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*JEL Classification Number*: G11, G12.

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## 1. INTRODUCTION

The relationship between risk and return is a core issue in modern asset pricing theory. The capital asset pricing model (CAPM) indicates a trade-off between risk and return, but empirical evidence shows that high-beta assets often deliver lower expected returns than low-beta assets. Black et al. (1972) find that in the 30 years preceding their studies, low-beta stocks performed better and the strategy of buying low-beta stocks and selling high-beta stocks resulted in positive excess returns, referred to as the "beta anomaly." Subsequently, a large number of studies have proved the existence of this anomaly (Baker et al., 2011; Bali et al., 2017; Black, 1972; Frazzini and Pedersen, 2014). In the meantime, a similar effect has been found in the Chinese stock market (Liu and Li, 2016). International evidence challenged researchers to pursue several potential explanations, such as borrowing constraints (Frazzini and Pedersen, 2014), representativeness (Baker et al., 2011), and preference for lotteries (Bali et al., 2017). In the Chinese stock market, Liu and Li (2016) show that the preference for lotteries is a contributing factor. This paper attempts to test the beta anomaly in the Chinese A-share stock market and provides an alternative explanation from the perspective of investors' heterogeneous beliefs and short-sale constraints.

The turnover rate, liquidity, and proportion of retail investors are much higher in the Chinese A-share stock market than in other places, indicating heavier heterogeneous beliefs and speculations. Meanwhile, there also exists short-sale constraints in China. Before 2010, short sales were prohibited; after the implementation of securities margin trading in 2010, it became possible for investors to short sell stocks. However, the cost and risk involved prevent investors from shorting, and short-sale constraints persist. Therefore, it is of practical significance to explain the beta anomaly in China based on heterogeneous beliefs and short-sale constraints.

Literature has fully discussed the impact of heterogeneous beliefs and short-sale constraints on stock prices. Miller (1977) proposes that under heterogeneous beliefs and short-sale constraints, investors have different estimates of returns, and demands for stocks come from the minority with optimistic expectations, leading to the overestimation of stock prices and a decrease in future returns. As the dispersion of opinion increases, the degree of overestimation increases and the future return decreases, which is supported by many following researches. Diether et al. (2002) use dispersion in analysts' earnings forecasts as a proxy for the heterogeneous beliefs of investors and analyze the role of heterogeneous beliefs in predicting the cross-section of future stock returns. They find that stocks with higher heterogeneous beliefs are more likely to be overestimated and earn lower future returns. Boehme et al. (2006) highlight the valuation effects of the interaction between heterogeneous beliefs and short-sale constraints and find that only stocks subject to both conditions simultaneously are likely to be overvalued. In the Chinese stock market, Zhang and Liu (2006) also argue that the negative relationship between turnovers and cross-sectional stock returns can be explained by the joint effect of heterogeneous beliefs and short-sale constraints. Yu et al. (2015) construct an indicator of investor disagreement using investor trading data from initial public offerings (IPOs). The disagreement can explain the fact that returns are high on the IPO day and decrease significantly in the following days. Deng and Wang (2014) find that heterogeneous beliefs also have a negative impact on firms' long-run market performance following private equity placements. Zhu et al. (2016) calculate unexpected trading volumes as a proxy for heterogeneous beliefs and find that stocks with a higher degree of heterogeneous beliefs earn lower future returns.

Stemming from Miller (1977), Hong and Sraer (2016) adopt heterogeneous beliefs to explain the beta anomaly. They introduce heterogeneous beliefs and short-sale constraints into CAPM model and explore the impact of aggregate disagreement (heterogeneous beliefs about the macroeconomy) on future returns of stocks with different betas. They believe that the shape of Security Market Line (SML), which reflects the relationship between expected returns and beta, is related to aggregate disagreement. Specifically, idiosyncratic disagreement is positively correlated with both aggregate disagreement and stocks' betas. Given the same aggregate disagreement, stocks with higher beta are faced with higher heterogeneous beliefs. Therefore, according to Miller (1977), stocks with higher beta are more likely to be overvalued and expected returns to decrease, referred to as the beta anomaly. This anomaly is severe in months with high aggregate disagreement. If the aggregate disagreement is high enough, the SML would take on an inverted U shape. The higher the aggregate disagreement, the more concave the SML. In this paper, we test the contribution of aggregate disagreement to explaining the beta anomaly in the Chinese stock market. Specifically, we analyze the beta anomaly in periods with different levels of aggregate disagreement and the impact of aggregate disagreement on the concavity of the SML.

There are three kinds of proxies for heterogeneous beliefs. The first is indicators that can affect heterogeneous beliefs, including firm age and historical income volatility in Berkman et al. (2009) and Bao and Xu (2015). Researchers think that firm age and historical income volatility can be used to represent the uncertainty of company information and future earnings, which would positively influence differences of opinion. The second is indicators influenced by heterogeneous beliefs, i.e., trading volume. Garfinkel and Sokobin (2006) suggest that unexpected trading volume reflects the divergence of opinion. Zhang and Liu (2006) also find that turnovers contain information about heterogeneous beliefs in the Chinese stock market. The third is indicators that directly measure heterogeneous beliefs, that is, analysts' forecasts. Diether et al. (2002) find that stocks with higher dispersion in analysts' earnings forecasts earns significantly lower future returns and postulate that dispersion in analysts' forecasts can be viewed as a measure of heterogeneous beliefs. The former two proxies tend to contain several kinds of information, and it is difficult to separate the pure indicator for heterogeneous beliefs. On the contrary, analysts' forecasts can avoid the preceding problem. With the gradual completion of analysts' forecast data in the Chinese A-share stock market, more empirical studies have begun to use analysts' forecasts as a proxy that directly measures heterogeneous beliefs (Sun, 2017; Xie and Cui, 2014). Therefore, this paper also uses the standard deviation of analyst forecasts of earnings per share (EPS) as a proxy for heterogeneous beliefs. However, the analyst forecasts are based on individual stocks. For aggregate disagreement, Yu (2011) proposes measuring aggregate disagreement as the cross-sectional value-weighted average of individual stock disagreement, while Hong and Sraer (2016) use the beta-weighted average. This paper constructs aggregate disagreement according to both methods. In addition, considering that divergence of opinions is influenced by the time interval between the forecast and release times of the annual report, we refer to Park (2005) to construct the monthly aggregate disagreement as the weighted average of the current- and following-year earnings forecasts.

This paper mainly discusses two issues: the existence of the beta anomaly in China and the contribution of aggregate disagreement over economic fundamentals to explaining the anomaly. To measure systematic risk, the key variable in analyzing the beta anomaly, we use the realized beta calculated from high-frequency data. High-frequency data contains more information than daily data, such as the immediate reaction of the market to announcements and market microstructure information. Therefore, the realized beta is a more accurate estimate. To reduce the inference of transaction noise contained in high-frequency data, we use the realized beta based on 5-minute data (Andersen et al., 2006). Considering the measure of disagreement in Diether et al. (2002), Park (2005), Yu (2011), and Hong and Sraer (2016), we first calculate individual disagreement as the standard deviation of analysts' forecasts on EPS, adjusted as the weighted average of the current- and following-year earnings forecasts. We then obtain the aggregate disagreement as the weighted average of the individual disagreement, where the weights are chosen as the current-month market caps and realized betas of individual stocks. We find that the beta anomaly in the Chinese stock market is significant, that is, stocks with lower betas have higher excess returns than stocks with higher betas. This anomaly cannot be explained by Fama-French three-factor model. We then examine the impact of short-sale constraints on the beta anomaly. The beta anomaly has decreased since the implementation of securities margin trading in 2010 but continues to persist. For stocks allowed short sale, the beta anomaly has disappeared. These results show that the beta anomaly in the Chinese stock market is quite robust and is caused by the stock mispricing from heterogeneous beliefs rather than the market risk premium. As for the relationship between heterogeneous beliefs and the beta anomaly, we first sort the stocks into groups according to aggregate disagreement and realized beta and find that the beta anomaly is more significant in periods with higher aggregate disagreement. Next, we use the Fama-MacBeth regression to analyze groups with different aggregate disagreement levels. We find that in periods with high aggregate disagreement, there is a significantly negative correlation between stock returns and realized beta, while the correlation in periods with low aggregate disagreement is no longer significant. Finally, we use the stepwise regression to find that the shape of the SML is related to investors' heterogeneous beliefs. The higher the aggregate disagreement, the more concave the SML, which indicates that high-beta stocks earn low future returns (the definition of beta anomaly). Therefore, we prove that aggregate disagreement can efficiently explain the beta anomaly in China. We also conduct several robustness checks to test the alternative proxies for aggregate disagreement and the long-term relationship between heterogeneous beliefs and the beta anomaly.

Compared with the existing literature, the main contributions of this paper are as follows: first of all, this paper examines the existence and robustness of the beta anomaly in the Chinese stock market using a hedging strategy based on realized betas and explores the impact of the implementation of securities margin trading on the beta anomaly. Second, we provide a new proxy for aggregate disagreement based on analysts' forecasts, which could reflect the aggregate disagreement more cleanly. In addition, we conduct portfolio analysis and Fama-MacBeth regressions to analyze the impact of aggregate disagreement on the beta anomaly and the relationship between the convexity of the Security Market Line and aggregate disagreement. The results show that aggregate disagreement could explain the beta anomaly in the Chinese stock market, which not only verifies the applicability of Hong and Sraer's (2016) model to China, but also adds an important supplement to studies of the beta anomaly in the Chinese A-share stock market.

## 2. DATA SOURCES AND VARIABLE DEFINITIONS

### 2.1 Data

The sample includes all of the A-share listed companies on the Shanghai and Shenzhen stock markets from January 1, 2005 to December 31, 2016, and the CSI 300 Index return is obtained as the market return. We then delete the firm-month observations (1) of which the company's net asset is negative, (2) within the first three months from listing, and (3) that have missing explanatory variable values. The total sample size is 200,032. The high-frequency data for the listed companies and CSI 300 Index are available in RESSET High Frequency database, while the companies' monthly trading and accounting data, analyst forecasts, and risk-free interest rates are obtained from CSMAR database.

### 2.2 Variable construction

This paper focuses on the beta anomaly in China and the explanatory power of aggregate disagreement for this anomaly. Therefore, market beta and aggregate disagreement are the two primary variables in our analysis. The variables used in this paper can be categorized into the following three groups.

#### *2.2.1 Market beta*

Andersen et al. (2006) argue that if market variances and individual equity covariances with the market are time-varying, betas are time-varying and the realized betas calculated based on high-frequency data reflect risk more accurately and flexibly. Considering Andersen et al. (2006) and Bollerslev et al. (2016), we use formula (1) to calculate the realized betas as the monthly systematic risk for individual stocks; specifically, we calculate the beta coefficient for individual stock $i$ in month $t$ using 5-minute returns from month $t$-12 to $t$-1.

$$\beta_{it} = \frac{\sum_{t=1}^{nT} r_{it} r_{mt}}{\sum_{t=1}^{nT} r_{mt}^2} \tag{1}$$

where $r_{it}$ is the 5-minute returns for individual stock $i$, $r_{mt}$ is the 5-minute market returns, $n$ is the number of observations of 5-minute returns in 1 day ($n = 48$ in general), and $T$ is the days from month t-12 to t-1.

*2.2.2 Aggregate disagreement*

Combining the methods used by Diether et al. (2002), Park (2005), Yu (2011), and Hong and Sraer (2016), we construct a proxy for monthly aggregate disagreement in the Chinese A-share stock market using analyst forecasts.

Diether et al. (2002) use the standard deviation of analysts' current-fiscal-year annual EPS forecasts as a proxy for individual-stock disagreement. Park (2005) considers the impact of difference in forecasting horizons when the disagreement is constructed. When the forecast horizon shortens as the calendar year progresses, the disagreement becomes smaller and the standard deviation of analysts' EPS forecasts cannot reflect the real aggregate disagreement. Therefore, the authors propose using the weighted average of the current- and following-year earnings forecasts, where the weights depend on the forecast horizon as the monthly aggregate disagreement. Yu (2011) suggests that aggregate disagreement can be calculated by value-weighted average of stock-level disagreement. Hong and Sraer (2016) argue that there are two sources of heterogeneous beliefs for individual stocks: idiosyncratic and aggregate disagreement. High-beta stock exposes to greater systematic risk and thus its heterogeneous belief varies more with aggregate disagreement. Therefore, they suggest that aggregate disagreement can be calculated by beta-weighted average of stock-level disagreement. Based on the preceding literature, we use the weighted average of the current- and following-year earnings forecasts as the stock-level disagreement, where the weights depend on the forecast horizon. We then calculate the aggregate disagreement as the value- or beta-weighted average of stock-level disagreement.

First, we keep the current- and following-year monthly analysts' EPS forecasts for individual stocks. As the annual reports are generally released in April of the following year, the analysts' forecasts for the current year gradually become homogeneous from April of the current year to March of the following year and may not reflect the real aggregate disagreement in the current month. Therefore, this paper makes the following adjustment when constructing stock-level disagreement:

$$HB_{it} = \begin{cases} SD_{i2t}/ME_{i2t} \ in\ December, January, February, and\ March \\ w_{it}SD_{i1t}/ME_{i1t} + (1-w_{it})\,SD_{i2t}/ME_{i2t}\ in\ April\ through\ November \end{cases} \tag{2}$$

where $SD_{i1t}$ is the standard deviation of current-year earnings forecasts for stock $i$ and $SD_{i2t}$ is the standard deviation of following-year earnings forecasts for stock $i$. $ME_{i1t}$ is the mean current-year earnings forecasts for stock $i$, and $ME_{i2t}$ is the mean following-year earnings forecasts for stock $i$. The standard deviation is normalized by the mean earnings forecasts to avoid the impact of changes in the absolute value of earnings forecasts on the dispersion. $w_{it}$ is the weight depending on the forecast horizon, which is 8/12 in April, 7/12 in May, and so on, ending at 1/12 in November. $HB_{it}$ is the individual disagreement in month *t* for stock $i$.

Next, we calculate the aggregate disagreement as the weighted average of the stock-level disagreement, where the weights are chosen as the current-month market caps or current-month realized betas of the individual stocks calculated using 5-minute data from month t-12 to t-1:

$$VWHB_t = \sum_{i=1}^{N} MKTCAP_{it} \cdot HB_{it} \Big/ \sum_{i=1}^{N} MKTCAP_{it} \tag{3}$$

$$BWHB_t = \sum_{i=1}^{N} \beta_{it} \cdot HB_{it} \Big/ \sum_{i=1}^{N} \beta_{it} \tag{4}$$

where $MKTCAP_{it}$ is the market cap in month *t* for stock $i$, $\beta_{it}$ is the realized beta in month *t* for stock $i$, $HB_{it}$ is the heterogeneous belief in month *t* for stock $i$, $VWHB_t$ is the value-weighted aggregate disagreement, and $BWHB_t$ is the beta-weighted aggregate disagreement. *N* is the number of individual stocks.

*2.2.3 Other control variables*

This paper considers the size effect and value effect into consideration and uses the Fama-French three-factor model to test the existence of beta anomaly. The size factor (small minus big, SMB) and value factor (high minus low, HML) are constructed from size/book-to-market benchmark portfolios that are double sorted by size (SIZE) and book-to-market (BM). In the Fama-MacBeth regressions, we control for SIZE and BM. In the regressions, to explore the relationship between the convexity of the SML and aggregate disagreement, we also control for the Fama-French benchmark factors (Novy-Marx, 2016).

### 2.3 Summary statistics

Table 1 shows the statistical description of aggregate disagreement and other indicators. $R$ and $R_M$ are the returns of individual stocks and the market, respectively. $\beta$ is a proxy for the monthly systematic risk for individual stock. *VWHB* and *BWHB* are two proxies for monthly aggregate disagreement. *TURN* is the monthly turnover rate of the stock index, measured as the average daily turnover rate. *ln(SIZE)* is the logarithm of the firm's market cap. *BM* is the book-to-market ratio. To avoid the influence of extreme values, we apply the Winsor method, replacing the highest and lowest 1% values with the next value counting inwards from the extreme.

## 3. EMPIRICAL RESULTS

This paper explores the contribution of aggregate disagreement to explaining the beta anomaly in the Chinese stock market. First, we conduct univariate portfolio analyses to verify the existence of the beta anomaly. Second, we conduct bivariate portfolio analyses and regressions to study the power of aggregate disagreement to explain the beta anomaly.

### 3.1 Existence of the beta anomaly

First, we analyze the portfolios sorted by market beta. If the strategy of buying low-beta portfolios and selling high-beta portfolios earns significantly positive excess returns, the beta anomaly may exist in the Chinese stock market. At the beginning of each month, we sort the sample stocks into five groups based on the realized betas estimated using the past 12 months of high-frequency data, where the beta of group 1 is the lowest and the beta of group 5 is the highest. Second, we compute the monthly returns on both the equal- and value-weighted portfolios from January to December 2016. Finally, we obtain the average rate of return (%) and CAPM alpha for each portfolio during this period. The results above are reported in Table 2.

To control the impact of size and book-to-market ratio, we also calculate the Fama-French three-factor alphas (FF3 Alpha) for portfolios formed by sorting on beta:

$$R_{it} - R_{ft} = \alpha_i + \beta_{i,m} \times \left(R_{mt} - R_{ft}\right) + \beta_{i,SMB} \times SMB_t + \beta_{i,HML} \times HML_t + \varepsilon_{it} \qquad (5)$$

where $R_{it}$ is the average return for stock $i$ in month $t$; $R_{ft}$ is the monthly risk-free rate, calculated from the one-year deposit rate; and $R_{mt}$ is the monthly market return in the A-share stock market. Following the method used by Fama and French (1993), we construct the six size/book-to-market portfolios as intersections of two portfolios sorted on size (Small and Big) and three portfolios sorted on book-to-market ratio (Value, Neutral, and Growth) at the end of every April. SMB is the average return on three small portfolios (SL, SM, SH) minus the average return on three big portfolios (BL, BM, BH). HML is the average return on the two value portfolios (SH, BH) minus the average return on the two growth portfolios (SL, BL). $\alpha_i$ stands for the fraction of the portfolio return that is unexplained by the preceding risk factors, which is also shown in Table 2.

Table 2 reports the monthly returns, CAPM alphas, and Fama-French three-factor alphas for the univariate portfolios sorted on market beta and the returns for the strategy of buying low-beta portfolios and selling high-beta portfolios. t-statistics are in parentheses. Both the equal- and value-weighted returns are reported. For the equal-weighted portfolio, the excess return, CAPM alpha, and Fama-French three-factor alpha of the strategy are 1.05%, 1.32%, and 1.16%, respectively, all of which are significant at the 5% level. For the value-weighted portfolio, the excess return, CAPM alpha, and Fama-French three-factor alpha of the strategy are 1.14%, 1.42%, and 1.14%, respectively, all of which are also significant at the 5% level. These results prove the existence of the beta anomaly in the Chinese stock market. In addition, as the market beta increases, the monthly return of the beta-sorted portfolio first increases and then decreases, which is preliminarily consistent with the conclusion by Hong and Sraer (2016) that the SML shows an inverted-U shape when aggregate disagreement is high.

Next, we examine the impact of short-sale constraints on the beta anomaly. On the one hand, we explore whether the beta anomaly still exists as the short-sale constraints have gradually relaxed in recent years. On the other hand, we test whether the beta anomaly disappears for the stocks without short-sale constraints.

In 2010, the Chinese stock market began to implement pilot programs for securities margin trading and gradually relaxed the short-sale constraints for more stocks. However, short selling is an investment with high cost and high risk. Therefore, many investors hesitate to participate, and short-sale constraints persist to some degree. To test the robustness of the beta anomaly after the implementation of securities margin trading and to avoid the extremely volatile period from 2007 to 2009, we analyze the sample after 2010. The results are shown in Table 3. From now on, we report only the results of the equal-weighted portfolios; the results of the value-weighted portfolios are similar. After 2010, the beta anomaly persists. The excess return, CAPM alpha, and Fama-French three-factor alpha of the strategy are 0.93%, 0.95%, and 0.97%, respectively, all of which are significant at the 10% level.

Furthermore, we test whether the beta anomaly disappears for the stocks without short-sale constraints. We divide the samples after 2010 into two groups—stocks with and without short-sale constraints—and construct univariate portfolios sorted on beta. Table 3 shows the average returns for each portfolio in the next month and the excess returns of the strategy based on market betas. In the group of stocks without short-sale constraints, the excess return, CAPM alpha, and Fama-French three-factor alpha of the strategy are 0.89%, 1.02%, and 0.62%, respectively. The results are smaller than those of the stocks with short-sale constraints (1.02%, 1.06%, and 0.94%) and not significant, indicating that the beta anomaly weakens or even disappears in the stocks without short-sale constraints. The significant influence of short-sale constraints on the beta anomaly indirectly shows that mispricing caused by heterogeneous beliefs rather than stock market risk premiums leads to the beta anomaly in China.

### 3.2 Aggregate disagreement and beta anomaly

To preliminarily demonstrate the power of aggregate disagreement to explain the beta anomaly, we employ bivariate portfolio analyses to assess the differences in beta anomaly across different periods of aggregate disagreement. We divide all of the stocks in the sample into three groups based on an ascending sort of value-weighted aggregate disagreement $VWHB_t$, which respectively represent the low-, medium-, and high-disagreement periods. We then sort all stocks in each group into five portfolios based on an ascending order of realized beta, in which portfolio 1 represents the low-beta portfolio and portfolio 5 represents the high-beta portfolio. Table 4 reports the average monthly returns for each portfolio and the excess return for the strategy of buying low-beta portfolios and selling high-beta portfolios. t-statistics are in parentheses. Similarly, we report the results of the bivariate analyses using beta-weighted aggregate disagreement $BWHB_t$ as the second sort variable.

Table 4 shows that when sorted based on value-weighted aggregate disagreement $VWHB_t$, the excess return of the beta strategy in the low-disagreement period is only 0.25% and not significant, showing that the beta anomaly does not exist when the aggregate disagreement is low. However, in the high-disagreement period, the excess return of the beta strategy is 2.12% and significant at the 5% level, which means that the beta anomaly exists when the aggregate disagreement is high. Similarly, when sorted based on beta-weighted aggregate disagreement $BWHB_t$, the excess return of the beta strategy in the low-disagreement period is only 0.06% and not significant, while the excess return is 1.99% in the high-disagreement period and significant at the 5% level. Above all, we know that aggregate disagreement affects the existence of the beta anomaly. Considering that the volatilities of stock price and aggregate disagreement are relatively low after the implementation of securities margin trading in 2010, we examine the samples after 2010 separately and find that the relationship between aggregate disagreement and the beta anomaly persists. In the low-disagreement period sorted by value- and beta-weighted aggregate disagreement, the excess returns of the beta strategy are 0.64% and 0.38%, respectively, and not significant. In the meantime, the excess returns of the beta strategy in the high-disagreement period are 2.10% and 2.54%, respectively, and significant. In conclusion, aggregate disagreement can explain the beta anomaly in the Chinese stock market.

Besides, we use Fama-MacBeth regressions to study the relationship between returns and market betas in periods with different levels of aggregate disagreement. Table 5 reports the results with and without controlling for size and book-to-market ratio. When the stocks are sorted by value-weighted aggregate disagreement $VWHB_t$, the coefficients on beta in the low-disagreement period are -0.57 and -0.43, both of which are not significant, indicating that the beta anomaly does not exist in the low-disagreement period. In the high-disagreement period, the coefficients on market beta are -3.42 and -2.55 and significant at the 5% and 10% levels, respectively, indicating that the beta anomaly exists when aggregate disagreement is high. Similarly, we sort stocks based on beta-weighted aggregate disagreement $BWHB_t$. The results show that in the low-disagreement period, the coefficients on beta are -0.31 and -0.41, both of which are not significant. In the high-disagreement period, the coefficients on beta are -3.39 and -2.09 and significant at the 1% and 10% levels, respectively. Ultimately, the level of aggregate disagreement affects the existence of the beta anomaly.

### 3.3 Aggregate disagreement and concavity of the Security Market Line

From the previous portfolio analysis, we show that the beta anomaly in the Chinese A-share stock market becomes significant as aggregate disagreement increases. Hong and Sraer (2016) suggest that the impact of aggregate disagreement on the beta anomaly is further reflected in the shape of the SML. In high-disagreement periods, the SML is no longer a straight line monotonously increasing with the market beta, but appears to be an inverted-U shape. The higher level of aggregate disagreement is associated with the lower returns for high-beta stocks and the more concave SML. In the following, we explore the relationship between the level of aggregate disagreement and the concavity of the SML using two-stage regressions. Specifically, we obtain the time series of coefficients on betas through the first-stage cross-sectional regression and then conduct the second-stage regression to test whether aggregate disagreement affects the first-stage coefficients, which represent the shape of the SML.

At the beginning of each month, we sort the stocks into 20 portfolios based on market betas estimated using data from the past 12 months. We then obtain the equal-weighted excess returns ($r_{Pt}$) for 20 portfolios from January 2006 to December 2016. According to Fama and French (1993), the realized betas for 20 portfolios are calculated as in formula (6):

$$\beta_P = \frac{\sum_{t=1}^{nT_0} r_{Pt} r_{mt}}{\sum_{t=1}^{nT_0} r_{mt}^2} \tag{6}$$

where $r_{Pt}$ is the equal-weighted average 5-minute return for portfolio *P*. $r_{mt}$ is the market 5-minute return. *n* is the number of 5-minute returns in one day, which is generally 48. $T_0$ is the number of days in the sample. $\beta_P$ is time-invariant (Fama and French, 1993). We first estimate the cross-sectional regression over 20 $\beta$-sorted portfolios as follows:

$$r_{Pt} = \kappa_t + \pi_t \times \beta_P + \phi_t \times (\beta_P)^2 + \varepsilon_{Pt} \tag{7}$$

where $r_{Pt}$ is the equal-weighted return for portfolio *P* in month *t*. $\beta_P$ is the market beta for portfolio *P*, calculated using full samples, which means it is time-invariant. Considering that the SML appears to be an inverted-U shape in the high-disagreement period, we introduce the square of beta, $(\beta_P)^2$, into the regression and obtain a time series of coefficient estimates for $\kappa_t$, $\pi_t$, and $\phi_t$ from the regressions.

In the second stage, to test the impact of aggregate disagreement on the shape of the SML, we regress the $\kappa_t$, $\pi_t$, and $\phi_t$ time series on lagged aggregate disagreement, $Agg.Disp._{t-1}$. Novy-Marx (2016) suggests that standard risk factors affect the shape of the SML. Therefore, we control the three Fama-French factors according to Novy-Marx (2016). The regressions are as follows:

$$\phi_t = c_\phi + \psi_\phi \times Agg.Disp._{t-1} + \delta_{\phi,m} \times R_{mt} + \delta_{\phi,HML} \times HML_t + \delta_{\phi,SMB} \times SMB_t + \zeta_t \tag{8}$$

$$\pi_t = c_\pi + \psi_\pi \times Agg.Disp._{t-1} + \delta_{\pi,m} \times R_{mt} + \delta_{\pi,HML} \times HML_t + \delta_{\pi,SMB} \times SMB_t + \omega_t \tag{9}$$

$$\kappa_t = c_\kappa + \psi_\kappa \times Agg.Disp._{t-1} + \delta_{\kappa,m} \times R_{mt} + \delta_{\kappa,HML} \times HML_t + \delta_{\kappa,SMB} \times SMB_t + \nu_t \tag{10}$$

where $Agg.Disp._{t-1}$ denotes the lagged aggregate disagreement, which means $VWHB_{t-1}$ and $BWHB_{t-1}$ in this paper. $R_{mt}$, $HML_t$, and $SMB_t$ are Fama-French factors.

Table 6 shows the results of the second-stage regression. In Column (1), we regress $\phi_t$ on $Agg.Disp._{t-1}$ only. In Column (2), we control for the Fama-French factors in the regression. Columns (3)-(4) and (5)-(6) rerun the above analysis after replacing the dependent variables with the estimated $\pi_t$ and $\kappa_t$, respectively. This paper mainly focuses on the coefficient $\phi_t$, which reflects the concavity of the SML. In both the univariate regressions and the regressions with additional control variables, the aggregate disagreement in the last period $Agg.Disp._{t-1}$ is negatively correlated with $\phi_t$. The *t*-statistics are between -2.41 and -2.06. In other words, the higher level of aggregate disagreement is associated with a lower $\phi_t$ and a more concave SML. As a result, high-beta stocks earn lower returns and the beta anomaly is more significant. Both proxies for aggregate disagreement prove the conclusions.

## 4. ROBUSTNESS CHECKS

### 4.1 Alternative proxies for disagreement: turnover rate

The choice of proxies for disagreement may influence our results. When the level of disagreement is high, the turnover rates of stocks are also relatively high, so turnover rate is a commonly used proxy for disagreement (Garfinkel and Sokobin, 2006; Zhu et al., 2016). Therefore, apart from value- and beta-weighted aggregate disagreement, we consider turnover rate as an alternative proxy for disagreement. The monthly index turnover (*TURN*) is defined as the arithmetic mean of the daily turnover rate of the CSI 300 Index, where the daily turnover rate is the ratio of daily trading volume to the total number of outstanding shares for the stock. Given that the Chinese A-share stock market has become increasingly active in recent years, we also consider the detrended monthly index turnover (*DTURN*) as another proxy. We then rerun the two-stage regressions in Section 3.3.

Table 7 shows the regression results. Columns (1), (3), and (5) are results that regress $\phi_t$ on $Agg.Disp._{t-1}$ only. Columns (2), (4), and (6) are results that introduce additional control variables. Table 7 shows that the relationship between lagged aggregate disagreement and $\phi_t$ is significantly negative in both of the specifications, with and without controls. The results are similar to the results using analysts' forecast data and further prove the robustness of the contribution that aggregate disagreement makes to explaining the beta anomaly in China.

### 4.2 Long-term relationship between disagreement and Security Market Line

Studies suggest that disagreement indicator is persistent (Campbell and Shiller, 1988; Summers, 1986), and the overvalued stock price gradually reverts to intrinsic value as aggregate disagreement decreases. As a result, the mispricing caused by disagreement lasts for several periods. Hong and Sraer (2016) suggest that the impact of aggregate disagreement on the SML also lasts a long time. With the gradual adjustment of stock price in each period, the beta anomaly for cumulative returns becomes more severe and the explanatory power of aggregate disagreement gradually increases. Therefore, we use the cumulative returns over the next 6, 12, and 18 months of 20 $\beta$-sorted portfolios as the dependent variables in the first-stage regression and control the cumulative risk factors in the second-stage regression.

Table 8 reports the coefficients on $Agg.Disp._{t-1}$ for the regressions in Section 3.3. The first row for each dependent variable is the univariate regression on $Agg.Disp._{t-1}$ only, while the second row is the multivariate regression adding control variables. When value-weighted aggregate disagreement is used as the proxy for aggregate disagreement in the univariate regressions over the next 6, 12, and 18 months, the coefficients on $Agg.Disp._{t-1}$ are -5.83, -6.66, and -7.35, respectively, all of which are significant at the 1% level. Compared with the coefficient of -1.79 for the univariate regression over the next 1 month in Table 6, the results show that the impact of aggregate disagreement on the concavity of the SML increases with the horizons. Similar conclusions can be drawn from the results using $BWHB_t$ as an alternative.

## 5. CONCLUSION

This paper studies the existence of beta anomaly and the power of aggregate disagreement to explain the beta anomaly using a sample of all listed companies in the Chinese A-share stock market. The main findings are as follows.

First, we find a significant beta anomaly in China; that is, high-beta stocks earn low future returns, which the Fama-French three-factor model cannot fully explain. Second, we conduct portfolio analysis and Fama-MacBeth cross-sectional regressions to analyze the role of aggregate disagreement in explaining the beta anomaly. We find that the beta anomaly disappears in low-disagreement periods and is significant in high-disagreement periods. Finally, we use the step-wise regressions to verify the relationship between aggregate disagreement and the shape of the SML. A higher level of aggregate disagreement is associated with the lower returns on high-beta stocks and the more concave SML. The findings of this paper are instructive for research on investment strategies and improve pricing efficiency in the Chinese A-share stock market.

## APPENDIX

**TABLE 1.**

Summary statistics

| Variable | Mean | Std | 50th | 25th | 75th |
|---|---|---|---|---|---|
| $R$ (%) | 2.492 | 16.124 | 1.568 | -6.879 | 10.909 |
| $R_M$ (%) | 1.317 | 9.097 | 1.801 | -4.463 | 5.366 |
| $\beta$ | 0.947 | 0.265 | 0.966 | 0.768 | 1.126 |
| *VWHB* | 0.142 | 0.109 | 0.111 | 0.090 | 0.146 |
| *BWHB* | 0.155 | 0.088 | 0.134 | 0.106 | 0.163 |
| *TURN* | 0.257 | 0.144 | 0.204 | 0.153 | 0.335 |
| *ln(Size)* | 15.357 | 1.092 | 15.194 | 14.616 | 15.924 |
| *BM* | 0.399 | 0.471 | 0.318 | 0.200 | 0.501 |
| SMB (%) | 1.061 | 3.137 | 1.163 | -0.289 | 2.932 |
| HML (%) | 0.149 | 4.061 | -0.100 | -2.093 | 2.148 |

**TABLE 2.**

Univariate portfolio analyses: existence of the beta anomaly in China (2005-2016)

| Returns (%) | 1 (Low) | 2 | 3 | 4 | 5 (High) | Low - High |
|---|---|---|---|---|---|---|
| | | | Equal-weighted | | | |
| Monthly Returns | 2.58 | 2.70 | 2.59 | 2.31 | 1.53 | 1.05** |
| | | | | | | (2.52) |
| CAPM Alpha | 1.34*** | 1.35*** | 1.19** | 0.86* | 0.02 | 1.32*** |
| | (2.77) | (2.91) | (2.48) | (1.82) | (0.05) | (3.51) |
| FF3 Alpha | 0.21 | 0.11 | -0.18 | -0.44* | -0.95*** | 1.16*** |
| | (0.89) | (0.49) | (-0.79) | (-1.66) | (-3.23) | (3.41) |
| | | | Value-weighted | | | |
| Monthly Returns | 2.61 | 2.64 | 2.58 | 2.27 | 1.47 | 1.14** |
| | | | | | | (2.54) |
| CAPM Alpha | 1.39*** | 1.30*** | 1.18** | 0.82* | -0.05 | 1.42*** |
| | (2.84) | (2.93) | (2.55) | (1.82) | (-0.13) | (3.46) |
| FF3 Alpha | 0.24 | 0.14 | -0.09 | -0.40 | -0.90*** | 1.14*** |
| | (1.03) | (0.74) | (-0.40) | (-1.61) | (-3.12) | (3.07) |

Note: t-statistics are in parentheses. *, **, and *** indicate statistically different from zero at the 10%, 5%, and 1% levels of significance, respectively.

**TABLE 3.**

Univariate portfolio analyses: short sale constraints and beta anomaly

| | 1 (Low) | 2 | 3 | 4 | 5 (High) | Low - High |
|---|---|---|---|---|---|---|
| **Returns for portfolios sorted on $\beta$: full samples in 2010-2016** | | | | | | |
| Monthly returns | 0.73 | 0.74 | 0.53 | 0.22 | -0.20 | 0.93** |
| | | | | | | (2.07) |
| CAPM Alpha | 0.63 | 0.63 | 0.42 | 0.10 | -0.32 | 0.95** |
| | (0.98) | (1.01) | (0.65) | (0.16) | (-0.50) | (2.42) |
| FF3 Alpha | -0.16 | -0.23 | -0.38 | -0.66** | -0.95*** | 0.79* |
| | (-0.50) | (-0.88) | (-1.30) | (-2.20) | (-2.94) | (1.72) |
| **Returns for portfolios sorted on $\beta$: samples w/o short sale constraints in 2010-2016** | | | | | | |
| | 1 (Low) | 2 | 3 | 4 | 5 (High) | Low - High |
| Monthly Returns | | | | | | |
| without constraints | 0.84 | 1.05 | 0.64 | -0.16 | -0.05 | 0.89 |
| | | | | | | (1.07) |
| with constraints | 1.99 | 2.04 | 1.77 | 1.50 | 0.97 | 1.02** |
| | | | | | | (2.20) |
| CAPM Alpha | | | | | | |
| without constraints | 0.55 | 0.70* | 0.28 | -0.54 | -0.46 | 1.02 |
| | (1.30) | (1.91) | (0.75) | (-1.31) | (-0.97) | (1.35) |
| with constraints | 1.69** | 1.73*** | 1.44** | 1.17* | 0.63 | 1.06** |
| | (2.52) | (2.70) | (2.23) | (1.80) | (0.98) | (2.39) |
| FF3 Alpha | | | | | | |
| without constraints | 0.15 | 0.34 | 0.01 | -0.93** | -0.47 | 0.62 |
| | (0.37) | (1.01) | (0.02) | (-2.14) | (-0.90) | (0.80) |
| with constraints | 0.14 | 0.14 | -0.15 | -0.44* | -0.20** | 0.94* |
| | (0.54) | (0.63) | (-0.63) | (-1.68) | (-2.17) | (1.93) |

Note: t-statistics are in parentheses. *, **, and *** indicate statistically different from zero at the 10%, 5%, and 1% levels of significance, respectively. We report only the results of equal-weighted portfolios, and the results of the value-weighted portfolios are similar.

**TABLE 4.**

Bivariate portfolio analyses: aggregate disagreement and beta anomaly

| 2005-2016 | | | | | | |
|---|---|---|---|---|---|---|
| Aggregate Disagreement | 1 (Low) | 2 | 3 | 4 | 5 (High) | Low-High |
| | | *VWHB* | | | | |
| Low | 4.92 | 5.15 | 5.05 | 4.90 | 4.67 | 0.25 |
| | | | | | | (0.34) |
| High | 1.92 | 1.80 | 1.46 | 1.07 | -0.20 | 2.12** |
| | | | | | | (2.43) |
| | | *BWHB* | | | | |
| Low | 3.57 | 3.85 | 3.70 | 3.66 | 3.51 | 0.06 |
| | | | | | | (0.08) |
| High | 2.64 | 2.69 | 2.33 | 1.90 | 0.65 | 0.99** |
| | | | | | | (2.27) |

| 2010-2016 | | | | | | |
|---|---|---|---|---|---|---|
| Aggregate Disagreement | 1 (Low) | 2 | 3 | 4 | 5 (High) | Low-High |
| | | *VWHB* | | | | |
| Low | 2.71 | 2.79 | 2.60 | 2.25 | 2.06 | 0.64 |
| | | | | | | (0.75) |
| High | 0.55 | 0.71 | 0.24 | -0.19 | -1.55 | 2.10* |
| | | | | | | (1.84) |
| | | *BWHB* | | | | |
| Low | 1.12 | 1.48 | 1.23 | 0.88 | 0.74 | 0.38 |
| | | | | | | (0.44) |
| High | 1.42 | 1.39 | 0.76 | 0.34 | -1.11 | 2.54** |
| | | | | | | (2.35) |

Note: t-statistics are in parentheses. *, **, and *** indicate statistically different from zero at the 10%, 5%, and 1% levels of significance, respectively.

**TABLE 5.**

Fama-MacBeth regressions: aggregate disagreement and beta anomaly

| | High-disagreement | | Low-disagreement | |
|---|---|---|---|---|
| | | $VWHB$ | | |
| $\beta$ | -3.42** | -2.55* | -0.57 | -0.43 |
| | (-2.16) | (-1.90) | (-0.49) | (-0.35) |
| *Size* | | -0.72** | | -0.18 |
| | | (-2.18) | | (-0.39) |
| $BM$ | | -0.17 | | 0.52 |
| | | (-0.52) | | (1.51) |
| R-square | 0.03*** | 0.06*** | 0.02*** | 0.07*** |
| | (6.11) | (9.94) | (4.11) | (6.49) |
| | | $BWHB$ | | |
| $\beta$ | -3.39*** | -2.09* | -0.31 | -0.41 |
| | (-2.29) | (-1.72) | (-0.27) | (-0.33) |
| *Size* | | -1.02*** | | 0.03 |
| | | (-3.19) | | (0.06) |
| $BM$ | | -0.32 | | 0.49 |
| | | (-0.95) | | (1.47) |
| R-square | 0.02*** | 0.06*** | 0.02*** | 0.07*** |
| | (5.25) | (9.64) | (4.31) | (6.33) |

Note: t-statistics are in parentheses. *, **, and *** indicate statistically different from zero at the 10%, 5%, and 1% levels of significance, respectively.

**TABLE 6.**

Disagreement and concavity of the Security Market Line

| | $\phi_t$ | | $\pi_t$ | | $\kappa_t$ | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | | | *VWHB* | | | |
| $Agg.Disp._{t-1}$ | -1.79** | -1.89** | 3.00** | 3.29** | 0.79 | 0.56 |
| | (-2.33) | (-2.41) | (1.99) | (2.13) | (0.80) | (0.56) |
| $R_{mt}$ | | -0.52 | | 1.14 | | -0.51 |
| | | (-1.23) | | (1.39) | | (-0.94) |
| $HML_t$ | | 0.43 | | -0.58 | | 0.36 |
| | | (0.36) | | (-0.25) | | (0.24) |
| $SMB_t$ | | -0.09 | | -0.23 | | 1.71 |
| | | (-0.08) | | (-0.10) | | (1.06) |
| Constant | -0.26*** | -0.12 | 0.40** | 0.07 | -0.03 | 0.11 |
| | (-2.82) | (-0.79) | (2.16) | (0.25) | (-0.22) | (0.59) |
| | | | *BWHB* | | | |
| $Agg.Disp._{t-1}$ | -1.59** | -1.68** | 2.83* | 3.10** | 0.60 | 0.41 |
| | (-2.06) | (-2.13) | (1.87) | (2.01) | (0.61) | (0.41) |
| $R_{mt}$ | | -0.50 | | 1.12 | | -0.52 |
| | | (-1.18) | | (1.36) | | (-0.96) |
| $HML_t$ | | 0.36 | | -0.44 | | 0.37 |
| | | (0.30) | | (-0.19) | | (0.24) |
| $SMB_t$ | | -0.24 | | 0.00 | | 1.76 |
| | | (-0.19) | | (0.00) | | (1.09) |
| Constant | -0.26** | -0.12 | 0.37* | 0.05 | -0.01 | 0.13 |
| | (-2.50) | (-0.75) | (1.81) | (0.16) | (-0.10) | (0.62) |

Note: t-statistics are in parentheses. *, **, and *** indicate statistically different from zero at the 10%, 5%, and 1% levels of significance, respectively.

**TABLE 7.**

Disagreement and concavity of the Security Market Line: alternative measures of disagreement

| | $\phi_t$ | | $\pi_t$ | | $\kappa_t$ | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | | | *TURN* | | | |
| $Agg.Disp._{t-1}$ | -0.68** | -0.70** | 1.39*** | 1.39** | -1.20*** | -1.17*** |
| | (-2.60) | (-2.59) | (2.71) | (2.61) | (2.88) | (-3.56) |
| $R_{mt}$ | | -0.29 | | 0.72 | | -0.33 |
| | | (-0.69) | | (0.88) | | (-0.64) |
| $HML_t$ | | 0.98 | | -1.62 | | 0.90 |
| | | (0.82) | | (-0.69) | | (0.62) |
| $SMB_t$ | | -0.74 | | 0.96 | | 1.28 |
| | | (-0.59) | | (0.39) | | (0.84) |
| Constant | -0.30*** | -0.22* | 0.40*** | 0.21 | 0.35*** | 0.41*** |
| | (-4.20) | (-1.74) | (2.88) | (0.87) | (3.01) | (2.74) |
| | | | *DTURN* | | | |
| $Agg.Disp._{t-1}$ | -0.68** | -0.71** | 1.39*** | 1.39** | -1.20*** | -1.17*** |
| | (-2.63) | (-2.61) | (2.74) | (2.64) | (-2.89) | (-3.60) |
| $R_{mt}$ | | -0.29 | | 0.71 | | -0.32 |
| | | (-0.69) | | (0.88) | | (-0.64) |
| $HML_t$ | | 0.98 | | -1.63 | | 0.91 |
| | | (0.82) | | (-0.70) | | (0.63) |
| $SMB_t$ | | -0.74 | | 0.97 | | 1.27 |
| | | (-0.59) | | (0.40) | | (0.84) |
| Constant | -0.48*** | -0.40*** | 0.76*** | 0.57** | 0.04 | 0.11 |
| | (-13.86) | (-3.50) | (11.31) | (2.56) | (0.79) | (0.83) |

Note: t-statistics are in parentheses. *, **, and *** indicate statistically different from zero at the 10%, 5%, and 1% levels of significance, respectively.

**TABLE 8.**

Disagreement and concavity of the Security Market Line: longer horizons

| | | 6 months | 12 months | 18 months |
|---|---|---|---|---|
| | | *VWHB* | | |
| $\phi_t$ | (1) | -5.83*** | -6.66*** | -7.35*** |
| | | (-3.41) | (-2.60) | (-2.60) |
| | (2) | -3.64** | -9.00*** | -9.18*** |
| | | (-2.45) | (-3.75) | (-2.72) |
| $\pi_t$ | (3) | 9.96** | 10.79* | 11.99** |
| | | (2.55) | (1.87) | (2.05) |
| | (4) | 7.78** | 16.22*** | 16.96** |
| | | (2.23) | (3.31) | (2.40) |
| $\kappa_t$ | (5) | -2.42 | -1.04 | 0.31 |
| | | (-1.02) | (-0.31) | (0.09) |
| | (6) | 1.64 | -2.31 | -1.49 |
| | | (1.03) | (-0.74) | (-0.47) |
| | | *BWHB* | | |
| $\phi_t$ | (7) | -6.75*** | -5.90 | -7.37* |
| | | (-2.58) | (-1.46) | (-1.74) |
| | (8) | -3.34 | -7.25* | -8.28* |
| | | (-1.38) | (-1.93) | (-1.91) |
| $\pi_t$ | (9) | 13.01** | 11.11 | 13.06 |
| | | (2.38) | (1.23) | (1.48) |
| | (10) | 9.05* | 14.47* | 15.23* |
| | | (1.70) | (1.90) | (1.74) |
| $\kappa_t$ | (11) | -2.20 | 2.48 | 3.96 |
| | | (-0.57) | (0.54) | (0.87) |
| | (12) | 3.06 | 1.82 | 3.13 |
| | | (1.34) | (0.42) | (0.77) |

Note: t-statistics are in parentheses. *, **, and *** indicate statistically different from zero at the 10%, 5%, and 1% levels of significance, respectively.

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