Size matters, book-to-market does not!

The Fama-French empirical CAPM revisited

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Framework

- **Common evidence**

  - Small stocks outperform large stocks
  - Value stocks outperform growth stocks
  - F&F risk factors

  Our paper revisits the way in which size and book-to-market effects translate onto risk factors and applies this approach to the whole US market over an extended period (1980-2007)

Scope of the paper

- **Three main research questions**
  - Is there a book value effect in the US stock market?
  - Is there any bias in the way the literature has estimated this book value effect, i.e. in the Fame-French methodology?
  - Should we redefine the F&F and Carhart empirical Capital Asset Pricing Model?

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Is there a book value effect in the US stock market?

- **Literature review**
  Pricing anomalies on the US stock markets have been documented since the early 1980s

  - Banz (1981, JFE): the small size effect
  - Basu (1983, JFE), Rosenberg, Reid and Lanstein (1985, JPM) and Fama and French (1992, JF) (1998, JF): value effect
  - Jegadeesh and Titman (1993, JF): momentum effect
  - Fama and French (1993, JFE): mimicking portfolios for constructing size and value factors

Is there a book value effect in the US stock market?

- **Fama and French estimates**

  F&F method proceeds in three steps:

  Step 1: for each June of year y, rank US stocks according to their market value (50% lowest and 50% highest) of December y-1 and BTM (30% lowest-40%-30% highest) of December y-1

  Step 2: for each month *t*, form 6 value-weighted portfolio at the intersection of the rankings of *t-1*

	Median ME	
70th BE/ME percentile	Small Value	Big Value
	Small Neutral	Big Neutral
30th BE/ME percentile	Small Growth	Big Growth

  Step 3: compute the risk factors as the difference between the average lowest (resp. highest) and the average highest (resp. lowest) portfolios

Descriptive statistics
Jan. 1980 – Dec. 2007
(monthly observations)

	F&F premiums	
	SMB	*HML*
Mean (%)	0.108	0.378
Std. Dev. (%)	3.225	3.129
t-stat	0.614	2.21**
# Obs.	336	336

Is there a book value effect in the US stock market?

- **Recent literature**

  While the factor construction method developed by Fama and French (1993) has become the standard means by which to construct both size and value (i.e. book-to-market) premiums, some more recent studies suggest that the premiums obtained with the Fama and French technique could be misspecified

  - Average returns on value and momentum spread portfolios decline with size and specification errors are high when applying the empirical model to Size/BTM or Size/Momentum portfolios (Petkhova and Zhang, 2005 JFE; Fama and French, 2012 JFE; Cakici et al., 2013, EMR; Atanasov and Nitschka, 2014 WP)
  - Cremers, Petajisto and Zitzewitz (2012, Critical Finance Review): value premium is overestimated in the F&F framework
  - Huij and Verbeek (2009, FM): F&F value premium is overestimated while momentum factor is underestimated
  - Brooks, Li and Miffre (2008, WP): size premium could capture part of the value premium

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Potential bias in the F&F methodology

- **Drawbacks in the independent sorting**

  - Under independent sorting, the six portfolios will have approximately the same number of stocks only if size and book-to-market are unrelated characteristics; that is, if there is no significant correlation between the risk fundamentals
  - Market capitalization and book-to-market levels in US stocks are correlated
    "using independent size and book-to-market sorts of NYSE stocks to form portfolio means that the highest book-to-market equity quintile is tilted toward the smallest stocks" (Fama & French, 1993, JFE, p. 12)

Potential bias in the F&F methodology

- Market capitalization and book-to-market levels in US stocks are correlated "using independent size and book-to-market sorts of NYSE stocks to form portfolio means that the highest book-to-market equity quintile is tilted toward the smallest stocks" (Fama & French, 1993, JFE, p. 12)

Size quintile	(BE/ME) quintiles				
	Low	2	3	4	High
	Average of annual B/E ratios for portfolio				
Small	0.30	0.62	0.84	1.09	1.80
2	0.31	0.60	0.83	1.09	1.71
3	0.31	0.60	0.84	1.08	1.66
4	0.31	0.61	0.84	1.09	1.67
Big	0.29	0.59	0.83	1.08	1.56
	Average of annual number of firms in portfolio				
Small	428.0	276.6	263.8	291.5	512.7
2	121.6	94.0	86.7	79.8	71.3
3	102.7	78.3	73.0	64.5	45.9
4	90.1	68.9	60.7	53.1	33.4
Big	93.6	63.7	52.7	44.0	23.6

Potential bias in the F&F methodology

- **Numerical experiment evidence**
  120-month sample period, 70 stocks, 100 runs
  - We constructed theoretical size and book-to-market premiums according to the Fama and French method. We contrasted two scenarios: one with and one without correlation between the rankings based on company size and on book-to-market ratios
  - Simulation: we simulated the two-dimensional ranking on company size and book-to-market ratios of 70 stocks, as well as their corresponding return, and constructed the size and book-to-market premiums under both scenarios
  - Test to be performed: the simulated premiums are expected to display descriptive statistics close to the input parameters of the model and should not display significant differences in descriptive statistics. In the case that the Fama and French methodology proved unable to deal with the correlated rankings, we expect a significant deviation between the statistical properties of these sets of premiums under the two scenarios

Potential bias in the F&F methodology

- **Numerical experiment evidence**
  120-month sample period, 70 stocks, 100 runs

  - Two scenarios: constructing size and book-to-market F&F premiums using generated random samples of stock returns
    - *Scenario 1*: correlation between the rankings on size and book-to-market
    - *Scenario 2*: no correlation between the rankings on size and book-to-market (based on historical average, i.e. 41%)
  - Two-way ranking on size and three-way ranking on BTM are simulated along a uniform low
  - Returns on 70 stocks simulated conditional on their ranking on size and btm. One stochastic model per category of portfolio – related to the six components of the premiums: multivariate Gaussian distribution, mean and variance estimated on historical data

Potential bias in the F&F methodology

- **Properties of the F&F simulated premiums under the two scenarios**

	Size premiums			Value premiums		
	S_SMB	*S_SMB*^{C}	*S_SMB*^{C}-*S_SMB*	*S_HML*	*S_HML*^{C}	*S_HML*^{C}-*S_HML*
Mean	0.117	0.074	-0.0441	0.336	0.380	0.0439
Std. Dev.	0.120	0.128	0.178	0.165	0.161	0.222
T-stat	9.75***	5.744***	-2.47**	20.35***	23.60	1.98**
t-stat*	0.77	-2.70***	-2.47**	-2.55**	0.10	1.98**
# Obs.	100	100	100	100	100	100

- The analysis suggests an undervaluation of size premium but an overvaluation of the book-to-market premium under the scenario of correlation between the rankings with regard to the no-correlation scenario
- As for the size effect, the premium defined under the no-correlation displayed statistical properties very similar to the original simulation input

Potential bias in the F&F methodology

- **Specification errors**
  - The value and momentum premiums are driven by small size effects: it delivers specification error pattern (Petkhova and Zhang, 2005 JFE; Fama and French, 2012 JFE; Cakici et al., 2013, EMR; Atanasov and Nitschka, 2014 WP)

	a					*t*(*a*)				
	Low	2	3	4	High	Low	2	3	4	High
North American size-B/M returns regressed on North American factors										
Three-factor										
Small	-0.45	-0.15	0.17	0.11	0.38	-2.75	-1.16	1.58	1.37	4.43
2	-0.45	-0.14	0.02	-0.01	-0.02	-3.71	-1.39	0.26	-0.12	-0.25
3	0.13	-0.18	0.01	-0.04	0.06	1.07	-1.64	0.12	-0.44	0.72
4	0.14	-0.05	0.05	-0.03	0.01	1.08	-0.46	0.46	-0.32	0.07
Big	0.15	-0.00	-0.08	-0.09	-0.34	2.05	-0.00	-0.97	-0.99	-3.20
Four-factor										
Small	-0.44	-0.13	0.17	0.13	0.35	-2.67	-0.94	1.52	1.53	4.03
2	-0.33	-0.12	0.02	0.04	0.00	-2.91	-1.15	0.24	0.55	0.02
3	0.07	-0.14	0.07	0.02	0.07	0.58	-1.29	0.71	0.23	0.87
4	0.11	-0.00	0.07	0.00	0.05	0.82	-0.04	0.64	0.03	0.65
Big	0.17	-0.01	-0.04	-0.06	-0.27	2.23	-0.07	-0.52	-0.66	-2.59

Source: Fama and French (2012)

Bias in F&F methodology

- **Reviewing the methodological framework**

  - *Sequential sorting versus independent sorting*

    A sequential sort for forming characteristic portfolios outperform an independent sort for isolating fundamental risk into portfolio returns
    cf. Lambert & Hübner (2013, JEF)

  - *Monthly rebalancing versus annual rebalancing*

    Dynamic risk premiums better fit investors' strategy
    To apply a monthly rebalancing strategy, we assumed market participants refer to the last quarterly reporting to form their expectations about each stock

Bias in F&F methodology

- **Reviewing the methodological framework**

  - *Three-way sort and whole-sample breakpoints versus mix of two-way/three-way sorts and NYSE-breakpoints*

The F&F methodology defines the breakpoints according to NYSE data in order to avoid breakpoints to be tilted towards small market capitalizations. Because of the large number of small stocks in NASDAQ and AMEX,
- small stocks are over-represented in the small stocks portfolios as shown from the number of stocks into the large stock portfolio;
- medium stocks are part of the small stock portfolios

By using a finer size classification (three-way sort) and whole-sample breakpoints, we avoid breakpoints to be tilted towards small capitalizations, avoid an over-representation of small stocks and finally flaws in medium stocks

Scope of the paper

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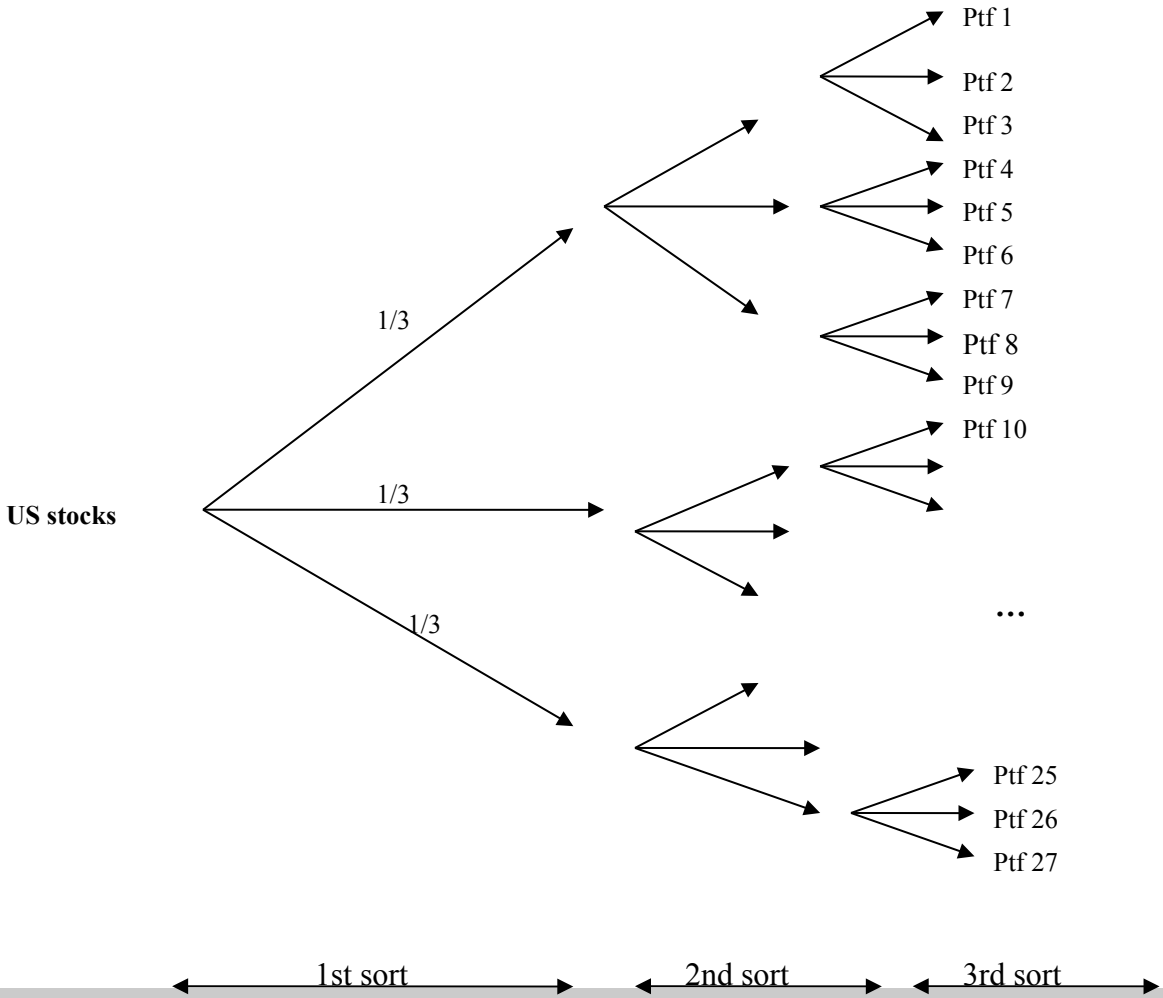
Modified F&F methodology

- **Main innovations**
  - Sequential sorting on size, book-to-market and momentum, ending with the dimension to be priced
  - Three-way sort of stocks into portfolios along three risk dimensions (market capitalization/book-to-market and 12-month momentum): 27 portfolios are formed
  - Monthly rebalancing
  - Whole-sample breakpoints

Modified F&F methodology

- **Illustration of the sequential and three-way sort approach**



Modified F&F methodology

- **Data**

  Sample of stocks from NYSE, AMEX and NASDAQ collected on Thomson Financial Datastream:

  - 6,579 dead and 4,798 live stocks
  - February 1973 to June 2008: usable sample May 1980 – April 2007 – 324 monthly observations

  Data collected:

  - Company annual total debt
  - Company total asset
  - Monthly official closing price adjusted for subsequent capital actions
  - Monthly market value

  Excluding outliers:

  - Market values ≤ 0
  - Stock returns ≥ 100%

Horse races between the two sets of premium

- **Tests**
  - Test 1 on descriptive statistics: the alternative premiums better match empirical observations
  - Test 2 on premiums' components: correlation bias appears in F&F portfolios, noisy return distribution using the F&F approach, noisy return distribution for the value premium using the modified approach
  - Test 3 on correlation between factors

Horse race 1

- **Theoretical vs alternative Fama and French factors**
  Descriptive statistics

	Panel A: F&F premiums			Panel B: Sequential premiums		
	SMB_{ff}	HML_{ff}	UMD_{ff}	SMB'	HML'	UMD'
Mean	0.14%	0.44%	0.79%	0.88%	-0.07%	0.91%
Median	-0.06%	0.38%	0.90%	0.84%	0.01%	0.92%
Maximum	21.96%	13.85%	18.39%	12.88%	19.15%	10.65%
Minimum	-16.79%	-12.40%	-25.06%	-11.71%	-14.16%	-11.26%
Std. Dev.	3.24%	3.16%	4.26%	3.12%	3.23%	2.71%
Skewness	0.76	0.07	-0.56	0.08	0.24	-0.25
Kurtosis	11.47	5.34	9.06	5.18	8.34	5.56
Jarque-Bera	999^{***}	74.5^{***}	512^{***}	64.4^{***}	388^{***}	91.9^{***}
t-stat	0.83	2.13^{**}	3.57^{***}	4.85^{***}	-0.35	6.21^{***}
# Obs.	324	324	324	324	324	324

The alternative premiums better match empirical data such the S&P 500 or the Citigroup Growth and Value indexes over the same period: the S&P/Citigroup Growth Index outperform the value indexes over this period

Horse race 2

- **Theoretical vs alternative Fama and French factors**
  Correlation issue in F&F framework: cross-correlations between the size return spreads and the value factor, size factor is contaminated by a book-to-market effect

	Mean (%)	Median (%)	Min (%)	Max (%)	S.D. (%)	Skewness	Kurtosis	J-B	$\rho_{SMB_{ff},spread_i}$	$\rho_{HML_{ff},spread_i}$	$\rho_{UMD_{ff},spread_i}$
Panel A: Size											
Spread 1. Low BTM	-0.2	-0.33	27.75	-22.54	4.17	0.6418	11.0458	896.17	93.89	-42.08	4.38
Spread 2. Mid BTM	0.29	0.14	19.94	-14.3	3.11	0.7586	10.0509	702.23	94.36	-32.91	12.19
Spread 3. High BTM	0.33	0.25	18.29	-13.71	3.12	0.5545	8.0572	361.87	91.7	-37.94	15.13
Average / (σ)	0.14	0.02	21.99	-16.85	3.47				93.32	-37.64	10.57
	(0.30)	(0.31)	(5.05)	(4.94)	(0.61)				(1.42)	(4.59)	(5.56)
Panel B: Book-to-market											
Spread 1. Low size	0.7	0.57	13.53	-17.1	3.68	-0.206	5.5328	88.90***	-49.29	93.37	-7.17
Spread 2. High size	0.17	0.1	14.91	-10.39	3.16	0.324	4.8724	53.00***	-24.12	90.84	-17.54
Average / (σ)	0.44	0.34	14.22	-13.75	3.42				-36.71	92.11	-12.36
	(0.37)	(0.33)	(0.98)	(4.74)	(0.37)				(17.80)	(1.79)	(7.33)
Panel C: Momentum											
Spread 1. Low size	1.23	1.36	20.84	-26	4.2	-0.7975	12.0118	1130.72***	10.29	-10.48	94.13
Spread 2. High size	0.34	0.65	19.23	-24.08	4.79	-0.3104	6.1806	141.77***	10	-13.66	95.55
Average / (σ)	0.79	1.01	20.04	-25.04	4.50				10.15	-12.07	94.84
	(0.63)	(0.50)	(1.14)	(1.36)	(0.42)				(0.21)	(2.25)	(1.00)

Horse race 2

- **Theoretical vs alternative Fama and French factors**
  Alternative premiums are less affected by correlations
  1) very low variations within the series of mean returns across the different size spreads 2) large correlation of the post-formation portfolios with the priced factor but low with other risk factors

Panel A: 9 size spread portfolios

	LLL-LLH	LML-LMH	LHL-LHH	MLL-MLH	MML-MMH	MHL-MHH	HLL-HLH	HML-HMH	HHL-HHH	Average / (σ)
Mean (%)	0.97	0.73	0.99	0.80	0.88	1.25	1.09	0.33	0.87	0.88/ (0.26)
Median (%)	0.62	0.57	1.19	1.05	0.72	0.87	1.17	0.22	0.81	0.80/ (0.31)
Min (%)	18.01	14.69	12.74	17.16	14.21	13.55	19.78	14.88	16.84	15.76/ (2.31)
Max (%)	-15.06	-12.82	-11.71	-24.87	-11.92	-14.12	-18.25	-13.84	-15.65	-15.36/ (4.10)
S. D. (%)	4.84	3.84	3.74	4.98	3.62	3.68	5.03	3.35	3.61	4.08 / (0.67)
Skewness	0.1687	0.2333	-0.0354	-0.5078	0.0733	0.0401	-0.1984	0.1209	0.0936	
Kurtosis	3.7854	4.4247	3.6944	6.7823	4.4983	3.9962	4.5764	5.2606	5.6633	
Jarque-Bera	9.86***	3.03***	6.58**	2.07***	3.06***	1.35***	3.57***	6.98***	9.62***	
$\rho_{SMB',spread_i}$	77.15	82.38	60.20	83.88	84.29	76.97	78.49	65.96	75.59	76.10/ (8.14)
$\rho_{HML',spread_i}$	-5.60	-10.23	-4.01	-24.65	-20.37	-25.80	-17.96	6.81	1.40	-11.16/ (11.68)
$\rho_{UMD',spread_i}$	13.04	2.27	-16.65	9.94	1.93	-7.69	9.66	5.65	-9.17	1.00/ (10.09)

Horse race 2

- **Theoretical vs alternative Fama and French factors**
  Alternative premiums are less affected by correlations
  1) very large variations within the series of mean returns across the different book-to-market spreads: noisy returns? 2) large correlation of the post-formation portfolios with the priced factor but moderate with other risk factors

Panel B: 9 book-to-market spread portfolios

	LLH-LLL	LMH-LML	LHH-LHL	MLH-MLL	MMH-MML	MHH-MHL	HLH-HLL	HMH-HML	HHH-HHL	Average / (σ)
Mean (%)	0.54	-0.54	0.27	-0.29	0.60	0.20	0.04	0.12	-1.63	-0.08/ (0.69)
Median (%)	0.22	-0.22	0.22	-0.33	0.83	0.19	0.19	0.29	-0.62	0.09/ (0.42)
Min (%)	-13.45	-9.65	-11.75	-17.14	-9.54	-19.68	-11.05	-125.79	-21.07	-26.57/ (37.45)
Max (%)	19.76	10.95	14.52	22.37	9.07	22.83	12.62	122.18	18.21	28.06/ (35.64)
S. D. (%)	5.14	3.71	4.12	4.22	2.94	4.49	3.39	17.98	3.90	5.54/ (4.71)
Skewness	0.1472	0.0094	0.3301	0.2708	-0.1031	0.0283	-0.0933	-0.4665	-0.0846	
Kurtosis	3.7096	2.9000	3.8073	5.8770	3.5258	6.4773	4.4572	21.6317	7.2400	
Jarque-Bera	7.97***	0.14	14.68***	115.70***	4.31***	163.28***	29.14***	4698.14***	243.09***	
$\rho_{SMB',spread_i}$	-21.67	-24.44	-19.21	-21.64	-24.18	-26.01	-10.45	6.66	-27.11	-18.67/(10.70)
$\rho_{HML',spread_i}$	39.57	51.48	56.32	57.27	59.12	61.61	40.28	76.29	50.99	54.77/ (11.20)
$\rho_{UMD',spread_i}$	-6.72	-0.74	-6.75	-9.70	0.15	-6.86	8.29	-6.03	-16.13	-4.94/ (6.87)

Horse race 3

- **Theoretical vs alternative Fama and French factors**
  Low intra-correlation among the alternative set of premiums versus contamination effect in the F&F framework

	SMB'	HML'	UMD'	SMB_{ff}	HML_{ff}	UMD_{ff}
SMB'	1					
HML'	-15.50***	1				
UMD'	2.56	-3.19	1			
SMB_{ff}	67.16***	-34.46***	3.24	1		
HML_{ff}	-18.87***	68.25***	2.35	-40.83***	1	
UMD_{ff}	9.61*	-12.03**	82.63***	10.66*	-12.85**	1

Scope of the paper

- **Three main research questions**
  - Is there a book value effect in the US stock market?
  - Is there any bias in the way the literature has estimated this book value effect, i.e. in the Fame-French methodology?
  - Should we redefine the F&F and Carhart empirical Capital Asset Pricing Model? **Does the revisited empirical CAPM outperform the original F&F and Carhart model?**

Specification tests

- **Tests**

  - Specification Test 1 or factor efficiency test: this test evaluates the specification errors displayed by both a modified and an original four-factor Carhart analysis on the set of 2x3 F&F portfolios and on a set of passive benchmark indices

  - Specification Test 2 or non-nested models: this test identifies the potential superiority of one set of empirical premiums (i.e. either those of Fama and French or our updated premiums) over the other set

Specification tests

- **Tests**

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  - Specification Test 2 or non-nested models: this test identifies the potential superiority of one set of empirical premiums (i.e. either those of Fama and French or our updated premiums) over the other set

Specification test 1

- **Tests**
  - Multivariate linear regression

$$R_{pt} = \alpha_p + \beta_m R_{mt} + \beta_{SMB} R_{SMBt} + \beta_{HML} R_{HMLt} + \beta_{UMD} R_{UMDt} + \varepsilon_{pt}$$

  - Joint test on the values of alphas – Gibbons, Ross and Shanken (1989, Econometrica)

Specification test 1

- **Result of the GRS test on F&F 2x3 portfolios**
  - The *F* statistic to test the joint significance of alphas when using the set of Fama and French premiums is 0.0597, so we cannot reject efficiency of the Fama-French model at the usual levels of significance
  - When using the sequential premiums, the *F* statistic is reduced even further to 0.0000272
  - In this way, both sets of premiums seem to efficiently explain stock returns, with a slight advantage to the sequential approach. In other words, the different changes performed on the original Fama and French methodology do not seem to affect the efficiency of the factors

Specification test 1

- **Pricing errors on passive benchmark indices**

	Panel A			Panel B		
	4-Factor Carhart Model :F&F specification			4-Factor Carhart Model: F&F modified Specification		
	All	Growth	Value	All	Growth	Value
Russell 1000	-0.0010***	0.0002	-0.0021**	0.0000	-0.0015	0.0024
Russell 2000	-0.0043***	-0.0043***	-0.0040***	-0.0040	-0.0065*	-0.0002
Russell 3000	-0.0013***	-0.0002	-0.0023**	-0.0003	-0.0020	0.0021
S&P 500	-0.0031***	-0.0021*	-0.0047***	-0.0021**	-0.0037**	-0.0008
S&P Mid Cap	-0.0033*	-0.0034*	-0.0035**	-0.0009	-0.0039	0.0021
S&P Small Cap	-0.0060***	-0.0062***	-0.0065***	-0.0044	-0.0070**	-0.0025

- The original four-factor model of Fama and French and Carhart produces significant levels of specification errors (alphas of the model) for almost all passive benchmark indices. This result is fully consistent with what Cremers, Petajisto and Zitzewitz (2010) demonstrated in their study conducted over the period 1980-2005
- The modifications brought to the Fama and French methodology enabled us to deliver a new set of risk premiums that better prices passive benchmark indices. Indeed, alphas of the four-factor Carhart model are mostly insignificant across all the regressions

Specification tests

- **Tests**

  - Specification Test 1 or factor efficiency test: this test evaluates the specification errors displayed by both a modified and original a four-factor Carhart analysis on the set of 2x3 F&F portfolios and on a set of passive benchmark indices

  - Specification Test 2 or non-nested models: this test identifies the potential superiority of one set of empirical premiums (i.e. either those of Fama and French or our updated premiums) over the other set

Specification test 2 – Non nested models

- **Test of specification of models 1 and 2**

Test of the superiority of M1 over M2, we construct the nested model M4*

$$R_{i,t} = \alpha_{i,4} + \beta_i \mu + (1 - \theta_{i,1})\delta_i X' + \theta_{i,1}\gamma_i Z' + \varepsilon'_{i,t}$$

Test of the superiority of M2 over M1, we construct the nested model M5*

$$R_{i,t} = \alpha_{i,5} + \beta_i \mu + \theta_{i,2}\hat{\delta}_i X' + \gamma^*_i Z' + \varepsilon''_{it}$$

The following hypotheses are jointly tested on all individual test assets:

Hypothesis I: $H_0 : \theta_{i,1} = 0 \ against \ H_1 : \theta_{i,1} \neq 0;$

Hypothesis II: $H'_0 : \theta_{i,2} = 0 \ against \ H'_1 : \theta_{i,2} \neq 0$

Specification test 2 – Non nested models

Among the four possible scenarios, we consider the two following cases:

- (H_0, H'_1), M1 is not rejected but M2 is;
- (H'_0, H_1), M2 is not rejected but M1 is.

- H'_0 and H_1 : 2275 (10%), 3431 (5%), 3786 (1%)
- H_0 and H'_1 : 2017 (10%), 2884 (5%), 3061 (1%)

To conclude…

- **Main conclusions**

  - The new set of premiums better matches empirical observations of slight outperformance of growth stock over value stocks (using S&P500/Citigroup data) over our sample period
  - The new set of risk premiums better prices passive benchmark indices
  - The new set of premiums demonstrates superior accuracy for pricing individual stocks
  - Are the results robust? What is the incremental effect of each change?

To conclude…

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  - Are the results robust? What is the incremental effect of each change?

Robustness check #1 – Marginal analysis

- Incremental effect of each single change brought to F&F framework
  - Finer size classification and whole-sample breakpoints
  - Sequential sorting
  - Monthly rebalancing

Robustness check #1 – Marginal analysis

- Incremental effect of each single change brought to the F&F framework
  - M1 – F&F factors: independent sorting, 2-way sort on size, 2-dimensional sort (market cap and BTM), NYSE breakpoints and annual rebalancing
  - M2 – Alternative F&F factors: sequential sorting, finer size classification (three-way sort), three-dimensional sort (market cap, BTM and momentum), whole-sample breakpoints and monthly reblancing
  - M3 – Independent sorting, finer size classification, three-dimensional sort, whole-sample breakpoints and monthly rebalancing
  - M4 – Independent sorting, finer size classification, 2-dimensional sort, whole-sample breakpoints and annual rebalancing
  - M5 – Independent sorting, finer size classification, 2-dimensional sort, whole-sample breakpoints and monthly rebalancing

Robustness check #1 – Marginal analysis

- Incremental effect of each single change brought to F&F framework
  - (T.1) test of the sequential sort over an independent sort: M3 versus M2
  - (T.2) test of finer size classification (small, mid and big caps) and whole-sample breakpoints versus NYSE breakpoints with two-dimensional size classification: M4 versus M1
  - (T.3) test of monthly rebalancing against annual rebalancing: M5 versus M4

Robustness check #1 – Marginal analysis

- **Descriptive statistics**

  Negative average spread for HML premium is only observed with the sequential sorting

	Panel A: F&F premiums			Panel B: Sequential premiums		
	SMB_{ff}	HML_{ff}	UMD_{ff}	SMB'	HML'	UMD'
Mean	0.14%	0.44%	0.79%	0.88%	-0.07%	0.91%
Median	-0.06%	0.38%	0.90%	0.84%	0.01%	0.92%
Maximum	21.96%	13.85%	18.39%	12.88%	19.15%	10.65%
Minimum	-16.79%	-12.40%	-25.06%	-11.71%	-14.16%	-11.26%
Std. Dev.	3.24%	3.16%	4.26%	3.12%	3.23%	2.71%
Skewness	0.76	0.07	-0.56	0.08	0.24	-0.25
Kurtosis	11.47	5.34	9.06	5.18	8.34	5.56
Jarque-Bera	999***	74.5***	512***	64.4***	388***	91.9***
t-stat	0.83	2.13**	3.57***	4.85***	-0.35	6.21***
# Obs.	324	324	324	324	324	324

	Panel A: M3			Panel B: M4		Panel C : M5	
	SMB_{M3}	HML_{M3}	UMD_{M3}	SMB_{M4}	HML_{M4}	SMB_{M5}	HML_{M5}
Mean	1.16%	1.27 %	0.67	0.87%	0.14%	1.14%	0.09%
Median	0.95%	0.95%	0.85	0.76%	0.001%	0.91%	0.07%
Maximum	14.34%	31.32%	10.26	13.12%	9.87%	15.49%	10.66%
Minimum	-10.47%	-16.13%	-14.81	-11.75%	-13.76%	-9.49%	-14.94%
Std. Dev.	3.49%	5.16%	3.15	3.30%	2.60%	3.69%	2.81%
Skewness	0.1719	1.6125	-0.6996	0.2224	-0.5962	0.419%	-0.4618
Kurtosis	4.3625	12.2657	6.0610	4.5063	7.2957	4.4347	7.6302
Jarque-Bera	26.4938***	1291.390***	151.97***	33.0970***	266.65***	37.0453***	99.09***
# Obs.	322	322	322	322	322	322	322

The three size premiums display higher skewness and as a consequence higher average return compared to our sequential premium

Robustness check #1 – Marginal analysis

- **Specification errors of passive investment indexes**

Independent sorting/ finer size classification S/M/B
3-dimensional/ whole-sample breakpoints/monthly

	All	Growth	Value
Russell 1000	0.0004	-0.0007	0.0021
Russell 2000	-0.0063**	-0.0092***	-0.0026
Russell 3000	-0.0017	-0.0015	0.0017
S&P 500	-0.0015*	-0.0011	-0.0023
S&P Mid Cap	-0.0020	-0.0042	-0.0001
S&P Small Cap	-0.0062**	-0.0053*	-0.0077**

For M3, 6 out of 18 indices presented significant alphas in both specifications, while the modified F&F premiums (M2) deliver only 4.

The Gibbons test rejects the null hypothesis that M3 could price passive indexes

Independent sorting/ finer size classification S/M/B
2-dimensional/ whole-sample breakpoints/annual

	All	Growth	Value
Russell 1000	-0.0005	0.0002	-0.0012
Russell 2000	-0.0045*	-0.0055**	-0.0030
Russell 3000	-0.0009***	-0.0003	-0.0014
S&P 500	-0.0027***	-0.0020	-0.0039***
S&P Mid Cap	-0.0026	-0.0034	-0.0021
S&P Small Cap	-0.0058**	-0.0066**	-0.0058**

M4 produces significant levels of specification errors for 8 indices out of 18. The F&F model displays significant level of specification errors for 16 out of 18.

The Gibbons test could not reject the null hypothesis that M4 could price passive indexes

Independent sorting/ finer size classification S/M/B
2-dimensional/ whole-sample breakpoints/monthly

	All	Growth	Value
Russell 1000	0.0000	0.0007	0.0005
Russell 2000	-0.0073***	-0.0084***	-0.0056**
Russell 3000	-0.0007*	-0.0001	-0.0010
S&P 500	-0.0021***	-0.0015	-0.0033***
S&P Mid Cap	-0.0034*	-0.0029	-0.0043*
S&P Small Cap	-0.0086***	-0.0092***	-0.0088***

Compared to M4, M5 delivers higher specification errors.

Though a Gibbons test could not reject the null hypothesis that M5 could price passive indexes

Robustness check #1 – Marginal analysis

- **Specification errors of passive investment indexes**

Superiority of the sequential sorting

Independent sorting/ finer size classification S/M/B
3-dimensional/ whole-sample breakpoints/monthly

	All	Growth	Value
Russell 1000	0.0004	-0.0007	0.0021
Russell 2000	-0.0063**	-0.0092***	-0.0026
Russell 3000	-0.0017	-0.0015	0.0017
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For M3, 6 out of 18 indices presented significant alphas in both specifications, while the modified F&F premiums (M2) deliver only 4.

The Gibbons test rejects the null hypothesis that M3 could price passive indexes

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The Gibbons test could not reject the null hypothesis that M4 could price passive indexes

Compared to M4, M5 delivers higher specification errors.

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Robustness check #1 – Marginal analysis

- **Specification errors of passive investment indexes**

Superiority of the finer size classification and the whole-sample breakpoints

Independent sorting/ finer size classification S/M/B 3-dimensional/ whole-sample breakpoints/monthly

	All	Growth	Value
Russell 1000	0.0004	-0.0007	0.0021
Russell 2000	-0.0063**	-0.0092***	-0.0026
Russell 3000	-0.0017	-0.0015	0.0017
S&P 500	-0.0015*	-0.0011	-0.0023
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Independent sorting/ finer size classification S/M/B 2-dimensional/ whole-sample breakpoints/annual

	All	Growth	Value
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S&P Mid Cap	-0.0034*	-0.0029	-0.0043*
S&P Small Cap	-0.0086***	-0.0092***	-0.0088***

For M3, 6 out of 18 indices presented significant alphas in both specifications, while the modified F&F premiums (M2) deliver only 4.

The Gibbons test rejects the null hypothesis that M3 could price passive indexes

M4 produces significant levels of specification errors for 8 indices out of 18. The F&F model displays significant level of specification errors for 16 out of 18.

The Gibbons test could not reject the null hypothesis that M4 could price passive indexes

Compared to M4, M5 delivers higher specification errors.

Though a Gibbons test could not reject the null hypothesis that M5 could price passive indexes

Robustness check #1 – Marginal analysis

- **Specification errors of passive investment indexes**

Mitigate results for monthly rebalancing

Independent sorting/ finer size classification S/M/B
3-dimensional/ whole-sample breakpoints/monthly

	All	Growth	Value
Russell 1000	0.0004	-0.0007	0.0021
Russell 2000	-0.0063**	-0.0092***	-0.0026
Russell 3000	-0.0017	-0.0015	0.0017
S&P 500	-0.0015*	-0.0011	-0.0023
S&P Mid Cap	-0.0020	-0.0042	-0.0001
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2-dimensional/ whole-sample breakpoints/annual

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Russell 2000	-0.0073***	-0.0084***	-0.0056**
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For M3, 6 out of 18 indices presented significant alphas in both specifications, while the modified F&F premiums (M2) deliver only 4.

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M4 produces significant levels of specification errors for 8 indices out of 18. The F&F model displays significant level of specification errors for 16 out of 18.

The Gibbons test could not reject the null hypothesis that M4 could price passive indexes

Compared to M4, M5 delivers higher specification errors.

Though a Gibbons test could not reject the null hypothesis that M5 could price passive indexes

Robustness check #1 – Marginal analysis

- **Non-nested models**

  - **(T.1) test of the sequential sort over an independent sort: M3 vs. M2**

    The analysis demonstrates the superiority of the sequential approach: At 5% significance, M.3 is rejected for 23% of individual stocks (and M2 accepted) while M.2 is only rejected for 19% of the 11,087 stocks

  - **(T.2) test of finer size classification (small, mid and big caps) and whole-sample breakpoints versus NYSE breakpoints with two-dimensional size classification: M4 vs. M1**

    The non-nested analysis on individual stocks does demonstrate the superiority of finer size classification with whole-sample breakpoints: At 5% significance, M.1 is rejected for 32% of individual stocks (and M4 accepted) while M.4 is only rejected for 17% of the 11,087 stocks

  - **(T.3) test of monthly against annual rebalancing: M5 vs. M4**

    The non-nested analysis on individual stocks does demonstrate the superiority of the monthly rebalancing: At 5% significance, M.4 is rejected for 15% of individual stocks (and M5 accepted) while M.5 is only rejected for
    10% of the 11,087 stocks

Robustness check #2 – Comparison with Cremers et al.

- The modified Fama and French model versus the Cremers et al. (2012) model

  - sequential/whole-sample breakpoints/equally-weighted portfolios approach (as in the modified Fama and French)

  Versus

  - independent/value-weighting of stocks into portfolios as proposed by Cremers et al. (M6)

Robustness check #2 – Comparison with Cremers et al.

- **Descriptive statistics: M.6 versus M.2**

	M6	
	SMB_{M6}	HML_{M6}
Mean	-0.09%	-0.001
Median	-0.1320%	0.001%
Maximum	1.96%	0.98%
Minimum	-1.05%	-1.11%
Std. Dev.	0.35%	0.25%
Skewness	0.8595	-0.4249
Kurtosis	6.7666	6.6790
Jarque-Bera	229.99***	191.29***
# Obs.	322	322

	Panel A: F&F premiums			Panel B: Sequential premiums		
	SMB_{ff}	HML_{ff}	UMD_{ff}	SMB'	HML'	UMD'
Mean	0.14%	0.44%	0.79%	0.88%	-0.07%	0.91%
Median	-0.06%	0.38%	0.90%	0.84%	0.01%	0.92%
Maximum	21.96%	13.85%	18.39%	12.88%	19.15%	10.65%
Minimum	-16.79%	-12.40%	-25.06%	-11.71%	-14.16%	-11.26%
Std. Dev.	3.24%	3.16%	4.26%	3.12%	3.23%	2.71%
Skewness	0.76	0.07	-0.56	0.08	0.24	-0.25
Kurtosis	11.47	5.34	9.06	5.18	8.34	5.56
Jarque-Bera	999***	74.5***	512***	64.4***	388***	91.9***
t-stat	0.83	2.13**	3.57***	4.85***	-0.35	6.21***
# Obs.	324	324	324	324	324	324

The average return on the HML becomes negative when value-weighted, as for the sequential definition of the premium. This supports the evidence supplied by Cremers et al. that value weighting of the portfolio could adjust for cross-size effects

Robustness check #2 – Comparison with Cremers et al.

- **Specification errors of passive investment indexes**

	Panel A			Panel B		
	4-Factor Carhart Model :F&F specification			4-Factor Carhart Model: F&F modified Specification		
	All	Growth	Value	All	Growth	Value
Russell 1000	-0.0010***	0.0002	-0.0021**	0.0000	-0.0015	0.0024
Russell 2000	-0.0043***	-0.0043***	-0.0040***	-0.0040	-0.0065*	-0.0002
Russell 3000	-0.0013***	-0.0002	-0.0023**	-0.0003	-0.0020	0.0021
S&P 500	-0.0031***	-0.0021*	-0.0047***	-0.0021**	-0.0037**	-0.0008
S&P Mid Cap	-0.0033*	-0.0034*	-0.0035**	-0.0009	-0.0039	0.0021
S&P Small Cap	-0.0060***	-0.0062***	-0.0065***	-0.0044	-0.0070**	-0.0025

Independent sorting/ finer size classification S/M/B
3-dimensional/ whole-sample breakpoints/monthly / VW

	All	Growth	Value
Russell 1000	-0.0033***	-0.0037***	-0.0033**
Russell 2000	0.0054	0.0050	0.0050
Russell 3000	-0.0027***	-0.0032***	-0.0028**
S&P 500	-0.0066***	-0.0072***	-0.0066***
S&P Mid Cap	-0.0002	0.0004	-0.0014
S&P Small Cap	0.0019	0.0018	0.0014

M.6 produces less specification error than the Fama-French model. Nevertheless, the sequential model still delivered the least specification errors when pricing passive indexes

To conclude…

- **Main conclusions**

  - Correlation bias in the F&F framework: the research demonstrates that the book-to-market premium of Fama-French is overvalued
  - Regarding the incremental effect of each change brought to the F&F methodology, the sequential sort stands out as the primary and decisive source of improvement
  - The changes brought (in this paper) to the F&F methodology achieve similar objectives as Cremers et al.'s value-weighting of portfolios

To conclude…

- **Agenda of future research**

  - Constructing the new sets of premium on CRSP database
  - New sets of empirical premiums from a size/BTM and a size/momentum framework
  - Idiosyncratic volatility puzzle?
  - Analyzing the conditional spread between the two specifications across market conditions

To conclude…

- **Agenda of future research**

  - Constructing the new sets of premium on CRSP database
  - New sets of empirical premiums from a size/BTM and a size/momentum framework
  - Idiosyncratic volatility puzzle?
  - Analyzing the conditional spread between the two specifications across market conditions
  - **Comments are welcome!**

Any further remarks/questions?