A Composite Four-Factor Model in China

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Abstract

We investigate investors' overreaction and underreaction and their implications to asset pricing in China stock market. The study first picks anomaly variables representing investors' overreaction and underreaction and then measures these two effects quantitatively. Both of them deliver significant excess returns, both statistically and economically, in China stock market. We then equip these two effects with the market and the size factor to construct a composite four-factor model and study how they price other assets. Extensive empirical analysis shows that this new model is suitable for China stock market. The maximum annual Sharpe ratio spanned by the four factors is 2.02, which is one time higher than those spanned by similar models such as Stambaugh and Yuan (2017) and Daniel, Hirshleifer and Sun (2020). In addition, using 149 anomaly candidates as test assets, the composite four-factor model exhibit good pricing capability, as there is only one test asset whose abnormal return given the model exceeds the 3.0 t-statistic threshold.

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1 Introduction

Classical asset pricing theory suggests that the excess returns of anomalies/factors come from the compensation for bearing systemic risks. In recent years, however, academia has found a large number of anomalies with significant excess returns, but can not provide them with a convincing risk-based explanation, which poses a great challenge to this argument. The development and advancement of behavioral finance, on the other hand, just complements this gap. In particular, behavioral finance says that investors are of limited rationality, and it is their systematic behavioral biases that lead to the common movement of stock returns. In this perspective, the reason behind anoamlies' excess returns is mispricing. In addition to the theoretical motivation, empirical evidence also shows that incorporating behavioral finance in asset pricing is helpful to expand the mean-variance efficient frontier[1].

Given the promising outlook of behavioral finance in asset pricing, a lot of important and insightful studies emerged in the last decade. Nevertheless, most of them, if not all, are about the US stock market. However, whether these findings are helpful in other markets remains a question. China is of extreme importance among those other markets. First of all, it is playing a much more significant role than ever before in terms of total market value[2] and has attracted much attention. For the latter, China's stock market has been included in many mainstream global stock indexes successively in recent years. Second, compared with institutional investors, retail investors are more likely to be subject to behavioral biases. This makes the China A-share market, whose investor structure has been dominated by retail investors for a long time, a natural carrier for the study of behavioral finance. Understanding how asset prices move through the lens of behavioral finance is also of great helpful to build better investment strategies in China stock market. As a result, we study the relationship between investors' behavior and asset prices in this paper.

A good starting point is to ask whether we can borrow the experience of the US stock market directly. For empirical asset pricing about the US stock market, there are two groundbreaking studies from the perspective of behavioral finance, and they are Stambaugh and Yuan (2017) and Daniel, Hirshleifer and Sun (2020). Both of them propose factor models that are deeply rooted in behavioral finance, and they describe the cross-section well in the US stock market. However, for

[1]Daniel, Hirshleifer and Sun (2020) show that adding behavioral finance factors to existing risk factors could improve the maximum Sharpe ratio spanned.

[2]According to WIND database, China's A-Share stock market has become the second largest stock market all over the world, with a total market value of 86.9 trillion RMB or equivalently 6.52 trillion USD at the end of December 2020.

the two reasons discussed below, we believe that they are not necessarily suitable for China stock market, and a new research angle for our target market is required.

1. Stambaugh and Yuan (2017) do not clearly explain the relationship between their PERF and MGMT factors and investors' behavioral biases. On the other hand, Daniel, Hirshleifer and Sun (2020) emphasize long-term financing-related behavioral biases by proposing the FIN factor. However, since stock buyback is uncommon in China A-share market, the impact of their FIN factor on asset pricing is very limited in China.

2. Behavioral biases mean that investors' response to new information is not as perfect as what is implied by the rational expectation model, but instead they either overreact or underreact. In particular, investors' overreaction in China stock market is widely acknowledged. Moreover, many empirical asset pricing studies indicate that many prominent anomalies are closely related to either overreaction (He, Wang and Yu 2021) or underreaction (Chen et al. 2021). To name a few, these anomalies include momentum (Barberis, Shleifer and Vishny 1998), long-term reversal (Hong and Stein 1999), value (Daniel, Hirshleifer and Subrahmanyam 1998, 2001), and PEAD (Hirshleifer, Lim and Teoh 2009).

Given the above reasons, we in this paper study how investors' overreaction and underreaction affect asset pricing in China stock market. Particularly, based on China A-share market data from January 2000 to May 2021, we analyze in detail the impact of investors' underreaction and overreaction on stocks' expected returns. To start with, we select a group of firm characteristics closely related to underreaction and overreaction according to the existing literature, and then define a score for each of them by averaging the anomaly variables of each group. Such a score indicates to what extent each stock is subject to investors' overreaction or underreaction. Using these scores as sorting variables allows us to futher construct long-short portfolios of the two and their excess returns quantify the magnitude of investors' overreaction and underreaction in China stock market. We further test the pricing ability of these two effects by considering them as pricing factors. In this regard, we equip them with the market and the size factors to construct a composite four-factor model and investigate how it prices other assets. The results reveal the ability of behavioral finance in explaining the cross-section of expected stock returns in China.

The empirical results show that both overreaction and underreaction effects are very significant statistically and economically in China. For overreaction, the average monthly excess return of the long-short portfolio is 2.01% (t-statistic=7.45) under equal weighting and 1.24% (t-statistic=3.20) under market-cap weighting, respectively. For underreaction, the monthly excess return of the long-short portfolio is 1.16% (t-statistic=4.29) under equal weighting and 0.91% (t-statistic=2.39) under market-cap weighting, respectively. The above results imply that overreaction is stronger than underreaction, which is consistent with the investor structure in China as retail investors tend to exhibit overreaction to the news. More importantly, unlike some anomalies whose excess returns mainly come from the short-leg or small-cap stocks, the returns of the long-leg of both effects are also very significant economically and statistically, and the average market value of the long-legs are large with good liquidity. This means that investors can effectively obtain the premium of these two effects in practice, and therefore these findings are of great value to practitioners.

As we turn to study the composite four-factor model, the monthly excess returns of the overreaction and underreaction factors are 1.14% (t-statistic=5.53) and 0.77% (t-statistic=4.20), respectively. In order to test the four-factor model, we then conduct a further test based on the methodology of Barillas and Shanken (2017), and the results reveal that the annualized maximum Sharpe ratio spanned by the factors contained in the model is as high as 2.02, which doubles those of Daniel, Hirshleifer and Sun (2020) three-factor model and Stambaugh and Yuan (2017) four-factor model. In addition, we further take a total of 149 potential anomaly candidates from 11 categories as test assets and find that the composite four-factor model has a satisfactory ability to explain the expected returns of the test assets. When the classical 2.0 is used as the threshold, the number of significant anomalies is 18. If we further take multiple hypotheses testing into account and choose 3.0 as the threshold based on the suggestion of Harvey, Liu and Zhu (2016), the number of anomalies that remain significant is sharply reduced to only 1. In all cases, the performance of this model is better than the two behavioral finance factor model, i.e., Stambaugh and Yuan (2017) four-factor model and Daniel, Hirshleifer and Sun (2020) three-factor model, which are proposed for the US stock market. The results confirm the necessity of using a research angle that is suitable for China stock market, instead of borrowing existing research that focuses on a different market.

The rest of the paper unfolds as follows. Section 2 introduces the data used in the empirical study of the paper. Section 3 explains how we select candidate variables and construct the scores for overreaction and underreaction. The excess returns of the two effects are tested. Section 4 proposes the composite four-factor model that consists of market, size, overreaction, and underreaction and tests how they price other assets. Section 5 concludes.

2 Data

We collect data from the WIND database (www.wind.com.cn), which is one of the most authoritative databases of Chinese financial markets. The dataset ranges from January 1st, 2000 to May 31st, 2021. The beginning of the sample is picked for the same reasons as explained by Liu, Stambaugh and Yuan (2019). First, the accounting standards of China have changed dramatically since 1999. Second, there were few listed companies to ensure enough stocks for the construction of anomaly or factor long-short portfolios before 2000.

The stocks considered in this paper are all China A-Share stocks. However, we impose some additional filters considering the unique features of China stock market. First, stocks under special treatment, i.e., the ST stocks, are excluded. Most of these firms have trouble with their business operating, and institutional investors are often not permitted to invest in such stocks. Besides, most of them have low liquidity and low value. Second, we exclude stocks going public within the past 12 months at the time of each sorting. Finally, we eliminate stocks whose trading has been suspended and those stocks have stayed at the limit up for a whole day, on the day of calculation. The purpose of this step is to eliminate those stocks that can not be traded at rebalancing dates and make the results of this paper more practical. We also conduct empirical studies following the conventions in academic studies without filtering out these stocks. The primary results are unchanged, and therefore we do not report those results in this paper. All these filters are put inplace using point-in-time data to ensure the analysis is free of look-ahead bias. More details on data are available in appendix A. For more background about China stock market, we refer to the overview of Hu, Pan and Wang (2020).

3 Measure Overreaction and Underreaction

3.1 Candidate Variables

The difficulty in studying investors' overreaction and underreaction is that they are unobservable. As a result, it is necessary to use appropriate proxy variables. In the past, extensive behavioral finance research has shown that mispricing caused by overreaction and underreaction is the root behind many stock market anomalies. Along this line of thinking, we pick representative anomalies that are explained by each group and use their anomaly variables to measure overreaction and underreaction. Based on existing literature and given the availability of data in the China stock market, we select five anomalies for each of overreaction and underreaction, respectively. Table 1 summarizes the variable, the original literature, and the calculation note of each anomaly.

Table 1: Candidate anomaly variables to measure overreaction and underreaction

This table summarizes the variable, the source, and the calculation note for each candidate variable for measuring overreaction or underreaction. More data processing instruction is given in appendix A.

Variable	Source	Note
Panel A: Overreaction		
Book-to-Market ratio (BM)	Fama and French (1992)	use the most recent quarterly book value
Short-term reversal (STR)	Jegadeesh (1990)	the cumulative return of the past 21 trading days
Idiosyncratic volatility (IVOL)	Ang et al. (2006)	calculate using residual of Fama and French (1993) three-factor model of the past 21 trading days
MAX	Asness et al. (2020)	the average of five largest daily returns of the past 21 trading days
Abnormal turnover (ABTO)	Liu, Stambaugh and Yuan (2019)	the ratio between average daily turnover of the past 21 trading days to that of the past 252 trading days
Panel B: Underreaction		
Standardized unexpected earnings (SUE)	Foster, Olsen and Shevlin (1984)	calculate using the earnings data from the last 12 quarters
ROA	Novy-Marx (2013)	gross profit to total assets of trailing 12 months
Accruals	Sloan (1996)	accruals to total assets of trailing 12 months
Momentum (MOM)	Jegadeesh and Titman (1993)	the cumulative return of the past 252 trading days (excluding the past 21 trading days)
Liquidity shock (LIQ)	Bali et al. (2014)	the liquidity shock of the past 252 trading days

Since most of these anomalies are proposed for the US stock market, we first test if they deliver significant excess returns in China. At the end of each month, we sort stocks into deciles based on a given candidate variable. Before sorting, each variable is sign-adjusted so that it is positively correlated with stock returns according to the literature. Then a long-short dollar-neutral portfolio is constructed by going long the top decile and simultaneously going short the bottom decile. We consider both equal weighting and market-cap weighting. In the latter case, we use total market value, i.e., price multiplied by the number of all the outstanding A shares, including nontradable shares.

Table 2: Portfolio sort test results of overreaction-related anomalies

This table reports monthly excess returns (%) of five overreaction-related anomalies, including BM, STR, IVOL, MAX, and ABTO. To construct each anomaly, we first sort stocks into deciles based on the given sign-adjusted anomaly variable, then build a long-short dollar-neutral portfolio by going long the top decile and simultaneously going short the bottom decile. Panel A gives the results under equal weighting, while Panel B presents the results under market-cap weighting. The numbers in the parentheses underneath the returns are the Newey and West (1987) adjusted t-statistics. The dataset ranges from January 1st, 2000 to May 31st, 2021.

BM	STR	IVOL	MAX	ABTO
Panel A: Equal weighting				
0.94	1.53	1.67	1.11	1.41
(2.94)	(5.49)	(8.59)	(4.78)	(5.28)
Panel B: Market-cap weighting				
0.80	0.97	0.92	0.60	0.92
(1.79)	(2.59)	(2.50)	(1.73)	(2.52)

Table 3: Portfolio sort test results of underreaction-related anomalies

This table reports monthly excess returns (%) of five underreaction-related anomalies, including SUE, ROA, Accruals, MOM and LIQ. To consturct each anomaly, we first sort stocks into deciles based on the given sign-adjusted anomaly variable, then build a long-short dollar-neutral portfolio by going long the top decile and simultaneously going short the bottom decile. Panel A gives the results under equal weighting, while Panel B presents the results under market-cap weighting. The numbers in the parentheses underneath the returns are the Newey and West (1987) adjusted t-statistics. The dataset ranges from January 1st, 2000 to May 31st, 2021.

SUE	ROA	Accruals	MOM	LIQ
Panel A: Equal weighting				
1.21	0.49	0.29	0.03	0.85
(5.84)	(1.85)	(2.20)	(0.10)	(3.52)
Panel B: Market-cap weighting				
0.89	0.60	0.36	0.25	0.34
(2.99)	(1.93)	(1.83)	(0.62)	(0.95)

Tables 2 and 3 provide the portfolio sort test results for overreaction and underreaction related anomalies, respectively, with Panel A using equal weighting and Panel B using market-cap weighting. In each cell, the number in the first row is the return, while the number in the second row is the Newey and West (1987) adjusted t-statistic. It is worth mentioning that because each anomaly variable has been sign-adjusted according to its relationship with stock returns before sorting, we expect the monthly excess return of the anomaly to be positive. For overreaction, all anomalies obtain significant excess returns under equal weighting. For example, the average monthly return of short-term reversal is 1.53% with a t-statistic of 5.49. When instead market-cap weighting is used, most of the overreaction-related anomalies are still significant but their performances weaken, indicating that they are affected by small-cap stocks. As we move on to examine the underreaction-related anomalies, overall speaking, their excess returns in China stock market are not as significant as those related to overreaction. Due to the high proportion of retail investors in China, it is expected that investors' overreaction is more severe than underreaction, and therefore the above results are consistent with this expectation. Nevertheless, some of the underreaction-related anomalies can still deliver significant excess returns. In addition, the weighting schema has less influence on the underreaction-related anomalies, as once we switch from equal weighting to market-cap weighting, their excess returns do not vary too much.

To summarize, we see from empirical evidence shown in Tables 2 and 3 that for both overreaction or underreaction, the selected anomalies exhibit positive excess returns in China stock market. Although some anomalies are less significant than the rest, we choose to retain all five anomalies of each group for the investigation that follows, rather than further screening variables purely based on the empirical results. This allows us to minimize the in-sample p-hacking concern[3]. On the other hand, combining multiple variables is also helpful to ensure the robustness of the empirical results.

3.2 Overreaction and Underreaction Scores

Given the empirical results of section 3.1, this section describes how to construct the overreaction and underreaction scores, which in turn will be used as the sorting variable to form long-short portfolios for the two effects. To derive a final score that combines the five anomalies of each group, we follow the practice of Stambaugh and Yuan (2017). Specifically, at the end of each month, we go through the following four steps to derive comprehensive scores for overreaction and underreaction:

1. Adjust the sign of each anomaly variable so that it is positively correlated with stock returns in theory, that is, the higher the value, the higher the expected return.

[3] See for example Harvey (2017), Harvey, Liu and Saretto (2020), and Chordia, Goyal and Saretto (2020) for a thorough discussion about the p-hacking issue in financial economics and empirical asset pricing.

2. Convert the value of each anomaly variable into ranking. The higher the ranking, the higher the score.

3. Average the ranking of five anomaly variables of each group and the average rank is taken as the final score of overreaction or underreaction for a given stock.

Again, once we have the scores, stocks are sorted into deciles, and the long-short portfolios for both overreaction and underreaction are formed by going long the top decile while going short the bottom decile. It is worth emphasizing that overreaction is negatively correlated with future returns, while underreaction is positively correlated to future returns. Therefore, for overreaction, stocks in the top decile are those investors overreact the least, while stocks in the bottom decile are those investors overreact the most. As a result, the long-leg of the overreaction portfolio consists of stocks with the weakest investors' overreaction while its short-leg has stocks with most severe investors' overreaction. On the contrary, for underreaction, stocks in the top decile are those investors underreact the most, while stocks in the bottom decile are those investors underreact the least. Consequently, the long-leg of the underreaction portfolio consists of stocks with the strongest investors' underreaction while its short-leg consists of stocks with the weakest investors' underreaction. Table 4 shows descriptive statistics of the ten groups for each of overreaction and underreaction.

Comparing the results of Panel A and Panel B in Table 4, we can see that for both overreaction and underreaction, their scores are positively correlated with the average market capitalization. As discussed before, for the former, a lower score indicates more severe overreaction, which means that small-cap stocks are more prone to investors' overreaction than larg-cap stocks. In contrast, for the latter, a higher score implies stronger underreaction, which means that large-cap stocks are more likely to be subject to investors' underreaction than small-cap stocks. Besides, overreaction score is negatively correlated with turnover rate and volatility, while underreaction score has no clear relationship with them. Finally, the price-to-book ratio (the reciprocal of book-to-market ratio) decreases with the overreaction score. This is expected as the book-to-market ratio is one of the anomaly variables used to construct the score. Similarly, ROA increases with underreaction score, because ROA is one of the anomaly variables to define underreaction score. With these scores, we are in a good position to test the overall overreaction and underreaction effects in China stock market.

Table 4: Descriptive statistics of overreaction and underreaction deciles

This table reports the descriptive statistics of overreaction and underreaction deciles, respectively. Panel A shows results for overreaction, while Panel B shows results for underreaction. The measures considered consist of market capitalization, average turnover calculated using past 252 trading days, annual volatility, price-to-book ratio (P/B), which is the reciprocal of the book-to-market ratio, and ROA. The value in each cell is the time-series average of a particular group for a specific measure. The dataset ranges from January 1st, 2000 to May 31st, 2021.

	Low	2	3	4	5	6	7	8	9	High
Panel A: Overreaction										
market cap (billion RMB)	9.18	9.76	10.61	10.49	10.65	11.82	12.58	13.60	15.14	17.79
turnover (%)	3.69	3.37	3.30	3.24	3.17	3.11	3.02	2.94	2.80	2.66
volatility (%)	50.18	48.21	47.41	46.73	45.98	45.28	44.58	43.67	42.57	41.26
P/B	9.11	6.04	6.17	5.37	4.91	4.79	4.18	4.23	3.42	2.89
ROA (%)	3.85	3.96	3.99	3.96	4.03	4.14	3.86	3.69	3.53	3.19
Panel B: Underreaction										
market cap (billion RMB)	8.86	10.38	10.70	11.27	11.82	12.42	12.65	13.52	13.82	16.18
turnover (%)	2.98	3.02	3.08	3.11	3.15	3.16	3.19	3.20	3.20	3.17
volatility (%)	45.56	45.29	45.45	45.49	45.51	45.52	45.65	45.68	45.67	45.75
P/B	4.45	4.84	4.93	4.89	4.39	4.99	5.10	5.18	5.55	6.96
ROA (%)	1.30	2.05	2.58	2.92	3.17	3.62	4.14	4.96	5.90	7.51

3.3 Test Overreaction and Underreaction Effects

Tables 5 and 6 summarize the portfolio sort test results based on overreaction and underreaction scores, respectively. In addition to deciles, the monthly excess return of the long-short hedged portfolio (High−Low) is also provided. With equal weighting, the effects of both overreaction and underreaction are very significant. For overreaction, its monthly excess return is 2.01% with a t-statistic of 7.45, while for underreaction, its monthly excess return is 1.16% with a t-statistic of 4.29. When we switch to market-cap weighting, both of them have varying degrees of attenuation. Specifically, for overreaction, its monthly excess return is 1.24% with a t-statistic of 3.20, while for overreaction, its monthly excess return is 0.91% with a t-statistic of 2.39. However, despite of the attenuation, they are still economically and statistically significant. The results also show that in China stock market, exploiting overreaction can achieve higher excess expected returns than utilizing underreaction.

Table 5: Portfolio sort test results for overreaction

This table reports monthly excess returns (%) of ten overreation decile portfolios as well as the long-short portfolio of overreaction (High−Low). The long-short portfolio is constructed by going long the top decile (High) and simultaneously going short the bottom decile (Low). Panel A gives the results under equal weighting, while Panel B presents the results under market-cap weighting. The numbers in the parentheses underneath the returns are the Newey and West (1987) adjusted t-statistics. The dataset ranges from January 1st, 2000 to May 31st, 2021.

Low	2	3	4	5	6	7	8	9	High	High−Low
Panel A: Equal weighting										
−0.17	0.62	0.99	1.27	1.36	1.58	1.71	1.77	1.84	1.84	2.01
(−0.26)	(0.92)	(1.44)	(1.88)	(2.05)	(2.29)	(2.56)	(2.66)	(2.74)	(2.71)	(7.45)
Panel B: Market-cap weighting										
0.00	0.43	0.71	0.74	1.19	1.16	1.11	1.36	1.00	1.23	1.24
(0.00)	(0.63)	(1.12)	(1.22)	(1.87)	(1.98)	(1.85)	(2.10)	(1.83)	(2.16)	(3.20)

Table 6: Portfolio sort test results for underreaction

This table reports monthly excess returns (%) of ten underreation decile portfolios as well as the long-short portfolio of underreaction (High−Low). The long-short portfolio is constructed by going long the top decile (High) and simultaneously going short the bottom decile (Low). Panel A gives the results under equal weighting, while Panel B presents the results under market-cap weighting. The numbers in the parentheses underneath the returns are the Newey and West (1987) adjusted t-statistics. The dataset ranges from January 1st, 2000 to May 31st, 2021.

Low	2	3	4	5	6	7	8	9	High	High−Low
Panel A: Equal weighting										
0.71	0.99	0.99	1.19	1.23	1.30	1.36	1.54	1.61	1.88	1.16
(0.99)	(1.42)	(1.43)	(1.77)	(1.77)	(1.93)	(2.06)	(2.40)	(2.50)	(3.02)	(4.29)
Panel B: Market-cap weighting										
0.52	0.62	0.40	0.58	0.57	0.44	1.08	0.91	1.19	1.43	0.91
(0.74)	(0.94)	(0.59)	(0.89)	(0.92)	(0.75)	(1.93)	(1.60)	(2.96)	(2.49)	(2.39)

Besides the usual hedged portfolios, the long-legs of the two effects also deserve some discussion. From asset pricing literature, we can see that there are many anomalies whose excess returns mainly come from the short-leg or small-cap stocks. However, this is not the case for either overreaction or underreaction. The long-legs of both effects can also deliver significant excess returns. Moreover, recall from the descriptive statistics of Table 4 that the average market capitalization of both long-legs are large, which ensures good liquidity. This means that investors can effectively obtain the excess return of these two effects in practice.

Table 7: Double sort test results for overreaction and underreaction

This table reports monthly excess returns (%) of independent double sort tests. In each double sort, the first variable is either overreaction or underreaction, while the second one is one of market capitalization, turnover, volatility, and book-to-market ratio. We group stocks into quartiles independently using each of the two variables, which gives 25 portfolios. The long-short portfolio of overreaction or underreaction given each quartile of the second variable is constructed, and its excess return is calculated. The average of the five returns from the five quartiles of the chosen second variable is finally used as the monthly excess return for overreaction or underreaction, and is reported in the corresponding cell in this table. Panel A gives the results under equal weighting, while Panel B presents the results under market-cap weighting. The numbers in the parentheses underneath the returns are the Newey and West (1987) adjusted t-statistics. The dataset ranges from January 1st, 2000 to May 31st, 2021.

	market capitalization	turnover	volatility	book-to-market
Panel A: Equal weighting				
overreaction	1.63 (7.76)	1.53 (7.00)	1.55 (6.80)	1.70 (7.62)
underreaction	1.08 (5.99)	0.97 (4.79)	0.97 (4.91)	1.14 (6.54)
Panel B: Market-cap weighting				
overreaction	1.61 (7.49)	1.00 (3.74)	0.98 (3.70)	1.05 (3.67)
underreaction	1.09 (6.07)	0.89 (3.89)	0.98 (3.86)	1.09 (4.90)

Next, in order to examine whether other common risk factors in China stock market have any potential impact on overreaction and underreaction, we also run independent double sort test, with overreaction or underreaction being the first variable while one of market capitalization, turnover, volatility, and book-to-value ratio is used as the second variable. We group stocks into quartiles independently using each of the two variables, which gives 25 portfolios. The long-short portfolio of overreaction or underreaction given each quartile of the second variable is constructed and its excess return is calculated. The average of the five returns from the five quartiles of the chosen second variable is finally used as the monthly excess return for overreaction or underreaction. Table 7 exhibits the average excess returns of overreaction and underreaction across five quartiles of a given second variable, while Appendix B provides detailed double-sorting test results. No matter if we use equal weighting or market-cap weighting, for both overreaction and underreaction, the monthly excess returns obtained by double sorting are very significant, both statistically[4] and economically. Moreover, the results confirm that for overreaction, its excess return is reduced once

[4] Most of the t-statistics exceed the 3.0 threshold (Harvey, Liu and Zhu 2016) by a high margin.

market-cap weighting is used as compared to equal weighting, suggesting that the overreaction is more common among small-cap stocks. On the other hand, however, the monthly excess return of underreaction is not sensitive to the chosen weighting schema.

4 A Composite Four-Factor Model

We in this section examine how we can use overreaction and underreaction reported in Section 3 to study the cross-section of stock returns in China stock market. To do this, we propose a composite four-factor model and test its pricing power.

4.1 The Model

Since Fama and French (1993) three-factor model, the use of linear factor models to study asset pricing has made great progress. As of today, academia has proposed about 10 multi-factor models for the US stock market[5], among which there are some important factor models derived from the perspective of behavioral finance, such as Stambaugh and Yuan (2017) four-factor model and Daniel, Hirshleifer and Sun (2020) three-factor model. Empirical asset pricing results about the US stock market indicates that the addition of factors from behavioral finance to existing risk factors can improve mean-variance efficient frontier, and this suggests the necessity of behavioral factors.

On the contrary, the only factor models specifically proposed for China stock market are Liu, Stambaugh and Yuan (2019) three/four-factor models. Their model largely inherits the spirit of Fama and French (1993) model, yet with some important distinction. First, their value factor is constructed by using earnings-to-price ratio instead of book-to-market ratio used by Fama and French (1993)[6]. Moreover, the 30% stocks with the smallest market capitalization are removed from the stock pool to eliminate the well known shell-value contamination issue that is specific to China stock market. Liu, Stambaugh and Yuan (2019)'s model exhibits good pricing ability in China for the period from 2000 to 2016. Nevertheless, as it is a tailored version of Fama and French (1993) for China, the model does not offer understanding about asset pricing from the perspective of behavioral finance. Therefore, it is particularly important to fill the gap and this becomes the motivation for us to propose the composite model in this paper.

[5]The readers are referred to Hou et al. (2019) for a comprehensive factor model comparison.

[6]This is, however, to some extent a data driven choice given the performance deterioration of book-to-market ratio to construct the value factor. See Liu, Shi and Lian (2019) for a comprehensive analysis of the BM ratio and its several refinements in China stock market.

The four-factor model considered here consists of the market factor (MKT), the size factor (SMB), the overreaction factor (Over) and the underreaction factor (Under):

$$\mathrm{E}[R_i^e] = \beta_{i,\mathrm{MKT}}(\mathrm{E}[R_M] - R_f) + \beta_{i,\mathrm{SMB}}\mathrm{E}[R_{\mathrm{SMB}}] + \beta_{i,\mathrm{Over}}\mathrm{E}[R_{\mathrm{Over}}] + \beta_{i,\mathrm{Under}}\mathrm{E}[R_{\mathrm{Under}}] \quad (1)$$

where $\beta_{i,\mathrm{MKT}}$, $\beta_{i,\mathrm{SMB}}$, $\beta_{i,\mathrm{Over}}$ and $\beta_{i,\mathrm{Under}}$ are stock i's exposure to the four factors respectively. To construct factors, we follow Fama and French (2015). In particular, the market factor is the market portfolio in excess of the risk free rate. The formation of the other three factors are stated below (unlike Fama and French (2015) which rebalance portfolios annually, we instead perform sorting and rebalance portfolios on a monthly basis given the high turnover ratio in China stock market than the US market):

1. Take the median market capitalization of all stocks listed on the main board as the size breakpoint, and divide all stocks into two groups according to their market capitalizations: small (S) and big (B).

2. Take the 30% and 70% quantiles of the overreaction scores of all stocks as break points, and divide all stocks into three groups: low overreaction (LO), medium overreaction (MO) and high overreaction (HO).

3. Take the 30% and 70% quantiles of the underreaction scores of all stocks as break points, and divide all stocks into three groups: low underreaction (LU), medium underreaction (MU) and high underreaction (HU).

4. Interact the two size groups with the three overreaction and three underreaction groups respectively, and this generates 12 basis portfolios: S/LO, S/MO, S/HO, B/LO, B/MO, B/HO, S/LU, S/MU, S/HU, B/LU, B/MU, and B/HU. Each basis portfolio is rebalanced monthly, and stocks in each group are weighted by market capitalization.

Using the above basis portfolios, the overreaction (Over), underreaction (Under) and size (SMB) factors are constructed as follows:

$$\mathrm{Over} = \frac{1}{2}(\mathrm{S/HO} + \mathrm{B/HO}) - \frac{1}{2}(\mathrm{S/LO} + \mathrm{B/LO}) \quad (2)$$

$$\mathrm{Under} = \frac{1}{2}(\mathrm{S/HU} + \mathrm{B/HU}) - \frac{1}{2}(\mathrm{S/LU} + \mathrm{B/LU}) \quad (3)$$

$$
\begin{aligned}
\text{SMB} &= \frac{1}{2}(\text{SMB}_{\text{Over}} + \text{SMB}_{\text{Under}}) \\
\text{where } \text{SMB}_{\text{Over}} &= \frac{1}{3}(\text{S/HO} + \text{S/MO} + \text{S/LO}) - \frac{1}{3}(\text{B/HO} + \text{B/MO} + \text{B/LO}) \qquad (4) \\
\text{SMB}_{\text{Under}} &= \frac{1}{3}(\text{S/HU} + \text{S/MU} + \text{S/LU}) - \frac{1}{3}(\text{B/HU} + \text{B/MU} + \text{B/LU})
\end{aligned}
$$

Table 8 reports the test results of the monthly average excess returns for the four factors[7]. For both overreaction and underreaction factors, their monthly excess returns are very significant. Specifically, the former is 1.14% with a t-statistic of 5.53, and the latter is 0.77% with a t-statistic of 4.20. The excess returns of the market factor and the size factor are 0.79% and 0.65% respectively.

Table 8: Factor premium of the composite four-factor model

This table reports factor monthly excess returns (%) of the composite four-factor model. The factors are constructed following Fama and French (2015). The numbers in the parentheses underneath the returns are the Newey and West (1987) adjusted t-statistics. The dataset ranges from January 1st, 2000 to May 31st, 2021.

MKT	SMB	Over	Under
0.79	0.65	1.14	0.77
(1.35)	(1.92)	(5.53)	(4.20)

4.2 Test the Model

We employee two prevailing methods to test the pricing ability of the proposed four-factor model. The first test follows the idea of Barillas and Shanken (2017). In particular, we compute the ex-post maximum annual Sharpe ratio spanned by the four factors of the model. To put the result in perspective provide, we also construct the two behavioral finance factor models proposed for the US market, i.e., the Stambaugh and Yuan (2017) four-factor model and the Daniel, Hirshleifer and Sun (2020) three-factor model, with the same China A-share data as our benchmark. It should be noted, however, that since these two models are not proposed for China stock market, it is not quite an apple-to-apple comparison. The purpose of including them in the comparison is simply to provide a good starting point. The maximum annual Sharpe ratios

[7]In unreported results, we also construct factors using single variable portfolio sort which is common in industry practice. The qualitative results remain the same.

spanned by the three models are shown in Table 9. The results show that, compared with the models proposed for the US stock market, the factors in the composite four-factor model span a much higher Sharpe ratio. Specifically, the maximum annual Sharpe ratio spanned by market, size, overreaction, and underreaction factors is 2.02, which doubles those spanned by the other two models. This emphasizes the importance to study the China stock market from a suitable angle.

Table 9: Maximum annual Sharpe ratios

This table reports the maximum annual Sharpe ratios spanned by different factor models, including the composite four-factor model proposed in this paper, the Stambaugh and Yuan (2017) four-factor model, and the Daniel, Hirshleifer and Sun (2020) three-factor model. The dataset ranges from January 1st, 2000 to May 31st, 2021.

model	maximum annual Sharpe ratio
The composite four-factor model	2.02
Stambaugh and Yuan (2017)	0.98
Daniel, Hirshleifer and Sun (2020)	0.80

In the second approach, we run time-series spanning tests to analyze how the composite four-factor model prices other assets. To do this, we prepare an extensive collection of anomaly candidates proposed by asset pricing literature and use them as test assets. To ensure the empirical analysis as comprehensive as possible, we use 149 test assets from 11 major style categories, including value (15), low-risk (17), profitability (18), earnings quality (16), growth (14), investment (17), operation (10), composite score (15), liquidity (8), momentum and reversal (16), and other (3). These test assets cover almost all the categories found by academia, so they can fully test the model.

Before testing the model, we must first check if these test assets can generate significant excess returns in the absence of a pricing model. To do so, we sign-adjust each sorting variable, construct the long-short portfolio, and test its average return for each test asset. Since the sorting variables are sign-adjusted, we expect them to exhibit positive excess returns. Otherwise, a negative excess return means that the empiricial evidence for the variable in China stock market contradicts the financial or economic theory related to that variable. Table 10 summarizes the descriptive statistics of t-statistics of these 149 test assets.

The results of Table 10 shows that not all of the test assets' excess returns are positive. As a matter of fact, a large fraction of test assets is not valid in China stock market. As we turn to those

Table 10: Descriptive statistics of t-statistics of 149 test assets

This table reports the descriptive statistics of the t-statistics of the 149 test assets. The t-statistics are Newey and West (1987) adjusted. Since the sorting variables are sign-adjusted, only a positive t-statistic implies that the empirical evidence of the variable is consistent with theory in China stock market. The dataset ranges from January 1st, 2000 to May 31st, 2021.

min	25%	50%	75%	max	#(t-statistic$\geq$ 2.0)	#(t-statistic$\geq$ 3.0)
-2.87	0.01	0.91	1.91	4.47	35	9

who deliever significant excess returns, if we choose the traditional 2.0 threshold for t-statistics, 35 out of 149 test assets stand out, without the usage of any pricing model. They become the test bases for our subsequent analysis to test factor models. Having said that, we must also point out that given the multiple hypotheses test concern, a 2.0 threshold does not necessarily indicate the validity of a test asset. Therefore, we apply the double-bootstrap method proposed by Harvey and Liu (2020) to calculate another threshold specific to these test assets. The new threshold raises the bar from 2.0 to 3.0, which is consistent with Harvey, Liu and Zhu (2016). With this new threshold, 9 out of 149 test assets are considered significant. In what follows, we use 3.0 along with 2.0 as t-statistic thresholds for identifying significant test assets' abnormal returns given a pricing model when we test factor models.

With the 35 anomalies whose excess returns' t-statistics exceed 2.0 as test assets, we run time-series regression of a given test asset on the factors of a given factor model, and report the t-statistic of the abnormal return of that given test asset. Once again, Stambaugh and Yuan (2017) four-factor model and Daniel, Hirshleifer and Sun (2020) three-factor models are considered here to provide a starting point, yet we focus the discussion on the pricing ability of the proposed composite four-factor model. Table 11 summarizes the time-series spanning test result.

Table 11: Time-series spanning test

This table reports numbers of significant test assets given different factor models, including the composite four-factor model proposed in this paper, the Stambaugh and Yuan (2017) four-factor model, and the Daniel, Hirshleifer and Sun (2020) three-factor model. Two t-statistic thresholds for the abnormal return are considered, and they are 2.0 and 3.0. The dataset ranges from January 1st, 2000 to May 31st, 2021.

model	#(t-statistic$\geq$2.0)	#(t-statistic$\geq$3.0)
The composite four-factor model	18	1
Stambaugh and Yuan (2017)	28	7
Daniel, Hirshleifer and Sun (2020)	23	5

With the proposed factor model, the numbers of anomalies under 2.0 and 3.0 thresholds are 18 and 1, respectively. On the contrary, those numbers given by Stambaugh and Yuan (2017) four-factor model and the Daniel, Hirshleifer and Sun (2020) three-factor model are 28 and 7, and 23 and 5, respectively. The comparison shows that the new composite model is capable of pricing a lot of anomalies, especially when the threshold raises to 3.0, after adjustment due to mitigating p-hacking concerns. The overall empirical tests conducted in this section indicate that the proposed factor model is capable to describe the cross-section of China stock market.

5 Conclusion

In China stock market, the investor structure is dominated by retail investors, and this implies that there are potentially a lot of mispricing in the stock prices. This paper first quantitatively studies overreaction and underreaction in China stock market and examines how they can be used to understand the cross-section of expected stock returns. As overreaction and underreaction are hard to be observed directly, five representative anomalies are selected, and the corresponding anomaly variables are used as proxy variables to measure overreaction and underreaction. Empirical tests confirm that the chosen variables are suitable for China. Overall scores for both overreaction and underreaction are calculated by averaging the five variables of each group. Portfolio sort tests suggest that both of them can achieve significant excess returns in China, and the results are robust to double sort test after we control for common risk factors.

Next, based on the above results, this paper proposes a composite four-factor model including market, size, overreaction and underreaction factors. This model provides new insights on understanding the cross-section from the lens of behavioral finance for China stock market. To test the model, we consider both Barillas and Shanken (2017) test and the usual time-series spanning test with a comprehensive set of 149 test assets across 11 major style categories. Empirical results show that the newly proposed model can price other assets very well, and the number of anomalies whose t-statistics exceed a 3.0 threshold reduces to only 1.

As for future research, overreaction and underreaction can be used to understand some prominent differences between US and China stock markets. For example, momentum is a prevailing anomaly in the US while it only weakly exists in China. Since the investor structures are quite different in these two markets, it is expected that overreaction and underreaction could play a potential role in resolving the puzzle. In this regard, overreaction and underreaction is particularly important, and they can help us better understand the expected returns of different anomalies or factors in China stock market.

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A Data Processing

This appendix provides details about the data source and data processing considered in this paper. We collect all stock trading data and relevant financial data from the WIND database. We consider all China A-share stocks from both the Shanghai and Shenzhen exchanges. Our risk-free rate comes from RESSET database, which is a financial database used widely in academic studies in China. RESSET uses different types of interest rates to represent the risk-free rate during different subperiods. Specifically, three-month deposit rate is used for days before August 6th, 2002, the coupon rate of three-month central bank bills is used for periods between August 7th, 2002 and October 7th, 2006, and three-month Shanghai Interbank offered rate (SHIBOR) is used since October 8th, 2006. The risk-free rate constructed by RESSET is widely accepted as it reflects the benchmark interest rate in China accurately. Our sample period is January 1st, 2000 through May 31st, 2021.

Considering that events such as dividends payout and split or merge of firms can have a huge impact on the calculation of stock returns, we calculate stock returns based on adjusted price data. The adjusted price for a stock is the price after adjustments for all applicable split and dividend distribution, hence, stock returns calculated based on these price data are reliable.

We also carefully deal with those abnormal stock returns data. Under most circumstances, the daily return should be between -10% and 10%, for stocks listed in China stock market due to the daily price limits. However, some stocks may have daily returns out of the limits due to abnormal trading activities. We winsorize daily returns that fall out of daily limits.

We calculate the 1-month indicators and 1-year indicators based on the data of past 21 and 252 trading days, respectively. We further require that stocks are tradable on at least two-thirds of the days when we calculate these indicators based on stock trading data. For example, when calculating the 1-month volatility, we require that a stock is tradable on at least 14 trading days over the last 21 trading days.

Finally, we use the most recent data available before the calculation dates when we construct anomaly and factor portfolios. As WIND provides the release dates of financial reports, this is applicable in practice. Importantly, as firms may adjust data after the release of original reports, we carefully keep track of all historical data and release date of each report to ensure that we only use the data available at calculation, and the whole calculation is free of the look-ahead bias.

B Double-Sort Test Results

This appendix provides details about double-sort test results. In each test, the first sorting variable is either overreaction or underreaction, while the second one is one of market capitalization, turnover, volatility, and book-to-market ratio. Tables B.1 to B.8 provide the results.

Table B.1: Overreaction and market capitalization double sort test

This table reports the independent double sort test results of overreaction and market capitalization. We group stocks into quartiles independently using overreaction and market capitalization, which gives 25 portfolios. The long-short portfolio of overreaction given each market capitalization quartile is constructed and its excess return is calculated. The average of the five returns from the five market capitalization quartiles is finally used as the monthly excess return for overreaction. Panel A gives the results under equal weighting, while Panel B presents the results under market-cap weighting. The numbers in the parentheses underneath the returns are the Newey and West (1987) adjusted t-statistics. The dataset ranges from January 1st, 2000 to May 31st, 2021.

	Over Low	2	3	4	High	High−Low
Panel A: Equal weighting						
market-cap Low	0.44 (0.62)	1.83 (2.49)	2.19 (2.93)	2.56 (3.47)	2.83 (3.84)	2.40 (9.44)
2	0.20 (0.28)	1.07 (1.50)	1.64 (2.36)	1.87 (2.62)	2.28 (3.26)	2.09 (9.70)
3	0.11 (0.16)	0.98 (1.38)	1.32 (1.90)	1.69 (2.44)	1.76 (2.47)	1.65 (6.71)
4	0.08 (0.12)	0.88 (1.28)	1.07 (1.61)	1.21 (1.86)	1.29 (1.90)	1.21 (4.43)
High	0.27 (0.40)	0.75 (1.15)	0.98 (1.50)	1.14 (1.81)	1.08 (1.76)	0.81 (2.73)
average	0.22 (0.33)	1.10 (1.62)	1.44 (2.13)	1.69 (2.52)	1.85 (2.73)	1.63 (7.76)
Panel B: Market-cap weighting						
market-cap Low	0.38 (0.53)	1.81 (2.46)	2.15 (2.87)	2.51 (3.4)	2.79 (3.8)	2.41 (9.73)
2	0.19 (0.26)	1.06 (1.49)	1.61 (2.33)	1.86 (2.62)	2.28 (3.26)	2.10 (9.62)
3	0.11 (0.17)	0.98 (1.38)	1.31 (1.9)	1.68 (2.42)	1.74 (2.44)	1.62 (6.58)
4	0.07 (0.11)	0.89 (1.29)	1.06 (1.61)	1.19 (1.82)	1.28 (1.88)	1.21 (4.40)
High	0.28 (0.41)	0.71 (1.10)	1.06 (1.66)	1.22 (1.97)	0.99 (1.63)	0.71 (2.15)
average	0.21 (0.31)	1.09 (1.61)	1.44 (2.16)	1.68 (2.54)	1.82 (2.69)	1.61 (7.49)

Table B.2: Underreaction and market capitalization double sort test

This table reports the independent double sort test results of underreaction and market capitalization. We group stocks into quartiles independently using underreaction and market capitalization, which gives 25 portfolios. The long-short portfolio of underreaction given each market capitalization quartile is constructed and its excess return is calculated. The average of the five returns from the five market capitalization quartiles is finally used as the monthly excess return for underreaction. Panel A gives the results under equal weighting, while Panel B presents the results under market-cap weighting. The numbers in the parentheses underneath the returns are the Newey and West (1987) adjusted t-statistics. The dataset ranges from January 1st, 2000 to May 31st, 2021.

	Under Low	2	3	4	High	High−Low
Panel A: Equal weighting						
market-cap Low	1.59 (2.15)	1.86 (2.52)	2.26 (3.02)	2.40 (3.35)	2.49 (3.46)	0.90 (5.76)
2	1.05 (1.42)	1.28 (1.82)	1.28 (1.81)	1.66 (2.50)	2.14 (3.14)	1.09 (5.57)
3	0.51 (0.71)	0.90 (1.32)	1.18 (1.69)	1.47 (2.10)	1.79 (2.71)	1.28 (6.53)
4	0.23 (0.33)	0.63 (0.94)	0.82 (1.2)	0.96 (1.46)	1.57 (2.54)	1.34 (5.17)
High	0.45 (0.66)	0.44 (0.66)	0.57 (0.87)	0.81 (1.33)	1.24 (1.98)	0.79 (2.70)
average	0.77 (1.09)	1.02 (1.51)	1.22 (1.79)	1.46 (2.22)	1.85 (2.87)	1.08 (5.99)
Panel B: Market-cap weighting						
market-cap Low	1.54 (2.08)	1.81 (2.46)	2.2 (2.95)	2.36 (3.29)	2.45 (3.4)	0.91 (5.81)
2	1.05 (1.43)	1.27 (1.8)	1.25 (1.77)	1.64 (2.47)	2.14 (3.15)	1.09 (5.50)
3	0.50 (0.69)	0.87 (1.28)	1.17 (1.68)	1.46 (2.09)	1.80 (2.71)	1.30 (6.53)
4	0.18 (0.26)	0.61 (0.92)	0.81 (1.19)	0.95 (1.46)	1.59 (2.56)	1.40 (5.43)
High	0.51 (0.76)	0.37 (0.54)	0.59 (0.91)	0.79 (1.36)	1.23 (1.95)	0.72 (2.26)
average	0.76 (1.08)	0.99 (1.46)	1.20 (1.78)	1.44 (2.23)	1.84 (2.87)	1.09 (6.07)

Table B.3: Overreaction and turnover double sort test

This table reports the independent double sort test results of overreaction and turnover. We group stocks into quartiles independently using overreaction and turnover, which gives 25 portfolios. The long-short portfolio of overreaction given each turnover quartile is constructed and its excess return is calculated. The average of the five returns from the five turnover quartiles is finally used as the monthly excess return for overreaction. Panel A gives the results under equal weighting, while Panel B presents the results under market-cap weighting. The numbers in the parentheses underneath the returns are the Newey and West (1987) adjusted t-statistics. The dataset ranges from January 1st, 2000 to May 31st, 2021.

	Over Low	2	3	4	High	High−Low
Panel A: Equal weighting						
turnover Low	0.63	1.14	1.48	1.59	1.68	1.05
	(0.98)	(1.77)	(2.26)	(2.48)	(2.58)	(4.06)
2	0.62	1.25	1.51	1.88	1.91	1.30
	(0.89)	(1.79)	(2.27)	(2.64)	(2.78)	(4.92)
3	0.60	1.20	1.48	1.85	2.10	1.50
	(0.85)	(1.70)	(2.16)	(2.72)	(2.86)	(5.53)
4	0.10	1.22	1.41	1.65	1.90	1.80
	(0.14)	(1.76)	(2.02)	(2.49)	(2.80)	(7.95)
High	−0.27	0.98	1.46	1.71	1.73	2.01
	(−0.40)	(1.38)	(2.12)	(2.47)	(2.47)	(7.32)
average	0.33	1.15	1.47	1.73	1.87	1.53
	(0.50)	(1.70)	(2.19)	(2.59)	(2.73)	(7.00)
Panel B: Market-cap weighting						
turnover Low	0.60	0.90	1.15	1.20	1.08	0.47
	(0.84)	(1.52)	(1.87)	(1.96)	(1.95)	(1.16)
2	0.38	0.75	1.29	1.20	1.21	0.83
	(0.55)	(1.15)	(2.05)	(1.81)	(2.03)	(2.29)
3	0.50	0.81	1.08	1.46	1.50	1.00
	(0.70)	(1.15)	(1.6)	(2.32)	(2.13)	(3.37)
4	0.07	0.72	1.10	1.39	1.44	1.37
	(0.11)	(1.04)	(1.63)	(2.18)	(2.27)	(4.03)
High	−0.33	0.75	1.09	1.38	0.98	1.31
	(−0.49)	(1.04)	(1.61)	(1.99)	(1.47)	(3.85)
average	0.23	0.79	1.14	1.32	1.24	1.00
	(0.37)	(1.21)	(1.83)	(2.14)	(2.04)	(3.74)

Table B.4: Underreaction and turnover double sort test

This table reports the independent double sort test results of underreaction and turnover. We group stocks into quartiles independently using underreaction and turnover, which gives 25 portfolios. The long-short portfolio of underreaction given each turnover quartile is constructed and its excess return is calculated. The average of the five returns from the five turnover quartiles is finally used as the monthly excess return for underreaction. Panel A gives the results under equal weighting, while Panel B presents the results under market-cap weighting. The numbers in the parentheses underneath the returns are the Newey and West (1987) adjusted t-statistics. The dataset ranges from January 1st, 2000 to May 31st, 2021.

	Under Low	2	3	4	High	High−Low
Panel A: Equal weighting						
turnover Low	1.12 (1.55)	1.29 (1.88)	1.21 (1.87)	1.32 (2.17)	1.73 (2.99)	0.61 (1.89)
2	1.18 (1.64)	1.15 (1.62)	1.53 (2.20)	1.62 (2.51)	1.95 (2.94)	0.77 (3.24)
3	0.89 (1.23)	1.17 (1.68)	1.51 (2.15)	1.74 (2.54)	2.04 (3.02)	1.15 (5.21)
4	0.65 (0.92)	1.01 (1.50)	1.15 (1.66)	1.55 (2.31)	1.73 (2.69)	1.09 (5.23)
High	0.28 (0.4)	0.82 (1.18)	1.02 (1.44)	1.15 (1.69)	1.54 (2.26)	1.25 (5.62)
average	0.83 (1.17)	1.09 (1.59)	1.28 (1.88)	1.48 (2.27)	1.80 (2.82)	0.97 (4.79)
Panel B: Market-cap weighting						
turnover Low	0.84 (1.2)	0.83 (1.25)	0.63 (1.06)	0.94 (1.66)	1.23 (1.97)	0.38 (0.98)
2	0.76 (1.14)	0.47 (0.67)	0.92 (1.45)	1.10 (1.97)	1.41 (2.21)	0.66 (1.94)
3	0.57 (0.78)	0.59 (0.83)	0.92 (1.42)	1.39 (2.05)	1.60 (2.45)	1.03 (3.48)
4	0.25 (0.36)	0.46 (0.68)	0.68 (0.99)	1.12 (1.69)	1.30 (2.2)	1.06 (3.61)
High	−0.1 (−0.15)	0.33 (0.48)	0.41 (0.56)	0.75 (1.12)	1.20 (1.78)	1.31 (4.92)
average	0.46 (0.69)	0.54 (0.81)	0.71 (1.13)	1.06 (1.76)	1.35 (2.23)	0.89 (3.89)

Table B.5: Overreaction and volatility double sort test

This table reports the independent double sort test results of overreaction and volatility. We group stocks into quartiles independently using overreaction and volatility, which gives 25 portfolios. The long-short portfolio of overreaction given each volatility quartile is constructed and its excess return is calculated. The average of the five returns from the five volatility quartiles is finally used as the monthly excess return for overreaction. Panel A gives the results under equal weighting, while Panel B presents the results under market-cap weighting. The numbers in the parentheses underneath the returns are the Newey and West (1987) adjusted t-statistics. The dataset ranges from January 1st, 2000 to May 31st, 2021.

	Over Low	2	3	4	High	High−Low
Panel A: Equal weighting						
volatility	0.56	1.09	1.26	1.42	1.64	1.08
Low	(0.93)	(1.75)	(2.00)	(2.29)	(2.62)	(3.74)
2	0.47	1.27	1.45	1.84	2.05	1.56
	(0.74)	(1.9)	(2.22)	(2.74)	(2.92)	(5.32)
3	0.50	1.18	1.65	1.98	1.98	1.48
	(0.74)	(1.66)	(2.41)	(2.85)	(2.83)	(6.04)
4	0.36	1.22	1.45	1.81	2.00	1.65
	(0.51)	(1.72)	(2.02)	(2.55)	(2.74)	(6.59)
High	−0.18	0.94	1.56	1.75	1.79	1.98
	(−0.26)	(1.3)	(2.17)	(2.46)	(2.46)	(7.02)
average	0.35	1.14	1.47	1.76	1.89	1.55
	(0.53)	(1.69)	(2.19)	(2.61)	(2.74)	(6.80)
Panel B: Market-cap weighting						
volatility	0.55	0.73	1.01	1.12	1.25	0.70
Low	(0.81)	(1.22)	(1.62)	(2.01)	(2.19)	(1.83)
2	0.59	1.05	1.35	1.44	1.48	0.89
	(0.86)	(1.71)	(2.33)	(2.40)	(2.26)	(2.52)
3	0.57	0.85	1.15	1.75	1.44	0.87
	(0.84)	(1.28)	(1.80)	(2.48)	(2.06)	(2.73)
4	0.21	0.79	1.15	1.29	1.38	1.17
	(0.29)	(1.11)	(1.62)	(1.83)	(1.95)	(3.60)
High	−0.14	0.65	1.30	1.60	1.15	1.30
	(−0.21)	(0.90)	(1.81)	(2.25)	(1.72)	(3.76)
average	0.36	0.81	1.20	1.44	1.34	0.98
	(0.54)	(1.28)	(1.91)	(2.28)	(2.08)	(3.70)

Table B.6: Underreaction and volatility double sort test

This table reports the independent double sort test results of underreaction and volatility. We group stocks into quartiles independently using underreaction and volatility, which gives 25 portfolios. The long-short portfolio of underreaction given each volatility quartile is constructed and its excess return is calculated. The average of the five returns from the five volatility quartiles is finally used as the monthly excess return for underreaction. Panel A gives the results under equal weighting, while Panel B presents the results under market-cap weighting. The numbers in the parentheses underneath the returns are the Newey and West (1987) adjusted t-statistics. The dataset ranges from January 1st, 2000 to May 31st, 2021.

	Under Low	2	3	4	High	High−Low
Panel A: Equal weighting						
volatility	1.11	1.09	1.23	1.37	1.78	0.68
Low	(1.65)	(1.68)	(1.92)	(2.33)	(2.98)	(2.92)
2	1.05	1.30	1.54	1.60	2.08	1.04
	(1.52)	(1.90)	(2.26)	(2.47)	(3.40)	(4.33)
3	1.10	1.25	1.55	1.68	1.91	0.81
	(1.52)	(1.75)	(2.20)	(2.55)	(2.93)	(3.48)
4	0.59	1.07	1.36	1.57	1.84	1.25
	(0.82)	(1.55)	(1.85)	(2.23)	(2.63)	(5.39)
High	0.33	0.63	0.78	1.23	1.38	1.05
	(0.44)	(0.90)	(1.13)	(1.74)	(2.02)	(4.16)
average	0.83	1.07	1.29	1.49	1.80	0.97
	(1.19)	(1.57)	(1.89)	(2.28)	(2.82)	(4.91)
Panel B: Market-cap weighting						
volatility	0.94	0.64	0.76	1.06	1.51	0.57
Low	(1.38)	(1.01)	(1.25)	(1.97)	(2.58)	(1.69)
2	0.67	0.90	0.95	1.05	1.79	1.11
	(1.08)	(1.31)	(1.59)	(1.80)	(2.89)	(3.28)
3	0.75	0.60	1.06	1.37	1.42	0.66
	(1.06)	(0.85)	(1.56)	(2.11)	(2.20)	(2.13)
4	0.02	0.35	0.88	1.06	1.31	1.29
	(0.03)	(0.50)	(1.21)	(1.51)	(1.82)	(4.07)
High	0.00	0.21	0.23	1.00	1.25	1.24
	(0.01)	(0.29)	(0.33)	(1.42)	(1.80)	(3.78)
average	0.47	0.54	0.78	1.11	1.45	0.98
	(0.71)	(0.81)	(1.21)	(1.82)	(2.33)	(3.86)

Table B.7: Overreaction and book-to-market ratio double sort test

This table reports the independent double sort test results of overreaction and book-to-market ratio. We group stocks into quartiles independently using overreaction and book-to-market ratio, which gives 25 portfolios. The long-short portfolio of overreaction given each book-to-market ratio quartile is constructed and its excess return is calculated. The average of the five returns from the five book-to-market ratio quartiles is finally used as the monthly excess return for overreaction. Panel A gives the results under equal weighting, while Panel B presents the results under market-cap weighting. The numbers in the parentheses underneath the returns are the Newey and West (1987) adjusted t-statistics. The dataset ranges from January 1st, 2000 to May 31st, 2021.

	OVer Low	2	3	4	High	High−Low
Panel A: Equal weighting						
book-to-market Low	0.16 (0.25)	1.15 (1.76)	1.49 (2.24)	1.58 (2.47)	1.44 (2.04)	1.27 (3.15)
2	0.33 (0.50)	1.21 (1.74)	1.46 (2.19)	1.80 (2.78)	1.75 (2.53)	1.42 (5.14)
3	0.23 (0.35)	1.25 (1.81)	1.52 (2.21)	1.73 (2.52)	1.97 (2.83)	1.73 (8.71)
4	0.11 (0.17)	0.95 (1.34)	1.53 (2.26)	1.70 (2.45)	1.97 (2.80)	1.85 (7.17)
High	−0.32 (−0.43)	0.73 (1.02)	1.35 (1.87)	1.85 (2.64)	1.91 (2.77)	2.23 (7.12)
average	0.11 (0.16)	1.06 (1.56)	1.47 (2.18)	1.73 (2.62)	1.81 (2.68)	1.70 (7.62)
Panel B: Market-cap weighting						
book-to-market Low	0.08 (0.12)	0.76 (1.23)	1.15 (1.92)	1.35 (2.15)	0.90 (1.28)	0.82 (1.59)
2	0.23 (0.36)	0.70 (1.13)	1.17 (1.89)	1.20 (1.91)	1.15 (1.88)	0.92 (2.91)
3	0.46 (0.66)	0.68 (1.07)	1.12 (1.74)	1.15 (1.78)	1.49 (2.26)	1.03 (3.33)
4	0.26 (0.33)	0.77 (1.17)	1.40 (2.22)	1.44 (2.14)	1.10 (1.69)	0.85 (2.20)
High	−0.22 (−0.28)	0.88 (1.16)	1.04 (1.39)	1.54 (2.26)	1.40 (2.27)	1.62 (3.85)
average	0.16 (0.24)	0.76 (1.22)	1.18 (1.90)	1.34 (2.16)	1.21 (2.00)	1.05 (3.67)

Table B.8: Underreaction and book-to-market ratio double sort test

This table reports the independent double sort test results of underreaction and book-to-market ratio. We group stocks into quartiles independently using underreaction and book-to-market ratio, which gives 25 portfolios. The long-short portfolio of underreaction given each book-to-market ratio quartile is constructed and its excess return is calculated. The average of the five returns from the five book-to-market ratio quartiles is finally used as the monthly excess return for underreaction. Panel A gives the results under equal weighting, while Panel B presents the results under market-cap weighting. The numbers in the parentheses underneath the returns are the Newey and West (1987) adjusted t-statistics. The dataset ranges from January 1st, 2000 to May 31st, 2021.

	Under Low	2	3	4	High	High−Low
Panel A: Equal weighting						
book-to-market Low	0.28 (0.38)	0.42 (0.62)	0.47 (0.73)	0.90 (1.41)	1.48 (2.30)	1.20 (4.05)
2	0.53 (0.79)	0.79 (1.16)	1.23 (1.73)	1.30 (1.99)	1.65 (2.56)	1.12 (5.43)
3	0.71 (1.00)	1.20 (1.70)	1.31 (1.97)	1.58 (2.30)	1.89 (2.90)	1.19 (6.20)
4	1.00 (1.39)	1.29 (1.87)	1.53 (2.15)	1.68 (2.54)	2.10 (3.05)	1.09 (5.99)
High	1.15 (1.60)	1.44 (2.09)	1.71 (2.45)	2.02 (2.91)	2.28 (3.31)	1.12 (4.75)
average	0.74 (1.05)	1.03 (1.51)	1.25 (1.85)	1.50 (2.28)	1.88 (2.90)	1.14 (6.54)
Panel B: Market-cap weighting						
book-to-market Low	−0.19 (−0.27)	−0.17 (−0.24)	0.17 (0.26)	0.70 (1.11)	1.14 (1.80)	1.33 (3.75)
2	0.18 (0.28)	0.13 (0.21)	0.82 (1.16)	0.85 (1.50)	1.10 (1.74)	0.91 (2.85)
3	0.25 (0.38)	0.81 (1.15)	0.56 (0.86)	0.99 (1.60)	1.41 (2.29)	1.15 (3.87)
4	0.70 (1.00)	0.83 (1.22)	0.95 (1.51)	1.11 (1.78)	1.70 (2.67)	1.00 (2.98)
High	0.95 (1.34)	0.86 (1.29)	1.14 (1.7)	1.38 (2.16)	2.01 (2.82)	1.05 (3.14)
average	0.38 (0.58)	0.49 (0.75)	0.73 (1.16)	1.01 (1.73)	1.47 (2.42)	1.09 (4.90)