Volume 21, Number 2 – June 2019
China Accounting and Finance Review
中国会计与财务研究
2019 年 6 月　第 21 卷　第 2 期

The Profitability and Investment Factors in the Chinese Stock Market *

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Received 12th of April 2018　Accepted 24th of August 2018

Abstract

We construct the five factors in Fama and French (FF, 2015) and the four factors in Hou, Xue, and Zhang (HXZ, 2015) for the Chinese stock market. Our objective is to identify a parsimonious factor model that builds on these factors and provides an adequate explanation for time-series and cross-sectional variations in Chinese stock returns. Our main findings are as follows: (1) neither the FF investment factor nor the HXZ investment factor earns a significant return in the Chinese stock market; (2) except for the value factor, the other FF factors can be explained by the four HXZ factors; (3) three of the four HXZ factors, namely size, profitability, and investment, cannot be explained by the five FF factors; (4) the best performance model is comprised of the market factor, the FF value factor, a modified HXZ size factor, and a modified HXZ profitability factor; (5) the maximum Sharpe ratio is achieved by investing about 5% in the market factor, 20% in the value factor, and roughly the same percentage in the size and profitability factors. The findings are consistent in the three time periods we analyse.

Keywords: Chinese Stock Market, Investment Factor, Profitability Factor, Sharpe Ratio, Value Premium

JEL classification: G11, G12, G15

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* We wish to thank the anonymous reviewer, Erica X.N. Li, Ji-Chai Lin, Bu Xu, Jin Xu, Xinpeng Xu, and participants at the 2017 Frontiers of Business Research in China International Symposium and the 2017 China Financial Research Conference for their helpful comments. Shaojun Zhang gratefully acknowledges the financial support received for this research project (Project Number: 2014.A6.045.15A) from the Public Policy Research Funding Scheme managed by the Policy Innovation and Co-ordination Office (the former Central Policy Unit) of the Hong Kong Special Administrative Region Government. All remaining errors are our own. The Chinese stock return factors are available at http://www.mypolyuweb.hk/afszhang/factors_in_Chinese_stock_market.xlsx.

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中国股票市场的盈利因子和投资因子

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摘要

本文基于中国股票市场历史数据构建了 Fama and French（FF，2015）提出的五个价格因子和 Hou, Xue and Zhang（HXZ，2015）提出的四个价格因子，并且利用这些因子来构建一个对中国股票价格在不同时间和不同公司之间的差异有解释力的精简因子模型。我们有如下的发现。首先，不论是 FF 提出的还是 HXZ 提出的投资规模因子在中国股票市场都不能获得显著盈利。其次，除了价值因子，FF 五因子模型中的其它因子都能被 HXZ 四因子模型在统计假设检验的意义下加以解释。再次，HXZ 四因子模型中公司市值因子、盈利因子和投资因子都不能被 FF 五因子模型在统计假设检验的意义下加以解释。最后，本文发现对中国股价变化解释力最好的因子模型由整体市场因子、FF 价值因子、修正后的 HXZ 市值规模因子，以及修正后的 HXZ 盈利因子构成。该模型的最大夏普比率可以通过投资大约 5%的资金在整体市场组合，20%的资金在价值效应组合，和差不多等份额的资金在市值规模组合和盈利水平组合来达到。以上这些结果在我们分析的三个样本时间段内基本一致。

I. Introduction

In a seminal paper, Fama and French (1993) develop an empirical asset pricing model that consists of the market factor, a size-related factor, and a value-related factor. The three-factor model has been widely used in finance research and practice (see Campbell, 2000; Harvey *et al.*, 2016; and the references therein).[2] Recent studies find that the three-factor model cannot explain the negative relation between investment and stock return, nor can it explain the positive relation between firm profitability and stock return in the US market (e.g. Titman *et al.*, 2004, 2013; Fama and French, 2006; Liu *et al.*, 2009; Novy-Marx, 2013). Fama and French (FF, 2015) propose a new factor model by adding an investment factor and a profitability factor to their three-factor model. The FF five-factor model is specified by the following equation:

$$R_{it} - r_{ft} = \alpha_i + \beta_i (R_{mt} - r_{ft}) + \gamma_i SMB_t + \eta_i HML_t + \lambda_i RMW_t + \mu_i CMA_t + e_{it} , \qquad (1)$$

where $R_{mt} - r_{ft}$ is the market factor, *SMB* is the size factor, *HML* is the value factor, *RMW* is the profitability factor, and *CMA* is the investment factor.

Fama and French (2006) explain the profitability and investment effects in the valuation theory framework. The value of a firm's stock is the present value of expected dividends:

$$M_t = \sum_{\tau=1}^{\infty} \mathrm{E}(D_{t+\tau}) / (1+r)^{\tau} , \qquad (2)$$

where M_t is the price at time t, $\mathrm{E}(D_{t+\tau})$ is the expected dividend at time $t+\tau$, and r is (approximately) the long-term average expected stock return. Using the accounting identity that the time t dividend, D_t, is earnings per share, Y_t, minus the change in book equity per share, $dB_t=B_t-B_{t-1}$, and dividing both sides of Equation (2) by time t book equity, we obtain the following equation:

$$\frac{M_t}{B_t} = \frac{\sum_{\tau=1}^{\infty} \mathrm{E}(Y_{t+\tau} - dB_{t+\tau}) / (1+r)^{\tau}}{B_t} . \qquad (3)$$

Equation (3) implies three predictions about expected stock return. First, *ceteris paribus*, expected return is positively related to the book-to-market ratio. Second, *ceteris paribus*, expected return is positively related to expected earnings (profitability). Third, *ceteris paribus*, expected return is negatively related to expected growth in book equity (investment).

In a recent paper, Hou, Xue, and Zhang (HXZ, 2015) propose the following four-factor

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2 As stated in the Scientific Background on the Nobel Prize Winners in Economics (2013), empirical asset pricing research has practical implications: "Today, passively managed funds, such as index funds and Exchange Traded Funds (ETFs), exist for a large variety of indexes and asset classes, including size and book-to-market. In 2012, these funds had over $3.6 trillion (U.S.) under management and accounted for 41% of the worldwide flows into mutual funds."

model:

$$R_{it} - r_{ft} = \alpha_i + \beta_i (R_{mt} - r_{ft}) + \phi_i ME_t + \pi_i ROE_t + \omega_i INV_t + \varepsilon_{it} , \quad (4)$$

where $R_{mt} - r_{ft}$ is the market factor, *ME* is the size factor, *ROE* is the profitability factor, and *INV* is the investment factor. The inspiration for Hou, Xue, and Zhang's (2015) empirical model comes from the neoclassical q-theory of corporate investment. They argue that the q-theory predicts a negative relation between investment and expected return and a positive relation between profitability and expected return (e.g. Liu *et al.*, 2009; Li and Zhang, 2010).

In this study, we construct the five factors in Fama and French (2015) and the four factors in Hou, Xue, and Zhang (2015) for the Chinese stock market. China is the second largest stock market in the world in terms of total market value (Carpenter *et al.*, 2015). The Chinese stock market has attracted a lot of attention from investors worldwide, especially after the inclusion of China's large-cap A-shares in the MSCI Emerging Markets Index on 31 May 2018. Foreign investors based in Hong Kong can now trade shares listed on the Shanghai Stock Exchange (SSE) and the Shenzhen Stock Exchange (SZE) through the cross-exchange connect programmes.[3] There is a growing body of studies on China's stock markets (see Carpenter and Whitelaw (2017) for a review of this literature). However, there is a lack of comprehensive analyses on the explanatory power of the empirical factors that are identified in the US market for Chinese stock returns. Our objective is to identify a parsimonious factor model that builds on these factors and provide an adequate explanation for time-series and cross-sectional variations in Chinese stock returns.

Five main findings emerge from our study. First, neither the FF investment factor nor the HXZ investment factor earns a significant return in the Chinese stock market. The market factor has a large mean monthly return (about 0.82%); however, this return is not significantly different from zero. The value factor *HML* has a positive but insignificant mean return. The FF profitability factor does not earn a significant return on average, but the mean return on the HXZ profitability factor is significantly positive. Both the FF size factor and the HXZ size factor have significantly positive mean returns, while the average return on the HXZ size factor is much larger than that on the FF size factor.

Second, Fama and French (2015) find that the average return on the value factor *HML* can be explained by the exposure of *HML* to the rest of factors. They conclude that "HML is redundant for describing average returns, at least in the U.S. data for 1963-2013" (page 12) and suggest that it would be "interesting to examine whether this result shows up in the U.S. data for the pre-1963 period or in international data" (page 12). We run spanning regressions to examine to what extent one factor can be explained by other factors in China. The factor-spanning tests also give us some guidance on whether certain factors are potentially redundant

[3] The Shanghai-Hong Kong Stock Connect programme started in November 2014, and the Shenzhen-Hong Kong Stock Connect programme started in December 2016.

in factor models. We find that, in contrast to the US finding, the value factor *HML* cannot be explained by the four HXZ factors. The other FF factors, $R_m - r_f$, *SMB*, *RMW*, and *CMA*, can be explained by the HXZ four-factor model. On the other hand, the HXZ factors, *ME*, *ROE*, and *INV*, cannot be explained by the FF five-factor model.

Third, we follow the methodology in Fama and French (2015) to construct three sets of test assets, each of which consists of 25 portfolios. The first set is constructed by sorting the assets by size and book-to-market (B/M) ratio, the second set by size and profitability, and the third set by size and investment. We run time-series regressions of each portfolio's monthly excess returns on the pricing factors and use four conventional metrics to evaluate model performance. First, the **GRS** statistic proposed by Gibbons, Ross, and Shanken (1989) tests the null hypothesis that the intercepts (i.e. alphas) for the 25 left-hand-side (LHS) portfolios in the same set are all equal to zero. Second, the average of the absolute value of alphas across the 25 LHS portfolios, $\mathbf{Avg|a_i|}$, shows the magnitude of the unexplained return. Third, the ratio of the dispersion of alphas to the dispersion of mean returns, $\mathbf{D_a/D_r}$, measures the unexplained proportion of return dispersion across the 25 LHS portfolios. Fourth, the average of the regression R^2 across the 25 LHS portfolios, $\mathbf{Avg(R^2)}$, measures the proportion of time-series variation that is explained by a model. We find that the conventional metrics provide some guidance in selecting useful factors, but they do not help us pick a convincing winner from the competing models.

Fourth, we use the maximum Sharpe ratio as a performance metric to evaluate models. For any given factor model, the maximum Sharpe ratio is the Sharpe ratio of the tangency portfolio of the investment opportunity set that is spanned by the factors. The analyses in Barillas and Shanken (2017) and Fama and French (2018) suggest that the model with the highest maximum Sharpe ratio provides the best explanation, among the competing models, of the expected returns on stocks from which the factors are constructed. We find that according to this metric, the best model is comprised of the market factor, the FF value factor, a modified HXZ size factor, and a modified HXZ profitability factor. The maximum Sharpe ratio is achieved by investing about 5% in the market factor, 20% in the value factor, and roughly the same percentage in the size and profitability factors.

Finally, since the establishment of the Chinese stock markets in 1991, there have been several changes that have had a significant market-wide impact. Three of these changes are particularly relevant for our analysis: (1) a set of modern accounting regulations became effective in January 1998; (2) Chinese listed firms began to issue financial reports on a quarterly basis in 2002; (3) most of the Chinese listed firms completed their share structure reform by the end of 2006. Hence, we analyse return patterns over three different time periods, namely July 1999 to December 2015, July 2002 to December 2015, and July 2008 to December 2015. Our findings are consistent in the three time periods.

II. Data and Methodology

2.1 Special Features in the Chinese Stock Market

Several features in the Chinese stock market may affect the construction and performance of empirical asset pricing factors. First, before April 2005, about two thirds of outstanding shares of Chinese listed firms were held by government agencies or government-related enterprises and were non-tradable in the secondary market. The Chinese government started the share structure reform in April 2005 to legally convert non-tradable shares into tradable shares. Most Chinese listed firms completed the reform by the end of 2006. However, a substantial number of shares are still restricted from trading because of the lock-up agreement. For example, at the end of 2012, more than 60% of A-shares were locked up in nearly one quarter of Chinese listed firms (Xu and Zhang, 2014). Second, China set up the Small and Medium Enterprise Board (SME Board) in May 2004 and the ChiNext market for growth enterprises in October 2009, both hosted by the Shenzhen Stock Exchange. The ChiNext and SME Board listed firms tend to be smaller in size than firms that are listed on the main board. Third, more than 170 Chinese listed firms have issued multiple classes of shares that have the same cash flow and voting rights but are listed in different markets. Some have A- and B-shares, some have A- and H-shares, while others have A-shares and another class of shares in other foreign markets.[4] For such firms, the market value of A-shares is only part of the firm's total market value, and thus it is incorrect to calculate the B/M ratio by dividing the firm's total book value of equity by the market value of its A-shares.

Previous studies do not present evidence on how these features affect the construction and performance of the empirical asset pricing factors in China (e.g. Wang and Xu, 2004; Chen, 2004; Liao and Shen, 2008; Liu and Yang, 2010; Mao *et al.*, 2008). Xu and Zhang (2014) carry out a comprehensive analysis and find that these special features have significant effects on the values of the three FF factors and the explanatory power of the FF three-factor model for Chinese stock returns. For example, during the period from July 1996 to June 2013, the average monthly excess return on the market portfolio is 0.94% if only tradable A-shares are included in the market portfolio but decreases to only 0.75% if both tradable and non-tradable shares are included in the market portfolio. Moreover, the adjusted R^2 of the market model is on average 82.9% if the market portfolio includes only tradable shares but decreases to 76.6% if the market portfolio includes both non-tradable and tradable shares.

Both A-shares and B-shares are traded on the stock exchanges in China. Our analysis focuses on A-shares for two reasons. First, B-shares are issued to foreign investors and traded in US dollars on the SSE and in Hong Kong dollars on the SZE. Domestic investors in China

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4 Both A and B shares are listed in Chinese domestic exchanges. A-shares are denominated and traded in RMB Yuan, while B-shares are denominated and traded in USD or HKD. Before the establishment of the Shanghai-Hong Kong Stock Connect programme, foreign individual investors could not open their own accounts and directly invest in A-shares. H-shares are listed on the Hong Kong Stock Exchange. Other foreign countries in which Chinese firms list their shares include the US, the UK, Singapore, and Germany.

were not allowed to invest in B-shares before February 2001. Second, B-shares account for a very small percentage of the total market value in recent years. The percentage of B-share market value, calculated as the market value of all B-shares divided by the sum of the tradable A-shares' market value and the B-shares' market value, has been less than 2% since 2008 and dropped to 0.63% in 2014.

2.2 Data and Preliminary Statistics

We obtain data on Chinese listed firms from the CSMAR databases, including financial statement items from the China Stock Market Financial Statements Dataset and stock return data from the China Stock Market Trading Dataset. We use monthly data that include the closing price, the stock return with cash dividend reinvested, the total number of shares outstanding, and the total number of tradable shares at the end of each month. The financial statement release dates are also obtained from CSMAR.

Some Chinese firms have multiple classes of shares listed on different stock exchanges: for example, A-shares and B-shares on the SSE and the SZE, H-shares on the Hong Kong Stock Exchange, and N-shares on the New York Stock Exchange. For such firms, it is incorrect to measure the B/M ratio of A-shares by a firm's total book value of equity divided by the market value of A-shares. Instead, we calculate the book-to-price (B/P) ratio of A-shares as the book value of equity per share divided by the market price of A-shares. The book value of equity per share is equal to the total book value of equity divided by the total number of outstanding shares in all classes. According to Xu and Zhang (2014), the number of firms for which the B/P ratio differs from the B/M ratio increased from 18 in 1992 to 174 in 2012.[5] Hence, we use the B/P ratio to replace the B/M ratio in our analysis.

We calculate two market values for each Chinese listed firm: the tradable market value of a listed firm is the end-of-month A-share market price multiplied by the number of the firm's tradable A-shares, while the total market value of a listed firm is the end-of-month A-share market price multiplied by the number of all the firm's outstanding A-shares (including both tradable and non-tradable A-shares). Starting from April 2005, the share structure reform has substantially reduced the percentage of non-tradable A-shares in the market. Xu and Zhang (2004) report that the proportion of the aggregate market value of all tradable A-shares to the total market value of all outstanding A-shares increases from nearly 30% in 1995 to above 80% in 2012.[6]

We calculate the book value of equity of Chinese listed companies in the same way that Fama and French (2015) did for US listed companies.[7] Specifically, the book value of equity

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5 Table 2 in Xu and Zhang (2014) reports the mean, median, and standard deviation of the B/P ratio, the B/M ratio, and the difference between the two ratios of the same firm in each year from 1992 to 2012.

6 Almost all of the Chinese listed firms completed the reform by the end of 2006. Some shares remain non-tradable after the reform is completed because of the lock-up agreement.

7 According to Fama and French (2015), the book value of equity of a US listed company is equal to shareholders' equity plus deferred taxes and investment tax credit (if available) minus the book value of

is equal to the shareholder equity in the annual balance sheet (Item A003000000 in the CSMAR database) plus the deferred taxes and investment tax credit (A001222000 and A002208000) (if available), minus the book value of preferred stock. If the balance sheet shareholder equity is missing, we use the book value of assets (A001000000) minus the total liabilities (A002000000). We hand collect the book value of preferred stock from the official websites of the SSE and the SZE because Chinese listed firms were not allowed to issue preferred stocks before 2014.

We measure a company's investment in year *t* by the percentage change in its total assets in year *t*, that is, the total assets in year *t* annual report divided by the total assets in year *t-1* annual report, and then minus 1. Fama and French (2015) form the portfolios for the profitability factor at the end of June each year by using firms' operating profitability in the fiscal year that ends in the previous calendar year. To construct the FF profitability factor for the Chinese market, we measure a company's profitability by its annual operating profit (B001300000) divided by the book value of equity in the same annual report. Hou, Xue, and Zhang (2015) form the portfolios for their profitability factor at the end of each month by using firms' quarterly operating profitability in the months immediately after quarterly financial reports are released to the public. To construct the HXZ profitability factor, we measure a firm's profitability at the end of each month by its most recent quarterly operating profit (B001300000) divided by the book value of equity in the previous financial report.[8]

The new *Accounting Regulation for Listed Companies* in China became effective in January 1998. Many studies report that Chinese listed firms before 1998 had poor earnings quality because of outdated accounting rules, the lack of accounting and auditing professionals, and other institutional weaknesses (e.g. Chen *et al.*, 1999; Xiang, 1998; Chen *et al.*, 2002). Hence, our analysis starts from 1998. We calculate summary statistics of the five variables for Chinese listed firms: firm size, B/M ratio, annual investment, annual profitability, and quarterly profitability. For each year, firm size is the total market value at the end of June in that year; B/M ratio is the book value of equity per share in that year's annual report divided by the December-end closing price of A-shares; annual investment is the percentage change in total assets in the year; annual profitability is the operating profit in the year's annual report divided by the book value of equity in the same report; and quarterly profitability is the operating profit in the most recent quarterly report divided by the book value of equity in the previous financial report. Table 1 reports the number of listed firms with non-missing values for each variable and the variable's mean and median across these firms in each year between 1998 and 2014 inclusive.

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preferred stock. For shareholders' equity, they use either the value (SEQ) in Compustat, or the sum of common equity (CEQ) plus the carrying value of preferred stock (PSTK), or the book value of assets (AT) minus total liabilities (LT), whichever of the three is available, in that order.

8 Chinese listed firms started to issue quarterly financial reports in 2002. We use the data from their semi-annual reports for the years before 2002.

Table 1 Descriptive Statistics of the Variables for the Fama -French Five Factors in China

We calculate five variables for the Chinese listed firms: firm size, book-to-market (B/M) ratio, annual investment, annual profitability, and quarterly profitability. For each year, firm size is the total market value (in RMB Yuan billions) at the end of June, B/M ratio is the book value of equity per share in the year's annual report divided by the December-end closing price of the firm's A-shares, annual investment is the percentage change in total assets in the year, annual profitability is the operating profit in the year's annual report divided by the book value of equity of the same year, and quarterly profitability is the operating profit in the most recent quarterly report divided by the book value of equity in the previous financial report. For each year between 1998 and 2014 inclusive, this table reports the number of listed firms that have a non-missing value of a variable and the variable's mean and median across these firms.

	Firm size			B/M ratio			Annual investment			Annual profitability			Quarterly profitability		
Year	# firms	Mean	Median	# firms	Mean	Median	# firms	Mean	Median	# firms	Mean	Median	# firms	Mean	Median
1998	872	3.40	2.35	821	0.29	0.27	721	0.236	0.145	822	0.022	0.112	825	0.020	0.024
1999	974	4.16	3.06	913	0.28	0.26	828	0.146	0.091	914	0.034	0.094	924	0.014	0.022
2000	1110	4.72	3.65	1045	0.19	0.18	921	0.216	0.122	1046	0.026	0.086	1060	0.019	0.022
2001	1144	4.08	2.71	1107	0.27	0.25	1037	0.124	0.074	1113	0.002	0.070	1136	0.011	0.020
2002	1208	3.37	1.96	1163	0.36	0.34	1115	0.113	0.070	1171	0.000	0.068	1193	0.018	0.014
2003	1297	3.05	1.51	1214	0.44	0.42	1174	0.160	0.107	1222	0.001	0.068	1259	0.031	0.015
2004	1346	2.30	1.03	1306	0.55	0.52	1236	0.128	0.087	1310	0.025	0.069	1350	0.022	0.016
2005	1302	3.28	1.47	1249	0.71	0.67	1286	0.080	0.055	1264	-0.027	0.061	1340	-0.083	0.013
2006	1383	11.76	3.18	1281	0.51	0.48	1268	0.135	0.070	1328	0.047	0.079	1363	0.010	0.017
2007	1517	11.48	2.46	1390	0.21	0.19	1357	0.407	0.140	1456	0.073	0.101	1440	0.041	0.027
2008	1562	12.83	3.32	1516	0.57	0.53	1506	1.367	0.063	1528	0.032	0.068	1559	0.007	0.016
2009	1821	10.58	3.52	1597	0.26	0.24	1546	2.733	0.108	1663	0.045	0.084	1662	0.029	0.022
2010	2144	12.18	4.25	1931	0.29	0.25	1687	0.520	0.150	2006	0.073	0.089	1990	0.024	0.022
2011	2375	9.43	3.15	2216	0.47	0.43	2055	3.522	0.116	2264	0.017	0.084	2267	0.144	0.020
2012	2408	8.64	3.03	2363	0.51	0.47	2277	0.768	0.098	2392	0.059	0.072	2432	0.022	0.017
2013	2389	9.92	4.13	2281	0.49	0.42	2338	0.609	0.099	2378	0.047	0.071	2407	0.009	0.016
2014	2543	21.98	9.95	2229	0.37	0.33	2289	0.410	0.105	2385	-0.426	0.070	2456	0.026	0.016

2.3. Construction of the FF Factors in China

We follow Fama and French (1993, 2015) to construct the five FF factors for the Chinese stock market. The monthly return of the market factor (Rm-Rf) is equal to the value-weighted monthly return of all A-shares that have returns in the CSMAR database, minus the risk-free rate of return. We use the tradable market value of each firm at the end of the previous month as the portfolio weight. The risk-free rate of return is the 3-month RMB deposit rates provided by the Industrial and Commercial Bank of China.[9]

The other four factors, SMB (small minus big, 'size'), HML (high minus low, 'value'), RMW (robust minus weak, 'profitability'), and CMA (conservative minus aggressive, 'investment'), are constructed by three separate 2x3 sorts as follows. All Chinese A-shares listed on the SSE and the SZE (including the A-shares listed on the SME and ChiNext boards) are used in the determination of portfolio breakpoints.

At the end of June each year, we sort firms into two size groups by using the median of the total market value of all Chinese A-shares as the size breakpoint and then independently sort them into three B/M groups by using the 30th and 70th percentiles of the B/M ratio of all Chinese A-shares as the breakpoints. The intersections of the two sorts form six portfolios that are held from the beginning of July until the end of the following June. The value factor HML is the average of the value-weighted monthly returns of the two high B/M portfolios minus the average of the value-weighted monthly returns of the two low B/M portfolios. We follow the recommendation in Xu and Zhang (2014) and use the tradable market value of a firm's A-shares at the end of month *t-1* as the weight in the calculation of value-weighted portfolio return for month *t*. The size-related factor SMB_{BM} is equal to the average of the value-weighted returns on the three small-size stock portfolios minus the average of the value-weighted returns on the three big-size stock portfolios. We use Rm-Rf, HML, and SMB_{BM} in the FF three-factor model.

Fama and French (2015) propose including the profitability factor RMW and the investment factor CMA in addition to the three factors Rm-Rf, HML, and SMB_{BM}. We follow their methodology to construct the RMW and CMA factors for the Chinese stock market. In fact, the RMW and CMA factors are constructed in the same way as HML except that the second sort is by annual profitability or annual investment, respectively. Another two size-related factors, SMB_{PRO} and SMB_{INV}, are obtained by using profitability and investment, respectively, in place of the B/M ratio in the 2x3 sorts. The size factor SMB in the FF five-factor model is equal to the average of the three size-related factors, SMB_{BM}, SMB_{PRO}, and SMB_{INV}.

[9] The risk-free rate of return that is available from the CSMAR database is based on the one-year fixed-term deposit rate or the one-year treasury note issued by the Chinese Government. We choose the 3-month deposit rate to go along with monthly returns in our study. We cannot find a long series of a market-based interest rate, such as the Shanghai Interbank Borrowing Rate (SHIBOR), that covers the whole period of our study.

2.4. Construction of the HXZ Factors for China

Hou, Xue, and Zhang (2015) propose a four-factor model that includes the market factor, a size factor, a profitability factor, and an investment factor. Their profitability and investment factors are based on a procedure that is different from that used in Fama and French (2015). To construct the HXZ factors, we follow their procedure by sorting the firms according to size, quarterly profitability, and annual investment independently. For each year, we sort firms into two size groups at the end of June using the median of the total market value as the size breakpoint and independently sort firms into three investment groups using the 30th and 70th percentiles of the previous year's investment as the two breakpoints. The size and investment groups remain the same from the beginning of July to the end of June the following year. On the other hand, we form three profitability groups at the end of each month using the 30th and 70th percentiles of the quarterly profitability as the two breakpoints.

At the end of each month, the intersections of the two size groups, the three investment groups, and the three profitability groups form 18 portfolios. We hold the portfolios for one month and calculate the monthly value-weighted returns on these portfolios by using the tradable market value of each A-share as the weight. The size factor ME is the average of the value-weighted returns on the nine small-size stock portfolios minus the average of the value-weighted returns on the nine big-size stock portfolios. The investment factor INV is the average of the value-weighted returns on the six low-investment stock portfolios minus the average of the value-weighted returns on the six high-investment stock portfolios. The profitability factor ROE is the average of the value-weighted returns on the six high-profitability stock portfolios minus the average of the value-weighted returns on the six low-profitability stock portfolios.

To sum up, we list the composition of the five FF factors and the four HXZ factors in Table 2. There are a few differences between the two sets of factors. First, Fama and French (2015) use annual profitability, while Hou, Xue, and Zhang (2015) use quarterly profitability. Second, Fama and French (2015) form portfolios once in a year, while Hou, Xue, and Zhang (2015) form portfolios on a monthly basis. Third, the FF size factor SMB uses three 2x3 sorts and involves all of the four characteristics: size, B/M ratio, profitability, and investment. The other three FF factors, HML, RMW, and CMA, are formed by a single 2x3 sort on two characteristics. The three HXZ factors, ME, ROE, and INV, use the 2x3x3 sort on size, profitability, and investment.

Table 3 reports descriptive statistics on the number of stocks in each of the portfolios underpinning the formation of these factors. For each portfolio, we count the number of stocks in each month and calculate the average, the median, the minimum, and the maximum of the number of stocks over the 198 months between July 1999 and December 2015 inclusive. Panel A reports these statistics for the five FF factors, while Panel B reports these statistics for the four HXZ factors. Because the five FF factors are built by 2x3 sorts and the four HXZ factors by 2x3x3 sorts, the portfolios underpinning the five FF factors tend to have a larger number of stocks than the portfolios for the four HXZ factors. The minimum number of stocks in a portfolio is 69 for the FF factors but only five for the HXZ factors.

Table 2 Variable Definitions and Factor Composition

This table gives definitions of the variables and the composition of each factor. To construct the FF factors, at the end of June each year, we sort firms into two size groups and independently sort them into three B/M groups. The intersections of the two groups form six portfolios that are held from the beginning of July until the end of the following June. The six portfolios are labelled SL, SM, SH, BL, BM, and BH, where S stands for small size, B for big size, and L, M, and H for low, medium, and high B/M ratio, respectively. The value factor HML is the average of the value-weighted monthly returns on the two high B/M portfolios minus the average of the value-weighted returns on the two low B/M portfolios. Thus, the composition for HML is (SH+BH)/2 – (SL+BL)/2. Similarly, we form six portfolios by independent sorts on size and profitability, and the FF profitability factor is (SR+BR)/2 – (SW+BW)/2, where R and W stand for high and low profitability, respectively. We form another six portfolios by independent sorts on size and investment, and the FF investment factor is (SC+BC)/2 – (SA+BA)/2, where C and A stand for conservative and aggressive investment, respectively.

To construct the HXZ factors, at the end of June each year, we sort firms into two size groups and independently sort firms into three investment groups. The size and investment groups remain the same from the beginning of July to the end of June the following year. On the other hand, we form three profitability groups at the end of each month. At the end of each month, the intersections of the two size groups, the three investment groups, and the three profitability groups form 18 portfolios. The label SRC stands for the portfolio of small-size, high-profitability, and low-investment firms; the label SMC for the portfolio of small-size, medium-profitability, and low-investment firms; the label BWA for the portfolio of big-size, low-profitability, and high-investment firms; and so on.

	Variable definition	Factor composition
Panel A: Five FF factors		
Rm-Rf	Monthly return of a market portfolio that includes only tradable A-shares minus the monthly return on 3-month bank deposit	**Rm-Rf** = (Rm - Rf)
Size	Total market value of outstanding A-shares	**SMB** = [(SL + SM + SH)/3 + (SR + SM + SW)/3 + (SC + SM + SA)/3]/3 – [(BL + BM + BH)/3 + (BR + BM + BW)/3 + (BC + BM + BA)/3]/3
Value	B/M ratio calculated as book equity per share divided by the A-share price	**HML** = (SH + BH)/2 – (SL + BL)/2
Profitability	Operating profit divided by the same year's book value of equity	**RMW** = (SR + BR)/2 – (SW + BW)/2
Investment	Annual rate of growth in total assets	**CMA** = (SC + BC)/2 – (SA + BA)/2
Panel B: Four HXZ factors		
Rm-Rf	Monthly return of a market portfolio that includes only tradable A-shares minus the monthly return on 3-month bank deposit	**Rm-Rf** = (Rm - Rf)
Size	Total market value of outstanding A-shares	**ME** = [(SRC + SRM + SRA)/3 + (SMC + SMM + SMA)/3 + (SWC + SWM + SWA)/3] /3 – [(BRC + BRM + BRA)/3 + (BMC + BMM + BMA)/3 + (BWC + BWM + BWA)/3]/3
Profitability	Operating profit divided by the previous quarter's book value of equity	**ROE** = [(SRC + SRM + SRA)/3 + (BRC + BRM + BRA)/3]/2 - [(SWC + SWM + SWA)/3 + (BWC + BWM + BWA)/3]/2
Investment	Annual rate of growth in total assets	**INV** = [(SRC + SMC + SWC)/3 + (BRC + BMC + BWC)/3]/2 - [(SRA + SMA+ SWA)/3 + (BRA + BMA + BWA)/3]/2

Table 3 Statistics on the Size of the Portfolios in the Formation of the Five FF Factors and the Four HXZ Factors

Panel A reports descriptive statistics on the number of stocks in each of the portfolios underpinning the formation of the five FF factors, while Panel B reports descriptive statistics concerning the four HXZ factors. We count the number of stocks in each month and calculate the statistics over the 198 months between July 1999 and December 2015 inclusive.

Panel A: Size of the portfolios in the formation of the five FF factors

To construct the FF factors, at the end of June each year, we sort firms into two size groups and independently sort them into three B/M groups. The intersections of the two groups form six portfolios that are held from the beginning of July until the end of the following June. The six portfolios are labelled SL, SM, SH, BL, BM, and BH, where S stands for small size, B for big size, and L, M, and H for low, medium, and high B/M ratio, respectively. Similarly, we form six portfolios by independent sorts on size and profitability and label them SW, SM, SR, BW, BM, and BR, where W, M, and R stand for low, medium, and high profitability, respectively. We form another six portfolios by independent sorts on size and investment and label them SC, SM, SA, BC, BM, and BA, where C and A stand for conservative and aggressive investment, respectively, and M stands for the middle investment group.

Small size (S)	**B/M ratio (L, M, H)**			**Profitability (W, M, R)**			**Investment (C, M, A)**		
	SL	**SM**	**SH**	**SW**	**SM**	**SR**	**SC**	**SM**	**SA**
Average # of stocks	204	306	200	300	308	121	263	267	150
Median	192	258	211	276	263	109	249	254	139
Minimum	122	182	103	157	175	69	132	149	89
Maximum	305	518	351	482	528	204	437	459	255
Big size (B)	**B/M ratio (L, M, H)**			**Profitability (W, M, R)**			**Investment (C, M, A)**		
	BL	**BM**	**BH**	**BW**	**BM**	**BR**	**BC**	**BM**	**BA**
Average # of stocks	231	277	239	143	290	328	152	292	270
Median	231	252	214	122	259	291	134	272	252
Minimum	124	146	142	78	154	170	84	137	127
Maximum	402	429	388	240	463	535	256	467	450

Panel B: Size of the portfolios in the formation of the four HXZ factors

To construct the HXZ factors, at the end of June each year, we sort firms into two size groups and independently sort firms into three investment groups. The size and investment groups remain the same from the beginning of July to the end of June the following year. On the other hand, we form three profitability groups at the end of each month. At the end of each month, the intersections of the two size groups, the three investment groups, and the three profitability groups form 18 portfolios. The label SRC stands for the portfolio of small-size, high-profitability, and low-investment firms; the label SMC for the portfolio of small-size, medium-profitability, and low-investment firms; the label BWA for the portfolio of big-size, low-profitability, and high-investment firms; and so on.

Small size (S)	**Low profitability (W)**			**Medium profitability (M)**			**High profitability (R)**		
	SWC	**SWM**	**SWA**	**SMC**	**SMM**	**SMA**	**SRC**	**SRM**	**SRA**
Average # of stocks	136	96	45	78	119	65	31	48	36
Median	132	90	43	69	109	63	29	41	35
Minimum	62	48	13	29	50	33	12	19	21
Maximum	233	153	92	158	236	115	61	88	56
Big size (B)	**Low profitability (W)**			**Medium profitability (M)**			**High profitability (R)**		
	BWC	**BWM**	**BWA**	**BMC**	**BMM**	**BMA**	**BRC**	**BRM**	**BRA**
Average # of stocks	52	57	41	57	115	95	40	117	132
Median	47	55	33	51	112	87	36	103	132
Minimum	28	23	5	22	55	38	10	36	42
Maximum	89	111	93	105	193	166	77	205	244

III. Empirical Results

3.1 Descriptive Statistics of All Factors

We study the monthly returns of the five FF factors and the four HXZ factors between July 1999 and December 2015. Panel A of Table 4 shows the mean monthly return, the standard deviation, the t-statistic of testing the null hypothesis of zero mean, the Sharpe ratio, and the cumulative wealth. The Sharpe ratio is equal to the mean divided by the standard deviation. Cumulative wealth is equal to the amount in RMB Yuan obtained by investing one RMB Yuan at the end of June 1999 and compounding at the monthly factor returns until the end of December 2015.

Table 4 Descriptive Statistics of All Factors

This table shows the descriptive statistics and correlation of all the factors under study. Section 2 describes how the five FF factors and the four HXZ factors are constructed for the Chinese stock market. Panel A reports summary statistics of monthly returns on these factors, including the mean, the standard deviation, and the t-statistic of monthly returns over the 198 months between July 1999 and December 2015. Sharpe ratio is equal to the mean divided by the standard deviation. Cumulative wealth is equal to the amount in RMB Yuan obtained by investing one RMB Yuan at the end of June 1999 and compounding at the monthly factor returns until the end of December 2015. Panel B reports the Spearman rank correlation coefficients between each pair of these factors.

	Rm-Rf	SMB	HML	RMW	CMA	ME	ROE	INV
Panel A: Descriptive statistics								
# of Observations	198	198	198	198	198	198	198	198
Mean	0.82	0.93	0.24	0.12	-0.06	1.13	0.74	0.20
Standard Deviation	8.45	4.55	3.57	3.57	2.12	3.98	3.49	1.69
t-statistics	(1.37)	(2.87)	(0.93)	(0.49)	(-0.42)	(4.00)	(3.00)	(1.68)
Sharpe Ratio	0.10	0.20	0.07	0.03	-0.03	0.28	0.21	0.12
Cumulative Wealth	2.50	5.08	1.41	1.13	0.84	7.92	3.86	1.45
Panel B: Spearman rank correlation coefficients								
Rm-Rf	1.00	0.15	0.13	-0.41	0.18	0.12	-0.30	0.10
SMB		1.00	-0.36	-0.74	0.52	0.98	-0.70	0.26
HML			1.00	-0.05	0.30	-0.42	0.00	0.37
RMW				1.00	-0.77	-0.66	0.87	-0.48
CMA					1.00	0.42	-0.65	0.86
ME						1.00	-0.59	0.22
ROE							1.00	-0.28
INV								1.00

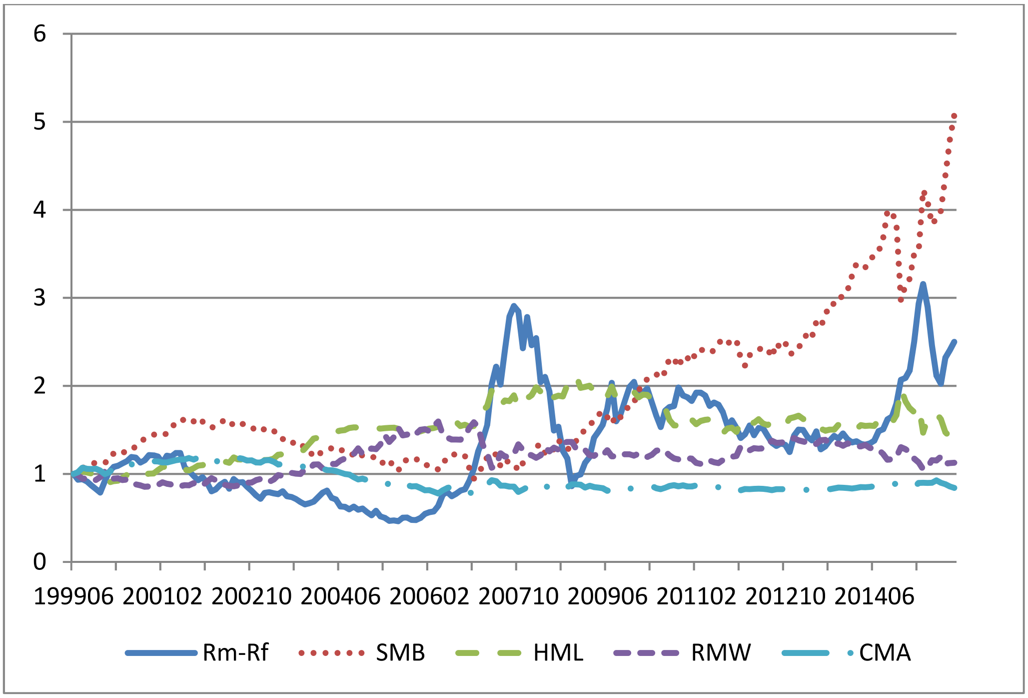
We have a few observations. First, out of the five FF factors, the size factor SMB is the only one that has a significant mean of monthly returns. The mean return on SMB is 0.93% per month, which is statistically significant with a t-statistic of 2.87. The market factor Rm-

Rf has a large mean monthly return of 0.82%; however, this return is insignificant because of the high standard deviation of 8.45%. The average monthly returns on the value factor HML and the profitability factor RMW are 0.24% and 0.12%, respectively, which are small in magnitude and statistically insignificant. The investment factor CMA has a negative mean return of -0.06%.[10] In a contemporaneous paper, Hu *et al.* (2019) use historical stock returns of Chinese listed firms from a different commercial data vendor and find that neither the market factor nor the value factor HML earns average monthly excess returns that are significantly different from zero. Guo *et al.* (2017) and Liu *et al.* (2018) also report evidence that the FF investment factor CMA does not play a significant role in explaining Chinese stock returns.

Second, the size factor ME and the profitability factor ROE proposed by Hou, Xue, and Zhang (2015) have large and statistically significant average returns of 1.13% and 0.74%, respectively. The investment factor INV has a positive mean return of 0.20%, which is small compared to the other HXZ factors and statistically insignificant. Both the FF investment factor CMA and the HXZ investment factor INV do not have significant returns, suggesting that the cross-sectional variation in Chinese stock returns is unrelated to firm investment.

Figure 1 Cumulative Wealth of the Five FF Factors

This figure plots the monthly series of the amount that is obtained by investing one RMB Yuan at the end of June 1999 and compounding at the monthly returns on each of the five FF factors until the end of December 2015.

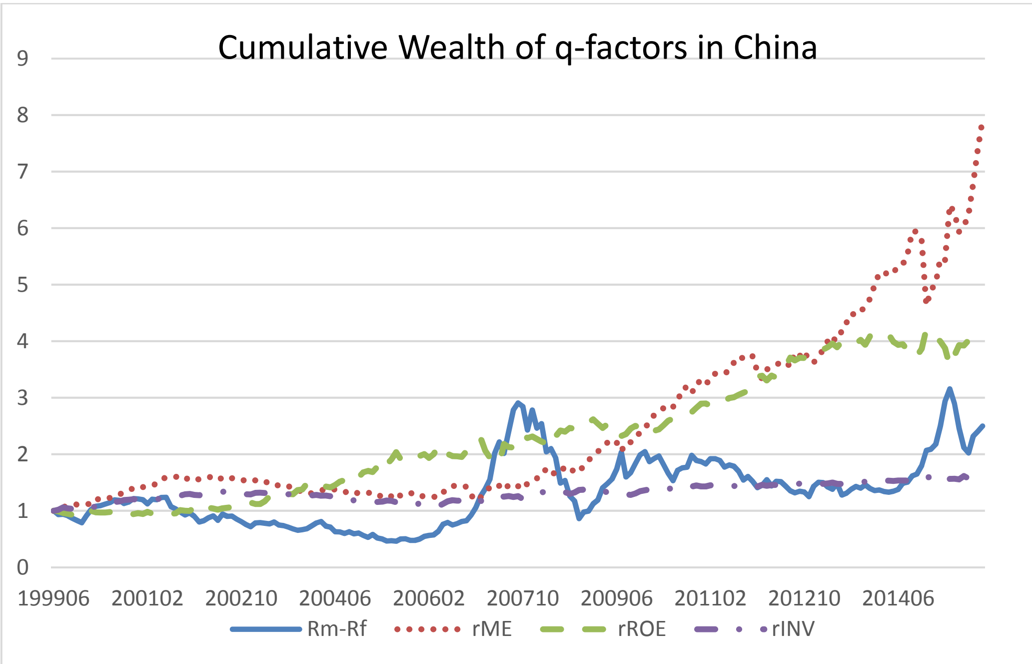


[10] This is in sharp contrast to the finding in Fama and French (2015) that the investment factor earns positive and statistically significant average returns in the US.

Third, the cumulative values of the buy-and-hold strategy over the period between July 1999 and December 2015 are consistent with the mean monthly returns. The size factor ME grows from a one RMB Yuan investment at the end of June 1999 to the amount of 7.92 RMB Yuan at the end of December 2015, thereby creating a great deal of wealth for investors. The market factor lags behind with a cumulative value of only 2.50 RMB Yuan at the end of December 2015. SMB and ROE have the second and third highest cumulative values, 5.08 Yuan and 3.86 Yuan, respectively. Figure 1 shows the time-series plots of the cumulated values for the five FF factors. Figure 2 shows the time-series plots of the cumulative values for the four HXZ factors. There are large swings in the cumulative value of the market factor Rm-Rf, which is consistent with the large standard deviation of market returns. The two size factors, SMB and ME, show steady growth in portfolio value over time. The cumulative values for RMW, CMA, and INV are almost flat throughout the period.

Figure 2 Cumulative Wealth of the Four HXZ Factors

This figure plots the monthly series of the amount that is obtained by investing one RMB Yuan at the end of June 1999 and compounding at the monthly returns on each of the four HXZ factors until the end of December 2015.



Lastly, Panel B of Table 4 reports the Spearman rank correlation coefficients between these factors' monthly returns. The market factor Rm-Rf has a low level of correlation with the other factors. This is not surprising because the other factors are designed to remove market influence given long-short portfolios. Several factor pairs, such as the SMB and ME pair, the RMW and ROE pair, and the CMA and INV pair, have very large correlation coefficients, more than 0.8. Although the two factors in each pair are constructed differently by Fama and French (2015) and Hou, Xue, and Zhang (2015), they capture the effect of the same firm characteristic on stock return. The value factor HML does not have a counterpart in the HXZ four-factor model and has relatively low correlation with all the other factors. The profitability factor RMW is significantly correlated with all the other factors except for the value factor HML.

3.2. Spanning Regression for Each Factor

Fama and French (2015) find that the value factor HML can be explained by the other factors in the spanning regressions for US stock returns. In this section, we run spanning regressions to examine to what extent one factor can be explained by the other factors in the Chinese stock market. Table 5 shows the results from these spanning regressions and reports the coefficients from each regression in the same row with the associated t-statistics in the row below. All regressions are estimated with 198 monthly observations between July 1999 and December 2015. Panel A reports results from using four factors in the FF five-factor model to explain the fifth. The intercept is highly significant in the spanning regressions for the market factor Rm-Rf, the size factor SMB, the value factor HML, and the profitability factor RMW, suggesting that these factors' returns cannot be fully explained by the other FF factors. The intercept is insignificant in the spanning regression for the investment factor CMA, which is not surprising given the small and insignificant mean of CMA's monthly returns.

Table 5 Spanning Regression for Each Factor

The table shows the results from spanning regressions that tell us to what extent each factor can be explained by other factors in the Chinese stock market. The construction of these factors is described in detail in Section 2. Each row reports the coefficients from one regression and the t-statistics in parentheses. The sample period is from July 1999 to December 2015.

Panel A: Using four factors in the FF five-factor model to price the fifth

Dependent	Intercept	Rm-Rf	SMB	HML	RMW	CMA	R^2	Adj. R^2
Rm-Rf	1.42**		-0.53**	0.28	-2.31***	-1.85***	0.292	0.277
	(2.50)		(-2.58)	(-1.41)	(-7.97)	(-4.37)		
SMB	1.23***	-0.06**		-0.52***	-0.93***	0.21	0.715	0.709
	(6.99)	(-2.58)		(-9.34)	(-9.97)	(1.39)		
HML	0.84***	0.04	-0.60***		-0.12	0.99***	0.468	0.457
	(4.15)	(1.41)	(-9.34)		(-0.95)	(6.80)		
RMW	0.51***	-0.11***	-0.37***	-0.04		-0.80***	0.816	0.812
	(4.31)	(-7.97)	(-9.97)	(-0.95)		(-10.44)		
CMA	-0.06	-0.05***	0.05	0.19***	-0.45***		0.705	0.699
	(-0.62)	(-4.37)	(1.39)	(6.80)	(-10.44)			

Panel B: Using three factors in the HXZ four-factor model to price the fourth

Dependent	Intercept	Rm-Rf	ME	ROE	INV	R^2	Adj. R^2
Rm-Rf	1.64**		-0.19	-0.84***	0.14	0.097	0.083
	(2.47)		(-1.08)	(-4.05)	(0.39)		
ME	1.62***	-0.03		-0.67***	0.16	0.352	0.342
	(6.72)	(-1.08)		(-9.38)	(1.11)		
ROE	1.40***	-0.09***	-0.46***		-0.28**	0.416	0.407
	(7.03)	(-4.05)	(-9.38)		(-2.40)		
INV	0.23*	0.01	0.04	-0.10**		0.083	0.069
	(1.70)	(0.39)	(1.11)	(-2.40)			

Panel C: Using the five FF factors to price each HXZ factor

Dependent	Intercept	Rm-Rf	SMB	HML	RMW	CMA	R^2	Adj. R^2
ME	0.25***	0.00	0.93***	-0.02	0.08**	-0.13***	0.972	0.972
	(4.68)	(0.23)	(47.26)	(-0.83)	(2.51)	(-3.04)		
INV	0.72***	0.03	-0.10*	-0.03	0.85***	0.13	0.765	0.759
	(5.25)	(1.51)	(-1.90)	(-0.73)	(10.59)	(1.27)		
ROE	0.22***	0.02**	-0.01	0.00	0.23***	0.97***	0.823	0.818
	(3.90)	(2.57)	(-1.90)	(0.21)	(6.96)	(21.94)		

Panel D: Using the four HXZ factors to price each FF factor

Dependent	Intercept	Rm-Rf	ME	ROE	INV	R^2	Adj. R^2
SMB	-0.02	-0.01	0.99***	-0.24***	0.05**	0.984	0.984
	(-0.48)	(-1.25)	(77.30)	(-15.47)	(2.13)		
HML	0.88***	0.04	-0.60***	-0.25***	0.95***	0.458	0.447
	(3.99)	(1.54)	(-10.18)	(-3.49)	(8.09)		
RMW	0.04	-0.07***	-0.20***	0.63***	-0.51***	0.871	0.868
	(0.37)	(-6.37)	(-6.88)	(18.32)	(-8.94)		
CMA	-0.03	-0.01*	0.00	-0.28***	0.92***	0.919	0.917
	(-0.56)	(-6.37)	(-0.35)	(-17.23)	(34.33)		

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Panel B reports the results from using three factors in the HXZ four-factor model to explain the fourth. The intercept is highly significant in the regressions for the market factor Rm-Rf, the size factor ME, and the profitability factor ROE, suggesting that their returns cannot be fully explained by the other HXZ factors. The intercept in the regression for the investment factor INV is insignificant.

Panel C reports the results from using the five FF factors to explain three HXZ factors: ME, ROE, and INV. It turns out that all three intercepts are statistically significant. Panel D reports the results from using the four HXZ factors to explain four FF factors: SMB, HML, RMW, and CMA. HML is the only factor that has a significant intercept. SMB, RMW, and CMA can be explained by the HXZ four-factor model.

In summary, the two investment factors CMA and INV can be explained by other factors. The four HXZ factors can explain the size factor SMB and the profitability factor RMW, but not the value factor HML. The five FF factors cannot explain ROE and ME. In the next section, we try to identify a parsimonious factor model for the Chinese stock returns that is comprised of the above factors.

3.3 Comparing Factor Models according to Conventional Metrics

In this section, we apply several conventional metrics in the finance literature to evaluate the performance of factor models that are built on the five FF factors and the four HXZ factors in explaining Chinese stock returns. We follow the methodology in Fama and French (2015) to construct three sets of test assets, each of which consists of 25 portfolios. The first set is constructed by sorting firms by size and B/M ratio. At the end of each June, we sort all Chinese A-shares into five quintiles by their total market value and independently sort A-shares into five quintiles by B/M ratio. The intersections of the two sorts form 25 size-B/M value-weighted portfolios. The second and third sets of portfolios are constructed in the same way except that the second sort is by annual profitability or annual investment, respectively. The portfolios are held from the beginning of July until the end of the following June. We follow Xu and Zhang (2014) and use all Chinese A-shares listed on the SSE and SZE (including the shares on the SME and ChiNext boards) in the determination of portfolio breakpoints and use the total value of a firm’s tradable A-shares as the portfolio weight in the calculation of value-weighted portfolio return. The monthly excess return on each portfolio is equal to its value-weighted return minus the risk-free rate.

Table 6 reports the average of the monthly excess returns on test portfolios from July 1999 to December 2015 in three panels. Panel A is for the set of 25 size-B/M portfolios, Panel B for the set of 25 size-profitability portfolios, and Panel C for the set of 25 size-investment portfolios. We observe strong cross-sectional differences associated with both size and B/M ratio in Panel A. Small-size stocks earn substantially higher returns than big-size stocks, and high-B/M stocks earn higher returns than small-B/M stocks. The return difference between small-size stocks and big-size stocks is greater than that between value stocks and growth stocks. The size effect is also strong in both panels B and C. There is some evidence for the profitability effect in Panel B: that is, high-profitability stocks earn higher returns than low-profitability stocks. However, the profitability effect does not seem to exist in the smallest size quintile. Panel C does not show any evidence of an investment effect.

Our objective is to identify a parsimonious factor model that provides an adequate explanation of time-series and cross-sectional variation in these test assets’ monthly returns. We run time-series regressions of each portfolio’s monthly excess returns on the pricing factors and evaluate the performance of each model according to four conventional metrics.

Table 6 Mean Monthly Excess Return on Test Portfolios

We construct three sets of 25 portfolios by following the methodology in Fama and French (2015). The first set is constructed by sorting on the basis of size and B/M ratio. At the end of each June, we sort all Chinese A-shares into five quintiles by market cap and independently sort stocks into five quintiles by B/M ratio. We calculate market cap as the total number of outstanding A-shares multiplied by its June closing price. We calculate the B/M ratio at the end of June in year *t* as the book value of equity per share for year *t-1* divided by the A-share closing price at the end of December in year *t-1*. The intersections of the two groups form 25 size-B/M value-weighted portfolios. The second set is constructed in the same way except for the second sort, which is on profitability. We measure profitability by the annual operating profit divided by the book value of equity in year *t-1* (OP/BE). The third set is again constructed in the same way except for the second sort, which is on investment. We calculate investment in year *t-1* as the total assets at the end of year *t-1* divided by the total assets at the end of year *t-2*, minus 1.

The portfolios are held from the beginning of July until the end of the following June. The monthly excess return on each portfolio is equal to its value-weighted return minus the risk-free rate of return. We use the total value of a firm's tradable A-shares as the portfolio weight in the calculation of value-weighted portfolio return. The table below reports the average of the monthly excess returns on each portfolio from July 1999 to December 2015.

Panel A: 25 Size-B/M Portfolios

Size	**Low B/M ratio**	**BM2**	**BM3**	**BM4**	**High B/M ratio**
Small	1.67	2.04	2.17	2.12	2.10
2	1.48	1.65	1.54	1.67	1.63
3	1.09	1.27	1.25	1.32	1.38
4	1.00	1.00	1.17	1.01	1.21
Big	0.24	0.54	0.59	0.90	0.83

Panel B: 25 Size-Profitability Portfolios

Size	**Low Profitability**	**Pro2**	**Pro3**	**Pro4**	**High Profitability**
Small	1.96	2.04	2.07	2.01	1.99
2	1.27	1.57	1.74	1.84	1.72
3	1.03	1.13	1.39	1.63	1.29
4	0.90	0.88	1.04	1.32	1.21
Big	0.35	0.47	0.59	0.77	0.67

Panel C: 25 Size-Investment Portfolios

Size	**Low Investment**	**Inv2**	**Inv3**	**Inv4**	**High Investment**
Small	1.86	2.04	2.16	2.08	1.91
2	1.50	1.60	1.63	1.62	1.55
3	1.07	1.19	1.28	1.36	1.44
4	0.95	0.97	1.13	1.06	1.35
Big	0.79	0.64	0.62	0.50	0.68

First, the **GRS** statistic proposed by Gibbons, Ross, and Shanken (1989) tests the null hypothesis that the intercepts (i.e. alphas) for the 25 LHS portfolios in the same set are all equal to zero. A large GRS statistic rejects the null hypothesis and suggests that the model does not adequately explain portfolio returns. Second, the average of the absolute value of alphas across the 25 LHS portfolios, **Avg|a$_i$|**, shows the magnitude of the unexplained return. Third, the ratio of the dispersion of alphas to the dispersion of mean returns, **D$_a$/D$_r$**, indicates the unexplained proportion of return dispersion across the 25 LHS portfolios.[11] The dispersion of alphas, **D$_a$**, is the average of the absolute deviation of each portfolio's alpha from the mean of all 25 portfolios' alphas. A portfolio's mean return is equal to the time-series average of a portfolio's monthly excess returns between July 1999 and December 2015. The dispersion of mean returns, **D$_r$**, is the average of the absolute deviation of each portfolio's mean return from the mean of all 25 portfolios' time-series means. A large **D$_a$/D$_r$** ratio suggests that the model does not provide an adequate explanation of the cross-sectional variation in portfolio returns. Fourth, the average of the regression R^2 across the 25 LHS portfolios, **Avg(R^2)**, measures the proportion of the time-series variation that is explained by a model. The first three metrics prefer a model with a smaller value, while the fourth metric prefers a larger value.

We consider 12 factor models that represent different combinations of the five FF factors and the four HXZ factors. The first six models are comprised of the five FF factors; for models 1 to 5, each includes a different subset of the five FF factors, while Model 6 is the full FF five-factor model. The next four models are comprised of the four HXZ factors; for models 7 to 9, each includes a different subset of the four HXZ factors, while Model 10 is the full HXZ four-factor model. The other two models are the mixture of the FF factors and the HXZ factors; Model 11 includes two FF factors, Rm-Rf and HML, and two HXZ factors, ME and ROE, while Model 12 includes the HXZ factor INV in addition to the factors in Model 11.

Table 7 reports the statistics on these models' performance in explaining the monthly excess returns of the 25 portfolios in each set. In Table 7, Panel A is for the set of 25 portfolios sorted by size and B/M ratio, Panel B is for the set of 25 portfolios sorted by size and profitability, and Panel C is for the set of 25 portfolios sorted by size and investment.

We have the following observations in regard to Table 7. First, the four metrics do not agree on a single model that should be chosen for Chinese stock returns. In other words, we cannot find a single model that is associated with the best value of all four metrics. For the 25 size-B/M portfolios in Panel A, Model 3 has the lowest GRS statistic and the lowest Avg|a$_i$|, Model 2 has the lowest D$_a$/D$_r$, and the FF five-factor model (i.e. Model 6) has the highest Avg(R^2). For the 25 size-profitability portfolios in Panel B, Model 5 has the lowest GRS statistic, the lowest Avg|a$_i$|, and the lowest D$_a$/D$_r$, while the FF five-factor model (i.e. Model 6) has the highest Avg(R^2). For the 25 size-investment portfolios in Panel C, Model 3 has the lowest GRS statistic, the lowest Avg|a$_i$|, and the lowest D$_a$/D$_r$, while the FF five-factor model (i.e. Model 6) has the highest Avg(R^2).

[11] Fama and French (2015) use the ratio $\text{Avg}|a_i|/\text{Avg}|\bar{r}_i|$, which essentially gives the same ranking as Avg|a$_i$|. Also, the arithmetic average of the alphas of the 25 portfolios is small in magnitude in the US, but it is not small in China. Hence, we choose to subtract the average from each regression alpha in calculating the ratio of the dispersion of alphas (i.e. D$_a$) to the dispersion of mean returns (i.e. D$_r$).

Table 7 Comparing Factor Models Based on Conventional Metrics

We construct three sets of 25 portfolios by following the methodology in Fama and French (2015). The first set is constructed by sorting on size and B/M ratio, the second set by sorting on size and profitability, and the third set by sorting on size and investment. Table 6 provides details about the constructions of these portfolios. We compare 12 models that build on the five FF factors and the four HXZ factors for the Chinese stock market. Section 2 describes how the five FF factors and the four HXZ factors are constructed for the Chinese stock market. We measure the performance of each model in explaining these portfolios' monthly excess returns according to four conventional metrics. First, the GRS statistic proposed by Gibbons, Ross, and Shanken (1989) tests the null hypothesis that, for the 25 left-hand-side (LHS) portfolios in a given set, the intercepts from time series regressions of monthly excess returns on a model's factors are all equal to zero. Second, the average of the absolute value of the intercepts (i.e. alphas) across the 25 LHS portfolios, Avg$|a_i|$, shows the magnitude of the unexplained return. Third, the ratio of the dispersion of alphas to the dispersion of mean returns, D_a/D_r, indicates the unexplained proportion of return dispersion across 25 LHS portfolios. The dispersion of alphas, D_a, is the average of the absolute deviation of each portfolio's alpha from the mean of all 25 portfolios' alphas. A portfolio's mean return is equal to the time-series average of a portfolio's monthly excess returns between July 1999 and December 2015. The dispersion of mean returns, D_r, is the average of the absolute deviation of each portfolio's mean return from the mean of all 25 portfolios' time-series means. Fourth, the average of the regression R^2 across the 25 LHS portfolios, Avg(R^2), measures the proportion of time-series return variation that is explained by a model. The first three metrics prefer a model with a smaller value, while the fourth metric prefers a larger value.

Panel A: 25 Size-B/M Portfolios

Id	**Model**					**GRS**	**p-value**	**Avg$\|a_i\|$**	**D_a/D_r**	**Avg(R^2)**
1	Rm-Rf	SMB				2.324	0.001	0.261	0.563	93.88
2	Rm-Rf	SMB	HML			2.167	0.002	0.207	0.401	95.51
3	Rm-Rf	SMB	HML	RMW		1.519	0.064	0.197	0.473	95.58
4	Rm-Rf	SMB	HML	CMA		1.695	0.027	0.214	0.463	95.58
5	Rm-Rf	SMB	RMW	CMA		2.240	0.001	0.349	0.846	94.65
6	Rm-Rf	SMB	HML	RMW	CMA	1.544	0.057	0.202	0.480	95.62
7	Rm-Rf	ME				3.470	0.000	0.445	0.707	93.28
8	Rm-Rf	ME	ROE			2.582	0.000	0.456	1.096	93.82
9	Rm-Rf	ME	INV			3.423	0.000	0.444	0.667	93.85
10	Rm-Rf	ME	ROE	INV		2.566	0.000	0.399	0.948	94.26
11	Rm-Rf	ME	ROE	HML		1.760	0.019	0.288	0.601	95.20
12	Rm-Rf	ME	ROE	HML	INV	1.858	0.012	0.289	0.610	95.25

Panel B: 25 Size-Profitability Portfolios

Id	**Model**					**GRS**	**p-value**	**Avg$\|a_i\|$**	**D_a/D_r**	**Avg(R^2)**
1	Rm-Rf	SMB				2.550	0.000	0.298	0.719	94.14
2	Rm-Rf	SMB	HML			3.359	0.000	0.347	0.810	94.42
3	Rm-Rf	SMB	HML	RMW		1.694	0.027	0.180	0.409	94.99
4	Rm-Rf	SMB	HML	CMA		2.601	0.000	0.290	0.678	94.67
5	Rm-Rf	SMB	RMW	CMA		1.549	0.056	0.175	0.401	95.00
6	Rm-Rf	SMB	HML	RMW	CMA	1.775	0.018	0.184	0.420	95.04
7	Rm-Rf	ME				2.833	0.000	0.263	0.802	93.47
8	Rm-Rf	ME	ROE			1.822	0.014	0.236	0.499	94.19
9	Rm-Rf	ME	INV			3.155	0.000	0.447	0.766	93.81
10	Rm-Rf	ME	ROE	INV		1.708	0.025	0.250	0.483	94.41
11	Rm-Rf	ME	ROE	HML		1.791	0.017	0.279	0.510	94.32
12	Rm-Rf	ME	ROE	HML	INV	1.797	0.016	0.274	0.513	94.46

Panel C: 25 Size-Investment Portfolios

Id	Model	GRS	p-value	Avg|a_i|	D_a/D_r	Avg(R^2)
1	Rm-Rf SMB	1.667	0.031	0.195	0.440	95.02
2	Rm-Rf SMB HML	2.015	0.005	0.214	0.461	95.33
3	Rm-Rf SMB HML RMW	0.911	0.590	0.176	0.423	95.53
4	Rm-Rf SMB HML CMA	1.519	0.064	0.216	0.492	95.63
5	Rm-Rf SMB RMW CMA	1.165	0.279	0.176	0.426	95.64
6	Rm-Rf SMB HML RMW CMA	1.142	0.302	0.183	0.442	95.72
7	Rm-Rf ME	2.890	0.000	0.410	0.624	94.31
8	Rm-Rf ME ROE	1.541	0.058	0.266	0.616	94.86
9	Rm-Rf ME INV	2.978	0.000	0.420	0.635	94.78
10	Rm-Rf ME ROE INV	1.415	0.103	0.246	0.562	95.24
11	Rm-Rf ME ROE HML	1.458	0.085	0.269	0.593	95.10
12	Rm-Rf ME ROE HML INV	1.459	0.085	0.269	0.602	95.34

Second, the models that are associated with the best value of some metrics are not satisfactory in view of the factor returns in Table 4. The profitability factor RMW does not have a significant mean return and yet appears in the best models in all three panels of Table 7. The investment factor CMA has a negative mean return but appears in the best models in both panels B and C.

Third, although these metrics do not seem to do particularly well in choosing the best models, they provide some useful guidance on selecting factors. For example, comparing Model 2 with Model 1 in Panel A, it is clear that adding HML improves all four metrics substantially: Avg|a_i| goes down from 0.261 to 0.207, D_a/D_r goes down from 0.563 to 0.401, and Avg(R^2) increases from 93.88 to 95.51. This suggests that HML plays an important role in explaining Chinese stock returns. Similarly, although RMW does not have a significant mean return, having RMW makes a model perform better under some metrics. The HXZ profitability factor ROE has a significant mean return and also improves model performance under some metrics. Adding the investment factors CMA and INV in a model has mixed consequences: it has a positive effect under some metrics but a negative effect under other metrics.

In summary, the evidence in Table 7 does not point to a clear winner among the competing models. To address this issue, we consider an alternative criterion for model selection in the next section.

3.4 Comparing Factor Models according to the Maximum Sharpe Ratio

Section 3.3 shows that the conventional metrics do not help us pick a convincing winner from the candidate models. The analyses in Barillas and Shanken (2017) and Fama and French (2018) suggest another metric of model performance, that is, the maximum squared Sharpe ratio. For an empirical factor pricing model, the maximum squared Sharpe ratio is the squared

Sharpe ratio of the tangency portfolio in the investment opportunity set that is spanned by the factors in the model. Barillas and Shanken (2017) and Fama and French (2018) argue that the model with the highest maximum squared Sharpe ratio provides the best explanation, among the competing models, of the expected returns on all stocks from which the factors are constructed. The rationale is that looking for a factor model to minimise the intercepts in return regressions is equivalent to identifying the portfolio of factors that maximises the squared Sharpe ratio. Since factors are portfolios of stocks by construction, they fall within the investment opportunity set spanned by all constituent stocks, as do the portfolios of factors.

Consider two models that are comprised of two different sets of factors. We calculate the maximum Sharpe ratio of the portfolios that are comprised of the factors in each set. The set with the higher maximum Sharpe ratio is better than the other set, and hence the factors in the first set form a better factor model. The higher the maximum Sharpe ratio obtained by one set of factors, the closer the efficient frontier spanned by the set of factors is to the efficient frontier spanned by all stocks. Hence, we search for one set of factors that gives the highest maximum Sharpe ratio.[12]

For each of the 12 models described in Section 3.3, we calculate the maximum Sharpe ratio of the portfolios that are comprised of the factors in the model. Table 8 reports the maximum Sharpe ratio, the mean and standard deviation of the tangency portfolio that achieves the maximum Sharpe ratio, the t-statistic for testing the null hypothesis that the tangency portfolio's mean return is zero, and each factor's weight in the tangency portfolio. Among models 1 to 6, the FF five-factor model (i.e. Model 6) has the highest maximum Sharpe ratio. This is expected because the other models include only a subset of the five factors and their efficient frontiers should fall within the efficient frontier spanned by Model 6. However, Model 6 is not desirable because (1) the investment factor CMA does not earn a significant mean return, (2) the tangency portfolio takes a short position on CMA, and (3) its maximum Sharpe ratio (0.525) is only slightly larger than the maximum Sharpe ratio of Model 3 (0.523).

The HXZ four-factor model (i.e. Model 10) has a much larger maximum Sharpe ratio (0.603) than Model 3. Model 11 combines the market factor Rm-Rf and the value factor HML from the FF model with the size factor ME and the profitability factor ROE from the HXZ model and achieves a maximum Sharpe ratio of 0.688. With the addition of the investment factor INV, Model 12 achieves a slightly higher maximum Sharpe ratio (0.690) than Model 11. An increase in the maximum Sharpe ratio is expected because adding a factor enlarges the investment opportunity set. Despite the larger maximum Sharpe ratio, Model 12 is undesirable for two reasons. First, Table 4 shows that INV does not earn a significant average return in China. Second, Panel A of Table 7 shows that Model 12 does not perform better than Model 11 according to the conventional metrics.

[12] We report the maximum Sharpe ratio instead of the maximum squared Sharpe ratio because the empirical factor models under study in our research all have positive maximum Sharpe ratios.

Table 8 Maximum Sharpe Ratio of Factor Portfolios

We use another metric of model performance, the maximum Sharpe ratio, that can be achieved with the factors in a given model. The model that has the highest value on this metric provides the best explanation, among the competing models, of the expected returns on the stocks from which the factors are constructed. This table reports the maximum Sharpe ratio for each of the models we study in Table 7 for the period from July 1999 to December 2015. We also include two additional models, Model 13 and Model 11'. Model 13 includes all the factors, while Model 11' includes the market and value factors from Fama and French (2015) and the modified size and profitability factors from Hou, Xue, and Zhang (2015). We obtain the modified size and profitability factors, ME_{XInv} and ROE_{XInv}, without using the Investment variable in the construction process.

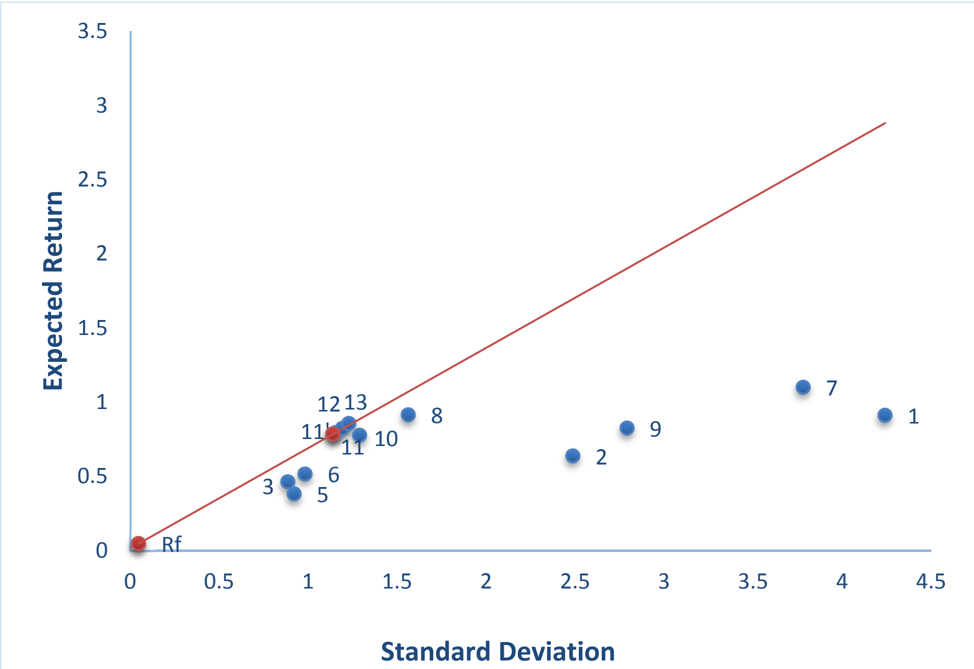
Model	Maximum Sharpe Ratio	Mean	Standard Deviation	t-value	Portfolio weights on constituent factors							
					Rm-Rf	**SMB**	**HML**	**RMW**	**CMA**	**ME**	**ROE**	**INV**
1	0.215	0.911	4.240	3.023	0.159	0.841						
2	0.256	0.637	2.487	3.604	0.046	0.539	0.414					
3	0.523	0.463	0.886	7.355	0.051	0.350	0.196	0.404				
4	0.405	5.413	13.360	5.701	0.155	4.229	3.796		-7.180			
5	0.414	0.382	0.921	5.832	0.073	0.299		0.453	0.176			
6	0.525	0.516	0.982	7.389	0.052	0.390	0.232	0.408	-0.082			
7	0.291	1.100	3.781	4.094	0.099					0.901		
8	0.586	0.915	1.562	8.245	0.069					0.430	0.501	
9	0.296	0.825	2.792	4.159	0.067					0.627		0.306
10	0.603	0.777	1.289	8.480	0.054					0.338	0.421	0.187
11	0.688	0.794	1.153	9.685	0.035		0.199			0.382	0.384	
12	0.690	0.823	1.193	9.702	0.036		0.220			0.406	0.395	-0.057
13	0.697	0.856	1.229	9.804	0.038	-0.019	0.235	0.054	-0.231	0.448	0.302	0.174
					Rm-Rf	**SMB**	**HML**	**RMW**	**CMA**	**ME_{XInv}**	**ROE_{XInv}**	**INV**
11'	0.689	0.785	1.139	9.699	0.036		0.222			0.371	0.371	

In addition to the 12 models described in Section 3.3, we consider two more models. Model 13 includes all the factors and is expected to have a larger investment opportunity set and a higher maximum Sharpe ratio than the other 12 models. With Model 13 as the benchmark, we can tell how much has been given up in terms of Sharpe ratio in order to obtain a parsimonious model with the best performance.

Model 11' is a modification of Model 11. Since investment does not seem to have a significant relation with stock returns in the Chinese stock market, we do not need to use the investment variable in the construction of the other pricing factors. Hence, we construct the modified size and profitability factors, ME_{XInv} and ROE_{XInv}, by following the same procedure as in Hou, Xue, and Zhang (2015) but sorting only by size and profitability. Model 11' uses the modified factors to replace the size and profitability factors in Model 11. Table 8 reports the maximum Sharpe ratios of models 13 and 11'. It turns out that the performance of Model 11' is comparable to that of Model 11. The tangency portfolio of Model 11' invests 3.6% in the market factor, 22.2% in the value factor, and 37.1% in each of the size and profitability factors.

Figure 3 Location of Tangency Portfolios on the Mean-Standard Deviation Plot

For each of the models in Table 8, we find the tangency portfolio of the investment opportunity set that is spanned by the factors in the model. The tangency portfolio gives the maximum Sharpe ratio that can be achieved by the model. Each tangency portfolio is represented by one dot on the mean-standard deviation plot. Next to the dot is the model number.



For each of the models in Table 8, we obtain the tangency portfolio of the investment opportunity set that is spanned by the factors in the model. The tangency portfolio gives the maximum Sharpe ratio that can be achieved by the model. Figure 3 presents each tangency portfolio by one dot on the mean-standard deviation plot and the model number next to the dot. According to the portfolio theory, models 12 and 13 have a larger number of factors than Model 11 and should have larger investment opportunity sets and hence larger maximum Sharpe ratios. Figure 3 shows that Model 11' is as good as models 12 and 13 and far better than the other models.

Table 9 The Best Model

Model 11' turns out to be the best model in Table 8. It includes the market and value factors from Fama and French (2015) and the modified size and profitability factors from Hou, Xue, and Zhang (2015). We obtain the modified size and profitability factors, ME_{XInv} and ROE_{XInv}, without using the investment variable in the construction process. This table reports the statistics that are related to this model.

Panel A: Descriptive statistics of factors in the model

	Rm-Rf	**ME_{XInv}**	**ROE_{XInv}**	**HML**
# of months	198	198	198	198
Mean	0.82	1.15	0.74	0.24
Standard deviation	8.45	4.24	3.77	3.57
t-statistic	(1.37)	(3.83)	(2.76)	(0.94)
Sharpe ratio	0.10	0.27	0.20	0.07
Cumulative wealth	2.50	8.15	3.75	1.41

Panel B: Pricing other factors

Dependent	**Intercept**	**Rm-Rf**	**ME_{XInv}**	**ROE_{XInv}**	**HML**	**R^2**	**Adj. R^2**
SMB	0.04	-0.01***	0.93***	-0.24***	-0.01	0.991	0.991
	(1.16)	(-2.67)	(85.67)	(-20.72)	(-1.29)		
RMW	0.02	-0.06***	-0.25***	0.64***	-0.12***	0.877	0.874
	(0.20)	(-5.55)	(-7.89)	(18.93)	(-3.85)		
CMA	-0.04	-0.02*	0.15***	-0.32***	0.24***	0.654	0.647
	(-0.40)	(-1.96)	(4.72)	(-9.41)	(8.00)		
INV	0.04	-0.01	0.15***	-0.07*	0.25***	0.342	0.328
	(0.31)	(-0.94)	(4.22)	(-1.96)	(7.46)		

Note: ***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively.

Panel C: Conventional performance metrics

	GRS	**p-value**	**Avg|a_i|**	**D_a/D_r**	**Avg(R^2)**
25 Size-BM Portfolios	1.792	0.016	0.283	0.632	95.66
25 Size-Pro Portfolios	1.811	0.015	0.263	0.501	94.84
25 Size-Inv Portfolios	1.397	0.111	0.261	0.593	95.54

The results in Tables 7 and 8 suggest that Model 11' is a parsimonious model with the best performance. We present more information related to Model 11' in Table 9. Panel A reports descriptive statistics on the four factors in Model 11'. The two modified factors, ME_{XInv} and ROE_{XInv}, show statistics similar to those of ME and ROE. Panel B shows that Model 11' can explain the other factors, SMB, RMW, CMA, and INV, because all of the intercepts are insignificant. Panel C presents the conventional metrics of Model 11' for the three sets of test assets. For the set of 25 size-B/M portfolios, Model 11' is comparable with Model 11. For the other two sets of 25 portfolios, Model 11' is clearly better than Model 11.

3.5. Two Other Time Periods

We repeat our analysis for two other time periods because of the significant market-wide changes that have occurred in China in the past. First, financial reporting frequency has changed from semi-annual to quarterly since 2002. The HXZ factors are based on firm profitability in the most recent financial reports. We use semi-annual reports for years before 2002 and quarterly reports for 2002 onwards. We repeat the analysis for the period from July 2002 to December 2015. Table 10 reports the maximum Sharpe ratios for the models under study. Overall, Model 11' is the preferred one among all the models. For this period, the tangency portfolio of Model 11' invests 4.6% in the market factor, 19.8% in the value factor, 35.4% in the size factor, and 40.2% in the profitability factor, which is close to the tangency portfolio between July 1999 and December 2015.

Second, we repeat the analysis for the period from July 2008 to December 2015 because of the share structure reform. The reform started in April 2005, and most Chinese firms completed their reform by the end of 2007. The value factor HML and the profitability factor RMW have a negative average return over this period. The size factors SMB and ME and the profitability factor ROE have significant positive returns. Table 11 reports the maximum Sharpe ratios for the models under study. Even though the value factor HML has a negative mean return, it actually has a long position in the tangency portfolios. Overall, Model 11' remains the preferred model. The tangency portfolio of Model 11' invests 5% in the market factor, 19.8% in the value factor, 36.2% in the size factor, and 39.0% in the profitability factor.

IV. Summary and Conclusion

We analyse Chinese stock returns over three different time periods, namely July 1999 to December 2015, July 2002 to December 2015, and July 2008 to December 2015. For each period, we construct the five factors in Fama and French (2015) and the four factors in Hou, Xue, and Zhang (2015). We conduct asset pricing tests and use multiple performance metrics to identify an empirical factor model that builds on these factors and explains the variation in Chinese stock returns. Our main findings are as follows. First, in contrast to what Fama and French (2015) and Hou, Xue, and Zhang (2015) discover in the US stock market, their investment factors do not earn a significant return in the Chinese stock market. Second, the HXZ four-factor model can explain four of the five FF factors, the exception being the value factor. Third, three of the four HXZ factors, namely the size, profitability, and investment factors, cannot be explained by the five FF factors. Fourth, the best performance model is

Table 10 Maximum Sharpe Ratio of Factor Portfolios for the Period 07/2002–12/2015

This table reports the maximum Sharpe ratio for each of the models we study in tables 7 and 8 for the period from July 2002 to December 2015.

Model	Maximum Sharpe Ratio	Mean	Standard Deviation	t-value	Portfolio weights on constituent factors							
					Rm-Rf	**SMB**	**HML**	**RMW**	**CMA**	**ME**	**ROE**	**INV**
1	0.196	0.890	4.537	2.497	0.233	0.767						
2	0.223	0.612	2.748	2.834	0.092	0.528	0.380					
3	0.538	0.484	0.900	6.845	0.062	0.338	0.174	0.426				
4	-0.433	-18.470	42.700	-5.505	-0.704	-12.488	-11.549		25.741			
5	0.439	0.460	1.049	5.584	0.090	0.319		0.489	0.102			
6	0.549	0.621	1.132	6.982	0.067	0.427	0.254	0.444	-0.192			
7	0.272	1.090	4.005	3.464	0.138					0.862		
8	0.636	0.974	1.530	8.101	0.077					0.398	0.525	
9	0.273	1.351	4.949	3.475	0.174					1.081		-0.255
10	0.641	0.880	1.373	8.157	0.069					0.352	0.478	0.101
11	0.725	0.841	1.159	9.230	0.044		0.176			0.368	0.413	
12	0.736	0.941	1.279	9.360	0.046		0.233			0.428	0.448	-0.155
13	0.742	0.936	1.262	9.444	0.048	-0.049	0.238	0.064	-0.167	0.488	0.344	0.034
					Rm-Rf	**SMB**	**HML**	**RMW**	**CMA**	**ME_{XInv}**	**ROE_{XInv}**	**INV**
11'	0.728	0.850	1.167	9.267	0.046		0.198			0.354	0.402	

Table 11 Maximum Sharpe Ratio of Factor Portfolios for the Period 07/2008–12/2015

This table reports the maximum Sharpe ratio for each of the models we study in tables 7 and 8 for the period from July 2008 to December 2015.

Model	Maximum Sharpe Ratio	Mean	Standard Deviation	t-value	Portfolio weights on constituent factors							
					Rm-Rf	**SMB**	**HML**	**RMW**	**CMA**	**ME**	**ROE**	**INV**
1	0.342	1.595	4.670	3.240	0.105	0.896						
2	0.455	0.845	1.858	4.313	0.007	0.559	0.434					
3	0.586	0.609	1.039	5.561	0.046	0.391	0.218	0.346				
4	0.493	1.386	2.814	4.673	0.001	0.931	0.778		-0.709			
5	0.499	0.484	0.970	4.731	0.071	0.279		0.437	0.213			
6	0.587	0.594	1.012	5.565	0.046	0.380	0.208	0.346	0.020			
7	0.411	1.764	4.289	3.902	0.090					0.910		
8	0.766	1.015	1.326	7.262	0.081					0.333	0.586	
9	0.440	0.952	2.162	4.177	0.052					0.454		0.494
10	0.803	0.839	1.044	7.619	0.067					0.267	0.462	0.204
11	0.846	0.916	1.082	8.029	0.051		0.170			0.367	0.413	
12	0.853	0.859	1.008	8.087	0.051		0.136			0.332	0.393	0.088
13	0.870	0.764	0.878	8.249	0.053	-0.320	0.122	0.106	0.207	0.630	0.234	-0.032
					Rm-Rf	**SMB**	**HML**	**RMW**	**CMA**	**ME_{XInv}**	**ROE_{XInv}**	**INV**
11'	0.825	0.938	1.137	7.828	0.050		0.198			0.362	0.390	

comprised of the market factor, the FF value factor, a modified HXZ size factor, and a modified HXZ profitability factor. Fifth, the maximum Sharpe ratio is achieved by investing less than 5% in the market factor, about 20% in the value factor, and roughly the same percentage in the size and profitability factors. Our findings are consistent in the three time periods.

This study's findings provide new evidence on the profitability and investment effects in China and contribute to our understanding of the priced risk factors in China's stock markets. The four-factor model that performs the best in our analysis can serve as a useful benchmark for future empirical analysis of Chinese stock returns.

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