The Profitability and Investment Factors in the Chinese Stock Market

Fangfang Hou[1] and Shaojun Zhang[2]

The Hong Kong Polytechnic University

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 an empirical factor model that builds on these factors and provides an adequate explanation of time-series and cross-sectional variation in Chinese stock returns. Our main findings are the following. First, neither the FF investment factor nor the HXZ investment factor earns a significant return in the Chinese stock market. Second, except for the value factor, the other FF factors can be explained by the HXZ four factors. Third, except for the market factor, the HXZ factors cannot be explained by the FF five factors. Fourth, the best performing model is 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. The findings are consistent in the three time periods we analyze.

JEL classification: G11, G12, G15

Keywords: Chinese stock market, investment factor, profitability factor, Sharpe ratio, value premium

[1] School of Accounting and Finance, Faculty of Business, The Hong Kong Polytechnic University, Kowloon, Hong Kong. Email: fangfang.hou@connect.polyu.hk.

[2] Corresponding author. School of Accounting and Finance, Faculty of Business, The Hong Kong Polytechnic University, Kowloon, Hong Kong. Tel: +852 3400-3458; fax: +852 2330-9845. Email: shaojun.zhang@polyu.edu.hk.

1. Introduction

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).[3] Recent studies find that the three-factor model cannot explain the negative relation between stock return and investment, nor can it explain the positive relation between stock return and firm profitability (e.g., Titman et al. (2004), Fama and French (2006), Liu et al., (2009), Novy-Marx (2013)). Fama and French (2015) add two new factors, an investment factor and a profitability factor, to their three-factor model. The FF five-factor model is specified by the following equation

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

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) provides an explanation of the profitability and investment effects in the valuation theory framework. The value of a firm's stock is the present value of expected dividends,

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

where M_t is the price at time t, $E(D_{t+\tau})$ 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,

[3] The Scientific Background on the Nobel Prize Winners in Economics (2013) includes such comments on the practical implications of the empirical asset pricing research as "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."

D_t, is equity 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

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

Equation (3) makes three predictions about expected stock return. First, everything else being the same, expected return is positively related to book-to-market ratio. Second, everything else being the same, expected return is positively related to expected earnings (profitability). Third, everything else being the same, expected return is negatively related to expected growth in book equity (investment).

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

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

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. Hou, Xue, and Zhang (2015) motivate this empirical model 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 (see, e.g., Liu et al. (2009), Li and Zhang (2010), and Sun et al. (2014)).

In this study, 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. China is the second largest stock market in the world in terms of the total market value. Foreign investors based in Hong Kong can now trade shares listed on the Shanghai Stock Exchange and the Shenzhen Stock Exchange through the cross-exchange connect programs.[4] Carpenter et al. (2015) argues that China's stock market is likely to become "the world's most important crystal ball". An intriguing question is to

[4] The Shanghai-Hong Kong Connect Program started in November 2014, and the Shenzhen-Hong Kong Connect Program started in December 2016.

what extent the empirical factors that are identified in the extant literature for the U.S. stock returns can explain the variation in Chinese stock returns. Our objective is to identify an empirical factor model that builds on these factors and provides an adequate explanation of time-series and cross-sectional variation in Chinese stock returns.

Our main findings are the following. 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%), which is, however, not significantly different from zero. The value factor 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 of the FF size factor.

Second, Fama and French (2015) find that the average return on the value factor HML can be explained by the exposures of HML to other factors. They conclude that "HML is redundant for describing average returns, at least in U.S. data for 1963-2013" (page 12), and suggest "It will be interesting to examine whether this result shows up in 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 Chinese stock returns. We find that, in contrast to the U.S. finding, the value factor is the only FF factor that cannot be explained by the HXZ four factors. The other four FF factors, Rm-Rf, SMB, RMW, and CMA can be explained by the HXZ four-factor model. On the other hand, the FF five-factor model cannot explain the HXZ factors, ME, ROE, and INV.

Third, the momentum factor has a positive average monthly return that is larger than the average return on the other factors, HML, RMW, CMA, and INV. It is however not significantly different from zero. We compare the performance of the FF three-factor model, the FF five-factor model, and the HXZ four-factor model in explaining the momentum factor. We find that the momentum factor has a significantly positive intercept in the FF three-factor model, whereas the intercepts in both the FF five-factor model and the HXZ four-factor model are insignificant.

Fourth, we follow the methodology in Fama and French (2015) to construct three sets of test assets, each set consisting of 25 portfolios. The first set is constructed by sorting on size and book-to-market ratio, the second set on size and profitability, and the third set on 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 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 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 the alphas to the dispersion of the mean returns, **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, **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 candidate models.

Fifth, we follow Brilas and Shanken (2016) and Fama and French (2016) to 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. Brilas and Shanken (2016) and Fama and French (2016) argue 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 less than 5% in the market factor, about 20% in the value factor, and roughly the same percentage in the size and profitability factors.

Moreover, after Chinese stock markets were established in 1991, several significant changes have happened that had significant market-wide effects. Three of them are particularly relevant for our analysis: (1) the set of modern accounting regulations became effective in January 1998; (2) the Chinese listed firms started to issue financial reports on a quarterly basis since 2002; (3) most of the Chinese listed firms completed their Share-Structure Reform by the end of 2006. Hence, we analyze return patterns over three different time periods, 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.

2. 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 in the Chinese listed firms were held by government agencies or government-related enterprises, and were non-tradable in the public market. The Chinese government started the Share-Structure Reform in April 2005 to legally convert non-tradable shares to be tradable. Most of the Chinese listed firms completed the reform by the end of 2006. However, a substantial number of shares are still restricted from trading because of lock-up agreement. For example, at the end of 2012, more than 60% of A-shares were locked up in about one quarter of the Chinese listed firms.

Second, China set up the Small Medium Enterprise Board (SME) and the Growth Enterprise Board (GEB) in May 2004 and October 2009, hosted by the Shenzhen Stock Exchange. It is unclear whether the GEB and SME listed firms should be included in determining the breakpoints for the size factor in China.

Third, more than 170 Chinese listed firms have issued multiple class shares that have the same cash flow and voting rights but are traded in different markets. Some have A- and B-shares, some have A- and H-shares, while others have A-shares and shares in other foreign markets.[5] For such firms, the market value of A-shares is only part of the firm's total market value, hence dividing the firm's total book value of equity by the market value of A-shares is an incorrect calculation of the book-to-market ratio for A-share investors.

Previous studies do not document evidence on how these features affect the construction and performance of the empirical asset pricing factors in China (see, e.g., Wang and Xu (2004), Chen (2004), Liao and Shen (2008), Liu and Yang (2010), and Mao et al. (2008)). Xu and Zhang (2014) carry out a systematic study and find that these special features have significant effects on the values of the FF three factors and the explanatory power of the FF three-factor model for Chinese stock returns. For example, in 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

[5] Both A and B shares are listed in Chinese domestic exchanges. A-shares are denominated and traded in Yuan while B-shares are denominated and traded in USD or HKD. Foreign individual investors cannot buy A-shares. H-shares are listed in the Hong Kong Stock Exchange. Other foreign countries in which Chinese firms listed their shares include the U.S., the U.K., Singapore, Germany, etc.

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. They also find that the average adjusted R^2 of the FF three-factor model is greater than 93%, which is a substantial improvement over the explanatory power of the market model.

2.2. Data and preliminary statistics

We obtain data about the Chinese listed companies from the CSMAR databases, including financial statement items from the China Stock Market Financial Statements Database and stock return data from the China Stock Market Trading Database. The monthly trading data include the closing price, the stock return with cash dividend reinvested, the total number of shares outstanding, and the total number of tradable shares. The financial statements 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 Shanghai Stock Exchange and the Shenzhen Stock Exchange, 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 book-to-market ratio (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 increases from 18 in 1992 to 174 in 2012.[6] Hence, we use the B/P ratio to replace the B/M ratio in our analysis, but the two terms are used interchangeably in the paper.

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 times the number of the firm's tradable A-shares, while the total market value of a liste firm is the end-of-month A-share market price times the number of the firm's all outstanding A-shares (including both tradable and non-tradable A-shares). Before April 2005, about two-thirds of the outstanding A-shares in the Chinese listed firms were held by government agencies or government-related entities, and were legally prohibited from trading in the public market. The Chinese government started the Share-Structure Reform in April 2005 to convert non-tradable A-shares to be tradable. Xu and Zhang (2004) reports 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.[7]

We calculate the book value of equity of Chinese listed companies in the same way as Fama and French (2015) for US listed companies.[8] Specifically, the book value of equity 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 total liabilities (A002000000). We hand collect the

[6] Table 2 in Xu and Zhang (2014) presents 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.
[7] 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 lockup agreement.
[8] According to Fama and French (2015), the book value of equity of a US listed company is equal to shareholder's equity plus deferred taxes and investment tax credit (if available), minus book value of preferred stock. For shareholder's equity, they use either the value (SEQ) in Compustat, or the sum of common equity (CEQ) plus 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.

book value of preferred stock from the official websites of the Shanghai and Shenzhen Stock Exchanges, 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, minus 1. Fama and French (2015) form the portfolios underlying their 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 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 (2014) form the portfolios underlying 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 for Chinese market, we measure a company's profitability by its quarterly operating profit (B001300000) divided by the book value of equity in the previous financial report.[9]

The new Accounting Regulation for Listed Companies in China became effective in January 1998. Many studies report that Chinese listed firms' financial reports before 1998 have poor earnings quality because of outdated accounting rules, lack of accounting and auditing professionals, and other institutional weaknesses (see, e.g., Chen et al. 1999; Xiang, 1999; Chen et al. 2002). Hence, our analysis starts from 1998. We calculate summary statistics of five variables for 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 at the end of June in that year, the B/M ratio is the book value of equity per share in that year's annual report

[9] The Chinese listed firms started to issue quarterly financial reports in 2002. We use the data from their semi-annual reports in the years before 2002.

divided by the December-end closing price of A-shares, the annual investment is the percentage change in total assets in the year, the annual profitability is the operating profit in the year's annual report divided by the book value of equity in the same year, the 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 companies with non-missing value of each variable and the variable's mean and median across these companies in each year between 1998 and 2014 inclusively.

[Table 1 is about there.]

2.3. Construction of the FF factors in China

We follow Fama and French (1993, 2015) to construct the FF five 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.[10]

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 both the Shanghai Stock Exchange and the Shenzhen Stock Exchange (including the A-shares listed on the

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

Small and Medium Enterprises (SME) Board and the Growth Enterprises Board (GEB)) 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 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 groups form six portfolios that are held from the beginning of July until the end of next 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 returns of the two low B/M portfolios. We follow the recommendation in Xu and Zhang (2014) to 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 the month t value-weighted portfolio return. 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 to include the profitability (RMW) factor and the investment (CMA) factor 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, they are constructed in the same way as HML except that the second sort is on annual profitability or annual investment, respectively. Two new size-related factors, SMB_{PRO} and SMB_{INV}, are obtained as a byproduct of the 2x3 sorts on profitability and investment, respectively. The size factor SMB in the FF five-factor model is redefined to be the average of the three size-related factors, SMB_{BM}, SMB_{PRO}, and SMB_{INV}.

2.4. Construction of the HXZ factors in China

Hou, Xue, and Zhang (2014) 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 Fama and French (2015). To construct the HXZ factors, we follow their procedure by sorting on size, quarterly profitability, and annual investment independently. At the end of June each year, we sort firms into two size groups 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 next 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. We measure a firm's quarterly profitability by the firm's most recently announced quarterly operating profits divided by its book value of equity in the previous financial report.

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 9 small-size stock portfolios minus the average of the value-weighted returns on the 9 big-size stock portfolios. The investment factor INV is the average of the value-weighted returns on the 6 low-investment stock portfolios minus the average of the value-weighted returns on the 6 high-investment stock portfolios. The profitability factor ROE is the average of the value-weighted returns on the 6 high-profitability stock portfolios minus the average of the value-weighted returns on the 6 low-profitability stock portfolios.

To sum up, we list the composition of the FF five factors and the HXZ four factors in Table 2. There are a few differences between the two sets of factors. First, Fama and French (2015) use annual profitability, while HXZ uses quarterly profitability. Second, Fama and French (2015) form portfolios once in a year, while HXZ form portfolios on a monthly basis. Third, the FF size factor SMB uses three 2x3 sorts and involves 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, uses the 2x3x3 sort on size, profitability, and investment.

[Table 2 about here.]

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, the maximum, the first quartile, and the third quartile of the number of stocks over the 198 months between July 1999 and December 2015 inclusively. Panel A reports these statistics for the FF five factors, while Panel B reports these statistics for the HXZ four factors. The FF five factors is built by 2x3 sorts, whereas the HXZ four factors is built by 2x3x3 sorts. Thus the portfolios underpinning the FF five factors tend to have a larger number of stocks than the portfolios for the HXZ four factors. The minimum number of stocks in the portfolios for the FF factors is 69, but only 5 in the portfolios for the HXZ factors.

[Table 3 about here.]

3. Empirical results

3.1. Descriptive statistics of all factors

We study the monthly returns of the FF five factors, the HXZ four factors, and the momentum factor 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. 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 is about there.]

We have a few observations. First, the size factor SMB is the only one of the FF five factors that have a significant mean of monthly returns. The mean return on SMB is 0.93% per month, which is statistically significant with the t-statistic of 2.87. The market factor Rm-Rf has a large mean monthly return of 0.82%, which is, however, 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 have a negative mean return of -0.06%. This is in sharp contrast to the finding in Fama and French (2015) that the investment factor in the U.S. earns positive and statistically significant average 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.

Third, the momentum factor is constructed by sorting stocks into ten deciles at the beginning of each month (i.e., month t) on their cumulative returns from the beginning of month t-7 till the end of month t-2. Stocks in each decile are held for six months from the beginning of month t till the end of month t+5. The momentum factor WML (winner minus loser) is the value-weighted return on the portfolio that long stocks in decile 10 and short stocks in decile 1. WML has a positive monthly return mean 0.49%, which is larger than the mean returns of HML, RMW, CMA, and INV. However, it is not statistically significant.

Fourth, the cumulative values of buying-and-holding these factors over the period between July 1999 and December 2015 are consistent in rank with the mean monthly returns. The size factor ME grows 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. The momentum factor WML is worse than the market factor, producing a cumulative value of only 1.95 dollars. Figure 1 shows the time-series plots of the cumulated values for the FF five factors. Figure 2 shows the time-series plots of the cumulated values for the HXZ four 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, shows steady growth in portfolio value over time. The lines for RMW, CMA, and INV are almost flat throughout the period.

[Figure 1 is about there.]

[Figure 2 is about there.]

At last, 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 being long-short portfolios are designed to remove market influence. Several factor pairs such as the SMB and ME pair, the RMW and ROE pair, the CMA and INV pair, have very large correlation coefficients, more than 0.8. Though the two factors in each pair are constructed in a different way by FF (2015) and HXZ (2015), they capture the effect of the same firm characteristic on stock return. The value factor HML does not have a counterparty in the HXZ four-factor model, and has relatively low correlation with all the other factors. The momentum factor WML has a high correlation with ROE of 0.51, but relative low correlation with the other factors. The profitability factor RMW is significantly correlated all the other factors, except 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 the U.S. 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 is about there.]

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

Table 6 compares the performance of the FF three-factor model, the FF five-factor model, and the HXZ four-factor model in explaining the momentum factor (WML). The intercept is statistically significant only in the FF three-factor model. This finding suggests that momentum returns cannot be explained by the FF three-factor model, but can be explained by the FF five-factor model or the HXZ four-factor model.

[Table 6 is about there.]

In summary, the two investment factors CMA and INV can be explained by other factors. The HXZ four factors can explain the size factor SMB and the profitability factor RMW, but not the value factor HML. The FF five factors cannot explain the HXZ factors, ME and ROE. Next, we try to identify an empirical 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 FF five factors and the HXZ four factors in explaining the Chinese stock return. We follow the methodology in Fama and French (2015) to construct three sets of test assets, each set consisting of 25 portfolios. The first set is constructed by sorting on size and book-to-market 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 book-to-market ratio (B/M). The intersections of the two groups form 25 size-B/M value-weighted portfolios. The second and third sets of portfolios are constructed in the same way except for the second sort being on annual profitability and investment, respectively. The portfolios are held from the beginning of July until the end of next June. We follow Xu and Zhang (2014) to use all Chinese A-shares listed on the Shanghai Stock Exchange and the Shenzhen Stock Exchange (including the shares on the Small and Medium Enterprises (SME) Board and the Growth Enterprises Board (GEB)) in the determination of portfolio breakpoints and use the total value of a firm's tradable A-shares as 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 7 is about there.]

Table 7 below reports the average of the monthly excess returns on each test portfolio from July 1999 to December 2015. Panel A shows strong cross-sectional differences in the Chinese stock returns associated with both size and book-to-market ratio. 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 the return difference between value stocks and growth stocks. The size effect is also strong in both Panel 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 effect does not seem to exist in the smallest size quintile. Panel C does not show any convincing evidence for an investment effect.

Our objective is to identify an empirical factor model that provides 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. *First*, the **GRS** statistic proposed by Gibbons, Ross, and Shanken (1989) tests the null hypothesis that the intercepts for the 25 left-hand-side (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 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 the alphas to the dispersion of the mean returns, **D_a/D_r**, indicates the unexplained proportion of return dispersion across the 25 LHS portfolios.[11] The dispersion of the 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

[11] FF (2015) uses the ratio Avg|a_i|/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 has a small magnitude in the U.S., but it is not small in China. Hence, we choose to subtract the average from each regression alpha and calculate the ratio of the dispersions D_a/D_r.

returns between July 1999 and December 2015. The dispersion of the mean returns, $\mathbf{D_r}$, 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 $\mathbf{D_a/D_r}$ ratio suggests that the model does not provide 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.[12] 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 FF five factors and the HXZ four factors. The first six models are comprised of the FF five factors; each of Models 1 to 5 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 HXZ four factors; each of Models 7 to 9 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 five factors and the HXZ four factors; Model 11 includes two FF factors, Rm-Rf and HML, and two HXZ factors, ME and ROE, while Model 12 includes an additional HXZ factor, INV.

Table 8 reports statistics on these models' performance in explaining returns of the 25 portfolios in each set. Panel A in Table 8 is for the set of 25 portfolios sorted by size and B/M ratio, Panel B for the set of 25 portfolios sorted by size and profitability, and Panel C for the set of 25 portfolios sorted by size and investment.

[Table 8 is about there.]

[12] The fourth metric in FF (2015), $\text{Avg}|\alpha_i^2|/\text{Avg}|\mu_i^2|$, is defined as $\text{Avg}|a_i^2|/\text{Avg}|\bar{r}_i^2|$, corrected for sampling error in the numerator and denominator. FF (2015) suggest that this ratio is "akin to 1–R^2 in the regression of LHS expected returns on the expected returns from a model" (page 10). Therefore, we use Avg(R^2) to replace this metric.

We have the following observations in Table 8. First, for the 25 size-B/M portfolios in Panel A, Model 3 (Rm-Rf SMB HML RMW) has the lowest GRS statistic and the lowest Avg|a_i|, Model 2 (Rm-Rf SMB HML) 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 (Rm-Rf SMB RMW CMA) 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 (Rm-Rf SMB HML RMW) 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).

The best performing models in Table 8 are not satisfactory in view of the factor returns we observe in Table 4. The profitability factor RMW does not have a significant mean return and yet appear in all of the best models. The investment factor CMA has a negative mean return but also appear in the best models in both Panel B and C.

Second, although these metrics do not seem to do particularly well in choosing the best models, they provide some useful guidance in selecting factors. For example, comparing Model 2 with Model 1 in Panel A, it is clear that adding HML improves all of the four metrics substantially; for example, Avg|a_i| goes down from 0.261 to 0.207, D_a/D_r reduces from 0.563 to 0.401, and Avg(R^2) increases from 93.88 to 95.51. This indicates the importance of HML 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 have mixed consequences; it has a positive effect under some metrics but a negative effect under other metrics.

Third, the mixture model (i.e. Model 11) that is comprised of Rm-Rf, HML, ME, and ROE. This model performs better than the models that includes only the HXZ factors (i.e., Models 6-10), but underperform some models that are comprised of the FF five factors.

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. Barillas and Shanken (2016) and Fama and French (2016) advocate another metric of model performance, that is, the maximum Sharpe ratio. For any model with one set of factors, the maximum Sharpe ratio is the Sharpe ratio of the tangency portfolio in the investment opportunity set that is spanned by the factors in the model. They argue that the model with the highest maximum 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 minimize the intercepts in return regressions is equivalent to identifying the portfolio of factors that maximizes the Sharpe ratio. Since factors are portfolios of stocks by construction, they fall within the investment opportunity set spanned by all constituent stocks, so 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 a set of factors that gives the highest possible maximum Sharpe ratio.

For each of the 12 models we discussed in Section 3.3, we calculate the maximum Sharpe ratio of the portfolios that are comprised of the factors in the model. Table 9 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 1-6, the FF five-factor model (i.e. Model 6) has the highest maximum Sharpe ratio. This is expected because the other models have 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) CMA does not earn a significant mean return, 2) the tangency portfolio takes a short position on the investment factor CMA, and 3) its maximum Sharpe ratio (0.525) is only slightly larger than the maximum Sharpe ratio of Model 3 (0.523).

[Table 9 is about there.]

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 the maximum Sharpe ratio (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 not desirable because INV does not earn a significant average return in the Chinese stock market.

In addition to the 12 models in Section 3.3, we consider two more models. Model 13 includes all the factors, and should 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 far off the other models' maximum Sharpe ratios are. 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 building the Chinese factors. Hence, we construct the modified size and profitability factors, ME_{XInv} and ROE_{XInv}, by following the same procedure in HXZ (2015) but sorting on only size and profitability. Model 11' replaces the size and profitability factors, ME and ROE, in Model 11 by the modified factors. Table 9 reports the maximum Sharpe ratio of Model 13 and 11'. It turns out that Model 11' has the highest maximum Sharpe ratio in Table 9, and all the other portfolios fall below the capital market line for 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.

For each of the models in Table 9, 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 Model 12 and 13, but is far better than the other models.

[Figure 3 is about there.]

The results in Tables 8 and 9 suggest that Model 11' is the best performing model. We present additional evidence on Model 11' in Table 10. Panel A reports descriptive statistics on the four factors in Model 11'. The two modified factors, rME_{XInv} and $rROE_{XInv}$, show statistics similar to ME and ROE. Panel B shows that Model 11' can explain the other factors SMB, RMW, CMA, INV, and WML, 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.

[Table 10 is about there.]

3.5. Two other time periods

We repeat our analysis for two other time periods because there were significant market-wide changes in the Chinese stock market in the past. First, the financial reporting frequency changed from semi-annual to quarterly since 2001. The HXZ factors are based on firm profitability in the most recent financial reports. We use semi-annual reports in years before 2001 and quarterly reports from 2001 onwards. We repeat the analysis for the period from July 2002 to December 2015 and present the results in the online Appendix. Table 11 reports the maximum Sharpe ratio for the models under study. Overall, Model 11' is the preferred choice 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 for the period between July 1999 and December 2015.

[Table 11 is about there.]

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 results are presented in Tables A5 to A8 in the Appendix. The value factor HML, the profitability factor RMW, and the momentum factor WML have a negative average return over this period. The size factors SMB and ME, and the profitability factor ROE have significant positive returns. Table 12 reports the maximum Sharpe ratio 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' is still the preferred choice. 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.

[Table 12 is about there.]

4. Summary and conclusion

We analyze Chinese stock returns over three different time periods, July 1999 to December 2015, July 2002 to December 2015, and July 2009 to December 2015. For each period, we construct the five factors in Fama and French (FF, 2015) and the four factors in Hou, Xue, and Zhang (HXZ, 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 the following. First, in contrast to what FF (2015) and HXZ (2015) discover in the U.S. stock market, their investment factors do not earn a significant return in Chinese stock market. Second, the HXZ four-factor model can explain four of the FF five factors, except for the value factor. Third, except for the market factor, the other three HXZ factors cannot be explained by the FF five-factor model. Fourth, the best performing model is 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.

We hope our findings shed new lights on the price formation process in the Chinese stock market and contribute to the understanding of the profitability and investment effects on stock returns. The four-factor model that performs the best in our analysis serves as a useful benchmark for future empirical analysis on Chinese stock returns.

References:

Barillas, F., & Shanken, J. (2016). Which alpha. *Working paper*.

Campbell, J. Y. (2000). Asset pricing at the millennium, *Journal of Finance, 55*, 1515-1567.

Carpenter, J. N., Lu, F., & Whitelaw, R. F. (2015). The real value of China's stock market. *NBER working paper* No. 20957.

Chen, C. J. P., Gul, F. A., & Su, X. (1999). A Comparison of Reported Earnings under Chinese GAAP vs. IAS: Evidence from the Shanghai Stock Exchange. *Accounting Horizons, 13*, 91-111.

Chen, S., Sun, Z., & Wang, Y. (2002). Evidence from China on whether harmonized accounting standards harmonize accounting practices. *Accounting Horizons, 16*, 183-197.

Chen, Z. (2004). Cross-sectional variations and three factors asset pricing model: Empirical evidences from China A share market. *Chinese Journal of Management Science, 6*, 13-18 (in Chinese).

Economic Sciences Prize Committee of the Royal Swedish Academy of Sciences (2013). Understanding Asset Prices: Scientific Background on the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel.

Fama, E. F., & French, K. R. (1993). Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics, 33*, 3-56.

Fama, E. F., & French, K. R. (2006). Profitability, investment, and average returns. *Journal of Financial Economics, 82*, 491–518.

Fama, E. F., & French, K. R. (2015). A five-factor asset pricing model. *Journal of Financial Economics, 116*, 1-22.

Fama, E. F. & French, K. R. (2016). Choosing factors. *Fama-Miller Working Paper*.

Harvey, C. R., Liu, Y., & Zhu, H. (2016). … and the Cross-Section of Expected Returns. *Review of Financial Studies, 29*, 5–68.

Hou, K., Xue, C., & Zhang L. (2015). Digesting anomalies: An investment approach. *Review of Financial Studies, 28*, 650–705.

Li, D., & Zhang, L. (2010). Does q-theory with investment frictions explain anomalies in the cross section of returns. *Journal of Financial Economics, 98*, 297-314.

Liao, L., & Shen, H. (2008). Fama-French three factors model and the effect of the split-share structure reform. *The Journal of Quantitative & Technical Economics, 9*, 117-125 (in Chinese).

Liu, G., & Yang, C. (2010). Application of Fama-French multi-factor model in China's bond market during recent financial crisis. *Journal of Zhejiang University (Science Edition), 4*, 396-400 (in Chinese).

Liu, L. X., Whited, T. M., & Zhang, L. (2009). Investment-based expected stock returns. *Journal of Political Economy, 117*, 1105-1139.

Mao, X., Chen, M., & Yang, Y. (2008). Long-run return performance following listed rights issue: Based on the improved three-factor model. *Journal of Financial Research, 5*, 114-129 (in Chinese).

Novy-Marx, R. (2013). The other side of value: The gross profitability premium. *Journal of Financial Economics, 108*, 1–28.

Sun, L., Wei, K. C. J., & Xie, F. (2014). On the explanations for the gross profitability effect: Insights from international equity markets. *Working paper*.

Titman, S., Wei, K. C. J., & Xie, F. (2013). Market development and the asset growth effect: International evidence. *Journal of Financial and Quantitative Analysis, 48*, 1405-1432.

Wang, F., & Xu, Y. (2004). What determines Chinese stock returns? *Financial Analysts Journal, 60*, 65-77.

Xiang, B. (1998). Institutional factors influencing China's accounting reforms and standards. *Accounting Horizons, 12*, 105-119.

Xu, J., & Zhang, S. (2014). The Fama-French three factors in the Chinese stock market. *China Accounting and Finance Review, 16*, 210-227.

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 in the year, the 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, the annual investment is the percentage change in total assets in the year, the annual profitability is the operating profit in the year's annual report divided by the book value of equity of the same year, the 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 inclusively, this table reports the number of listed firms that have non-missing value of the 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

Table 2. Variable definitions and factor composition

This table gives the definition 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 next June. The six portfolios are labeled as SL, SM, SH, BL, BM, and BH, where S is for small size, B is for big size, L, M, and H stand 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 next 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 stand for the portfolio of small-size, high-profitability, and low-investment firms, the label SMC is for the portfolio of small-size, medium-profitability, and low-investment firms, the label BWA is for the portfolio of big-size, low-profitability, and high-investment firms, and so on.

Table 2. (continued)

	Variable definition	Factor composition
Panel A: the FF five 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	Book-to-market ratio calculated as book equity per share divided by 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: the HXZ four 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 FF five factors and the HXZ four factors

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

Panel A: Size of the portfolios in the formation of the FF five 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 next June. The six portfolios are labeled as SL, SM, SH, BL, BM, and BH, where S is for small size, B is for big size, L, M, and H stand for low, medium, and high B/M ratio, respectively. Similarly, we form six portfolios by independent sorts on size and profitability, and label them as 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 as SC, SM, SA, BC, BM, and BA, where C and A stand for conservative and aggressive investment respectively and M is 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
Minimum	122	182	103	157	175	69	132	149	89
1st quartile	169	230	124	217	235	95	189	199	122
Median	192	258	211	276	263	109	249	254	139
3rd quartile	248	418	233	396	402	149	322	323	170
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
Minimum	124	146	142	78	154	170	84	137	127
1st quartile	147	219	183	111	230	240	116	232	194
Median	231	252	214	122	259	291	134	272	252
3rd quartile	316	344	344	195	395	449	181	388	333
Maximum	402	429	388	240	463	535	256	467	450

Table 3. (continued)

Panel B: Size of the portfolios in the formation of the HXZ four 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 next 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 stand for the portfolio of small-size, high-profitability, and low-investment firms, the label SMC is for the portfolio of small-size, medium-profitability, and low-investment firms, the label BWA is 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
Minimum	62	48	13	29	50	33	12	19	21
1st quartile	97	75	33	53	86	52	22	33	30
Median	132	90	43	69	109	63	29	41	35
3rd quartile	170	115	54	97	139	74	40	65	42
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
Minimum	28	23	5	22	55	38	10	36	42
1st quartile	40	41	25	42	93	69	27	84	90
Median	47	55	33	51	112	87	36	103	132
3rd quartile	68	78	58	66	130	117	51	165	165
Maximum	89	111	93	105	193	166	77	205	244

Table 4. Descriptive statistics of all factors

This table shows the descriptive statistics and correlation of all factors under study. Section 2 describes how the FF five factors and the HXZ four factors are constructed for the Chinese stock market. The momentum factor WML is constructed by sorting stocks into ten deciles at the beginning of each month (i.e., month t) according to their cumulative returns from the beginning of month t-7 till the end of month t-2. Stocks in each decile are held for six months from the beginning of month t till the end of month t+5. The momentum factor WML (winner minus loser) is the value-weighted return on the portfolio that long stocks in decile 10 and short stocks in decile 1. 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**	**WML**
Panel A: Descriptive statistics									
# of Observations	198	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	0.49
Standard Deviation	8.45	4.55	3.57	3.57	2.12	3.98	3.49	1.69	5.49
t-statistics	1.37	2.87	0.93	0.49	-0.42	4.00	3.00	1.68	1.24
Sharpe Ratio	0.10	0.20	0.07	0.03	-0.03	0.28	0.21	0.12	0.09
Cumulative Wealth	2.50	5.08	1.41	1.13	0.84	7.92	3.86	1.45	1.95
Panel B: Spearman rank correlation coefficients									
Rm-Rf	1.00	0.15	0.13	-0.41	0.18	0.12	-0.30	0.10	-0.14
SMB		1.00	-0.36	-0.74	0.52	0.98	-0.70	0.26	-0.21
HML			1.00	-0.05	0.30	-0.42	0.00	0.37	-0.21
RMW				1.00	-0.77	-0.66	0.87	-0.48	0.37
CMA					1.00	0.42	-0.65	0.86	-0.30
ME						1.00	-0.59	0.22	-0.16
ROE							1.00	-0.28	0.51
INV								1.00	-0.15
WML									1.00

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 details in Section 2. Each row reports the coefficients from one regression and the t-statistics in the 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 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)			

Table 5. (continued)

Panel C: Using the FF five 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 HXZ factors to explain 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)		

Table 6. Explaining the momentum factor

This table compare the performance of the Fama-French three factor model, and the Fama-French five factor model, and the HXZ four factor models in explaining the momentum factor (WML). Section 2 describes how these factors are constructed for the Chinese stock market. The momentum factor is described in Table 4. The sample period is from July 1999 to December 2015.

Model	Intercept	Rm-Rf	HML	SMB	RMW	CMA	ME	ROE	INV	R^2	Adj. R^2
1	0.95**	-0.03	-0.37***	-0.46***						0.144	0.130
	(2.54)	(-0.59)	(-4.40)	(-4.21)							
2	0.52	0.05	-0.05	-0.42***	0.78***	0.47				0.191	0.170
	(1.30)	(1.02)	(-0.33)	(-3.03)	(3.34)	(1.53)					
3	-0.61	0.02					0.30***	1.02***	-0.06	0.295	0.280
	(-1.58)	(0.54)					(2.86)	(8.16)	(-0.29)		

Table 7. 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 size and book-to-market 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 book-to-market ratio (B/M). We calculate market cap as the total number of outstanding A-shares multiplied by its June closing price. We calculate the book-to-market ratio at the end of June year t as the book value of equity per share for year t-1 divided by A-share closing price at the end of December 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 being 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 being 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 next 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 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: Sorted by size and book-to-market					
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: Sorted by size and profitability					
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: Sorted by size and investment					
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

Table 8. 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 book-to-market ratio, the second set on size and profitability, and the third set on size and investment. Table 6 provides the details about the constructions of these portfolios. We compare 12 models that builds on the FF five factors and the HXZ four factors for Chinese stock market. Section 2 describes how the FF five factors and the HXZ four factors are constructed for 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 the alphas to the dispersion of the mean returns, **D_a/D_r**, indicates the unexplained proportion of return dispersion across 25 LHS portfolios. The dispersion of the 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 the 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

Table 8. (continued)

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

Table 9. Maximum Sharpe ratio of factor portfolios

Barillas and Shanken (2016) and Fama and French (2016) advocate 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 8 for the period from July 1999 to December 2015. We also include two additional models, Model 13 and Model 11'. Model 13 includes all 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-statistic**	**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	

Table 10. The best model

Model 11' turns out to be the best model in Table 9. 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 variable	**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)		
WML	-0.36	0.03	0.21*	0.85***	-0.19*	0.279	0.264
	(-0.88)	(0.63)	(1.76)	(6.77)	(-1.68)		

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

Table 11. 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 8 and 9 for the period from July 2002 to December 2015.

Model	Maximum Sharpe Ratio	Mean	Standard Deviation	t-statistic	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 12. 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 8 and 9 for the period from July 2008 to December 2015.

Model	Maximum Sharpe Ratio	Mean	Standard Deviation	t-statistic	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	

Figure 1. Cumulative wealth of the FF five 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 FF five factors until the end of December 2015.

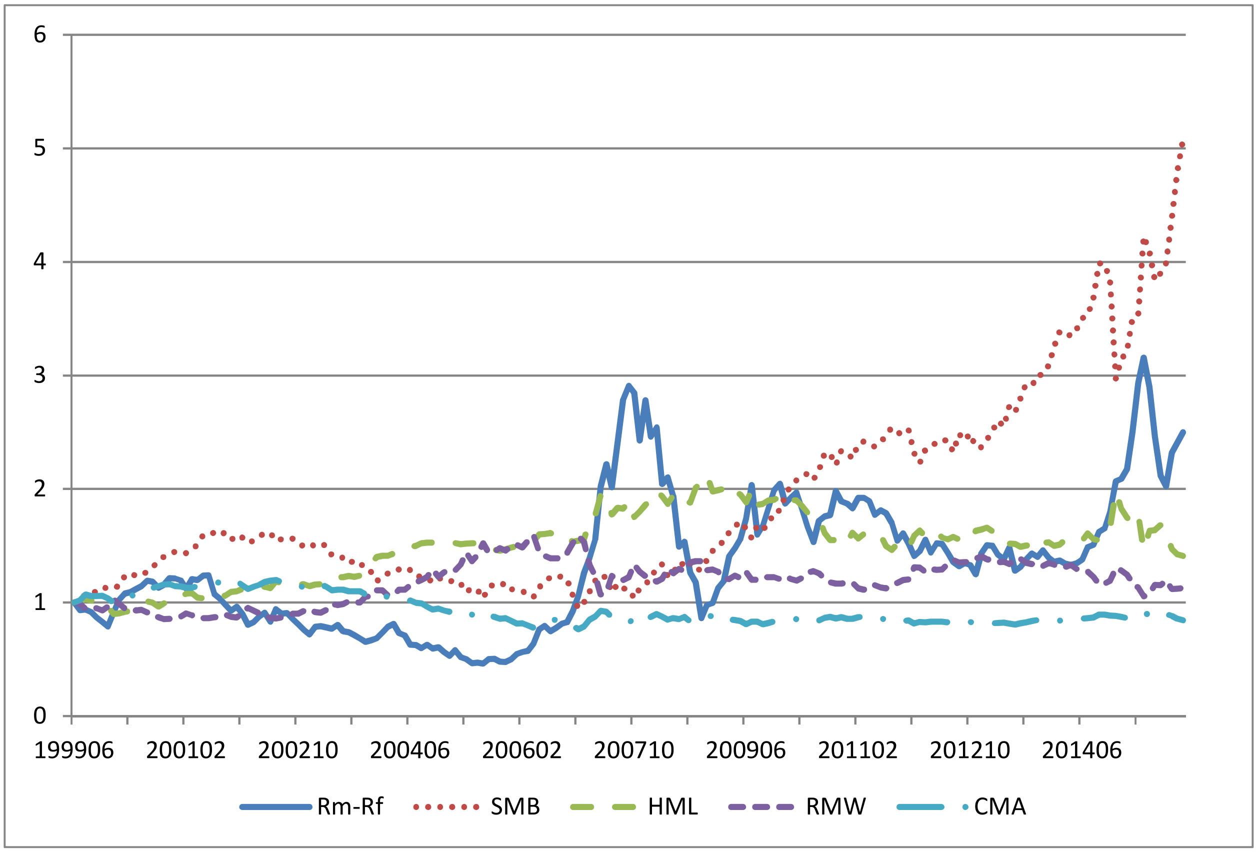

Figure 2. Cumulative wealth of the HXZ four factors

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 HXZ four factors until the end of December 2015.

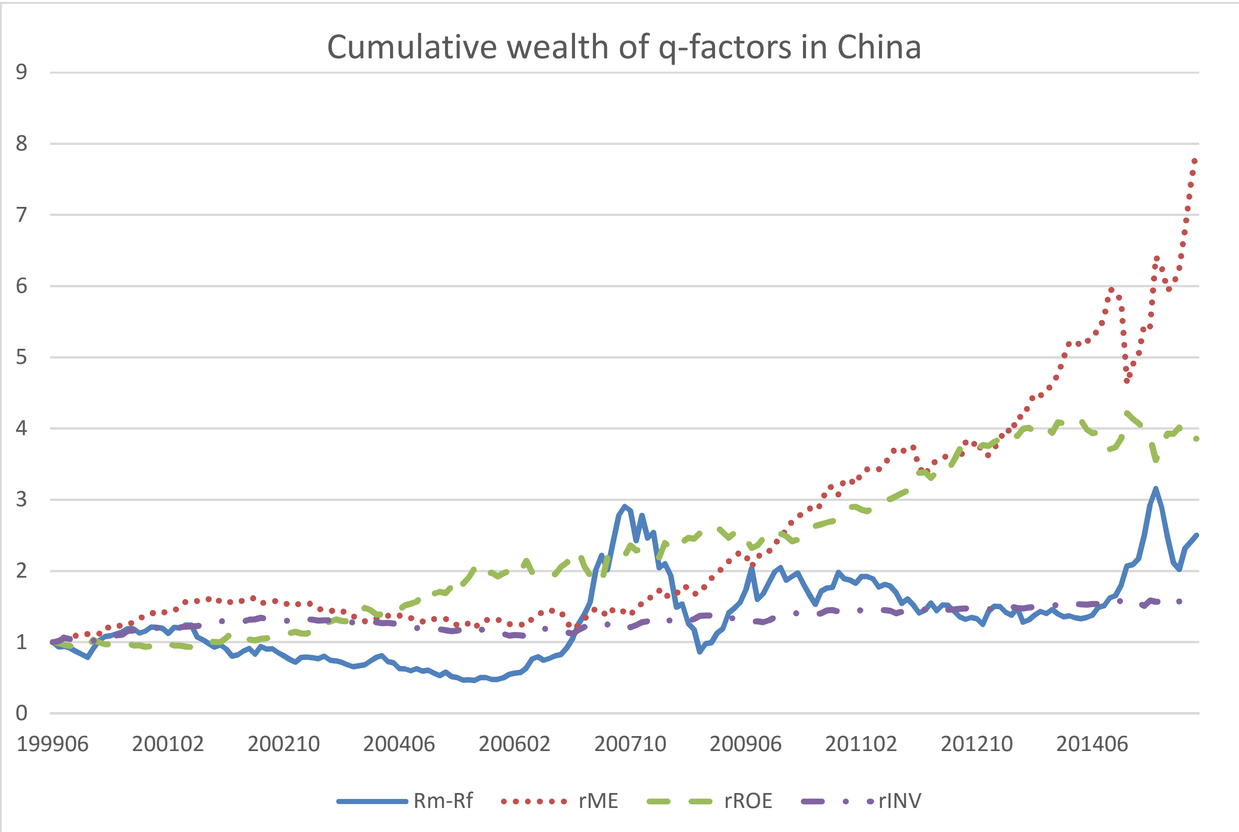

Figure 3. Location of tangency portfolios on the mean-standard deviation plot

For each of the models in Table 9, 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.