The four-factor model and stock returns: evidence from Sri Lanka

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Abstract: There have been numerous studies that have attempted to explain the cross-sectional variation in average returns in developed and emerging markets. However, there is a dearth in the published evidence of research that has looked at frontier markets regarding this aspect. Sri Lanka is considered to be a frontier market and hence the objective of this study is to test the ability of the Carhart four-factor model to explain the variation in the cross-section of average stock returns in the Colombo Stock Exchange (CSE) and to evaluate it in comparison to the capital asset pricing model (CAPM) and the Fama and French three-factor model. The study finds that the four-factor model, incorporating the market factor, size factor, value factor and momentum factor, provides a satisfactory explanation of the variation in the cross-section of average stock returns in the CSE. Further, it is found that the four-factor model performs better than the CAPM and the three-factor model.

Keywords: Carhart four-factor model; GRS F-test; Colombo Stock Exchange; CSE; frontier markets; momentum; Sri Lanka.

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1 Introduction

Explaining the variation in the cross-section of average returns has been a key area of research in finance for nearly four decades. Sharpe (1964), Lintner (1965) and Black (1972) postulate in their capital asset pricing model (CAPM) that the expected returns on securities are positively and linearly related to the security's market beta. Basu (1977) finds that high earnings-to-price (E/P) stocks generate on average higher returns than low E/P stocks. Banz (1981) and Reinganum (1981) document a size effect, where average returns of small-cap stocks are higher than big-cap stocks. Bhandari (1988) reports that expected stock returns positively relate to leverage. Stattman (1980) and Rosenberg et al. (1985) show that average returns and book-to-market (B/M) equity ratio have a positive relationship. Many of these factors are likely to be related; Fama and French (1992) find strong evidence that size and B/M combined, capture the variation in average returns that is related to market beta, leverage and E/P.

Given the findings of the factors explained above, Fama and French (1993) propose a three-factor model, which posits that the cross-section of average returns can be explained by the excess market return ($Rm_t - Rf_t$), a size factor (SMB_t) and a B/M factor (HML_t). In 1993, Jegadeesh and Titman document an anomaly termed 'momentum', where short term winners continue to win and short term losers continue to lose. Fama and French (1996) find that the three-factor model fails to capture momentum, reinforcing further research on this anomaly. Carhart (1997) proposes the addition of a momentum factor (WML_t) to the Fama and French three-factor model. In this paper, this model shall be referred to as the Carhart four-factor model or simply the four-factor model.

These models have been empirically tested extensively in both developed and emerging markets. In terms of its explanatory power, the four-factor model performs better than the Fama and French (1993) three-factor model in developed markets; however, in terms of the GRS F-test the results are not consistent in rendering regressions where the true intercepts are jointly zero (Bello, 2008; Brighi et al., 2010; Fama and French, 2012; Humphrey and O'Brien, 2010). Conversely when the GRS F-test is applied to emerging and developing markets the four-factor model is found to be more successful (Nartea et al., 2009; Lam et al., 2009; Lai and Lau, 2010; Cakici et al., 2013; Unlu, 2013; Hasnaoui and Ibrahim, 2013; Vo, 2015; Balakrishnan, 2015). However, there seems to be a dearth in the published evidence that test these models in frontier markets. A frontier market is considered to be market which is smaller than an emerging market but more developed than countries considered to be 'least developing countries'. Hence, it would be important for both policymakers and investors to know how these factors behave in frontier markets as well. Sri Lanka could be considered to be a frontier market given its recent economic growth and development of the stock market. Therefore, it provides an ideal setting to empirically test these models in a frontier market.

In the Sri Lankan context, much of the research that has been done on CAPM rejects it with regard to its ability in explaining the variation in the cross-section of average returns (Samarakoon, 1997; Nimal, 1997; Alles and Murray, 2008). Conversely the three-factor model introduced by Fama and French (1993) performs well in the Colombo Stock Exchange (CSE) (Seneviratne and Nimal, 2008; Nanayakkara, 2008; Randeniya and Wijerathna, 2012). The momentum effect when studied as a separate phenomenon indicates its presence in the CSE (Pathirawasam and Weerakoon Banda, 2008;

Pathirawasam and Kral, 2012; Anuradha and Nimal, 2013). However, published evidence of research that tests the four-factor model in Sri Lanka is not to be found. Therefore, the objective of this research is to test the ability of the four-factor model to explain the variation in the cross-section of average stock returns in the CSE and to evaluate its explanatory power relative to the CAPM and the three-factor model.

The rest of the paper is organised as follows; Section 2 describes the sample and data, and Section 3 deals with the methodology used in the study. Section 4 presents the summary statistics, and Section 5 turns to the tests of asset pricing models. Section 6 concludes the paper.

2 Sample and data

The CSE was established in 1985; however, given the availability of data the sample period of this study extends from October 1997 to September 2012. Following the methodology of Fama and French (1993, 1996) the companies in the financial sector are excluded owing to their high financial leverage. Even though a total of 233 companies[1] have been used in this study, the number of companies qualifying each year to be included in a portfolio (based on the selection criteria emphasised in this Section and in Section 3) range, from 80 companies to 160 companies. Following Nimal (2006), monthly stock returns are calculated as percentage returns incorporating the net effect of capital gains/losses, dividends, stock splits, bonus issues and right issues on the assumption that they are reinvested in the same security. Information required in calculating the monthly stock returns are obtained from the CSE. Similar to Pathirawasam and Weerakoon Banda (2008) and Anuradha and Nimal (2013), monthly stock returns greater than + 50% or less than –50% are considered as outliers and are removed from the sample. Monthly excess returns are calculated as the returns in excess of the risk-free rate.

The percentage change in the total return index (TRI), which is a value weighted index, is used as a surrogate for the market return. The TRI reflects returns due to both price changes and dividends; it is calculated under the assumption that dividends earned are reinvested in the market. The monthly risk-free rates are derived from the 91-days Treasury bill rates obtained from the Central Bank of Sri Lanka.

3 Methodology

Empirical asset pricing tests require specifying the risk factors (explanatory variables) and the test assets (dependent variables) which are to be used in the regressions. In doing so portfolios are formed to generate the explanatory and dependent variables. The four-factor model involves estimating the following regression:

$$R_{it} - Rf_t = a_i + b_i \left[Rm_t - Rf_t \right] + s_i SMB_t + h_i HML_t + w_i WML_t + e_{it}$$

The portfolios forming the explanatory variables are referred to as the right-hand side (RHS) portfolios and the portfolios generating the dependent variables are referred to as the left-hand side (LHS) portfolios.

3.1 Portfolio formation

Following the factor mimicking portfolio approach of Fama and French (1996, 2012) portfolios are formed based on size and B/M ratio, and on size and momentum, in order to obtain explanatory returns for the regressions. All portfolio returns are calculated using excess stock returns.

Company size is measured in terms of market capitalisation. Book equity is calculated as the difference between total assets and total liabilities. The B/M ratio is calculated at the end of the fiscal year of each company; i.e. the book equity of a company at the end of its fiscal year is divided by the market capitalisation of the company at the end of its fiscal year. As the fiscal years of companies listed in the CSE end either in December or March, this generates a series of B/M ratios on the 31st of December for December-end companies and another series of B/M ratios on the 31st of March for March-end companies. Further, following the Fama and French (1996, 2012) methodology stocks with negative B/M ratios are not considered.

In the present study similar to Fama and French (2012), momentum is represented by the lagged return. Lagged momentum return of a stock is its cumulative equally weighted excess return from $t - 11$ to $t - 1$. Skipping the sort month in this manner is a standard practice in momentum tests, due to Jegadeesh's (1990) evidence of negative correlation (i.e. reversal rather than continuation) of month-to-month returns. It is to be noted that the first momentum calculation absorbs a year of data; therefore, the sample period for the regressions are actually 14 years, although data of 15 years are used for the calculations.

The explanatory returns are calculated by forming RHS portfolios from 2 × 3 sorts on size and B/M. Portfolios are formed at the end of September of year t and the monthly equal-weighted stock return for each portfolio is calculated from October of year t to September of year $t + 1$; after which portfolios are reformed in September of year $t + 1$. The CSE requires each company to publish their audited accounts by June for December-end companies and by September for March-end companies. Therefore, following Samarakoon (1997) September 31st is chosen as the portfolio formation date in order to provide a gap between the financial year-end and the return calculation period. This is done in order to avoid the 'look-ahead' bias as emphasised by Banz and Breen (1986). Furthermore, to be included in a size-B/M portfolio a stock is required to have a return for each of the *12 months* following the portfolio formation.

In the 2 × 3 sorts on size and B/M; stocks are grouped into two portfolios based on the median market capitalisation. Further, the same stocks are grouped in to three portfolios based on B/M ratio, where the breakpoints are taken as the 30th and 70th percentiles of the B/M ratio. The intersection of the independent 2 × 3 sorts on size and B/M produces six portfolios: SG, SN, SV, BG, BN and BV, where S and B indicate small and big and G, N and V indicate growth, neutral and value respectively. Growth firms have a lower B/M (below the 30th percentile) and value firms have a higher B/M (above the 70th percentile).

The monthly size factor (SMB) is calculated as the difference between the average return on the three small-cap stock portfolios and the three big-cap stock portfolios. The monthly value factor (HML) is calculated as the difference between the average return of the two high B/M portfolios (value portfolios) and the average return of the two low B/M portfolios (growth portfolios). In order to generate returns to be used for the regressions as dependent variables, LHS portfolios are created using 3 × 3 sorts on size and B/M, resulting in nine portfolios. Given the minute size of the CSE, using quartiles or quintiles as the breakpoints results in some portfolios having zero stocks; hence tertiles are used.

In order to calculate the monthly momentum factor (WML) another 2 × 3 sort is used where B/M is replaced by the lagged return. Since momentum returns are short term (Jegadeesh and Titman, 1993) size-momentum portfolios are formed monthly and the returns of the portfolios are calculated for the succeeding month (Fama and French, 2008, 2012). Therefore, to be included in a size-momentum portfolio, a stock is required to have a return for the month following the portfolio formation. All other mechanics of portfolio formation remain the same, thus generating another set of six portfolios: SL, SN, SW, BL, BN and BW, where S and B indicate small and big, and L, N and W indicate losers, neutral and winners respectively. Losers are firms with a lagged return below the 30th percentile and winners are firms with a lagged return higher than the 70th percentile.

The monthly momentum factor (WML) is calculated as the difference between the average return of the two winners' portfolios and the average return of the two losers' portfolios. A group of LHS portfolios are formed with tertiles as the breakpoints by using 3 × 3 sorts on size and momentum. This is done so that another set of regressions could be run using these nine portfolio returns as the dependent variables.

3.2 Statistical methods

In order to evaluate the overall validity of the four-factor model in its ability to explain the variation of cross-sectional average excess returns in the CSE and to compare its performance relative to the CAPM and the three-factor model; the GRS F-statistic along with its p-value, the average absolute intercept (denoted by $| a |$), the average adjusted R^2, the average standard error of the intercepts [denoted by $s(a)$] and the Sharpe ratio for the intercepts [denoted by $SR(a)$] are reported and analysed.

The GRS F-statistic is used to test the hypothesis that the regression intercepts for a set of nine portfolios are statistically indistinguishable from zero (Gibbons et al., 1989). The $SR(a)$ is the maximum Sharpe ratio for excess returns on the portfolios of the LHS assets contracted to have zero slopes on the RHS returns. In other words it can be termed as the Sharpe ratio for the intercepts (i.e. unexplained average returns) of a model (Fama and French, 2012). Given the above definition for the $SR(a)$ it follows that lower the Sharpe ratio for the intercepts, better the model is.

As the $SR(a)$ combines information about both the magnitude and the precision of the intercepts into one summary statistic, the average absolute intercept (as a measure of the relative magnitude) and the average adjusted R^2 and the average standard error of the intercepts (as measures of precision) are also reported separately so that information on the magnitude and the precision of intercepts are not lost.

4 Summary statistics

4.1 Explanatory returns (factors)/RHS portfolio returns

Given in Table 1 are the average factors and their standard deviations for the period under consideration. t-mean is the ratio of the mean to its standard error. Fama and French (2012) in their study find the market factor to range between –0.12% (Japan) and

0.86% (Asia Pacific) per month with a global factor of 0.44%. Agarwalla et al. (2013) report a monthly market factor of 0.29% in India. For the period under consideration an average market factor of 1.17% (t = 2.00) per month is seen with respect to the CSE. The market factor for the period is more volatile compared to the other factors with a standard deviation of 7.58%.

Table 1 Summary statistics for explanatory variables

	$R_m - R_f$	*SMB*	*HML*	HML_S	HML_B	HML_{S-B}	*WML*	WML_S	WML_B	WML_{S-B}
Mean	1.17	0.09	0.54	0.52	0.57	–0.06	0.00	–0.22	0.21	–0.43
Standard deviation	7.58	2.93	3.55	4.79	4.67	6.25	4.17	5.28	4.89	5.84
t-mean	2.00	0.42	1.99	1.40	1.59	–0.12	–0.01	–0.54	0.57	-0.96

Notes: Portfolios are formed at the end of September each year t by sorting stocks into two market-cap and three B/M groups. Big-cap stocks are those stocks above the median market cap and small-cap stocks are those below the median market cap. The B/M breakpoints are the 30th and 70th percentiles of B/M. The independent 2 × 3 sorts on size and B/M produce six portfolios, SG, SN, SV, BG, BN, and BV, where S and B indicate small and big and G, N, and V indicate growth, neutral, and value (bottom 30%, middle 40%, and top 30% of B/M) respectively. Monthly returns on the portfolios are calculated from October to the following September. SMB is the equal-weight average of the returns on the three small-cap stock portfolios minus the average of the returns on the three big-cap stock portfolios. The 2 × 3 sorts on size and lagged momentum are similar, but the size-momentum portfolios are formed monthly. For portfolios formed at the end of month t, the lagged momentum return is a stock's cumulative return for $t - 11$ to $t - 1$. The independent 2 × 3 sorts on size and momentum produce six portfolios, SL, SN, SW, BL, BN, and BW, where S and B indicate small and big and L, N, and W indicate losers, neutral, and winners (bottom 30%, middle 40%, and top 30% of lagged momentum) respectively. All returns are in Sri Lankan Rupees. $R_m - R_f$ is the return calculated from the TRI minus the one-month T-bill rate (derived from the '91-days' Treasury bill rate). Size is the market capitalisation at the end of September of each year t. The book equity is calculated as the difference between total assets and total liabilities. Negative book equity firms are excluded. The B/M ratio used to form portfolios in September of year t is the book common equity for the fiscal year ending in March (December) of year t ($t - 1$) divided by the market equity on the same day. The t-Mean is the ratio of the mean to its standard error. Value-growth returns for small-cap and big-cap stocks as well as winner-loser returns for small-cap and big-cap stocks are presented as well. HML_S = SV – SG and HML_B = BV – BG, and HML is the equal-weight average of HML_S and HML_B. WML_S = SW – SL and WML_B = BW – BL, and WML is the equal-weight average of WML_S and WML_B. HML_{S-B} (WML_{S-B}) is the difference between HML_S and HML_B (WML_S and WML_B).

Similar to Fama and French (2012), the average size factor is found to be close to zero in the present study. These results are also consistent with Agarwalla et al. (2013) who report an average size factor of a negative 0.06% per month in India.

The average value factor per month is 0.54% (t = 1.99) in the present study; Fama and French (2012) report an average value factor per month ranging from 0.33% (North America) to 0.62% (Asia Pacific). Agarwalla et al. (2013) in their study find the monthly value factor to be 0.50% in India. Further, in the present study the value factors are larger in big-cap stocks than in small-cap stocks. This finding contrasts with the findings with regard to developed markets (Fama and French, 2012; Kothari et al., 1995;

Loughran, 1997) and mimic the findings with respect to emerging markets (Cakici et al., 2013; Hanauer and Linhart, 2013). In Japan, Fama and French (2012) document a value factor which is similar for both small-cap and big-cap stocks.

While Asness et al. (2013), Chui et al. (2010) and Fama and French (2012) find strong momentum factors in North America, Asia Pacific and Europe, the average momentum factor per month is found to be very close to zero in the present study. Fama and French (2012) report an average momentum factor of 0.64% for North America, 0.69% for Asia Pacific and 0.92% for Europe per month. The results of the present study are similar to the findings of Fama and French (2012) with regard to Japan, where the average momentum factor was found to be a very minute 0.08% per month. It is interesting to note that Agarwalla et al. (2013) report a fairly high monthly momentum factor of 1.77% in India.

In the present study, the momentum factors are larger (and positive) in big-cap stocks and are negative in the case of small-cap stocks indicating that there is no momentum factor in the small-cap stocks. These findings contrast with findings related to both developed and emerging markets, where small-cap stocks have higher momentum factors (Fama and French, 2012; Hong et al., 2000; Cakici et al., 2013).

4.2 Dependent variables/LHS excess portfolio returns

The standard size effect (i.e. smaller firms having a larger average return) is not to be seen in the data presented in Table 2, and there appears to be no persistent pattern in the size effect. Although traces of a reverse size effect can be seen, it is indisputably seen only in the neutral stocks (0.85, 0.89, and 0.91). Fama and French (1993, 2012) find a reverse size effect in small growth stocks in USA and other developed markets. With the exception of Japan, Fama and French (2012) report a standard size effect for the value stocks in their study.

Table 2 Summary statistics for the 9 size-B/M portfolios' average excess returns

	B/M equity (tertiles)						
Size	*1*	*2*	*3*		*1*	*2*	*3*
	Mean excess returns				*Standard deviation*		
1	0.81	0.85	1.18	1	9.06	7.54	7.66
2	0.11	0.89	0.98	2	8.96	7.74	8.36
3	0.62	0.91	1.61	3	6.48	7.59	9.25

Notes: At the end of September of each year, size-B/M portfolios are constructed using tertiles as the breakpoints. The intersections of the 3×3 independent size and B/M sorts produce 9 size-B/M portfolios.

In the present study, consistent with previous research (Fama and French, 1992, 1995, 1996, 2012) there is a value pattern to be seen in all size groups; that is the average returns increase from left to right in every row of the size-B/M matrices. The spread in value versus growth average returns is highest for the big-cap stocks; i.e. 0.99% (= 1.61% – 0.62%).

In Table 3, the momentum pattern prevails in big-cap stocks; i.e. when you move from left (last year's losers) to right (last year's winners) the average return increases. However, there is a reversal of the momentum pattern for small-cap stocks, suggesting a 'contrarian' pattern with the average return decreasing when moving from left to right. The spread in momentum average returns is highest in the small-cap stocks; i.e. –0.67% (= 0.39% – 1.06%). Regarding the portfolios formed on size and momentum Fama and French (2012) document momentum returns in all regions except Japan. Contrary to Fama and French (2012), who find a size effect in the winners' stocks, the winners in the present study depict a clear reverse size effect. Similar to Fama and French (2012) the present study finds that there is no consistent relationship between size and average return for the losers' stocks.

Table 3 Summary statistics for the 9 size-momentum portfolios' average excess returns

	Momentum (tertiles)						
Size	*1*	*2*	*3*		*1*	*2*	*3*
	Mean excess returns				*Standard deviation*		
1	1.06	1.03	0.39	1	8.73	8.10	7.98
2	0.52	0.96	0.76	2	8.86	8.10	8.20
3	0.61	0.78	1.03	3	8.12	7.12	7.23

Notes: The 3 × 3 sorts on size and momentum use the same breakpoint conventions as the size-B/M sorts, except that the size-momentum portfolios are formed monthly. For portfolios formed at the end of month t, the lagged momentum return is a stock's cumulative monthly return for $t - 11$ to $t - 1$. The intersections of the independent 3 × 3 size and momentum sorts produce 9 size-momentum portfolios.

5 Asset pricing tests

Tables 4 and 5 report detailed regression results for the 9 size-B/M portfolios and the 9 size-momentum portfolios respectively. Based on the regression coefficients a clear size effect is seen in both sets of regressions in the current study. A value effect is clearly seen when the portfolios are formed on size and B/M, with the loading on HML increasing when moving from growth stocks to value stocks (Table 4). These findings are consistent with the findings of Al-Mwalla (2012), regarding the regressions run for size-B/M portfolios formed for the Amman Stock Exchange.

Similarly the loading on WML increases when moving from losers to winners of portfolios formed on size and momentum (Table 5), showing a clear momentum effect; these results confirm the presence of momentum patterns in the CSE observed in previous studies (Pathirawasam and Weerakoon Banda, 2008; Pathirawasam and Kral, 2012; Anuradha and Nimal, 2013). When observing the market betas they are closer to 0.90 in the present study; in contrast Fama and French (1993) find their market betas to be closer to 1.00.

Regarding the significance of the regression coefficients in the current study, most of the coefficients are significant while the intercepts are insignificant. These findings are consistent with the findings of Lam et al. (2009) with respect to their study on the Hong Kong Stock Exchange; they conclude that the evidence of significant coefficients on the four factors and the insignificant intercepts provide strong support to the applicability of the four- factor model in the Hong Kong Stock Exchange.

Table 4 Regression results for the 9 size-B/M portfolios

		B/M equity (tertiles)					
Size	*1*	*2*	*3*		*1*	*2*	*3*
	Regressions: $R_{it} - R_{ft} = a_i + b_i(R_M - R_f)_t + s_i SMB_t + h_i HML_t + w_i WML_t + e_{it}$						
		a_i				*t-stat*	
1	–0.16	–0.29	–0.15	1	–0.44	–0.96	–0.54
2	–0.83	–0.32	–0.43	2	–2.00*	–1.17	–1.29
3	–0.13	–0.13	0.22	3	–0.58	–0.50	0.56
		b_i				*t-stat*	
1	0.93	0.80	0.79	1	18.76*	20.33*	21.88*
2	0.94	0.90	0.89	2	16.90*	24.49*	20.02*
3	0.78	0.90	0.96	3	27.01*	25.74*	18.34*
		s_i				*t-stat*	
1	1.20	0.82	1.06	1	9.16*	7.82*	11.13*
2	0.42	0.40	0.69	2	2.91*	4.09*	5.95*
3	–0.06	0.12	–0.03	3	–0.81	1.26	–0.19
		h_i				*t-stat*	
1	–0.43	0.22	0.55	1	–3.91*	2.53*	6.98*
2	–0.36	0.22	0.56	2	–2.98*	2.68*	5.80*
3	–0.30	–0.04	0.50	3	–4.70*	–0.49	4.39*
		w_i				*t-stat*	
1	–0.14	–0.20	–0.15	1	–1.55	–2.84*	–2.29*
2	–0.27	–0.03	–0.07	2	–2.73*	–0.42	–0.84
3	–0.10	–0.11	–0.17	3	–1.90**	–1.80**	–1.85**
		R^2				*t-stat*	
1	0.73	0.75	0.80	1	112.52*	126.29*	165.84*
2	0.65	0.80	0.75	2	79.982*	163.82*	123.97*
3	0.82	0.81	0.71	3	193.29*	176.63*	104.41*

Notes: The regressions use the four-factor model to explain the excess returns on portfolios formed on independent size and B/M sorts. The intercepts (a_i), loading on the market factor (b_i), loading on SMB (s_i), loading on HML (h_i), loading on WML (w_i) and their respective t-statistics are presented along with the adjusted R^2 and F-statistic for each regression. Statistical significance of a coefficient at a 5% level of confidence is indicated by a star mark (*) and statistical significance at a 10% level of confidence is indicated by two star marks (**) on the respective t-stat. The statistical significance of the F-stat is also indicated in the same manner.

Table 5 Regression results for the 9 size-momentum portfolios

	Momentum (tertiles)						
Size	*1*	*2*	*3*		*1*	*2*	*3*
Regressions: $R_{it} - R_{ft} = a_i + b_i(R_M - R_f)_t + s_i SMB_t + h_i HML_t + w_i WML_t + e_{it}$							
		a_i				*t-stat*	
1	–0.16	–0.20	–0.74	1	–0.51	–0.59	–2.00*
2	–0.70	–0.34	–0.52	2	–2.03*	–1.02	–1.63
3	–0.42	–0.19	0.05	3	–1.42	–0.80	0.21
		b_i				*t-stat*	
1	0.90	0.84	0.80	1	21.60*	18.71*	16.43*
2	0.92	0.86	0.93	2	20.13*	19.42*	21.98*
3	0.84	0.85	0.87	3	21.40*	26.85*	26.59*
		s_i				*t-stat*	
1	0.95	1.06	1.15	1	8.61*	8.90*	8.91*
2	0.62	0.64	0.59	2	5.19*	5.48*	5.32*
3	0.07	0.09	–0.06	3	0.64	1.04	–0.69
		h_i				*t-stat*	
1	0.14	0.26	0.14	1	1.50	2.63*	1.31
2	0.16	0.42	0.25	2	1.59	4.31*	2.67*
3	0.06	–0.06	–0.05	3	0.72	–0.89	–0.76
		w_i				*t-stat*	
1	–0.54	–0.06	0.32	1	–7.17*	–0.73	3.65*
2	–0.56	–0.13	0.37	2	–6.83*	–1.61	4.83*
3	–0.63	–0.10	0.29	3	–8.92*	–1.76**	4.90*
		R^2				*t-stat*	
1	0.79	0.72	0.66	1	160.23*	108.03*	82.61*
2	0.76	0.73	0.76	2	132.92*	113.19*	131.44*
3	0.79	0.82	0.81	3	154.99*	191.49*	184.00*

Notes: The regressions use the four-factor model to explain the excess returns on portfolios formed on independent size and momentum sorts. The intercepts (a_i), loading on the market factor (b_i), loading on SMB (s_i), loading on HML (h_i), loading on WML (w_i) and their respective t-statistics are presented along with the adjusted R^2 and F-statistic for each regression. Statistical significance of a coefficient at a 5% level of confidence is indicated by a star mark (*) and statistical significance at a 10% level of confidence is indicated by two star marks (**) on the respective t-stat. The statistical significance of the F- stat is also indicated in the same manner.

In Table 6, as the GRS F-statistic for the CAPM regressions is 6.64, and is far into the right tail of the relevant F-distribution, CAPM is rejected. However, when shifting from CAPM to the three-factor model or the four-factor model there is a large drop in the GRS F-statistic and the p-value increases substantially. Therefore, the null hypothesis stating that all regression intercepts are statistically equal to zero is not rejected, i.e. the three-factor model and four-factor model appear suitable for the LHS portfolios in Table 6. Further, when moving from CAPM to the three-factor and four-factor model, all other summary statistics mark a clear improvement implying that the three-factor and four-factor model capture the cross-section of average returns better than the CAPM. Further, the other summary statistics (with the exception of the average adjusted R^2) improve in favour of the four-factor model in comparison to the three-factor model.

Table 6 Summary statistics for regressions to explain excess returns on the 9 size-B/M portfolios

	GRS test		$\lvert a \rvert$	R^2	*s(a)*	*SR(a)*
	F-stat	*p*				
CAPM	6.64*	0.00	0.29	0.67	0.11	0.62
Three-factor	1.04	0.41	0.30	0.75	0.08	0.25
Four-factor	0.81	0.61	0.30	0.74	0.09	0.22

Notes: The regressions use the CAPM, three-factor and four-factor models to explain the returns on portfolios formed on size and B/M. The GRS F-statistic tests whether all intercepts in a set of 9 (3 × 3) regressions are zero; $\lvert a \rvert$ is the average absolute intercept for a set of regressions; $s(a)$ is the average standard error of the intercepts; R^2 is the average adjusted R^2 and $SR(a)$ is the Sharpe ratio for the intercepts.

When portfolios are formed on size and momentum (Table 7), the results are different from the size-B/M portfolios in two aspects. Firstly, all three models are accepted based on the GRS F-test, as the p-values of the respective F-statistics are higher than 0.05. Secondly, the four-factor model turns out to be indisputably the superior model compared to both the CAPM and the three-factor model, as the GRS F-statistic, the average adjusted R^2 and $SR(a)$ all improve in favour of the four-factor model when moving away from the CAPM or the three-factor model.

Table 7 Summary statistics for regressions to explain excess returns on the 9 size-momentum portfolios

	GRS test		$\lvert a \rvert$	R^2	*s(a)*	*SR(a)*
	F-stat	*p*				
CAPM	1.36	0.21	0.24	0.66	0.09	0.28
Three-factor	1.18	0.31	0.38	0.72	0.08	0.27
Four-factor	0.83	0.59	0.37	0.76	0.09	0.22

Notes: The regressions use the CAPM, three-factor and four-factor models to explain the returns on portfolios formed on size and momentum. The GRS F-statistic tests whether all intercepts in a set of 9 (3 × 3) regressions are zero; $\lvert a \rvert$ is the average absolute intercept for a set of regressions; $s(a)$ is the average standard error of the intercepts; R^2 is the average adjusted R^2 and $SR(a)$ is the Sharpe ratio for the intercepts.

Therefore, based on the GRS F-test, it is concluded that the four-factor model is not to be rejected with regard to the CSE; it effectively captures the average returns of all size-B/M and size-momentum portfolios. These results directly contrast with the findings with regard to developed markets (Fama and French, 2012) and are more in line with the findings for emerging markets (Cakici et al., 2013; Hanauer and Linhart, 2013). In many studies done with regard to developed markets, though the R^2 and GRS F-statistic improve when moving from CAPM to the four-factor model (through the three-factor model), they reject the four-factor model based on the GRS F-test. In addition, Brighi et al. (2010) find that adding the momentum factor does not improve the performance of the three-factor model in its application in the Milan Stock Exchange. Looking at developing markets, Hasnaoui and Ibrahim (2013) accept the four-factor model and reject the three-factor model based on the GRS F-test for their study done on the Tunis Stock Exchange; Unlu (2013) accepts both the three-factor model and four-factor model for the Istanbul Stock Exchange based on the GRS F-test.

In Fama and French (2012), the average adjusted R^2 values are above 0.89 for the local four-factor models. However, in the present study it is 0.74 and 0.76 for size-B/M and size-momentum portfolios respectively. It is interesting to note that Bello's (2008) documents an identical average adjusted R^2 of 0.71 for CAPM, the three-factor model and the four-factor model in his study done with USA stocks. In Al-Mwalla's (2012) study of the Amman Stock Exchange the average adjusted R^2 does not increase substantially when moving from the three-factor model (0.59) to the four-factor model (0.61) for portfolios formed on size-B/M. Lam et al. (2009) report an average adjusted R^2 of 0.70 in their study of the four-factor model in the Hong Kong Stock Exchange.

Previous studies done in Sri Lanka have shown the presence of size and value patterns through the application of the three-factor model (Seneviratne and Nimal, 2008.; Nanayakkara, 2008; Randeniya and Wijerathna, 2012) and the presence of momentum patterns through momentum tests (Pathirawasam and Weerakoon Banda, 2008; Pathirawasam and Kral, 2012; Anuradha and Nimal, 2013). The regression loadings of the present study confirm the presence of these size, value and momentum patterns.

6 Summary and conclusions

This study investigates whether the Carhart four-factor model can capture the variation in the cross-section of average stock returns in the CSE and compares its performance to the CAPM and three-factor model. It uses monthly stock return data from October 1997 to September 2012, excluding the financial sector of the CSE. The factor mimicking portfolio approach of Fama and French (1996, 2012) is applied in this study; portfolios are formed based on size and B/M as well as on size and momentum. To test the ability of the four-factor model in explaining the average stock returns and to evaluate its performance in comparison to the CAPM and the three-factor model, the adjusted R^2, GRS F-test and the Sharpe ratio for the intercepts are used.

In addressing the research objective stated in Section 1, the following conclusions are drawn from this study:

- The four-factor model successfully captures the cross-section of average returns in the CSE.

- The four-factor model performs better than the CAPM in all circumstances considered in the present study. In comparison to the three-factor model the four-factor model does marginally better.

The findings of this study are found to be consistent with many of the studies done in emerging markets. However, when compared to the studies done in developed markets the findings of the current study differ on many aspects, such as with the results of the GRS F- test. Given that the CSE is a frontier market, these findings have important implications for policymakers and investors of such markets. For example these findings are suggestive that frontier markets fundamentally operate in a similar way to emerging markets; hence, policymakers could take into consideration the structure, regulations etc. of emerging markets when developing policies regarding frontier markets. For investors in the CSE these findings suggest that they could follow a trading strategy where they invest in small-cap, high B/M stocks and in stocks that have performed well over the past 12 months; furthermore, these findings suggest that size, B/M and momentum effects should be taken in to consideration when evaluating portfolio performance.

However, the external validity of these findings could be questionable; i.e. this study looks only at one frontier market. Its findings may not uniformly apply to other frontier markets. Nevertheless, this study contributes to the literature by showing the applicability of the widely tested four-factor model in a frontier market and evaluates its performance compared to the three-factor model and CAPM. Identifying plausible economic or behavioural explanations on what state variables are captured by size, B/M and momentum factors would further enhance the understanding of these anomalies.

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Notes

1 Given the size of the CSE and comparatively low level of trade activity it is questionable whether the assumptions of CAPM hold in this market.