2 × 4 × 4) portfolios for each combination of variables.

## Results

### Summary statistics

The summary statistics for the factors are reported in Table 1.

Echoing previous research, the market risk premium is not significantly different from zero. Despite the prevalence of the value premium in the prior literature, HML cannot be considered statistically significant at any conventional level. The investment factor, CMA, is also not statistically significant. SMB and all four profitability-based factors can be considered statistically significant at the 1% level.

$RMW_{NI}$ has the highest mean of any of the factors (1.24% per month) and also has the highest standard deviation of the four profitability factors. $RWM_{OP}$ (the profitability factor used by Fama and French 2015) has the second highest mean

**Table 2** Correlations between factors, October 1989 to September 2016

| | RM – RF | SMB | HML | $RMW_{OP}$ | CMA | $RMW_{GP}$ | $RMW_{FCF}$ | $RMW_{NI}$ |
|---|---|---|---|---|---|---|---|---|
| RM – RF | 1.00 | | | | | | | |
| SMB | 0.14 | 1.00 | | | | | | |
| HML | 0.13 | 0.07 | 1.00 | | | | | |
| $RMW_{OP}$ | – 0.47 | 0.13 | – 0.08 | 1.00 | | | | |
| CMA | – 0.12 | – 0.00 | 0.64 | 0.14 | 1.00 | | | |
| $RMW_{GP}$ | – 0.32 | – 0.01 | – 0.31 | 0.60 | 0.09 | 1.00 | | |
| $RMW_{FCF}$ | – 0.28 | 0.11 | – 0.17 | 0.72 | 0.03 | 0.57 | 1.00 | |
| $RMW_{NI}$ | – 0.45 | 0.13 | – 0.08 | 0.97 | 0.13 | 0.60 | 0.72 | 1.00 |

The table reports the correlations between the various factors tested. RM – RF is the market risk premium. SMB, HML, CMA, $RMW_{OP}$, $RMW_{GP}$, $RMW_{FCF}$, and $RMW_{NI}$ are all formed from six intersecting portfolios. The construction of SMB, HML, CMA, and $RMW_{OP}$ follows Fama and French (2015). The construction of the $RMW_{GP}$, $RMW_{FCF}$, and $RMW_{NI}$ factors follows $RMW_{OP}$, except the factors that are formed using gross profit, free cash flow, and net income, respectively, rather than operating profit. A detailed explanation of the construction of the factors is provided in the text

(1.22% per month) and the highest level of skewness among the profitability factors. $RMW_{GP}$ has the lowest mean (0.51% per month) and lowest skewness (0.1) among the profitability factors.

The correlations in Table 2 reveal that the FF93 factors are positively correlated with other. The CMA and profitability factors are all negatively correlated with the market risk premium. The CMA factor exhibits quite a high degree of positive correlation with HML. Predictably, the factors formed from the four different specifications of profitability all exhibit strong positive correlation with each other.

Table 3 shows the results from the Fama and Macbeth (1973) style regressions of stock returns against OP, GP, FCF, NI, and investment. The regressions include controls for BP and size.

BP and size are both statistically significant at the 1% level, indicating that both the size and value premiums are present in the sample. All four measures of profitability are also statistically significant at the 1% level. However, investment has far less explanatory power than any of the profitability factors. The results are consistent with the findings of Novy-Marx (2013) in showing that GP has more power than NI and FCF. Furthermore, OP—the measure of profitability used by Fama and French (2015)—has a substantially lower *t*-statistic than GP. This finding and the fact that Fama and French (2015) are silent with regards to why they choose OP over GP (or some other measure of profitability), despite citing Novy-Marx (2013) as the motivation for including a profitability term, highlights the need to test FF15 using RMW formed from different measures of profitability.

## Tests of factor models

Tables 4, 5, 6, 7 and 8 report the results from testing various factor models against an array of test portfolios.

**Table 3** Average slope coefficients and *t*-statistics from monthly Fama–MacBeth (1973) regressions of individual firms' returns on operating profit, gross profit, free cash flow, net income, investment, BP, and ME, October 1989 to September 2016

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Operating profitability | | | | 0.00165 | | | | |
| | | | | (5.68) | | | | |
| Gross profitability | | | | | 0.01264 | | | |
| | | | | | (8.63) | | | |
| Free cash flow | | | | | | 0.00159 | | |
| | | | | | | (4.36) | | |
| Net income | | | | | | | 0.00167 | |
| | | | | | | | (5.30) | |
| Investment | | | | | | | | 0.00106 |
| | | | | | | | | (1.23) |
| ln(BP) | 0.00189 | | 0.00299 | 0.00282 | 0.00423 | 0.00282 | 0.00273 | 0.00300 |
| | (2.81) | | (4.19) | (4.00) | (5.60) | (3.87) | (3.87) | (4.26) |
| ln(ME) | | 0.00141 | 0.00180 | 0.00158 | 0.00207 | 0.00166 | 0.00158 | 0.00177 |
| | | (3.80) | (4.54) | (4.04) | (5.18) | (4.22) | (4.05) | (4.43) |

The table reports Fama–Macbeth regressions of returns on investment and four different measures of profitability. Regressions include controls for BP and size

Operating Profitability is calculated as annual revenue minus cost of goods sold, interest expense, and selling, general, and administrative expenses, all divided by book value of equity

Gross profitability is calculated as gross profit (revenue minus cost of goods sold) divided by book value of assets

Net income is calculated as income before extraordinary items scaled by book value of equity

Free cash flow is calculated as net income plus amortization and depreciation minus changes in working capital and capital expenditures all divided book value of equity

Table 4 reports the average premiums and *t*-statistics from testing the factor models using the 25 size-BP test portfolios. The FF93 model returns a marginally significant value premium of 0.31% per month (*t*-statistic = 1.77) and a highly significant size premium of 0.38% per month (*t*-statistic = 4.28). This is an unusual finding given that previous studies have found the value effect to be durable across samples, while the size effect tends to be transient.

FF15 (which uses operating profitability for the RMW factor) yields a positive and marginally significant market risk premium of 0.52% per month. The size premium falls to 0.24% per month but remains significant at the 1% level. The value premium falls by less than the size premium and is now 0.32% per month and becomes significant at the 1% level. The OP premium is 1.04% per month and is highly significant. However, the investment premium is insignificant. Adding OP and investment factors to FF93 increases the *r*-squared from 0.37 to 0.50. These results provide an interesting contrast to the findings of Fama and French (2015) as they report that HML is significant in the three-factor model but when CMA and $RMW_{OP}$ are added to the model, the value factor becomes redundant.

**Table 4** Fama and MacBeth (1973) regressions on test portfolios formed from size and book-price

| $\lambda_0$ | $\lambda_{RMRF}$ | $\lambda_{SMB}$ | $\lambda_{HML}$ | $\lambda_{RMWOP}$ | $\lambda_{RMWCMA}$ | $\lambda_{RMWGP}$ | $\lambda_{RMWFCF}$ | $\lambda_{RMWNI}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|
| −0.0002 | −0.0030 | 0.0038 | 0.0031 | | | | | | 0.37 |
| (−0.06) | (−0.75) | (4.28) | (1.77) | | | | | | |
| −0.0071 | 0.0052 | 0.0024 | 0.0032 | 0.0104 | 0.0058 | | | | 0.50 |
| (−2.66) | (1.75) | (2.75) | (2.88) | (3.04) | (1.02) | | | | |
| −0.0082 | 0.0061 | 0.0041 | 0.0034 | | 0.0126 | 0.0133 | | | 0.54 |
| (−1.95) | (1.30) | (4.29) | (2.22) | | (2.11) | (2.36) | | | |
| −0.0058 | 0.0035 | 0.0028 | 0.0028 | | 0.0081 | | 0.0085 | | 0.41 |
| (−1.43) | (0.80) | (3.27) | (2.48) | | (1.20) | | (2.03) | | |
| −0.0071 | 0.0055 | 0.0023 | 0.0030 | | 0.0058 | | | 0.0116 | 0.51 |
| (−2.69) | (1.84) | (2.78) | (2.89) | | (1.00) | | | (3.09) | |

The table reports Fama and MacBeth (1973) average factor premiums, *t*-statistics, and adjusted $R^2$ for test portfolios double sorted on size and book-price. RMRF is the market risk premium. SMB and HML are the Fama and French (1993) factors. CMA is the Fama and French (2015) investment factor. $RMW_{OP}$ is the Fama and French (2015) profitability factor. The construction of the $RMW_{GP}$, $RMW_{FCF}$, and $RMW_{NI}$ factors follows $RMW_{OP}$, except the factors that are formed using gross profit, free cash flow, and net income, respectively, rather than operating profit. A detailed explanation of the construction of the factors is provided in the text

FF15 using $RMW_{GP}$ yields a marginally higher *r*-squared (0.54) than FF15 using $RMW_{OP}$. At 0.41% per month, the size premium for FF15 using $RMW_{GP}$ is similar to the size premium for FF93 and remains statistically significant at the 1% level. The value premium of 0.34% per month is very similar to the value premium for both FF93 and FF15 using $RMW_{OP}$; however, it is only significant at 5% for FF15 using $RMW_{GP}$. The GP premium is 1.33% per month, slightly higher than the OP premium, and is significant at 5%. In contrast to the other models tested, the investment premium is now significant at the 5% level and increases substantially to 1.26% per month.

The five-factor model using $RMW_{FCF}$ yields the lowest *r*-squared (0.41) out of all the five-factor models tested on size-BP sorts. The size premium is 0.28% per month and significant at 1%. The value premium is 0.28% per month and significant at 5%. The FCF premium is 0.85% per month and significant at 5% (*t*-statistic = 2.03). The market risk and investment premiums are insignificant.

FF15 using $RMW_{NI}$ returns an *r*-squared of 0.51. The market risk premium is positive and marginally significant (*t*-statistic = 1.84). The size and value premiums are 0.23% per month and 0.3% per month, respectively (*t*-statistics = 2.78 and 2.89, respectively). The NI premium is 1.16% per month and is highly significant. The investment premium is insignificant.

Overall, the five-factor models have more explanatory power than the three-factor model. Firstly, all four five-factor models have a higher *r*-squared than the three-factor model (although the improvement is only marginal in the case of FF15 using $RMW_{FCF}$). Secondly, although HML is only marginally significant when used in the three-factor model, its explanatory ability increases when it is incorporated into the five-factor models—becoming significant at 1% for FF15 using $RMW_{OP}$

**Table 5** Fama and MacBeth (1973) regressions on test portfolios formed from size and profitability

| $\lambda_0$ | $\lambda_{RMRF}$ | $\lambda_{SMB}$ | $\lambda_{HML}$ | $\lambda_{RMWOP}$ | $\lambda_{RMWCMA}$ | $\lambda_{RMWGP}$ | $\lambda_{RMWFCF}$ | $\lambda_{RMWNI}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|
| Panel A: size and operating profitability sorts | | | | | | | | | |
| 0.0150 | −0.0179 | 0.0031 | 0.0019 | | | | | | 0.50 |
| (4.15) | (−4.84) | (2.13) | (0.32) | | | | | | |
| −0.0009 | −0.0009 | 0.0018 | 0.0052 | 0.0120 | 0.0047 | | | | 0.74 |
| (−0.16) | (−0.16) | (2.07) | (1.11) | (8.40) | (0.69) | | | | |
| Panel B: size and gross profitability sorts | | | | | | | | | |
| −0.0008 | −0.0016 | 0.0041 | −0.0018 | | | | | | 0.26 |
| (−0.19) | (−0.36) | (2.68) | (−0.50) | | | | | | |
| −0.0109 | 0.0092 | 0.0035 | 0.0061 | | 0.0208 | 0.0064 | | | 0.59 |
| (−1.93) | (1.48) | (4.73) | (1.30) | | (2.12) | (4.17) | | | |
| Panel C: size and FCF sorts | | | | | | | | | |
| 0.0105 | −0.0131 | 0.0033 | 0.0009 | | | | | | 0.23 |
| (2.42) | (−2.82) | (1.76) | (0.18) | | | | | | |
| −0.0027 | 0.0011 | 0.0026 | 0.0010 | | 0.0036 | | 0.0111 | | 0.57 |
| (−0.65) | (0.24) | (2.16) | (0.20) | | (0.36) | | (9.78) | | |
| Panel D: size and NI sorts | | | | | | | | | |
| 0.0147 | −0.0177 | 0.0030 | 0.0093 | | | | | | 0.56 |
| (5.69) | (−6.57) | (2.22) | (1.38) | | | | | | |
| 0.0011 | −0.0027 | 0.0025 | 0.0100 | | 0.0071 | | | 0.0114 | 0.75 |
| (0.19) | (−0.42) | (2.74) | (1.78) | | (1.06) | | | (9.57) | |

The table reports Fama and MacBeth (1973) average factor premiums, *t*-statistics, and adjusted $R^2$ for test portfolios double sorted on size and four different measures of profitability. RMRF is the market risk premium. SMB and HML are the Fama and French (1993) factors. CMA is the Fama and French (2015) investment factor. $RMW_{OP}$ is the Fama and French (2015) profitability factor. The construction of the $RMW_{GP}$, $RMW_{FCF}$, and $RMW_{NI}$ factors follows $RMW_{OP}$, except the factors that are formed using gross profit, free cash flow, and net income, respectively, rather than operating profit. A detailed explanation of the construction of the factors is provided in the text

and $RMW_{NI}$ and significant at 5% for FF15 using $RMW_{GP}$ and $RMW_{FCF}$. All four five-factor models have a statistically significant profitability factor: $RMW_{OP}$ and $RMW_{NI}$ are significant at 1% and $RMW_{GP}$ and $RMW_{FCF}$ are significant at 5%. This strongly indicates that UK equity returns include a priced profitability factor. However, the performance of the investment factor is much weaker and CMA is only priced for FF15 using $RMW_{GP}$.

The finding that the CMA factor is only significant for FF15 using $RMW_{GP}$ initially seems striking—however, it is actually consistent with finance theory. Out of the four profitability measures tested, GP is the only one which does not exclude interest expense.[1] If interest expense is subtracted from the measure of profitability used, the effects of aggressive capital expenditure financed by debt

[1] Fama and French's (2015) definition of operating profit is rather unusual in that it involves subtracting interest.

**Table 6** Fama and MacBeth (1973) regressions on test portfolios formed from size and investment

| $\lambda_0$ | $\lambda_{RMRF}$ | $\lambda_{SMB}$ | $\lambda_{HML}$ | $\lambda_{RMWOP}$ | $\lambda_{RMWCMA}$ | $\lambda_{RMWGP}$ | $\lambda_{RMWFCF}$ | $\lambda_{RMWNI}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|
| −0.0104 | 0.0054 | 0.0088 | 0.0117 | | | | | | 0.60 |
| (−2.09) | (1.01) | (5.25) | (2.72) | | | | | | |
| −0.0188 | 0.0146 | 0.0080 | 0.0244 | 0.0095 | 0.0018 | | | | 0.75 |
| (−3.99) | (2.92) | (4.88) | (3.20) | (3.94) | (0.81) | | | | |
| −0.0099 | 0.0042 | 0.0098 | 0.0230 | | 0.0011 | −0.0051 | | | 0.66 |
| (−2.02) | (0.89) | (5.39) | (2.62) | | (0.39) | (−0.90) | | | |
| −0.0146 | 0.0096 | 0.0090 | 0.0234 | | 0.0011 | | 0.0059 | | 0.70 |
| (−2.88) | (1.87) | (4.79) | (2.86) | | (0.45) | | (1.66) | | |
| −0.0183 | 0.0142 | 0.0080 | 0.0233 | | 0.0015 | | | 0.0112 | 0.75 |
| (−4.11) | (2.98) | (4.79) | (3.11) | | (0.66) | | | (4.12) | |

The table reports Fama and MacBeth (1973) average factor premiums, *t*-statistics, and adjusted $R^2$ for test portfolios double sorted on size and investment. RMRF is the market risk premium. SMB and HML are the Fama and French (1993) factors. CMA is the Fama and French (2015) investment factor. $RMW_{OP}$ is the Fama and French (2015) profitability factor. The construction of the $RMW_{GP}$, $RMW_{FCF}$, and $RMW_{NI}$ factors follows $RMW_{OP}$, except the factors that are formed using gross profit, free cash flow, and net income, respectively, rather than operating profit. A detailed explanation of the construction of the factors is provided in the text

will appear in both RMW and CMA: The CMA factor will capture the increase in assets and the RMW factor will capture the increased interest cost. Therefore, aggressive capital expenditure financed by borrowing will be effectively double-counted if RMW is constructed using OP, FCF, or NI. In contrast, an increase in interest expense due to borrowing to finance investment will not directly affect GP. However, the capital expenditure will be captured by CMA from the resulting increase in assets. Therefore when using $RMW_{GP}$ to measure profitability, only CMA will directly capture capital expenditure (regardless of how it was financed). While finance theory is able to offer an explanation for these findings, it does not explain why the results from the UK sample are inconsistent with those reported by Fama and French (2015).

The results so far appear to favor calculating RMW using GP, rather than Fama and French's (2015) measure of OP. The rest of the paper examines whether the above findings are robust for test portfolios formed using different variables.

Table 5 reports results from using the factor models to explain returns from 25 test portfolios formed using size and four different measures of profitability.

Panel A contains the results from the cross-sectional regressions using test portfolios formed from size and OP. The FF93 model yields an *r*-squared of 0.50, and this increases to 0.74 for the five-factor model. The market risk premium is negative and highly significant for the FF93 model. It remains negative but becomes only marginally significant in the five-factor model. In the FF93 model, SMB is significant at 5% and has a premium of 0.31% per month. The size premium falls to 0.18% per month in the FF15 model and remains significant at the 5% level. The value premium is not significant for either FF93 or FF15. The OP premium is 1.2% per month and the factor is highly significant. The investment premium is insignificant.

**Table 7** Fama and MacBeth (1973) regressions on test portfolios formed from size, measures of profitability, and investment

| $\lambda_0$ | $\lambda_{RMRF}$ | $\lambda_{SMB}$ | $\lambda_{HML}$ | $\lambda_{RMWOP}$ | $\lambda_{RMWCMA}$ | $\lambda_{RMWGP}$ | $\lambda_{RMWFCF}$ | $\lambda_{RMWNI}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|
| Panel A: size-operating profitability-investment sorts | | | | | | | | | |
| 0.0041 | −0.0085 | 0.0055 | −0.0015 | | | | | | 0.44 |
| (1.40) | (−1.65) | (5.81) | (−0.82) | | | | | | |
| 0.0041 | −0.0058 | 0.0044 | 0.0021 | 0.0136 | −0.0018 | | | | 0.53 |
| (0.79) | (−1.09) | (3.65) | (1.24) | (3.09) | (−0.91) | | | | |
| Panel B: size-gross profitability-investment sorts | | | | | | | | | |
| 0.0068 | −0.0085 | 0.0055 | −0.0015 | | | | | | 0.44 |
| (1.40) | (−1.65) | (5.81) | (−0.82) | | | | | | |
| −0.0006 | −0.0012 | 0.0077 | 0.0060 | | 0.0013 | 0.0077 | | | 0.70 |
| (−0.16) | (−0.30) | (7.56) | (2.69) | | (0.84) | (3.69) | | | |
| Panel C: size-FCF-investment sorts | | | | | | | | | |
| 0.0032 | −0.0055 | 0.0075 | −0.0021 | | | | | | 0.56 |
| (0.77) | (−1.21) | (5.35) | (−0.76) | | | | | | |
| 0.0012 | −0.0030 | 0.0062 | 0.0013 | | −0.0007 | | 0.0106 | | 0.66 |
| (0.34) | (−0.76) | (5.99) | (0.89) | | (−0.29) | | (2.79) | | |
| Panel D: size-NI-investment sorts | | | | | | | | | |
| 0.0062 | −0.0078 | 0.0055 | −0.0030 | | | | | | 0.27 |
| (1.38) | (−1.58) | (4.14) | (−1.31) | | | | | | |
| 0.0047 | −0.0063 | 0.0048 | 0.0000 | | −0.0028 | | | 0.0107 | 0.31 |
| (0.88) | (−1.12) | (2.96) | (0.00) | | (−1.39) | | | (4.01) | |

The table reports Fama and MacBeth (1973) average factor premiums, *t*-statistics, and adjusted $R^2$ for test portfolios triple sorted on size, investment and four different measures of profitability. RMRF is the market risk premium. SMB and HML are the Fama and French (1993) factors. CMA is the Fama and French (2015) investment factor. $RMW_{OP}$ is the Fama and French (2015) profitability factor. The construction of the $RMW_{GP}$, $RMW_{FCF}$, and $RMW_{NI}$ factors follows $RMW_{OP}$, except the factors that are formed using gross profit, free cash flow, and net income, respectively, rather than operating profit. A detailed explanation of the construction of the factors is provided in the text

Panel B reports the results from regressions using test portfolios formed from size and GP. The market risk premium and the value factor are insignificant for both the three- and five-factor models. The size premium for the three- and five-factor models is 0.41 and 0.35% per month, respectively. The size factor is significant for the three-factor model (*t*-statistic = 2.68) and highly significant for the five-factor model (*t*-statistic = 4.73). In the five-factor model, the GP premium is 0.64% per month and highly significant. The investment premium is 2.08% per month and significant at the 5% level.

The results from the regressions using the size-FCF sorts are shown in Panel C. The addition of FCF and investment factors to FF93 substantially increases the cross-sectional *r*-squared from 0.23 to 0.57. The size factor is marginally significant for the three-factor model (*t*-statistic = 1.76) and the factor becomes significant at the 5% level (*t*-statistic = 2.16) for the five-factor model. HML is insignificant in both models. In the five-factor model, the FCF premium is 1.11%

**Table 8** Fama and MacBeth (1973) regressions on test portfolios formed from size, book-price, and investment

| $\lambda_0$ | $\lambda_{RMRF}$ | $\lambda_{SMB}$ | $\lambda_{HML}$ | $\lambda_{RMWOP}$ | $\lambda_{RMWCMA}$ | $\lambda_{RMWGP}$ | $\lambda_{RMWFCF}$ | $\lambda_{RMWNI}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.0062 | −0.0078 | 0.0055 | −0.0030 | | | | | | 0.27 |
| (1.38) | (−1.58) | (4.14) | (−1.31) | | | | | | |
| 0.0047 | −0.0064 | 0.0045 | 0.0007 | 0.0107 | −0.0024 | | | | 0.31 |
| (0.95) | (−1.24) | (2.93) | (0.28) | (3.84) | (−1.32) | | | | |
| 0.0085 | −0.0103 | 0.0076 | 0.0013 | | −0.0029 | 0.0084 | | | 0.33 |
| (1.95) | (−2.28) | (4.19) | (0.52) | | (−1.43) | (3.40) | | | |
| 0.0065 | −0.0082 | 0.0056 | 0.0010 | | −0.0028 | | 0.0081 | | 0.29 |
| (1.17) | (−1.41) | (3.44) | (0.29) | | (−1.33) | | (4.57) | | |
| 0.0047 | −0.0063 | 0.0048 | 0.0000 | | −0.0028 | | | 0.0107 | 0.31 |
| (0.88) | (−1.12) | (2.96) | (0.00) | | (−1.39) | | | (4.01) | |

The table reports Fama and MacBeth (1973) average factor premiums, *t*-statistics, and adjusted $R^2$ for test portfolios triple sorted on size, book-price, and investment. RMRF is the market risk premium. SMB and HML are the Fama and French (1993) factors. CMA is the Fama and French (2015) investment factor. $RMW_{OP}$ is the Fama and French (2015) profitability factor. The construction of the $RMW_{GP}$, $RMW_{FCF}$, and $RMW_{NI}$ factors follows $RMW_{OP}$, except the factors that are formed using gross profit, free cash flow, and net income, respectively, rather than operating profit. A detailed explanation of the construction of the factors is provided in the text

per month and is highly significant (*t*-statistic = 9.78). The investment factor is insignificant.

Turning to the regressions using test portfolios sorted on size and NI in Panel D, the addition of the NI and investment factors increases the cross-sectional *r*-squared from 0.56 for the three-factor model to 0.75 for the five-factor model. The size premium is 0.03% per month for both the three- and five-factor models. The value premium is insignificant for the three-factor model and only marginally significant for the five-factor model. The NI premium is highly significant (*t*-statistic = 9.57) and carries a monthly premium of 1.14%. The investment term is insignificant.

In summary, the results in Table 5 support the findings from the earlier size-BP-sorted portfolios. Firstly, for all four measures of profitability, the five-factor model returns a higher *r*-squared than the three-factor model. Secondly, the investment factor is only significant for FF15 using $RMW_{GP}$. In contrast to the results from the size-BP sorts, the HML factor lacks explanatory power in both the three- and five-factor models. It is important to note that because the test portfolios in each panel were formed using different measures of profitability, the *r*-squared values cannot be compared across panels: *R*-squared is only comparable for tests using the same dependent variables.

Table 6 shows the results from the Fama and MacBeth (1973) regressions using test portfolios sorted on size and investment.

FF93 yields an *r*-squared of 0.6. The market risk premium is insignificant. The size and value premiums are both significant at the 1% level (*t*-statistics = 5.25 and 2.72, respectively). Turning to the five-factor models, the market risk premium is significant at the 1% level for FF15 using $RMW_{OP}$ and FF15 using $RMW_{NI}$

($t$-statistics = 2.92 and 2.98, respectively), and it is marginally significant for FF15 using $RMW_{FCF}$ and insignificant for FF15 using $RMW_{OP}$. The size premium is highly significant for all four five-factor models. The value premium is significant at the 1% level for all five-factor models. Turning to the profitability premiums, the OP premium (0.95% per month) and the NI premium (1.12% per month) are both significant at the 1% level ($t$-statistics = 3.94 and 4.12, respectively). The $RMW_{GP}$ and $RMW_{FCF}$ factors are insignificant. Troublingly, the investment factor is insignificant for all four five-factor models.

Overall, although the HML and SMB factors work well, only two of the four profitability measures have explanatory power. The FF15 model, with OP as the profitability factor, has the most explanatory ability. Surprisingly, considering the earlier results, the five-factor model formed using $RMW_{GP}$ is the worst performer. The most striking result is that the investment factor has no explanatory power for size-investment-sorted test portfolios.

Table 7 shows the results from testing the factor models using 32 triple-sorted test portfolios constructed using size, four different profitability measures, and investment.

The results from the regressions using size-OP-investment-sorted test are shown in Panel A. The size premium is 0.55% per month for the three-factor model and 0.44% per month for the five-factor model and is statistically significant in both models ($t$-statistics = 5.81 and 3.64, respectively). The OP premium is 1.36% per month ($t$-statistic = 3.09). The investment premium is insignificant.

Panel B shows the results using size-GP-investment sorts. The size premium is 0.55% per month in the three-factor model and 0.77% per month in the five-factor model and is highly significant ($t$-statistics = 5.81 and 7.56, respectively). The value premium is not significant in the three-factor model, but becomes significant at the 1% level in the five-factor model ($t$-statistic = 2.69). GP carries a monthly premium of 0.77% and is highly significant ($t$-statistic = 3.69). The investment premium is not significant.

Panel C reports the results from testing factor models on size-FCF-investment-sorted portfolios. The monthly size premium is 0.75% for the three-factor model and 0.62% for the five-factor model and is highly significant in both models ($t$-statistics = 5.36 and 5.99, respectively). The FCF premium is 1.06% per month and is statistically significant ($t$-statistic = 2.79). The market risk and value premiums are insignificant for both models.

The results from the tests using size-NI-investment-sorted portfolios are shown in Panel D. The monthly size premium is 0.55% in the three-factor model and 0.48% in the five-factor model—the premium can be considered significant in both models ($t$-statistics = 4.14 and 2.96, respectively). The NI factor carries a monthly premium of 1.07% and is highly significant ($t$-statistic = 4.01).

As with the tests for portfolios formed from size and profitability in Table 5, the $r$-squared values cannot be compared across panels because the dependent variables are different. However, comparing the performance of the three- and five-factor models within the panels, using GP as the profitability factor offers the largest increase in $r$-squared over the three-factor model. However, the investment factor has very little explanatory power.

Table 8 shows the results from test portfolios formed from size-BP-investment sorts.

The three-factor model returns a highly significant size premium of 0.55% per month ($t$-statistic = 4.14). The size factor remains statistically significant at the 1% level for all four five-factor models and the monthly premium ranges from 0.76% for FF15 using $RMW_{GP}$ model to 0.45% for FF15 using $RMW_{OP}$. The four different measures of profitability tested are all highly significant, with monthly premiums ranging from 0.81% for the FCF factor to 1.07% for the OP factor. The value premium is insignificant for all five models tested. There is also no evidence of an investment premium in any of the five-factor models tested.

Consistent with the results from other test portfolios formed using investment sorts, the CMA factor lacks explanatory power. The HML factor is not significant for FF93 or any of the five-factor models. Only the size and profitability factors have been consistently priced in the tests run—these findings raise serious doubts about usefulness of FF93 and FF15 for explaining equity returns in the UK.

## Conclusion

FF93 and subsequent factor models motivated by it have become the dominant methods for estimating equity returns. Most recently, FF15 adds profitability and investment terms to FF93. Like FF93, FF15 is empirically motivated and this has created a requirement to test the model outside the US. This paper contributes by evaluating the FF93 and FF15 models in Europe's largest equity market and offering independent evidence to the debate regarding whether FF15 provides a better description of equity returns. In addition to providing an out-of-sample test, the paper extends Fama and French's (2015) work by examining the effects of using a range of different profitability measures to construct the RMW factor—an issue that previous research has overlooked.

The main findings can be summarized as follows: First, the Fama and MacBeth (1973) tests of individual stock returns (not sorted into portfolios) regressed on different measures of profitability are consistent with the findings of Novy-Marx (2013) in showing that GP has more power than both NI and FCF. Furthermore, OP—the measure of profitability used by FF15—has a substantially lower $t$-statistic than GP. Second, asset pricing tests using FF93 and different specifications of FF15 to explain returns for size-BP-sorted test portfolios are consistent with previous research in finding that FF15 outperforms FF93. However, it seems clear that both FF93 and Fama and French's (2015) specification of FF15 have problems explaining cross-sectional returns: the three-factor model's HML term and the five-factor model's CMA term both lack explanatory power on size-BP-sorted test portfolios. Interestingly, when FF15 is respecified with a profitability factor based on GP, the size, value, investment, and profitability factors are all statistically significant. One possible explanation for this finding may be Fama and French's (2015) unusual definition of operating profit which involves subtracting interest expense: aggressive capital expenditure financed by borrowing will therefore directly affect both $RMW_{OP}$ (in the form of an increased interest expense) and CMA (in the form of an increased book value of assets). Specifying profitability using $RMW_{GP}$ means that the profitability factor will not be directly affected by an aggressive increase in assets financed by borrowing and the effect of this capital expenditure will only be captured by CMA. While this offers a possible explanation as to why GP works better than OP, it leaves the question of why a profitability factor formed from OP works for Fama and French's (2015) sample unresolved. This paper's primary concern is to determine if the FF15 factors are consistently priced across the various test portfolios. These test results are disappointing and reveal that only the size and profitability factors are consistently priced; the explanatory ability of the investment and value factors is transient depending on the variables used to form the test portfolios. Nichol and Dowling's (2014) conclusion that FF15 is the most promising of the factor models they tested in the UK is based entirely on the results from size-BP sorts—an approach which this paper calls into serious question.

Summing up, the results show that size and profitability are the main drivers of UK stock returns. However, the tests fail to clearly identify which specification of profitability best describes UK equity returns. The market, value, and investment factors are not consistently priced. The low explanatory power of the market factor is in line with the findings of previous studies. However, previous research has consistently found the value effect to be an empirical regularity, so HML's low explanatory power represents an unusual finding. In conclusion, as well as underlining the importance of evaluating asset pricing models using a range of test portfolios formed from different variables, the findings raise serious concerns about the applicability of the three- and five-factor models in the UK: researchers and practitioners should be cautious in applying either model as a risk benchmark.

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