Journal of Positive School Psychology http://journalppw.com
2022, Vol. 6, No. 5, 8985 – 8997

A comparative test of multifactor asset pricing models in the dynamic regimes of Financial Crisis: Evidence from emerging market regions Asia, EMEA, and Americas

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ABSTRACT
This research study extends the asset-pricing literature by investigating the relative performance of five different asset-pricing models, including CAPM by Sharpe (1964) and Lintner (1965), 3FM by Fama and French (1993), Carhart's (1997) 4FM, 5FM by Fama-French (2015), and the author's proposed 10FM, which in addition to market risk, size, value, profitability, and investment factors, incorporate momentum, liquidity, leverage, government bonds risk, and commodity risk as additional asset-pricing factors. This study aims to test the well-advocated asset-pricing factors jointly and comprehensively in one model. It also checks the robustness of all considered asset-pricing models around the GFC. Following this, the entire sample period of 21 years, consisting of 252 months split up into three sub-periods: pre-crisis, crisis, and post-crisis. We employed panel data analysis covering an extensive sample of financial equities from 21 emerging markets across the three regions of MSCI's classified emerging market economies: Asia, EMEA, and Americas. Moreover, the GRS-F test suggested by Gibbons et al. (1989) was applied to select the best model. Findings are stimulating as CAPM failed to prove valid ubiquitously; however, we conclude that 3FM is a successful and most appropriate asset-pricing model in describing the average portfolio returns for region Asia. While 5FM is better than other asset-pricing models for the region, EMEA and 10FM is the second-most appropriate model for the region. And for the region, Americas 10FM is the most suitable and reliable multifactor model since it outperformed all other asset-pricing models.

Keywords: *Financial Crisis, CAPM, 3FM, 5FM, 10FM, LHS Portfolios, RHS Portfolios, MSCI*

1. Introduction

The present research study evaluates and compares the performance of five different Asset-Pricing (AP) models: Capital Asset Pricing Model (CAPM), Fama and French (1993) Three-Factor Model (3FM), Carhart (1997) Four-Factor-Model (4FM), Fama and French (2015) Five-Factor Model (5FM), and author's proposed Ten-Factor Model (10FM) across the financial sector of three Emerging Market (EM) regions Asia, EMEA (Europe Middle East and Africa), and Americas. The author aims to provide a "horserace" of the competing AP models around the three regimes of the Global Financial Crisis (GFC) 2008: pre-crisis, crisis, and post-crisis sub-periods, using data from the financial sector of global EM.

In multifactor AP literature, persuasive research studies were conducted by Novy-Marx (2012) and (2013). Those were inspired by the MM's (Miller & Modigliani, 1961) Dividend Discount Model (DDM). In their influential research, the incorporation of another firm fundamental characteristic, that is, gross profitability measure, suggested as a new development into the existing 3FM. Following them, FF (2015a) confirmed the plausibility of two more explanatory factors operating profitability (RMW) and investment (CMA), in the existing 3FM. Further, the 5FM is evaluated over the developed international markets by FF (2015b), FF (2017), and FF (2016) to capture the increased variation in stock returns. Since then, extensive empirical studies have been conducted around the globe to either check for validity or compare the power of various AP models and reported mixed evidence. In a recent study, FF developed a six-factor model by adding Carhart's momentum factor into the 5FM to capture most of the patterns of average stock returns (FF, 2018).

Concerning the AP empirical literature, Karolyi (2016) emphasized that a large number of research studies have investigated the capital market of the United States and anomalies present therein, which refers to the U.S "home bias" (U.S.-based studies). Karolyi (2016) also voices "foreign bias" (other more often studied countries) as a considerable number of AP research focused on developed markets or prominent EM. For instance, FF (2012), FF (2017), Griffin (2002), and Rouwenhorst (1998). As the developed markets are substantially integrated, the similar results of many developed markets'-based studies are not confounding, and the significance of the same risk factors across the developed markets is not surprising. However, Ali et al. (2020) argued EM is relatively less integrated and possesses unique characteristics. Moreover, little attention is given to EM due to the lack of high-quality data (Zaremba et al., 2019a). Hence, insufficient evidence about the application of AP models across the EM necessitates the out-of-sample test to understand the list of anomalies present in these economies.

Asset-pricing models continue to develop, and the discovery of new return anomalies is ongoing. Researchers are continuously proposing and testing new AP models to precisely capture the cross-section of asset returns. But so far, no consensus has been established. The authenticity and superiority of one AP model in EM are yet to evaluate. Cakici et al. (2013) took an extensive sample of EM to test 3FM and found value effect is much stronger than the size effect in average stock returns. Recently, researchers also focused on other main developed capital markets to test the application of 5FM, such as Elliot et al. (2018) and Huynh (2018) considered the capital market of Australia, while Kubota and Takehara (2018) analyzed the equity market of Japan. Although, results reported by these studies provide mixed evidence for different regions. Jacob (2016) revealed that various regions show the presence of other anomalies, and the significance of a specific risk factor also varies across the regions. Asness, Moskowitz, and Pedersen (2013) tested Carhart's momentum factor and reported that it performed effectively in developed markets. In comparison, the Japanese developed market showed exceptions to the effectiveness of the momentum factor (Asness 2011; FF 2012). For the Asian EM, the momentum factor was found unclear and irrelevant in describing patterns of average returns in China, Korea, etc. (Chui, Wei, and Titman 2010; Lin 2017).

However, in Asia, Lin (2017) compared the efficiency of both 3FM and 5FM over the most significant EM, China, and reports that 5FM is superior that consistently surpasses 3FM. Additionally, the findings of Lin's (2017) research contribute that in China value effect remained indispensable even after the inclusion of investment and profitability factors which contradicts FF (2015b), who confirmed the redundancy of value premium in the US after 5FM.

In the Eastern Europe region, Foye et al. (2013) confirmed the presence of a significant value premium while the size premium was absent when conducting an international test of 3FM over the broad set of all European Union countries. Correspondingly, Waszczuk (2013) validates that 3FM is efficient and captures a considerable number of anomalies in the average returns of polish stocks. Like many other studies, the robustness of the value factor is much stronger than the size factor. Afterward, Zaremba and Czapkiewicz (2017) tested the performance of 5FM on the five prominent EM of the Eastern Europe region and found that 5FM outperformed 3FM.

In Latin America, both size and value factors were insignificant (Grandes et al., 2010). Howbeit, market risk measured by beta captures almost one-third of the total variation in stock returns, which is noticeably different and more significant than in developed capital markets (for instance, UK, US, Japan, Canada, etc.). Unfortunately, until now, minimal research has been conducted, and scarce evidence is available to support or reject the 5FM in Latin America.

Keeping these facts in mind, the main objective of this research study is to have an extensive out-of-sample test of the new comprehensive 10FM and compare its overall performance with other parsimonious AP models across the GFC sub-periods. In addition, we aim to check the relevance of various pricing factors and establish the superiority of the most appropriate AP model in each region of the EM. The empirical studies closest to present research are Cakici (2015), FF (2012; 2017), Foye (2018), Lalwani and Chakraborty (2020), and Leite et al. (2018), as they are all based on testing the application of multifactor risk-adjusted return models across multiple economies. However, no study has tested the proposed 10FM over the broad sample of the financial sector of Asia, EMEA, and Americas regional EM in pre-crisis, crisis, and post-crisis sub-periods.

The rest of the research paper proceeds as follows: the next section outlines the proposed 10FM and other empirical AP models. The second section details the data and methods, including the processes used to construct (right-hand-side) RHS factors and (left-hand-side) LHS test portfolios. The third section provides a detailed discussion of summary statistics, correlations, GRS-test, and AP models tests. Finally, the last section highlights conclusions and future research.

2. The Empirical Models

2.1. Models' definitions

In the present research study, the following models are tested:

The CAPM is:

$$R_{pt} - R_{ft} = \alpha_p + \beta_{pt}\,(R_{mt}-R_{ft}) + \varepsilon_{pt} \quad (1)$$

Where $R_{pt} - R_{ft}$ is the excess return over test portfolio p

FF three-factor model is:

$$R_{pt} - R_{ft} = \alpha_p + \beta_{pt}\,(R_{mt}-R_{ft}) + s_pSMB_t + h_pHML_t + \varepsilon_{pt} \quad (2)$$

Carhart four-factor model is:

$$R_{pt} - R_{ft} = \alpha_p + \beta_{pt}\,(R_{mt}-R_{ft}) + s_pSMB_t + h_pHML_t + w_pWML_t + \varepsilon_{pt} \quad (3)$$

FF five-factor model is:

$$R_{pt} - R_{ft} = \alpha_p + \beta_{pt}\,(R_{mt}-R_{ft}) + s_pSMB_t + h_pHML_t + r_pRMW_t + c_pCMA_t \quad (4)$$

Proposed Multifactor Risk-Adjusted Return Model is:

$$R_{pt} - R_{ft} = \alpha_p + \beta_{pt}\,(R_{mt}-R_{ft}) + s_pSMB_t + h_pHML_t + r_pRMW_t + c_pCMA_t + w_pWML_t + l_{liqp}L_{liq}MH_t + l_{levp}L_{lev}MH_t + g_p\,(R_{GBIt}-R_{ft}) + c_p\,(R_{CIt}-R_{ft}) + \varepsilon_{pt} \quad (5)$$

Here the symbol 'R_m- R_f' denotes the excess return on the value-weighted market portfolio, Small Minus Big (SMB) size factor, High Minus Low (HML) value factor, Robust Minus Weak (RMW) operating profitability factor, Conservative Minus Aggressive (CMA) investment factor, the Carhart momentum factor Winners Minus Losers (WML), Liquidity factor (Low Minus High: L_{liq}MH), leverage factor Low Minus High (L_{lev}MH), excess return over government bond index (R_{GBIt}-R_{ft}) and excess return over the commodity index R_{CIt}-R_{ft}).

2.2. Data and Methods

Following the empirical studies (including Cakici et al., 2013; Foye, 2018; Gilmore & Hayashi, 2013; Hanauer & Linhart, 2015), we picked the Morgan Stanley Capital International (MSCI) EM' classification accessed by the authors in June 2015. Countries with minimal data on the early years of sampled period are eliminated (such as Peru, Greece, and UAE). Regional analysis is conducted (just as FF 2012; 2017) to compare and achieve well-diversified portfolios reasonably. We test 21 EM, divided into three MSCI-defined conventions: Americas (Brazil, Chile, Colombia, Mexico); EMEA (Czech Republic, Egypt, Hungary, Poland, Qatar, Russia, South Africa, Turkey); and Asia (China, India, Indonesia, South Korea, Malaysia, Pakistan, Philippines, Taiwan, and Thailand). The sample encompasses financial equities from 21 EM covering the period from December 1997 to June 2019. Comparable to Kostin, Runge, & Charifzadeh (2022) and Miss, Charifzadeh, and Herberger (2020), the entire period of 21 years, consisting of 252 months, is further categorized into three subperiods around the GFC to determine the efficacy of AP models under dynamic regimes. The subperiods are the pre-crisis sub-period (from July 1998 to June 2007), the crisis sub-period (from July 2007 to June 2010), and the post-crisis sub-period (from July 2010 to June 2019). The timeframe chosen for the crisis subperiod is picked from the literature (July 2007 to June 2010). While the periods for pre-and post-crisis sub-periods are pushed up to the time for which data is accessible to the researcher (Nasir & Du, 2018; Wang, Xie, Lin, & Stanley, 2017). We attempted to procure homogeneity in compared samples by taking equal periods before and after the crisis _(Lux & Moss, 2016). The data frequency is monthly and collected in three stages: 1) market data, 2) accounting data, and 3) risk-free rate data. Market data is collected from Trading Economics, Investing.com, Thomson Reuters Datastream, and respective stock exchange sources of every EM. The indexes contain both active and dead stocks to avoid survivorship bias. At the same time, accounting data comes from the Worldscope database and year-ending annual financial statements of every firm listed in the financial sector of each EM. We converted the monetary returns data to U.S dollars from the local currency of each EM, and lastly, as a proxy of the risk-free rate of return, the one-month U.S T-bills rate is obtained. To be in the sample, each financial firm must have accounting data for the financial year (t-1). Each financial cycle in this study is marked from July of the year (t) to the end of June of the following year (t+1). At the end of June, each year (t) portfolios are refreshed and rebalanced. While accounting data is collected for forming and creating portfolios from December (t-1). Following the literature, it is ensured that companies with a negative book value of equity are screened out.

2.3. RHS factors construction

After computing variables, the right-hand-side (RHS) factors from equations (1) to (5) above are calculated by following the FF (1993) methodology. At first, we compute country-wise annual portfolios and later arrange them for panel data analyses under their respective regions. The first RHS factor, market risk premium (R_m-R_f), is calculated by taking the difference between monthly values of market return (R_m) and the risk-free rate of return (R_f) for each year ‘t’ (July to June). Next, equation (2) representing 3FM requires the construction of size and value factors in addition to the market factor. The first data point is set on 31st December 1997, as relying on observed market capitalization and book-to-market equity value of ‘t-1’, portfolios of ‘t’ are sorted at the end of June 1998. For each sampled country, factor breakpoints are drawn individually at the end of June of every year ‘t’. The formation of size and value factors started with sorting sampled stocks independently in ascending order of their market capitalization and B/M ratio. Using the median as a cut-off point for stocks ranked on market capitalization, two size groups are created, Small (S) and Big (B). The below-median stocks are characterized as ‘S’, and those above-median are considered ‘B’. This approach of relying on median stock capitalization value is in line with Czapiewski (2016), Czapkiewicz and Wojtowicz (2014), Roszkowska and Langer (2016), and Waszczuk (2013). Then, sorting on B/M ratio, three sub-groups, High (H), Medium (M), and Low (L), are formed by using the 30th and 70th percentile. From the intersection of two-size (S & B) and three-B/M (H, M & L) sorts, six size-B/M double-sorted (2×3) portfolios are created. These are S/H, S/M, S/L, B/H, B/M, and B/L. Monthly value-weighted stock returns are calculated for these six portfolios from July of year ‘t’ to June of next year ‘t+1’. Hence, $SMB_{B./M,t}$ (Small Minus Big) is the difference between the average monthly value-weighted returns of three small portfolios (S/H, S/M, S/L) and the average monthly value-weighted returns of three big portfolios (B/H, B/M, B/L). And HMLt (High Minus Low) is the difference between simple averages of two value-weighted monthly returns portfolios of high B/M (S/H, B/H) and two value-weighted monthly returns portfolios of low B/M (S/L, B/L).

Table 1 Computation of variables

Variable	Formula	Description
Stock Returns	$R_{i,t} = \ln (P_{i,t} / P_{i,t-1})$	Return on financial equity ‘i’ for a time period ‘t’
Commodity Index Returns	$R_{CI\,(i,t)} = \ln (CI_{i,t} / CI_{i,t-1})$	Return on commodity index over each country ‘i’ as on ‘t’
Government Bonds Index Returns	$R_{GBI(i,t)} = \ln (GBI_{i,t} / GBI_{i,t-1})$	Return on government bonds index over each country ‘i’ as on ‘t’
Market Return	$R_{mt} = \ln (\text{Market Index}_{i,t} / \text{Market Index}_{i,t-1})$	Expected rate of return on a market portfolio (market index) for each country ‘i’ as on ‘t’
Risk-free Rate	$R_f = \ln (P_{risk\text{-}free(i,t)} / P_{risk\text{-}free(i,t)-1})$	The risk-free rate of return over each country

		‘i’ as on ‘t’
Market Capitalization	$ME_{i,t} = P_{i,t} \times SO_{i,t}$	Product of closing market price of stock ‘i’ and no. of shares outstanding, computed at the end of December of each year ‘t-1’
Book Equity	$BE_{i,t}$ = Total $Assets_t$ – Total $Liabilities_t$	Difference between a firm’s total assets and total liabilities computed at the end of December of each year ‘t-1’
Book to Market Ratio	B/M_t = Book Equity $_{t-1}$ / Market $Equity_{t-1}$	The ratio of BE to ME; to avoid time inconsistency bias, both are calculated (at the same time) at the end of December of the financial year ‘t-1’
Momentum	$MOM_{i,t} = \sum^{12}_{J=1} R_{i,t-J} / 12$	Calculated by taking the moving average of past 12-months’ stock returns
Operating Profit	$OP_{i,t} = (EBIT_{i,t} - INT_{i,t}) / BE_{i,t}$	‘OP i,t’ is computed by taking annual earnings before taxes (EBT) as the numerator and book value of equity as the denominator computed at the end of December of the financial year ‘t-1’
Investment	$INV_{i,t} = TA_{i,t-1} - TA_{i,t-2}) / TA_{i,t-2}$	The growth in book value of total assets held by a company ‘i’ from year ‘t-2’ to ‘t-1’
Leverage ratio	$LEV_{i,t}$ = Long-term Debts $_{i,t}$ / $TA_{i,t}$	For each financial stock ‘i’ the ratio of total long-term debts to the firm’s total assets computed at the end of December of the financial year ‘t-1’
Turnover Ratio	$TR_{i,t}$ = Total Volume Traded $_{i,t}$ / $SO_{i,t}$	Dividing the total volume traded by no. of shares outstanding of stock ‘i’

Further, equations (3) and (4) represent 4FM by adding momentum risk factor (WML) and 5FM after adding profitability and investment factors (RMW and CMA) into the 3FM, respectively. WML, RMW, and CMA are constructed similarly to HML, except that the second sort variable is now MOM_t, OP_t, and INV_t rather than the B/M ratio.

In detail, WML_t is formed by ranking the stocks according to their past performance, measured as monthly nominal stock returns for the last eleven months lagged by one month. In this way, the top 30% of stocks are grouped as Winners (W) with the highest average past market performance, and the bottom 30% of stocks are considered Losers (L) as they performed poorly in the past. Then, six-2×3 double sorted size-MOM_t value-weighted portfolios S/L, S/M, S/W, B/L, B/M, and B/W are established. Finally, WML_t is a difference between the simple average monthly returns of winners and loser portfolios.

To create RMW_t (Robust Minus Weak) risk factor, three OP groups (Weak, Neutral & Robust) are calculated at 30^{th} and 70^{th} percentile cut-off points. Then, six-2×3 double sorted size-OP value-weighted monthly return portfolios S/R, S/N, S/W, B/R, B/N, and B/W are established. Finally, RMW_t is a difference between the simple average-monthly returns of two robust (S/R, B/R) and simple average-monthly returns of two weak (S/W, B/W) portfolios.

To create a CMAt (Conservative Minus Aggressive) risk factor, three INV categories (Conservative, Neutral & Aggressive) are calculated using 30^{th} and 70^{th} percentile breakpoints. INV_t represents an investment which is a yearly increase in total assets value. Then, six-2×3 double sorted size-Inv value-weighted portfolios S/C, S/N, S/A, B/C, B/N, and B/A are determined. Hence, CMA_t corresponds to a difference between the simple average monthly returns of two conservative portfolios (S/C, B/C) and the simple average monthly returns of two weak (S/A, B/A) portfolios. The 10FM’s equation (5) requires the construction of four more pricing factors, liquidity ($L_{liq}MH_t$), leverage ($L_{lev}MH_t$), government bond index (GBI), and commodity index (CI). Both $L_{liq}MH_t$ and $L_{lev}MH_t$ risk factors are constructed by mimicking the HML. For $L_{liq}MH_t$, three liquidity sorted groups High (H_{liq}), Medium (M_{liq}), and

Low (L_{liq}) portfolios S/L_{liq}, S/M_{liq}, S/H_{liq}, B/L_{liq}, B/M_{liq}, and B/H_{liq} are created. The $L_{liq}MH_t$ is the difference between monthly value-weighted average returns of two low turnover ratio portfolios and between monthly value-weighted average returns of two high turnover ratio portfolios.

To form $L_{lev}MH_t$, three leverage groups High (H_{lev}), Medium (M_{lev}), and Low (L_{lev}), are sorted. Then, six 2×3 double sorted size-Lev value-weighted portfolios S/L_{lev}, S/M_{lev}, S/H_{lev}, B/L_{lev}, B/M_{lev}, and B/H_{lev} are created. The $L_{lev}MH_t$ is the difference between monthly value-weighted average returns of two low leverage portfolios and between monthly value-weighted average returns of two high leverage portfolios. Lastly, the two macroeconomic risk factors, i.e., long-term government bond risk and commodity risk, are created. For this purpose, the author used a monthly yield of 5-years Pakistan’s government bonds. Hence, the monthly time series for both risk factors are computed by independently subtracting the risk-free monthly rate of return from RGBI and RCI (as calculated in Table 2).

Our construction of variables has resulted in six versions of SMB, i.e., $SMB_{B/M}$, SMB_{OP}, $SMB_{INV,}$ $SMB_{MOM,}$ SMB_{Liq}, and $SMB_{Lev.}$ In addition, as suggested by FF (2015a), for any given factors model SMB factor has to be adjusted for other non-market explanatory factors in that model. Thus, for testing the factor models, equations (3), (4), and (5), the relevant SMB factor used are shown in equations (i), (ii), and (iii), respectively. Table 2 summarizes the details for all RHS factors computations.

Table 2 Construction of explanatory factors

Factors	Equation
Market Risk	$Mkt = R_m - R_f$
	$SMB = (SMB_{B/M} + SMB_{MOM})\ 1/2$ ……….. (i)
	$SMB = (SMB_{B/M} + SMB_{OP} + SMB_{INV})\ 1/3$ ……. (ii)
	$SMB = (SMB_{B/M} + SMB_{OP} + SMB_{INV} + SMB_{MOM} + SMB_{Liq} + SMB_{Lev})\ 1/6$ ……(iii)
Size	$SMB_{B/M} = (S/L + S/M + S/H)\ 1/3 – (B/L + B/M + B/H)\ 1/3$
	$SMB_{MOM} = (S/W + S/M + SL/)\ 1/3 – (B/W + B/M + B/L)\ 1/3$
	$SMB_{OP} = (S/R + S/N + S/W)\ 1/3 – (B/R + B/N + B/W)\ 1/3$
	$SMB_{INV} = (S/C + S/N + S/A)\ 1/3 – (B/C + B/N + B/A)\ 1/3$
	$SMB_{Liq} = (S/L_{liq} + S/M_{liq} + S/H_{liq})\ 1/3 – (B/L_{liq} + B/M_{liq} + B/H_{liq})\ 1/3$
	$SMB_{Lev} = (S/L_{lev} + S/M_{lev} + S/H_{lev})\ 1/3 – (B/L_{lev} + B/M_{lev} + B/H_{lev})\ 1/3$
Value	$HML= (S/H + B/H)\ 1/2 - (S/L + B/L)$ ½
Momentum	$WML = (S/W + B/W)\ 1/2 - (S/L + BL)1/2$
Profitability	$RMW = (S/R + B/R)\ /1/2 - (SW + BW)\ /1/2$
Investment	$CMA = (S/C + B/C)\ /1/2 - (SA + BA)\ /1/2$
Liquidity	$L_{liq}MH = (S/L_{liq} + B/L_{liq})\ 1/2 - (S/H_{liq} + B/H_{liq})$ ½
Leverage	$L_{lev}MH = (S/L_{lev} + B/L_{lev})\ 1/2 - (S/H_{lev} + B/H_{lev}$ ½
Government Bonds Risk	$GBI = R_{GBI} - R_f$
Commodity Risk	$CI = R_{CI} - R_f$

2.4. LHS test portfolios construction

Following the literature, to analyze the performance of all AP models from equation (1) to (5), we form test portfolios left-hand-side (LHS) dependent portfolios. By the direction of FF (1993, 2015a), these LHS regression portfolios are created similarly to the explanatory factors in the previous section. At the end of each year, 't' (end of June) stocks are ranked independently into five size groups using market capitalization percentiles, calculated on 31st December of year 't-1. Likewise, four breakpoints of 20th, 40th, 60th, and 80th percentile are used to divide the sample into five equal groups for B/M, MOM, OP, INV, LEV, and LIQ, independently.

	Low	**2**	**3**	**4**	**High**
Small	S_L (S_a, S_b, S_c, S_d, S_e, S_f, S_g, S_x, S_y, S_z)	S_2	S_3	S_4	S_H
2	2_L	2_2	2_3	2_4	2_H
3	3_L	3_2	3_3	3_4	3_H
4	4_L	4_2	4_3	4_4	4_H
Big	B_L	B_2	B_3	B_4	B_H

Figure A1. 5×5 matrix of 25 size-B/M double sorted test portfolios

At the intersection of bivariate sorting of five-size and five-second sorted variable categories, the 5×5 matrix, 25 double sorted value-weighted test portfolios are created for each combination of size-B/M, size-OP, size-INV, size-LEV, and size-LIQ. Hence, the returns on LHS test portfolios are computed as the monthly excess returns, and the process of portfolio construction (both LHS and RHS) is repeated each year at the end of June ‘t’ so that they are ready to analyze from July ‘t’ to June ‘t+1’ in the following year.

3. Results and Discussion

3.1. Summary statistics

Overall, from the results reported in descriptive statistics, strong evidence in favor of size premium is confirmed for all three regions. In both regions of EMEA and Asia, the size premium is positively significant, ranging from 0.54%-0.83% per month and 0.34%-0.85% per month, respectively, for pre, during, and post-crisis periods meaning small firms outperform big firms, which is in line with Lin (2017). While in the Americas, the average SMB premium is negative, ranging from -0.63% to -0.79% per month, but significant which means small stocks underperformed big stocks. A negative (insignificant) size premium was also reported by Foye (2018) for region Latin Americas and by Cakici and Tan (2014) for a few European and Asia Pacific countries. Similarly, a significant non-zero value premium is present in all regions like FF (2012). The HML means are positive and significant in almost all sub-periods for each region. Echoing the results of Cakici et al. (2013) and Foye (2018) in a recent research study, a distinctively high HML premium is observed for Asia in the post-crisis period (0.83% per month, t > 3.00). The results affirms significant and large profitability premiums ranging from 0.76%-1.25% per month for EMEA and 0.83%-1.41% per month for Americas. Among all other risk factors, summary statistics of leverage risk factor (L_{lev}MH) are found comparatively poorer in each region Asia, EMEA, and Americas. The results comparable to the present study are Boubaker, Hamza, and Vidal-Garcia (2018) and Elshqirat and Sharifzadeh (2018).

Additionally, the correlation between RHS factors for each region, Asia, EMEA, and America's degree of association between AP factors is determined. Panel A, B, and C of Table A2 of the correlation matrices present the correlation among factors for regions Asia, EMEA, and America individually. Summing up the findings of correlation analysis for each region, it is reasonable to state that in region Asia, microcaps tend to have high-value premium, higher market beta, low profitability, low investments, low liquidity, and lower prior returns. While, high B/M (value) stocks probably have lower profitability, low investment, high liquidity, highly leveraged, small-capitalization, and high market beta in Asia. These correlations make sense because lower profitability firms would have fewer funds to invest and hence make fewer investments and vice versa (Ali et al., 2020; Foye, 2018; Lin, 2017).

However, correlation results for region EMEA lead to conclude that microcaps outperformed mega-caps and proved more profitable. A significant positive relationship between SMB and Rm-Rf confirms extensive empirical literature of high systematic risk for small firms. In the region of EMEA, high B/M value firms have high profitability. There is almost zero (no correlation) profitability and investment factors signaling the irrelevance of investment strategy in bringing up more profits in EM of EMEA. Moreover, in this region, mega-caps are liquid and less profitable stocks, whereas microcaps yield a high illiquidity premium accompanied by higher profitability. Therefore, high leverage firms are likely to have high systematic risk and high profitability.

On the other hand, a negative correlation between SMB with MKT and RMW and a positive correlation between SMB and HML in the region Americas confirms that big firms face higher market risk and are more profitable than small firms. It asserts that strong, profitable firms tend to have high prior returns and follow conservative investment strategies. In region Americas, L_{liq}MH has a significant positive correlation with SMB, HML, RMW, and CMA, confirming small firms yield a high illiquidity premium accompanied by a high-value premium and higher profitability yet follow a conservative investment approach. A distinct and independent role of each RHS risk factor is confirmed, as none of the correlations is observed to be problematic.

On the other hand, a negative correlation between SMB with MKT and RMW and a positive correlation between SMB and HML in the region Americas confirms that big firms face higher market risk and are more profitable than small firms. It asserts that strong, profitable firms tend to have high prior returns and follow conservative investment strategies. In region Americas, L_{liq}MH has a significant positive correlation with SMB, HML, RMW, and CMA, confirming small firms yield a high illiquidity premium accompanied by a high-value premium and higher profitability yet follow a conservative investment approach. A distinct and independent role of each RHS risk factor is confirmed, as none of the correlations is observed to be problematic.

3.2. GRS test statistics

To test the plausibility of competing multifactor AP models on regional EM of Asia, EMEA, and Americas across three subperiods around the GFC 2008: pre-crisis, crisis and post-crisis, the mean-variance efficiency test known as the GRS F-test is employed. Gibbons, Ross, and Shanken (1989) developed the GRS-test to determine the efficacy of empirical AP models and measure if all the alphas derived from individual regression models are insignificantly different from zero. The GRS F-test tests the following null hypothesis for each AP model under investigation:

H_0: All the alpha coefficients of an AP model for a range of portfolios are jointly equal to zero (or insignificantly different from zero)

H_1: All the alpha coefficients of an AP model for a range of portfolios are jointly distinguishable from zero (or significantly different from zero)

Hence, to accept the null hypothesis of the GRS F-test, the p-value must be higher than the confidence interval (p-value > 5%).

The GRS F-statistic is calculated by using the following equation:

$$fGRS = \left(\frac{T}{N}\right)\left(\frac{T-N-L}{T-L-1}\right)\left[\frac{\hat{\alpha}\hat{\Sigma}-1\hat{\alpha}}{1+\bar{\mu}\hat{\Omega}-1\bar{\mu}}\right] \sim \mathrm{F}(\mathrm{N}, \mathrm{T}-\mathrm{N}-\mathrm{L})$$

Where:
T= Number of observations
N= Number of test portfolios
L= Number of explanatory factors in RHS of the AP equation
$\hat{\alpha} = N \times 1$ vector of estimated intercepts
$\hat{\Sigma}$ = an unbiased estimate of the residual covariance matrix
$\bar{\mu} = L \times 1$ vector of the factor portfolios' sample means
$\hat{\Omega}$ = an unbiased estimate of the factor portfolios' covariance matrix

Table A3 summarises the results of the GRS test that includes the GRS F-statistic and associated p-value for all the AP models under investigation over the region Asia, EMEA, and
Americas with Panel A, B, and C represent pre-crisis, during, and post-crisis sub-periods. Results for the other four versions of LHS 25 (5×5) double-sorted test portfolios are also computed for each combination of 25 size-OP, size-INV, size-LEV, and size-LIQ. They lead toward similar findings and conclusions established for 25 size-B/M test portfolios. To keep the brevity, outcomes for other sets of test portfolios are not interpreted here in this section and can be available on demand.

['Insert Table A3 here']

3.3. Comparison of RHS factor slopes and asset pricing models performance

The results of the panel regression analysis on 25 value-weighted size-B/M sort portfolios for each considered AP model subject to the performance analysis. To compare the power of all models, check the relevance of pricing factors, and establish the lead of an AP model above others. In addition, the authors assess and discuss the significance of intercept coefficients of models, sensitivity (factors slopes) of the LHS portfolios with the RHS factors, the explanatory power of the AP model, and GRS statistics.

For comparison among AP models, the benchmarks are laid down. First, an AP model with the smallest GRS statistic and highest p-value can be regarded as an ideal AP model because a high p-value represents the level of confidence for rejecting the alternate hypothesis and supports that the intercepts are jointly equal to zero. Second, the AP model with a reduced number of significant alphas and increased value of adjusted-R^2 is considered appropriate. Because such a model has an explanatory power to explain average excess stock returns to the greatest degree (Hanauer & Linhart, 2015; Rugwiro & Choi, 2019).

Discussing the pricing and relevance of risk factors begins with the analysis of factor slopes. The market risk factor (R_m-R_f) and size factor (SMB) seem to play the same role throughout the three sub-periods, captured by all tested AP models in the region of Asia. Regardless of the different AP models, the MKT slopes lie between 0 to 1 and display a size pattern of b slopes meaning relatively higher beta for microcaps and lower beta for mega-caps which is in line with the correlation results reported in Table A2. However, the slopes are steeper (b > 1) during the crisis sub-period. A significant size pattern is present in region Asia for all subperiods, meaning that SMB slopes are high (positive) for small-cap portfolios and low (negative) for large-cap portfolios.

In contrast, in region EMEA, that the CAPM produces significantly non-zero intercepts and negative and insignificant b slopes during all sub-periods. Thus, reflecting the failure of CAPM in EMEA. Nevertheless, the sensitivity to market risk becomes positive and significant in outcomes of 3FM after the addition of SMB and HML. The results of current study reveals that 3FM performs poorly in region EMEA during the crisis as there is a cluster of significant intercepts at extreme microcap-low growth and high-value portfolios. Table A3 of GRS test results confirms the low-ranking performance of 3FM among other AP models for EMEA during-crisis sub-period

Although by focusing the Americas region, MKT and SMB risk factors are significant and relevant throughout the sub-periods. And there exists a negative size effect (reverse size effect), meaning that SMB slopes are low (or slightly negative) for small-cap portfolios and high (positive) for big-cap portfolios. It is in line with the correlation results reported in Table A2. The b slopes are positive and significant across all the models in the Americas, showing the presence of size pattern and relatively sharper beta slopes during-crisis regime depicting high systematic risk.

Turning to the relevance of the HML pricing factor in all regions gauged through different AP models. The AP models' results for the pre-crisis sub-period for regions Asia, EMEA, and Americas, respectively. This study advocates no evidence of value effect for region Asia. Although in region EMEA, there is a significant HML premium with negative h slopes for low B/M portfolios (growth stocks) and positive h slopes for high B/M (value stocks). It is strongly captured by 5FM, and the superior significance of the value effect is confirmed in region Americas. The AP test outcomes for during-crisis subperiod regions Asia, EMEA, and Americas, respectively. In Asia, a value pattern is detected in HML slopes on size-B/M portfolios but is insignificant.

Similarly, the recognizable value effect is confirmed in region Americas during the crisis showing high B/M stocks outperformed low B/M stocks. The AP test results of the post-crisis sub-period. Interestingly, the value effect becomes insignificant in EMEA and displays decreased HML sensitivity (*h slopes*) from pre-crisis to post-crisis regimes in the Americas. At the same time, there appears to be a significant value effect in region Asia. Overall, we may conclude that value premium is priced in all three regions of EM, especially in the Americas, where the value effect is most substantial.

For the WML risk factor, after observing the similarity is found in regions of Asia and EMEA. WML is found redundant and a mispriced risk factor in both regions. For region Americas, the AP models' results for pre, during, and post-crisis sub-periods, respectively. The intercepts are improved from 3FM to 4FM in pre-crisis Americas after the addition of WML. In contrast to Asia and EMEA regions, a strong and significant WML premium exists here. It is consistent with the findings of FF (2010 & 2012), who applied 4FM to developed markets and found a better description of stock returns by 4FM instead of 3FM. Curiously, in the post-crisis subperiod, the outcomes of 4FM and 10FM contradict each other. Results of Table A3 of GRS statistics confirm the reliability of 10FM over 4FM as the former has passed the GRS test while later could not.

The results affirms that it is clear that there is no relevance of both RMW and CMA in region Asia throughout the three sub-periods as both factors are persistently insignificant and non-monotonic to explain excess portfolio returns in Asia. The region of EMEA show CMA factor constantly remains irrelevant and insignificant in all sampled sub-periods for this region. However, results affirms that in pre-crisis EMEA outcomes, RMW factor slopes are significantly negative in low B/M quintiles, and positive r slopes occur in high B/M quintiles, confirming that value firms are robust and growth firms are weak. In line with Table A2, panel B outcomes of correlation results for region EMEA establish a positive correlation between RMW and HML. Furthermore, observing the AP test outcomes of region Americas for pre and during-crisis sub-periods, respectively, display the identical pattern of RMW and CMA slopes.

Despite the adequate relevance of the liquidity risk factor in all three EM regions, it shows slightly different patterns in capturing the portfolio returns. Thus, it can be considered an essential risk factor among all RHS risk factors. For the pre-crisis subperiod, in all regions, the liquidity risk factor (L_{liq}MH) is significantly showing positive l_{liq} slopes for microcaps and negative slopes for mega-caps. It confirms the correlation results reported in Table A2, where L_{liq}MH and SMB are positively correlated. In the sub-period of the GFC, the significant L_{liq}MH effect disappeared in region Asia, although it remained equally significant and relevant in region EMEA and Americas. It indicates that the liquidity risk factor failed to sustain economic shock in Asia. In the post-crisis period, L_{liq}MH regains importance in Asia and is equally relevant in EMEA. The post-crisis AP test estimates for region Americas exhibits higher negative l_{liq} slopes at low B/M portfolios and smaller positive l_{liq} slopes at high B/M portfolios. These outcomes are consistent with Table A2 correlation results showing a positive correlation between L_{liq}MH and HML.

As for the leverage risk factor, in the pre-crisis period, significant l_{lev} slopes indicate the relevance of the L_{lev}MH factor in all three regions, but leverage slopes failed to catch any size or value pattern. The AP estimate for the pre-crisis subperiod in region Asia, EMEA, and Americas, respectively. During the crisis, the L_{lev}MH factor becomes insignificant/irrelevant for region Asia. At the same time, increased l_{lev} sensitivity and higher negative slopes show higher leverage in EMEA with relatively low significance. Instead, for the region Americas, the L_{lev}MH factor dropped its significance during the crisis and showed weakened relevance in the post-crisis regime.

Persistently, the slopes of both GBI and CI risk factors are found positively significant throughout all the three regimes for all three regions of EM. Interestingly, it is observed in results are indifferent of the region, the *g* and *c* slopes are relatively higher during the sub-period of GFC. The increased sensitivity (slopes) may indicate that in the economic crisis, there is a high probability of political risk in emerging economies influxes by economic instability and high inflation factor causes rise in commodity prices too.

After analyzing the sensitivity of LHS portfolios to the RHS risk factors, it is essential to get an additional insight into the performance of various AP models. The intercepts and adjusted-R^2 help choose the more appropriate AP model that better describes average returns of LHS portfolios in a particular EM region (Asia, EMEA, and Americas) across the different sub-periods around the GFC.

The results proposed 10FM showed the highest value of adjusted-R^2 irrespective of the region (Asia, EMEA, Americas) and sub-period (pre, during, and post-crisis) studied. Furthermore, FF (2015a), Skocir and Loncarski (2018), and Novy-Marx (2013) highlighted the fact which suggests an increase in the number of RHS risk factors in an AP model is reflected through the rise in the value of R-square. Thus, it may conclude that 10FM's produced high values of adjusted-R^2 are contributed by adding more explanatory risk factors into the AP model equations.

Focusing on the region of Asia, the results from Table A3 show that 4FM gives the worst performance throughout the three sub-periods, as evidenced by high GRS statistic values and an increased number of significant non-zero intercepts. On the contrary, Zaremba, Maydybura, Czapkiewicz, and Arnaut (2019b) found that 4FM outperforms FF (2015a) 5FM in frontier markets. As well as 5FM couldn't offer an improvement and was rejected too. These outcomes are complemented by the irrelevance of both RMW and CMA risk factors in Asia. On the other hand, 3FM performed very well and constantly proved to be the perfect AP model in describing the average portfolio returns for region Asia by passing the GRS F-test with the lowest *f*-GRS value, and highest p-value in all three sub-periods signifying the 3FM intercepts are jointly equal to zero. The average returns and Tables A4 of AP regression test outcomes also confirm the region's strong and significant relevance to MKT, size, and value risk factors. Surprisingly, CAPM is valid and performs equally well as 3FM only for region Asia. However, 3FM wins in terms of high explanatory power (adjusted-R^2), reduced intercepts, and GRS F-test. The results contradict FF (2015a) and Khudoykulov's (2020) findings that 5FM outperforms CAPM and 3FM, and Lin (2017) declared the superior performance of 5FM over China.

Conversely, the results are in line with the findings of Foye (2018), who found 3FM outperformed 5FM in EM of region Asia. And Foye & Valentinčič (2020) reported only a trivial improvement in the explanation of average returns by 5FM in emerging Asia. Chui and Wei (2010) confirmed the reliability of 3FM when they investigated five EM in the Asia-Pacific region. Similar results were reported by Xie and Qu (2016) for China's stock market, where both CAPM and 3FM were found valid, but 3FM stood better. In the post-crisis sub-period, the proposed 10FM passed GRS F-test implies the model's efficacy in describing the region's portfolio returns. However, it couldn't outperform 3FM and CAPM (Table A3).

It is identified that in regions EMEA and Americas, both CAPM and 3FM constantly failed to produce a reduced number of significant intercepts throughout the three sub-periods, as evidenced by high GRS statistic values and low p-value (Table A3). Lalwani and Chakraborty (2020) and Shi and li (2020) also confirmed the superiority of 5FM above 3FM and 4FM in developed markets. Among all panels of Table A3, panel B of region EMEA caught attention as, strikingly, three AP models, including 4FM, 5FM, and 10FM, are found robust in the GFC sub-period and produced slight differences in p-values and absolute values of the GRS test.

Moreover, the measure of unexplained variances of portfolio returns (1-R^2) has decreased from 5FM (8%-28%) to 10FM (5%-17%). Still, 5FM outperformed 10FM and 4FM in terms of reduced intercepts and the highest p-value.

Turning to the post-crisis sample of region EMEA, none of the models produced intercepts that are jointly close to zero. However, 10FM outperformed 5FM regarding reduced intercepts and high explanatory power. Table A3 shows that 5FM was successful in region EMEA from pre-crisis to during-crisis regimes as it outperformed CAPM, 3FM, 4FM, and 10FM. Similarly, Foye (2018) also reported strong pertinence of 5FM for the EM region of Eastern Europe. FF (2015) reported that HML becomes a redundant risk factor after adding RMW and CMA risk factors. On the contrary, there is evidence of pronounced value premium in all three regions of EM. Moreover, in the post-crisis regime, the proposed 10FM wins in terms of high explanatory power (adjusted-R^2), reduced intercepts, and GRS F-test, which is in line with the results of Jareno, Gonzalez, and Escolastico (2020).

In the region Americas, 10FM is the best and the only robust AP model because of its ability to pass the GRS F-test even in the period of GFC (panel B of Table A3). Furthermore, multifactor 10FM outperformed all other AP models under evaluation in the post-crisis period, producing low (close to zero) intercepts and the lowest *f*-GRS. Likewise, Roy's (2021) findings also supported the six-factor model above 4FM and 5FM, and Skocir and Loncarski (2018) tested the eight-factor AP model and stated that the multifactor model performed better than FF (1993) and (2015a)'s three and five-factor models.

4. Conclusions

In this research study, we responded to the research question: Is the new comprehensive 10FM superior to other parsimonious AP models in explaining the cross-section of stock returns in each region of EM around the sub-periods of GFC? And what AP factors are relevant in EM regions? Summing up, the findings of this study lead us to conclude that market, size, value, liquidity, and macroeconomic risk factors are relevant and priced risk factors in region Asia. In comparison, the main drivers of excess portfolio returns are size, value, and profitability risk factors in region EMEA. Guo et al. (2017) reported similar findings. MKT, LliqMH, GBI, and CI are also found to be priced and relevant risk factors. And lastly, for the region of the Americas, value, investment, and liquidity factors are the most important driver of excess portfolio returns. MKT, SMB, RMW, GBI, and CI are also priced risk factors in the Americas.

In short, we conclude that 3FM is a successful and most appropriate multifactor AP model describing the average portfolio returns for region Asia. While consistent with the findings of Lalwani and Chakraborty (2020) and Shi and li (2020), 5FM is better than other AP models for region EMEA, and 10FM can be regarded as the second-best model for this region. Consistent with Roy's (2021) findings favoring multifactor model above 4FM, we found 10FM to be the most suitable and reliable model in region Americas since it outperformed all other AP models.

Although the current study is broad in spectrum and provides deep insight into the EM economies, it has a limitation in that it does not discuss the debate regarding the choice of the best possible proxy for profitability, investment, liquidity, and leverage of firms. Means which accounting variable should be used as a proxy. Furthermore, this does not consider the newly discovered anomalies attached to the profitability and investment factors (Ball et al., 2015).

Future researchers should consider the issue of varying accounting standards and their effect on the computation of accounting-based pricing factors (for instance, profitability and investment) while testing international markets. Also, instead of regional comparison, researchers can do a country-wise analysis by considering the country-specific financial reporting environment. Additionally, the most obvious area for further research is to analyze the effects of Covid-19 on the financial markets of both developed and emerging economies and check the performance of AP models under the pandemic.

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<u>Annexure</u>

Table A2: *Correlation coefficients among pricing factors in each region*

Panel A: Asia

	R_m-R_f	SMB	HML	RMW	CMA	WML	LIQ	LEV	GBI	CI
R_m-R_f	1.00									
SMB	**0.461**	1.00								
HML	**0.067**	**0.291**	1.00							
RMW	**-0.177**	-0.187	**-0.426**	1.00						
CMA	0.097	0.045	0.182	-0.11	1.00					
WML	**-0.031**	-0.071	-0.020	0.199	-0.394	1.00				
L_{liq}MH	**-0.086**	**0.194**	**-0.113**	**0.637**	0.249	-0.082	1.00			
L_{lev}MH	**-0.198**	-0.228	**-0.483**	**-0.052**	-0.063	-0.206	**-0.542**	1.00		
GBI	**0.210**	0.104	**0.194**	**0.142**	0.096	0.214	0.134	-0.075	1.00	
CI	**0.136**	0.209	**0.140**	**0.226**	0.103	0.180	0.183	0.048	0.112	1.00

Panel B: EMEA

	R_m-R_f	SMB	HML	RMW	CMA	WML	LIQ	LEV	GBI	CI
R_m-R_f	1.00									
SMB	**0.108**	1.00								
HML	0.203	**-0.082**	1.00							
RMW	**-0.417**	**0.536**	**0.242**	1.00						
CMA	**-0.302**	-0.156	0.064	-0.020	1.00					
WML	**-0.024**	-0.107	-0.093	**0.172**	-0.286	1.00				
L_{liq}MH	**-0.259**	**0.484**	**-0.238**	**0.286**	0.168	0.078	1.00			
L_{lev}MH	**-0.193**	-0.132	-0.051	**-0.131**	0.015	0.135	-0.238	1.00		
GBI	**0.206**	0.078	**0.203**	**0.083**	0.174	0.164	0.052	-0.078	1.00	
CI	**0.028**	0.261	**0.065**	**0.317**	0.081	0.220	0.033	0.194	0.044	1.00

Panel C: Americas

	R_m-R_f	SMB	HML	RMW	CMA	WML	LIQ	LEV	GBI	CI
R_m-R_f	1.00									
SMB	**-0.143**	1.00								
HML	-0.291	**0.385**	1.00							
RMW	**-0.540**	**-0.164**	**0.233**	1.00						
CMA	**0.032**	-0.012	0.164	**0.172**	1.00					
WML	**-0.057**	0.046	0.192	**0.316**	-0.652	1.00				
L_{liq}MH	**-0.604**	**0.221**	**0.205**	**0.498**	**0.250**	0.021	1.00			
L_{lev}MH	**-0.249**	-0.082	-0.117	**-0.072**	0.197	0.093	-0.347	1.00		
GBI	**0.498**	0.191	**0.282**	**0.142**	0.263	0.079	0.105	-0.033	1.00	
CI	**0.537**	0.248	**0.045**	**0.274**	0.192	0.232	0.054	0.109	**0.026**	1.00

Table A3: *Results of GRS Tests*

	Asia		Europe Middle East & Africa		Americas	
	GRS-F Test	p-value	GRS-F Test	p-value	GRS-F Test	p-value
Panel A: Pre-Crisis Period						
CAPM	3.31	0.00	4.80	0.00	3.84	0.00
3FM	2.26	0.14	3.76	0.00	3.36	0.00
4FM	3.72	0.00	3.24	0.00	2.67	0.10
5FM	3.40	0.00	2.39	0.04	2.50	0.12
10FM	3.55	0.00	2.98	0.00	3.09	0.00
	Asia		Europe Middle East & Africa		Americas	
	GRS-F Test	p-value	GRS-F Test	p-value	GRS-F Test	p-value
Panel B: During-Crisis Period						
CAPM	2.18	0.17	4.13	0.00	3.12	0.00
3FM	2.06	0.26	3.59	0.03	3.04	0.00
4FM	2.60	0.00	2.82	0.12	2.43	0.00
5FM	2.35	0.00	2.51	0.17	1.85	0.00
10FM	2.29	0.00	2.77	0.14	1.79	0.20
	Asia		Europe Middle East & Africa		Americas	

	GRS-F Test	p-value	GRS-F Test	p-value	GRS-F Test	p-value
Panel C: Post-Crisis Period						
CAPM	4.40	0.09	10.01	0.00	8.06	0.00
3FM	4.28	0.12	9.52	0.00	7.75	0.00
4FM	4.73	0.00	9.89	0.00	7.99	0.00
5FM	4.88	0.00	9.47	0.01	7.60	0.07
10FM	4.66	0.07	9.34	0.03	7.47	0.19