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Article

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FINANCIAL ECONOMICS | RESEARCH ARTICLE

MAX, lottery-type stocks, and the cross-section of stock returns: Evidence from the Chinese stock market

Hoang Van Hai^{1*}

Abstract: This study empirically investigates a relationship between MAX and lottery-type stocks in the Chinese stock markets. We find that the lottery-type stocks, which are preferred for lottery demand of investors, are negatively priced in the Chinese market. Moreover, the MAX effect as a proxy for lottery stock is not strongly exhibited as the lottery behavior in the Chinese stock market. Our results show that the higher MAX stocks in the lowest price stocks are stronger than those in the highest price ones. This can explain why the MAX phenomenon of the Chinese market is different from that in the developed market regarding the candidate of the IVOL puzzle explanation.

Subjects: Corporate Finance; Investment & Securities; Risk Management

Keywords: Lottery-type stocks; MAX effect; Idiosyncratic volatility puzzle; limits of arbitrage; Chinese stock market

JEL classification: G11; G17; G12

1. Introduction

The literature initiated by Bali et al. (2011) points out that the negative predictive power of idiosyncratic volatility disappears after controlling for MAX as a lottery-type stock in the US market. Several subsequent papers find similar results in other international markets (Annaert et al., 2013; Hou & Loh, 2016; Walkshäusl, 2014; Zhong & Gray, 2016). However, Nartea et al. (2017) and Wan (2018) find that MAX is not a source of the idiosyncratic volatility puzzle in the Chinese stock market. Therefore, the reason why MAX cannot be a good candidate to explain IVOL in the Chinese market is still not well understood. In this paper, we propose that the MAX effect is not strongly exhibited as a lottery-type stock's behavior in the Chinese market. This can explain why the MAX phenomenon of the Chinese market is different from that in the US market regarding the candidate of the IVOL puzzle explanation. The hypothesis used in this study follows that introduced by other studies (Bali et al., 2017, 2011; Han & Kumar, 2013; Kumar, 2009) investigating the pricing of MAX as lottery demand.

Our rationale is as follows. The MAX effect, small, lower price, and higher IVOL, is widely documented in the international market as the lottery-type stocks (Bali et al., 2011; Cheon & Lee, 2018; Nartea et al., 2017). Following Barber and Odean (2008), among so many stocks listed

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on the stock market, because of the limited attention of investors, the lottery stocks are more likely to grab investors' attention, and investors are more likely to overpay for these stocks. Regarding the lottery-type stocks, Kumar (2009) shows that investors are likely to exhibit a preference for lottery-type stocks, which are defined as low-priced stocks with high idiosyncratic volatility and high idiosyncratic skewness.

These characteristics are consistent with the MAX in the developed market (Bali et al., 2011; Walkshäusl, 2014; Zhong & Gray, 2016). Thus, we posit that MAX with the highest exhibit as lottery-type stock can explain the IVOL in the developed markets. However, for the Chinese market, the high-MAX stocks have a high price with high idiosyncratic volatility and high idiosyncratic skewness (see e.g. Nartea et al., 2017; Wan, 2018). Additionally, the explanation power of MAX on the IVOL puzzle is deducted when the low-priced stocks (stock price less than \$5) are removed from the sample (Egginton & Hur, 2018). Therefore, we argue that the MAX effect is not strongly exhibited as a lottery-type stock's behavior in the Chinese market.

In this study, we also posit that the higher exhibit lottery-type stocks features can lead to higher limits on arbitrage. Following Cao and Han (2016) and Bergsma and Tayal (2019), the lottery-stock features are associated with the higher arbitrage costs; therefore, the arbitrageurs can take the smaller positions in these stocks, resulting in their less contribution to the correcting mispricing. This mispricing should be larger in the most lottery-type stocks, which receive the least arbitrage resources. Hence, as stocks become more lottery-like due to the costly arbitrage, the higher arbitrage risk can be an explanation for the IVOL puzzle (Cao & Han, 2016; Gu et al., 2018; Stambaugh et al., 2015).

We conduct our empirical hypothesis tests in several ways. We demonstrate that the returns, associated with the lottery-type stocks (LOT) following Kumar (2009)¹, are significantly negatively priced in the cross-sectional return in the Chinese market. Next, our findings show that the MAX effect is strongly exhibited as a lottery-type stock's behavior in the Chinese market. We also investigate the effect of limits of arbitrage on the lottery-type stocks. Empirically, data support our hypothesized relationships.

This study provides an understanding of the LOT proxy in the empirical dimension, as well as the MAX effect associated with LOT contents in the cross-sectional return. Importantly, our empirical findings can explain why the MAX phenomenon of the Chinese market is different from that in the developed markets such as US and European markets regarding the candidate of the IVOL puzzle explanation. Our finding is in line with the finding of Bi et al. (2022), as they find that the MAX effect is triggered by the institutional investor's trading behavior in China, which maybe the reason that the MAX effect in China is different from the US. In addition, interestingly, the negative premium of lottery-type stocks is much stronger in stocks with high limits of arbitrage.

This study is divided into four sections. Section 2 presents the discussion on data and methodologies. In section 3, the main results are interpreted and discussed. Our conclusion is presented in section 4.

2. Data and Methodology

2.1. Data

The sample for the Chinese stock market is drawn from the China Stock Market and Accounting Research (CSMAR) database, which contains temporal data of all stocks from July 2000 to June 2020. We also obtain the daily and monthly Fama-French three-factor data from the CSMAR

database. We use only stock A type in the Shanghai and Shenzhen stock exchanges, and normal treatment stocks. The database also contains listed and delisted companies. Furthermore, several dynamic screens are applied to ensure high data quality: (1) the firms in the financial sectors and firms with a negative book value of equity are deleted (Fama & French, 1992); (2) firms with less than 250 trading days throughout the sample period are deleted; (3) we delete the trading days under special treatment and IPO days that are not subject to daily price limits; (4) we delete the firm-month observations with less than 15 trading days within 1 month. (5) For constructing the CH3 and CH4 factor models, we further exclude the stocks in the bottom 30% of firm size, to avoid their shell-value contamination following Liu et al. (2019).

Regarding the lottery-type stocks proxy in this paper, following Kumar (2009), Kumar et al. (Han & Kumar, 2013), Bali et al. (2019), we choose three stock characteristics: (i) price, (ii) idiosyncratic volatility, and (iii) idiosyncratic skewness. The price is the previous monthly stock price. The idiosyncratic volatility (idiosyncratic skewness)² measure is the variance (skewness) of the residual obtained by fitting a three-factor model to the daily stock returns time series. Specifically, the model can be defined as below.

$$R_{i,d} = \beta_0 + \beta_1 \text{RMRF}_d + \beta_2 \text{SMB}_d + \beta_3 \text{HML}_d + \varepsilon_{i,d} \quad (1a)$$

$$\text{IVOL}_{i,t} = \sqrt{\text{Var}(\varepsilon_{i,d})} * \sqrt{N_t} \quad (1b)$$

$$\text{IDSKEW}_{i,t} = \frac{\frac{1}{N} \sum_{d=1}^N \varepsilon_{i,d}^3}{\left(\frac{1}{N} \sum_{d=1}^N \varepsilon_{i,d}^2 \right)^{3/2}} \quad (1c)$$

where $R_{i,d}$ is the stock i excess return on the day d . RMRF_d , SMB_d , and HML_d are the daily returns of Fama and French's (1993) three factors, which are obtained from the CSMAR database. We compute monthly idiosyncratic volatility (IVOL) and idiosyncratic skewness (IDSKEW) constructed based on equation (1b) and (1c), respectively. N_t is the number of trading days in month t within a requirement of at least 15 observations per month.

To capture the three characteristics in one measure, we establish a monthly composite index based on the three characteristics, including PRICE, IVOL, and IDSKEW following Stambaugh et al. (2015) method. First, we separately utilize percentile rank to categorize stocks into 10 groups according to PRICE, IVOL, and IDSKEW. As mentioned by Kumar (2009), the lottery-type stocks have lower PRICE, higher IVOL, and higher IDSKEW, therefore, we will assign the higher PRICE rank for the lower stock price, the higher IVOL rank for the higher stock within higher idiosyncratic volatility, and the higher IDSKEW rank for higher stock within higher idiosyncratic skewness. Subsequently, the higher rank groups will contain the lower PRICE, higher IVOL, and higher IDSKEW, which can be considered as the lottery-type stock characteristic group. We define the lottery-type stocks index (LOT) proxy as the average of its ranking percentiles for each of the three characteristics.

In fact, stocks with the lowest level of IVOL and IDSKEW and the highest level of PRICE are assigned a rank of 1, while stocks with the highest level of idiosyncratic volatility (IVOL) and idiosyncratic skewness (IDSKEW) and the lowest level of PRICE are assigned a rank of 10. All of the three indicators are required to be included in computing our LOT composite index. Through this proceed, for each firm in each month, the LOT index will range from 3 (the

lowest LOT index including highest price, lowest idiosyncratic volatility, lowest idiosyncratic skewness) to 30 (the highest LOT index including lowest price, highest idiosyncratic volatility, and highest idiosyncratic skewness). All of the three indicators are required to be included to compute our LOT composite index. We prefer the stocks within the highest LOT index as the individual investors' perceived lottery-type stocks, and those with the lowest value index as individual investors' perceived non-lottery-type stocks.

Next, we will provide a brief of interested-variable constructions. Following Bali et al. (2011), MAX is defined as the extremely positive daily return in the previous month. Beta is the Fama and French (1992) market beta, estimated by computing for all firms using observations of 60 months and requiring at least 24-month observations. Following Huang et al. (2010), the short-term reversal (REV) represents the previous monthly stock return to control for the return reversal effects. Momentum (MOM) is the cumulative return on the stock from month $t-7$ to month $t-2$. For size and book-to-market ratio effect proxies, we use log of size (LOGME) as the natural logarithm of firm market capitalization for a firm in June. The book-to-market (BM) ratio is estimated as the book value of equity divided by market capitalization at the end of the year. Illiquidity (ILLIQ) is the absolute value of the monthly stock return scaled by the dollar trading volume in that month as in Amihud (2002) (at least 10 days of returns are required). We define the limits of arbitrage index as the average of all available limits of arbitrage indicator dummy variables for a stock to produce its limits of arbitrage index (with the requirement that a minimum of two indicators is available) following Gu et al. (2018).

2.2. Methodology

We employ portfolio-level analysis and firm-level cross-sectional regressions. These methods are commonly used in the empirical asset pricing literature. We follow Fama and MacBeth (1973) to run the following firm-level regressions with monthly data:

$$R_{i,t+1} = \beta_0 + \beta_{LOT} LOT_{i,t} + \beta_{X_n} X_{i,n,t} + \epsilon_{i,t+1} \quad (n = 1, 2, \dots, 7) \quad (2)$$

$$R_{i,t+1} = \alpha_0 + \beta_{MLOTk} MLOTk_{i,t} + \beta_{LOT} LOT_{i,t} + \beta_{X_n} X_{i,n,t} + \epsilon_{i,t+1} \quad (n = 1, 2, \dots, 6) \quad (3)$$

where the dependent variable ($R_{i,t+1}$) is the excess return of each stock in month $t+1$. $MLOTk$ is the interaction term between MAX and LOT. $LOTk$ is a dummy variable, which will take a value of 1 if stock i belongs to the k^{th} LOT quintile ($k = 1, 2, 3, 4$, and 5), otherwise zero. The independent variables include LOT ($LOT_{i,t}$) is the lottery-type stocks index, control variables ($X_{i,n,t}$, $n = 1, 2, \dots, 7$) of market beta (BETA, $n = 1$), log market capitalization (LOGME, $n = 2$), log book-to-market ratio (BM, $n = 3$), momentum (MOM, $n = 4$), short-term reversal (REV, $n = 5$), illiquidity (ILLIQ, $n = 6$), and MAX (MAX, $n = 7$).

3. Results

3.1. Summary statistics

Table 1 presents the time-series averages of cross-sectional mean, standard deviation, and correlations of variables including MAX, LOGME, BM, MOM, REV, IVOL, ILLIQ, and PRICE.

The LOT index has the highest correlation with the idiosyncratic skewness (0.663), followed by the idiosyncratic volatility (0.527) and the price (-0.394). We also find a positive correlation between LOT and MAX (0.489). So far, the correlation of each lottery feature is the same sign as we expect.

Table 1. Summary of descriptive statistics

	LOT	IVOL	IDSKEW	PRICE	MAX	BETA	LOGME	BM	MOM	REV	ILLIQ
Mean	4.507	0.090	0.345	12.374	0.057	1.108	15.173	-1.146	0.089	0.014	0.002
Std	1.675	0.039	0.782	8.827	0.038	0.150	0.859	0.655	0.269	0.121	0.002
LOT	1										
IVOL	0.527	1									
IDSKEW	0.663	0.177	1								
PRICE	-0.394	0.144	-0.022	1							
MAX	0.489	0.690	0.393	0.110	1						
BETA	0.100	0.064	-0.015	-0.151	0.030	1					
LOGME	-0.156	-0.124	0.032	0.246	-0.063	-0.538	1				
BM	0.116	-0.183	0.030	-0.382	-0.076	-0.052	0.064	1			
MOM	-0.071	0.170	-0.051	0.268	0.052	-0.031	0.058	-0.063	1		
REV	0.175	0.324	0.166	0.119	0.399	0.010	-0.018	0.009	-0.033	1	
ILLIQ	0.016	-0.022	-0.037	-0.107	-0.074	0.299	-0.513	-0.124	-0.135	-0.007	1

The table presented the time-series averages of cross-sectional mean, standard deviation, and correlations of variables including LOT, IVOL, IDSKEW, PRICE, MAX, LOGME, BM, MOM, REV, and LIQ. LOT is lottery-type stock index. IVOL is idiosyncratic return volatility. IDSKEW is idiosyncratic return skewness. PRICE is price of stock in each month. MAX is the highest daily return in the previous month. LOGME is the log firm market capitalization. BM is the log book value of equity scaled by market capitalization. MOM is the 6-month return of the stock during the period beginning 7 months prior to and ending one month prior to the measurement month. REV represents the lagged 1-month return. ILLIQ is the stock illiquidity following Amihud (2002).

Table 2. The LOT effect

Portfolio	Value weight		Equal weight	
	Ex.Ret	FF3 alpha	Ex.Ret	FF3 alpha
L	0.0070 (1.01)	0.0019 (1.27)	0.0137* (1.79)	0.0060*** (3.96)
2	0.0081 (1.05)	0.0017 (1.17)	0.0136* (1.67)	0.0043*** (2.90)
3	0.0055 (0.71)	-0.0012 (-0.67)	0.0107 (1.32)	0.0008 (0.48)
4	0.0050 (0.66)	-0.0038** (-2.24)	0.0080 (0.97)	-0.0029** (-1.96)
H	0.0023 (0.28)	-0.0090*** (-5.52)	0.0051 (0.58)	-0.0077*** (-4.67)
H-L	-0.0047 (-1.56)	-0.0109*** (-5.22)	-0.0086*** (-4.30)	-0.0137*** (-6.68)

This table shows results on the lottery-type (LOT) stocks. Monthly portfolios are formed by sorting all stocks in the Chinese samples into the quintile portfolios. For each Panel, the first two columns (the last two columns) show the average value-weighted (equal-weighted) one-month-ahead excess return (Ex.Ret) as well as risk-adjusted return extracted from the Fama and French (1993) (FF3 alpha) for each of the quintile portfolios. The last row presents the difference between the 5th portfolio and 1st portfolio. The t-values in parentheses are estimated based on Newey-West (Newey & West, 1987), and their significance is presented by ***, **, and * based on the significance levels of 1%, 5%, and 10%, respectively.

3.2. Demand for lottery-type stocks

Table 2 shows the average monthly excess returns relative to risk-free rates (Ex.Ret) and risk-adjusted returns of the Fama-French three-factor model (FF3 alpha) for quintile portfolios using equal-weighted (EW) and value-weighted (VW) returns based on the LOT index. The performances of the H-L zero-cost portfolio, which is the difference between the highest portfolio (H) and the lowest portfolio (L), are presented in the last row of the table.

The results in the last row of Table 2 support our hypothesis of the negative pricing of LOT regardless of the weighting schemes. Particularly, the value weight (equal weight) excess return of the H-L zero-cost portfolio is -0.0073 (-0.0128) with a t-statistic of -2.25 (-4.22), and value weight (equal weight) risk-adjusted return of the H-L zero-cost portfolio is -0.0082 (-0.0124) with a t-statistic of -2.61 (-4.07). This result is consistent with numerous standard previous studies that documented that lottery-type stocks have low expected returns. In addition, we also find that the equal weight LOT return is much higher than the value weight LOT return. This seems to be influenced by small stocks, which are stocks expected to be preferred as lottery-type stocks by individual investors. This is consistent with the finding of Han and Kumar (2013) who mention that lottery-type stocks is heavily traded by retail investors.

Table 3 shows the characteristics of firm-specific variables for each LOT index quintile portfolio using value-weighted returns. Following the definition of the lottery-type stocks, not surprisingly, high LOT tend to be stocked within higher IVOL, higher IDSKEW, and lower PRICE.

Next, we conduct the FM73 cross-sectional regressions under control variables. In each month, we estimate the regression coefficients of equation (1) and then report the average values of each coefficient in Table 4.

Table 3. Characteristics of LOT-sorted portfolio

Quintile	LOT	IVOL	IDSKEW	PRICE	MAX	LOGME	BM	MOM	REV	ILLIQ
L	2.223	0.064	-0.328	18.351	0.039	15.507	-1.244	0.074	-0.017	0.001
2	3.539	0.078	-0.003	14.255	0.046	15.364	-1.127	0.094	0.001	0.001
3	4.421	0.086	0.285	12.524	0.051	15.298	-1.104	0.072	0.007	0.002
4	5.395	0.100	0.639	11.461	0.060	15.233	-1.093	0.089	0.023	0.002
H	6.898	0.120	1.146	8.006	0.077	15.104	-1.037	0.051	0.036	0.003

This table presents the characteristics for stocks in quintile portfolios formed by the MAX. The average values are reported on LOT, IVOL, IDSKEW, PRICE, MAX, LOGME, BM, MOM, REV, and ILLIQ, which are calculated using all stocks in each portfolio.

Table 4. Fama–MacBeth cross-sectional regression

Model	LOT	BETA	LOGME	BM	MOM	REV	ILLIQ	MAX
1	-0.0019*** (-4.60)							
2	-0.0023*** (-3.16)	0.0007 (0.21)	-0.0005 (-0.32)	0.0035*** (3.12)	-0.0011 (-0.21)	-0.0478*** (-4.24)	9.1166*** (3.37)	-0.0279* (-1.70)

The table presents the results of Fama and MacBeth (1973) cross-sectional regression. Dependent variable is the one-month-ahead excess return. Independent variables are MAX as well as control variables of market beta (BETA), log market capitalization (LOGME), log book-to-market ratio (BM), momentum (MOM), short-term reversal (REV), illiquidity (ILLIQ), and maximum return (MAX). Regression is conducted in each month during completely testing period. Results are average values of each regression coefficient. The t-values in parentheses are estimated based on Newey-West (Newey & West, 1987), and their significance is presented by ***, **, and * based on the significance levels of 1%, 5%, and 10%, respectively.

The negative pricing of LOT is significant and robust with/without control variables. Moreover, the table shows that inclusion of the other controls does not strongly affect the coefficient of LOT. The regression coefficients of the LOT are -0.0019 ($t=-4.60$) in Model 1 and -0.0023 ($t = -3.16$) in Model 2. These results show robust evidence supporting the negative predictive power of LOT stocks for China. Also, the results are consistent with previous studies of Kumar (2009) who mention that LOT is independently priced in the market after controlling for other variables in the US market.

3.2. MAX and lottery-type stocks

In this section, we will examine the hypothesis that whether or not the MAX effect is strongly exhibited as a lottery-type stock's behavior in the Chinese market. We provide the MAX portfolio characteristics along with PRICE, IVOL, IDSKEW, and LOT index by using single portfolio sort, double portfolio sort, and FM73 regression.

3.2.1. Single portfolio sort

We first present the MAX portfolio characteristics along with PRICE, IVOL, and IDSKEW using a single portfolio sort. In each month, we shaped the stocks into MAX quintile portfolios in the previous month. Then, we report the monthly mean of MAX, PRICE, IVOL, and IDSKEW for stocks in each of the MAX quintile portfolios. All of these variables are measured in the previous month. The results are presented in Table 5.

Table 5 presents that high-MAX stocks have higher PRICE, higher IVOL, and higher IDSKEW

The average of PRICE (3.5598), IVOL (0.0760), and IDSKEW (0.7250) between the H-L MAX portfolio are highly statistically significant, with a t-statistic of 6.25, 28.05, and 18.79, respectively. This result is consistent with previous papers in the Chinese market, such as Nartea et al. (2017) and Wan (2018). However, this result indicates that the high-MAX stocks for China do not totally exhibit lottery-type stock's behavior in the past, especially in the PRICE feature. We will continuously verify this conclusion by using the double portfolio sort in the next part.

3.2.2. Double sorts

In this part, we examine the MAX effect and future return after controlling for three stock-type features (PRICE, IVOL, and IDSKEW), as well as LOT index by using double-sorting portfolio analysis. Motivated by Bali et al. (2011) who mentioned MAX as a lottery-type stocks phenomenon, we observe that the significantly negative MAX should be most pronounced among stocks with the lottery-type features. For each month, the quintile portfolios are formed based on PRICE (IVOL, IDSKEW, and LOT) and then within each portfolio, we construct quintile portfolios by MAX. We report the summary portfolio returns in Table 6 (we can check the results in the Appendix for further details). This is a 5×5 double-sorted PRICE-MAX (IVOL-MAX, IDSKEW-MAX, and LOT-MAX) portfolio. Finally, we evaluate the test hypothesis focusing on the H-L zero-cost portfolio by using both the excess return and the risk-adjusted return for each quintile portfolio of PRICE (IVOL, IDSKEW, and LOT).

From Panel A, the patterns in average returns of PRICE-MAX portfolios are consistent with the above prediction. The MAX effect in the lowest-PRICE stocks is stronger than that in the highest-PRICE stocks. For IVOL in Panel B and IDSKEW in Panel C, among the groups with highest MAX, high-IVOL, and high-IDSKEW firms tend to earn the lower subsequent returns. In general, the evidence supporting the MAX effect, which has a significant negative relationship with the future return, can be strongly observed in the lower-level PRICE and higher levels among IVOL and IDSKEW quintile portfolios. Regarding the relationship between MAX and LOT index in Panel D, we find that the MAX effect exists only in the lottery-type stocks. This finding is consistent with those in several papers such as Bali et al. (2011), Han and Kumar (2013).

Table 5. Single-sorted portfolio returns

	L	2	3	4	H	H-L
MAX	0.0275	0.0405	0.0508	0.0650	0.1023	0.0748*** (14.06)
PRICE	12.6252	14.5252	15.7094	17.5241	16.1850	3.5598*** (6.25)
IVOL	0.0527	0.0676	0.0797	0.0960	0.1287	0.0760*** (28.05)
IDSKEW	0.1143	0.2874	0.3798	0.5659	0.8393	0.7250*** (18.79)

This table reports the value-weight average monthly MAX stocks characteristics in quintile portfolios. We firstly allocate all stocks into five portfolios based on the past MAX. Then, we report the average portfolio value-weight of MAX, PRICE, IVOL, and IDSKEW in that month in each of five portfolios. H-L is the long versus short positions of MAX, PRICE, IVOL, and IDSKEW. The t-values in parentheses are estimated based on Newey-West (Newey & West, 1987), and their significance is presented by ***, **, and * based on the significance levels of 1%, 5%, and 10%, respectively.

3.2.3. Fama–MacBeth regressions

In this part, we conduct FM73 regressions as a robust methodology to examine the change of MAX phenomenon under the LOT level. We employ two models: Model 1 is a single-factor model with the LOT, Model 2 is a multi-factor model with all influential variables along with the LOT and the interaction terms of LOT and MAX. The results are shown in Table 7.

Table 7 reveals the strong evidence of MAX appearing only in the higher LOT stocks with/without controlling variables. The negative power of MAX dramatically increases when we move from the 1st quintile to the 5th LOT quintile. Particularly, in Model 1, the regression coefficient of the MAX in 1,2,3,4, and 5 LOT quintile is -0.1052 ($t=-1.67$), -0.1145 ($t=-2.54$), -0.1603 ($t=-4.05$), -0.1909 ($t=-5.12$), -0.2020 ($t=-5.95$), respectively. In other words, this result implies that the magnitude of the negative of MAX on LOT level is lower in stocks lower in LOT (higher in stocks higher in LOT). This also supports the evidence of the MAX effect in higher LOT stocks for China.

In summary, from Table 5, Table 6, and Table 7, we can conclude that the MAX does not contain all the necessary properties, as it is inherently a LOT of stocks in the Chinese market. This can explain why the MAX effect in the Chinese market is different compared to that in the US market.

3.3. Lottery-type stocks and limits of arbitrage

In this section, we examine the lottery effect on the limits of arbitrage (LAI) level based on the double-sorted portfolios, which is the same with Table 6 procedure. We expect to see that the lottery-type stocks is the strongest and negative significant in the highest LAI index. It means that the higher exhibit lottery-type stock features, the higher the limits to arbitrage. The results are presented in Table 8 for the LAI-LOT result in Panel A and for the LAI-MAX result in Panel B.

The patterns in average returns of LAI-LOT and LAI-MAX portfolios in Table 8 are consistent with the explanation of the MAX in the concept of limits of arbitrage. It means that the negative return premium of high MAX (LOT) stocks is more prominent in the high limits-of-arbitrage portfolio. This result is in line with Cao and Han (2016), and Bergsma and Tayal (2019) who mention that the higher exhibit lottery-type stocks features, higher the limits of arbitrage. This result is also supported by Zhong & Gray (2016) who argument that the MAX anomaly is primarily due to mispricing, which can persist due to the limits of arbitrage.

3.4. Alternative factor models and LOT and MAX effects

Liu et al. (2019) indicate that their CH3 model, with factors for size (eliminate the smallest 30% of stocks), value (VMG is constructed based on EP), and the market, performs well as a factor model in China, and it captures most documented anomalies. Thus, in this part, we evaluate the pricing of LOT and MAX effects in the Chinese stock market. Specifically, we report the average returns, Chinese three-factor (CH3) and Chinese four factor (CH4) models following the Liu et al. (2019) method, for LOT in Panel A (MAX in Panel B) sorted portfolios. In each month, we sort all stocks into quintiles based on their LOT in Panel A (MAX in Panel B) in the last month and hold the portfolio for month t . Finally, we report the average return and alphas in both value weighting (VW) and equal weighting (EW) portfolio schemes. In the (H–L) column, the return is for a zero-investment portfolio that is long the quintile of stocks with the LOT (MAX) and short the quintile of stocks with the lowest LOT (MAX). Our sample is from July 2000 to June 2020. Robust Newey–West t -statistics (estimated with four lags) are given in parentheses. We denote statistical significance at the 1%, 5%, and 10% levels with ***, **, and *, respectively. The results are presented in Table 9.

Table 6. Double-sorted portfolio returns

Portfolio	L	3	H	H-L	FF3 alpha	L	3	H	H-L	FF3 alpha
	Panel A: PRICE-MAX					Panel B: IVOL-MAX				
L	0.0158	0.0178	0.0078	-0.0080*** (-2.69)	-0.0101*** (-3.13)	0.0013	0.0145	0.0095	0.0082** (2.38)	0.0063** (2.04)
3	0.0072	0.008	0.004	-0.0032 (-0.91)	-0.0047 (-1.39)	0.0082	0.0082	0.006	-0.0022 (-0.73)	-0.0021 (-0.67)
H	0.0057	0.0079	-0.0061	-0.0118*** (-3.10)	-0.0136*** (-3.54)	0.0025	-0.0021	-0.0082	-0.0107*** (-3.66)	-0.0137*** (-4.69)
H-L	-0.0101** (-2.14)	-0.0099** (-2.39)	-0.0139*** (-2.89)	-0.0038 (-0.31)		0.0012 (0.30)	-0.0166*** (-3.99)	-0.0177*** (-4.65)	-0.0189** (-2.38)	
FF3 alpha	-0.0007 (-0.20)	0.0022 (0.81)	-0.0042 (-1.21)			-0.0001 (-0.02)	-0.0149*** (-3.71)	-0.0201*** (-4.83)		
AVE	0.0095 (1.17)	0.0100 (1.15)	0.0013 (0.14)	-0.0082*** (-3.58)	-0.0095*** (-4.37)	0.0062 (0.78)	0.0075 (0.89)	0.0041 (0.46)	-0.0021 (-1.15)	-0.0034** (-1.97)
	Panel C: IDSKEW-MAX					Panel D: LOT-MAX				
L	0.009	0.0124	0.0049	-0.0041 (-1.21)	-0.0047 (-1.19)	0.0046	0.0118	0.0069	0.0023 (0.64)	0.0045 (1.29)
3	0.0040	0.0083	0.0001	-0.0039 (-0.95)	-0.0043 (-1.20)	0.0081	0.0088	0.0006	-0.0075** (-2.07)	-0.0024 (-0.78)
H	0.0062	0.0031	-0.0012	-0.0074** (-2.10)	-0.0100*** (-2.81)	0.0097	0.0032	-0.0041	-0.0138*** (-4.95)	-0.0137*** (-4.92)

(Continued)

Table 6. (Continued)

Panel C: IDSKEW-MAX					Panel D: LOT-MAX				
H-L	-0.0028 (-1.19)	-0.0093*** (-3.11)	-0.0061* (-1.77)	-0.0033 (-0.71)		0.0051 (1.40)	-0.0086*** (-2.91)	-0.0110** (-2.58)	-0.0161*** (-4.29)
FF3 alpha	-0.0027 (-1.01)	-0.0077** (-2.39)	-0.0080** (-2.31)			-0.0012 (-0.47)	-0.0129*** (-5.04)	-0.0193*** (-5.75)	
AVE	0.0072 (0.92)	0.0093 (1.11)	0.0011 (0.13)	-0.0061** (-2.15)	-0.0069** (-2.35)	0.0085 (1.03)	0.0077 (0.94)	0.0022 (0.26)	-0.0062** (-2.33)
									-0.0034 (-1.39)

The table presents results on the MAX effect under control for three lottery-type stocks (PRICE, IVOL, and IDSKEW) and LOT index through a double-sorted quintile portfolio. Each month, we sorted all stocks into a quintile portfolio based on interest variable, and within each portfolio, stocks are sorted into a quintile portfolio based on MAX. The results for the average MAX portfolio within each interest variable quintile are also presented in the last row (AVE). This is double-sorted between interest variable and MAX quintile portfolio. Table reports average excess returns and risk-adjusted returns of portfolios based on value-weighting scheme. The t-values in parentheses are estimated based on Newey–West (Newey & West, 1987), and their significance is presented by ***, **, and * based on the significance levels of 1%, 5%, and 10%, respectively.

Table 7. Fama–MacBeth cross-sectional regression

	MODEL1	MODEL2
MLOT1	-0.1052* (-1.67)	0.0295 (0.57)
MLOT2	-0.1145** (-2.54)	-0.0008 (-0.02)
MLOT3	-0.1603*** (-4.05)	-0.0012** (-1.99)
MLOT4	-0.1909*** (-5.12)	-0.0553*** (-2.95)
MLOT5	-0.2020*** (-5.95)	-0.0665*** (-3.17)
LOT	-0.0005** (-1.98)	-0.0014 (-1.11)
BETA		-0.0030 (-1.03)
SIZE		-0.0012 (-0.74)
BM		0.0035*** (3.19)
MOM		-0.0009 (-0.16)
REV		-0.0458*** (-4.07)
ILLIQ		7.1335*** (3.36)

The table presents the results of Fama and MacBeth (1973) cross-sectional regression. The dependent variable is the one-month-ahead excess return. Independent variables are MAX, LOT_k (k=1, 2, 3, 4, and 5) are the five dummies according to the LOT index quintiles, LOT_{i,t} is the lottery-type stock index value for stock *i*, as well as control variables of market beta (BETA), log market capitalization (SIZE), log book to market ratio (BM), short-term reversal (REV), and illiquidity (ILLIQ). Regression is conducted in each month during the completely testing period. Results are the average values of each regression coefficient. The *t*-values in parentheses are estimated based on Newey-West (Newey & West, 1987), and their significance is presented by ***, **, and * based on the significance levels of 1%, 5%, and 10%, respectively.

First, we use the CH3 model, our portfolio alphas are statistically and economically significant when forming portfolios on LOT in Panel A. For example, the LOT return on the VW (EW) CH3 alpha portfolio is -0.0059 (-0.0090) and significant at 5% (1%) level. In contrast, the MAX return on the EW (VW) CH3 alpha portfolio is -0.0097 (-0.0103) with a *t*-statistics of -1.38 (-1.15). It means that CH3 model can explain the pricing of MAX effect in the Chinese stock market. When we move on to the CH4 model results, it can be seen that the predictive power of LOT is still statistically and economically significant. We also find that CH4 can eliminate the MAX effect in the Chinese stock market. This result is consistent with Liu et al. (2019), who revealed that the MAX effect is subsumed by the CH3 model.

4. Conclusions

In this paper, we study whether MAX is a good proxy for lottery-type stocks in the Chinese market. We first find a significantly negative return premium for stocks with higher LOT following Kumar (2009). We then find that the MAX effect is stronger in the higher LOT effect for China. For further

Table 8. Relationship LOT, MAX, and LAI for the Chinese market

Portfolio	Panel A: LAI-LOT					Panel B: LAI-MAX				
	L	3	H	H-L	FF3 alpha	L	3	H	H-L	FF3 alpha
L	0.0086	0.0076	0.0041	-0.0045 (-1.17)	-0.0098*** (-3.20)	0.0083	0.008	0.004	-0.0043 (-1.20)	-0.0059* (-1.66)
3	0.0093	0.0065	0.0034	-0.0059* (-1.84)	-0.0113*** (-3.96)	0.0113	0.0146	-0.0024	-0.0138*** (-3.43)	-0.0120*** (-2.91)
H	0.0157	0.0102	0.0046	-0.0111*** (-3.47)	-0.0164*** (-5.27)	0.0178	0.011	-0.001	-0.0188*** (-5.29)	-0.0184*** (-7.95)
H-L	0.0071** (2.43)	0.0026 (0.53)	0.0005 (0.10)	-0.0066** (-2.28)		0.0095* (1.84)	0.0030 (0.68)	-0.005 (-1.12)	-0.0145*** (-3.75)	
FF3 alpha	0.0035** (2.39)	-0.0002 (-0.06)	-0.0030* (-1.92)			0.0050** (2.00)	0.0003 (0.12)	-0.0075*** (-3.21)		

The table presents results on the LOT (MAX) effect under control for limits to arbitrage (LAI) through double-sorted quintile portfolio. Each month, we sorted all stocks into quintile portfolio based on LAI, and within each portfolio, stocks are sorted into quintile portfolio based on LOT (MAX). This is double-sorted LAI-LOT (LAI-MAX) quintile portfolio in Panel A (Panel B). Table reports average excess returns and risk-adjusted returns of portfolios based on value-weighting scheme. The Newey-West (Newey & West, 1987) adjusted t-values are presented in parentheses, and their significance is presented by ***, **, and * based on the significance levels of 1%, 5%, and 10%, respectively.

Table 9. The results of the alternative factors model and LOT, MAX effect

Portfolio	Panel A: LOT		Panel B: MAX	
	Value weight	Equal weight	Value weight	Equal weight
L	0.0070 (1.01)	0.0137* (1.79)	0.0072 (0.99)	0.0139 (1.69)
2	0.0081 (1.05)	0.0136* (1.67)	0.0094 (1.26)	0.0148 (1.81)
3	0.0055 (0.71)	0.0107 (1.32)	0.0106 (1.41)	0.0130 (1.58)
4	0.0050 (0.66)	0.0080 (0.97)	0.0034 (0.44)	0.0081 (1.02)
H	0.0023 (0.28)	0.0051 (0.58)	-0.0001 (-0.02)	0.0011 (0.13)
H-L	-0.0047 (-1.56)	-0.0086*** (-4.30)	-0.0073** (-2.25)	-0.0128*** (-4.22)
FF3 alpha	-0.0109*** (-5.22)	-0.0137*** (-6.68)	-0.0081*** (-2.61)	-0.0124*** (-4.37)
CH3 alpha	-0.0059** (-2.59)	-0.0090*** (-3.17)	-0.0097 (-1.38)	-0.0103 (-1.15)
CH4 alpha	-0.0089*** (-3.14)	-0.0099*** (-4.58)	-0.0037 (-1.06)	-0.0063* (-1.87)

This table shows results on the lottery-type (LOT) stocks in Panel A and MAX in Panel B. Monthly portfolios are formed by sorting all stocks in the Chinese samples into the quintile portfolios. For each Panel, the first columns (the last columns) show the average value-weighted (equal-weighted) one-month-ahead excess return (Ex.Ret) as well as risk-adjusted return extracted from the Fama and French (1993) (FF3 alpha), the Chinese three-factor (CH3 alpha) and four-factor (CH4 alpha) models proposed by Liu et al. (2019), for each of the quintile portfolios. The t-values in parentheses are estimated based on Newey-West (Newey & West, 1987), and their significance is presented by ***, **, and * based on the significance levels of 1%, 5%, and 10%, respectively.

analysis, the MAX at a lower price is stronger than that at a higher one. This finding implies that MAX does not contain all the necessary properties, as it is inherently a LOT of stocks behavior in the Chinese market. This can explain why the MAX effect in the Chinese market is different compared to that in the US market or European market.

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Notes

1. We posit that the use of Kumar's (2009) lottery method would be appropriate in our study for the following reasons. First, Kumar (2009) point out that their method is concentrated on individual gambling investors, not institutional investors. It means that their method is more likely to be used by individual investors to identify the stocks within lottery characteristics. Second, the Chinese market trading activities are dominated by individual investors (Lee et al., 2010). Taken together, the Kumar (2009) method is appropriate to achieve our research goals.
2. IVOL, IDSKEW is estimated following Ang et al. (2006), Boyer et al. (2010) as the one month period variance, skewness of the residuals from a regression of excess stock returns on Fama and French (1993) three factors using daily return data.

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Appendix A1: Relationship between PRICE and MAX

The table presents results on the MAX effect under control for stock price (PRICE) through a double-sorted quintile portfolio. Each month, we sorted all stocks into quintile portfolio based on PRICE, and within each portfolio, stocks are sorted into quintile portfolio based on MAX. The results for the average MAX portfolio within each PRICE quintile are also presented in the last row (AVE). This is a double-sorted PRICE-MAX quintile portfolio. Table reports average excess returns and risk-adjusted returns of portfolios based on value and equal-weighting schemes. The t-values in parentheses are estimated based on Newey–West (Newey & West, 1987), and their significances are presented by ***, **, and * based on the significance levels of 1%, 5%, and 10%, respectively.

VW PRICE-MAX portfolio							
	Lowest MAX	2	3	4	Highest MAX	H_L	FF3 alpha
Lowest PRICE	0.0158	0.0154	0.0178	0.0138	0.0078	-0.0080*** (-2.69)	-0.0101*** (-3.13)
2	0.0097	0.0097	0.0091	0.0071	0.0023	-0.0074** (-2.25)	-0.0085*** (-2.71)
3	0.0072	0.0111	0.008	0.0018	0.004	-0.0032 (-0.91)	-0.0047 (-1.39)
4	0.0089	0.0099	0.0072	0.0012	-0.0017	-0.0106*** (-3.75)	-0.0125*** (-4.89)
Highest PRICE	0.0057	0.0083	0.0079	0.0029	-0.0061	-0.0118*** (-3.10)	-0.0136*** (-3.54)
H_L	-0.0101** (-2.14)	-0.0071 (-1.61)	-0.0099** (-2.39)	-0.0109** (-2.09)	-0.0139*** (-2.89)	-0.0038 (-0.81)	
FF3 alpha	-0.0007 (-0.20)	0.0034 (1.12)	0.0022 (0.81)	0.0002 (0.08)	-0.0042 (-1.21)		
AVE	0.0095 (1.17)	0.0109 (1.32)	0.01 (1.15)	0.0054 (0.62)	0.0013 (0.14)	-0.0082*** (-3.58)	-0.0099*** (-4.37)

EW PRICE-MAX portfolio							
	Lowest MAX	2	3	4	Highest MAX	H_L	FF3 alpha
Lowest PRICE	0.0184	0.0195	0.0192	0.0153	0.0081	-0.0103*** (-5.21)	-0.0138*** (-2.59)
2	0.0145	0.0162	0.0152	0.0113	0.0036	-0.0109*** (-6.41)	-0.0120*** (-5.06)
3	0.0137	0.0141	0.0111	0.0066	0.0002	-0.0135*** (-9.24)	-0.0092*** (-4.63)
4	0.0117	0.0125	0.0104	0.0049	-0.0016	-0.0133*** (-7.26)	-0.0094*** (-3.14)
Highest PRICE	0.0093	0.0103	0.0095	0.0058	-0.005	-0.0143*** (-6.43)	-0.0090*** (-3.11)
H_L	-0.0091** (-2.15)	-0.0092** (-2.19)	-0.0097*** (-2.64)	-0.0095** (-2.43)	-0.0131*** (-3.52)	-0.004 (-1.35)	
FF3 alpha	0.0002 (0.07)	0.0017 (0.66)	0.0013 (0.54)	0.0015 (0.53)	-0.003 (-0.97)		
AVE	0.0135 (1.52)	0.0145 (1.64)	0.0131 (1.46)	0.0088 (0.99)	0.0011 (0.12)	-0.0124*** (-6.67)	-0.0130*** (-5.98)

Appendix A2: Relationship between IVOL and MAX

The table presents results on the MAX effect under control for idiosyncratic volatility (IVOL) through a double-sorted quintile portfolio. Each month, we sorted all stocks into quintile portfolio based on IVOL, and within each portfolio, stocks are sorted into quintile portfolio based on MAX. The results for the average MAX portfolio within each IVOL quintile are also presented in the last row (AVE). This is a double-sorted IVOL-MAX quintile portfolio. Table reports average excess returns and risk-adjusted returns of portfolios based on value and equal-weighting schemes. The t-values in parentheses are estimated based on Newey–West (Newey & West, 1987), and their significances are presented by ***, **, and * based on the significance levels of 1%, 5%, and 10%, respectively.

VW IVOL-MAX portfolio							
	Lowest MAX	2	3	4	Highest MAX	H_L	FF3 alpha
Lowest IVOL	0.0013	0.0136	0.0145	0.0133	0.0095	0.0082** (2.38)	0.0063** (2.04)
2	0.0111	0.0105	0.0123	0.0126	0.009	-0.0021 (-0.69)	-0.0018 (-0.47)
3	0.0082	0.0072	0.0082	0.0134	0.006	-0.0022 (-0.73)	-0.0021 (-0.67)
4	0.0079	0.0035	0.0047	0.0051	0.0043	-0.0036 (-1.42)	-0.0057* (-1.86)
Highest IVOL	0.0025	0.0001	-0.0021	-0.0072	-0.0082	-0.0107*** (-3.66)	-0.0137*** (-4.69)
H_L	0.0012 (0.30)	-0.0135*** (-3.42)	-0.0166*** (-3.99)	-0.0205*** (-5.34)	-0.0177*** (-4.65)	-0.0189** (-2.38)	
FF3 alpha	-0.0001 (-0.02)	-0.0116*** (-3.17)	-0.0149*** (-3.71)	-0.0195*** (-4.84)	-0.0201*** (-4.83)		
AVE	0.0062 (0.78)	0.0070 (0.87)	0.0075 (0.89)	0.0074 (0.87)	0.0041 (0.46)	-0.0021 (-1.15)	-0.0034** (-1.96)

EW IVOL-MAX portfolio							
	Lowest MAX	2	3	4	Highest MAX	H_L	FF3 alpha
Lowest IVOL	0.0102	0.0158	0.0187	0.0189	0.0193	0.0091*** (3.64)	0.0077*** (3.21)
2	0.0142	0.0155	0.0166	0.0152	0.0146	0.0004 (0.20)	-0.0004 (-0.22)
3	0.0126	0.0121	0.0124	0.0135	0.0123	-0.0003 (-0.19)	-0.0002 (-0.09)
4	0.013	0.0082	0.007	0.0069	0.0051	-0.0079*** (-4.21)	-0.0081*** (-4.03)
Highest IVOL	0.0034	0.0034	-0.0026	-0.0058	-0.0055	-0.0089*** (-5.16)	-0.0108*** (-6.82)
H_L	-0.0068** (-2.45)	-0.0124*** (-4.51)	-0.0213*** (-6.27)	-0.0247*** (-6.98)	-0.0248*** (-6.90)	-0.0180*** (-5.77)	
FF3 alpha	-0.0065** (-2.05)	-0.0109*** (-3.86)	-0.0190*** (-5.63)	-0.0220*** (-5.55)	-0.0250*** (-4.78)		
AVE	0.0107 (1.23)	0.0109 (1.25)	0.0104 (1.18)	0.0097 (1.09)	0.0091 (1.00)	-0.0016 (-1.43)	-0.0023** (-2.15)

Appendix A3: Relationship between IDSKEW and MAX

The table presents results on the MAX effect under control for idiosyncratic skewness (IDSKEW) through a double-sorted quintile portfolio. Each month, we sorted all stocks into quintile portfolio based on IDSKEW, and within each portfolio, stocks are sorted into quintile portfolio based on MAX. The results for the average MAX portfolio within each IDSKEW quintile are also presented in the last row (AVE). This is a double-sorted IDSKEW-MAX quintile portfolio. Table reports average excess returns and risk-adjusted returns of portfolios based on value and equal-weighting schemes. The t-values in parentheses are estimated based on Newey–West (Newey & West, 1987), and their significances are presented by ***, **, and * based on the significance levels of 1%, 5%, and 10%, respectively.

VW IDSKEW-MAX portfolio							
	Lowest MAX	2	3	4	Highest MAX	H_L	FF3 alpha
Lowest IDSKEW	0.009	0.0132	0.0124	0.0125	0.0049	-0.0041 (-1.21)	-0.0047 (-1.19)
2	0.0098	0.0131	0.0096	0.0066	0.0009	-0.0089** (-2.01)	-0.0084* (-1.89)
3	0.004	0.0118	0.0083	0.0063	0.0001	-0.0039 (-0.95)	-0.0043 (-1.20)
4	0.0071	0.0104	0.0132	0.0051	0.0009	-0.0062 (-1.52)	-0.0073** (-1.96)
Highest IDSKEW	0.0062	0.0059	0.0031	0.0015	-0.0012	-0.0074** (-2.10)	-0.0100*** (-2.81)
H_L	-0.0028 (-1.19)	-0.0073*** (-2.97)	-0.0093*** (-3.11)	-0.011*** (-3.99)	-0.0061* (-1.77)	-0.0033 (-0.71)	
FF3 alpha	-0.0027 (-1.01)	-0.0056** (-2.01)	-0.0077** (-2.39)	-0.0109*** (-3.42)	-0.0080** (-2.31)		
AVE	0.0072 (0.92)	0.0109 (1.34)	0.0093 (1.11)	0.0064 (0.76)	0.0011 (0.13)	-0.0061** (-2.15)	-0.0069** (-2.35)

EW IDSKEW-MAX portfolio							
	Lowest MAX	2	3	4	Highest MAX	H_L	FF3 alpha
Lowest IDSKEW	0.0149	0.0182	0.0187	0.0153	0.0071	-0.0078*** (-3.17)	-0.0066** (-2.15)
2	0.0133	0.0148	0.0143	0.0107	0.0033	-0.01*** (-4.39)	-0.0087*** (-3.21)
3	0.0119	0.0146	0.0121	0.0097	0.0015	-0.0104*** (-5.34)	-0.0101*** (-4.52)
4	0.0117	0.0117	0.0128	0.006	0.0005	-0.0112*** (-4.65)	-0.0114*** (-4.59)
Highest IDSKEW	0.0124	0.0105	0.0077	0.0022	-0.0013	-0.0137*** (-6.59)	-0.0152*** (-6.78)
H_L	-0.0025** (-2.07)	-0.0077*** (-4.19)	-0.011*** (-4.49)	-0.0131*** (-4.63)	-0.0084*** (-3.83)	-0.0059** (-2.29)	
FF3 alpha	-0.0020 (-1.55)	-0.0067*** (-4.21)	-0.0096*** (-4.58)	-0.0129*** (-4.92)	-0.0106*** (-4.39)		
AVE	0.0128 (1.44)	0.0140 (1.55)	0.0131 (1.45)	0.0088 (1.00)	0.0022 (0.25)	-0.0106*** (-6.74)	-0.0104*** (-5.08)

Appendix A4: Relationship between LOT and MAX

The table presents results on the MAX effect under control for lottery-type stock index (LOT) through double-sorted quintile portfolio. Each month, we sorted all stocks into quintile portfolio based on LOT, and within each portfolio, stocks are sorted into quintile portfolio based on MAX. The results for the average MAX portfolio within each LOT quintile are also presented in the last row (AVE). This is a double-sorted LOT-MAX quintile portfolio. Table reports average excess returns and risk-adjusted returns of portfolios based on value and equal-weighting schemes. The t-values in parentheses are estimated based on Newey–West (Newey & West, 1987), and their significances are presented by ***, **, and * based on the significance levels of 1%, 5%, and 10%, respectively.

VW LOT-MAX portfolio							
	Lowest MAX	2	3	4	Highest MAX	H_L	FF3 alpha
Lowest LOT	0.0046	0.0102	0.0118	0.0069	0.0069	0.0023 (0.64)	0.0045 (1.29)
2	0.0073	0.0119	0.0101	0.0102	0.0074	0.0001 (0.02)	0.0032 (0.75)
3	0.0081	0.0094	0.0088	0.0057	0.0006	-0.0075** (-2.07)	-0.0024 (-0.78)
4	0.0126	0.0083	0.0049	0.0027	0.0003	-0.0123*** (-3.16)	-0.0087** (-2.36)
Highest LOT	0.0097	0.0044	0.0032	0.0001	-0.0041	-0.0138*** (-4.95)	-0.0137*** (-4.92)
H_L	0.0051 (1.40)	-0.0058* (-1.74)	-0.0086*** (-2.91)	-0.0068* (-1.86)	-0.0110** (-2.57)	-0.0161*** (-4.29)	
FF3 alpha	-0.0012 (-0.47)	-0.0115*** (-3.29)	-0.0129*** (-5.04)	-0.0135*** (-5.40)	-0.0193*** (-5.75)		
AVE	0.0085 (1.03)	0.0089 (1.08)	0.0077 (0.94)	0.0051 (0.61)	0.0022 (0.26)	-0.0062** (-2.33)	-0.0034 (-1.39)

EW LOT-MAX portfolio							
	Lowest MAX	2	3	4	Highest MAX	H_L	FF3 alpha
Lowest LOT	0.0106	0.0166	0.0158	0.0148	0.0108	0.0002 (0.10)	0.0029 (1.24)
2	0.0155	0.0152	0.0147	0.0132	0.0091	-0.0064** (-2.27)	-0.0021 (-0.86)
3	0.013	0.014	0.0128	0.0088	0.0047	-0.0083*** (-3.04)	-0.0033 (-1.40)
4	0.0146	0.0124	0.0091	0.0037	0.0003	-0.0143*** (-4.87)	-0.0102*** (-3.92)
Highest LOT	0.0132	0.0082	0.0056	0.0001	-0.0019	-0.0151*** (-5.06)	-0.0145*** (-7.17)
H_L	0.0026 (0.96)	-0.0084*** (-3.63)	-0.0102*** (-4.20)	-0.0147*** (-4.42)	-0.0127*** (-4.98)	-0.0153*** (-5.57)	
FF3 alpha	-0.0012 (-0.47)	-0.0115*** (-3.29)	-0.0130*** (-5.04)	-0.0135*** (-5.40)	-0.0193*** (-5.75)		
AVE	0.0134 (1.43)	0.0133 (1.49)	0.0116 (1.31)	0.0081 (0.94)	0.0046 (0.53)	-0.0088*** (-4.26)	-0.0054*** (-2.82)

Appendix A5: Single-sorted portfolio returns

This table reveals the characteristics of MAX portfolios. In each month, we form the stocks into quintile portfolios based on MAX. Panel A (Panel B) presents the time-series means of the monthly equal-weighting average month t+1 values of MAX, PRICE, IVOL, and IDSKEW for stocks in each of the MAX decile portfolios. The column labeled High-Low MAX presents results for the difference in average stock characteristics between the decile 10 portfolio and the decile 1 portfolio. The t-values in parentheses are estimated based on Newey-West (Newey & West, 1987), and their significances are presented by ***, **, and * based on the significance levels of 1%, 5%, and 10%, respectively.

Variables	L	2	3	4	H	H-L
MAX	0.0286	0.0405	0.0508	0.0649	0.1000	0.0714*** (21.78)
PRICE	10.7403	11.4526	12.3510	13.7594	13.5497	2.8094*** (6.86)
IVOL	0.0601	0.0717	0.0840	0.1009	0.1345	0.0744*** (20.89)
IDSKEW	0.0102	0.1924	0.3470	0.5568	0.8705	0.8603*** (22.83)

Appendix A6: Relationship among LOT, MAX, and LAI for the Chinese market
The table presents results on the LOT effect under control for limits to arbitrage (LAI) through a double-sorted quintile portfolio. Each month, we sort all stocks into a quintile portfolio based on LAI, and within each portfolio, stocks are sorted into a quintile portfolio based on LOT. This is a double-sorted LOT-LAI quintile portfolio. Table reports average excess returns and risk-adjusted returns of portfolios based on a value-weighting scheme. The Newey–West (Newey & West, 1987) adjusted t-values are presented in parentheses, and their significances are presented by ***, **, and * based on the significance levels of 1%, 5%, and 10%, respectively.

	Lowest LOT	2	3	4	Highest LOT	H_L	FF3 alpha
Panel A: Value-weighted							
Lowest LAI	0.0086	0.0055	0.0076	0.0073	0.0041	-0.0045 (-1.17)	-0.0098*** (-3.20)
2	0.0058	0.002	0.0021	-0.001	-0.0005	-0.0063 (-1.57)	-0.0132*** (-3.69)
3	0.0093	0.0147	0.0065	0.0048	0.0034	-0.0059* (-1.84)	-0.0113*** (-3.96)
4	0.0164	0.014	0.0112	0.0084	0.0093	-0.0071* (-1.84)	-0.0138*** (-4.46)
Highest LAI	0.0157	0.0156	0.0102	0.0068	0.0046	-0.0111*** (-3.47)	-0.0164*** (-5.27)
H_L	0.0071** (2.43)	0.0101** (2.08)	0.0026 (0.53)	-0.0005 (-0.11)	0.0005 (0.10)	-0.0066** (-2.28)	
FF3 alpha	0.0035** (2.39)	0.0066** (2.53)	-0.0002 (-0.06)	-0.0039* (-1.69)	-0.0030* (-1.92)		

(Continued)

(Continued)							
	Lowest LOT	2	3	4	Highest LOT	H_L	FF3 alpha
Panel B: Equal-weighted							
Lowest LAI	0.0095	0.009	0.0081	0.0068	0.0055	-0.0040 (-1.41)	-0.0093*** (-4.13)
2	0.0074	0.0065	0.004	0.002	0.0001	-0.0073* (-1.97)	-0.0133*** (-3.94)
3	0.0139	0.0158	0.0104	0.0072	0.0040	-0.0099*** (-3.60)	-0.0156*** (-4.62)
4	0.0216	0.0181	0.0153	0.0146	0.0126	-0.0090*** (-2.96)	-0.0135*** (-5.14)
Highest LAI	0.0196	0.0188	0.0128	0.0098	0.0063	-0.0133*** (-4.85)	-0.0175*** (-7.56)
H_L	0.0101*** (2.92)	0.0098*** (2.67)	0.0047 (1.24)	0.0030 (0.89)	0.0008 (0.26)	-0.0093*** (-2.85)	
FF3 alpha	0.0077*** (3.76)	0.0072*** (3.39)	0.0027 (1.03)	0.0022 (1.09)	-0.0005 (-0.23)		

Appendix A7: Relationship between MAX and LAI for the Chinese market
The table presents results on the MAX effect under control for limits to arbitrage (LAI) through a double-sorted quintile portfolio. Each month, we sorted all stocks into quintile portfolio based on LAI, and within each portfolio, stocks are sorted into quintile portfolio based on MAX. This is a double-sorted LAI-MAX quintile portfolio. Table reports average excess returns and risk-adjusted returns of portfolios based on a value-weighting scheme. The Newey–West (Newey & West, 1987) adjusted t-values are presented in parentheses, and their significances are presented by ***, **, and * based on the significance levels of 1%, 5%, and 10%, respectively.

	Lowest MAX	2	3	4	Highest MAX	H_L	FF3 alpha
Panel A: Value-weighted							
Lowest LAI	0.0083	0.0092	0.008	0.0071	0.004	-0.0043 (-1.20)	-0.0059* (-1.66)
2	0.0052	0.006	0.0063	-0.0023	-0.0018	-0.0071* (-1.79)	-0.0076** (-2.08)
3	0.0113	0.0166	0.0146	0.0047	-0.0024	-0.0138*** (-3.43)	-0.0120*** (-2.91)
4	0.0174	0.0227	0.0161	0.0125	-0.0012	-0.0185*** (-5.49)	-0.0183*** (-5.42)
Highest LAI	0.0178	0.0178	0.011	0.0084	-0.001	-0.0188*** (-5.29)	-0.0184*** (-7.95)
H_L	0.0095* (1.84)	0.0086** (2.05)	0.0030 (0.68)	0.0013 (0.27)	-0.005 (-1.12)	-0.0145*** (-3.75)	
FF3 alpha	0.0050** (2.00)	0.0060*** (2.89)	0.0003 (0.12)	-0.0032 (-1.09)	-0.0075*** (-3.21)		

(Continued)

(Continued)							
	Lowest MAX	2	3	4	Highest MAX	H_L	FF3 alpha
Panel B: Equal-weighted							
Lowest LAI	0.009	0.0098	0.0082	0.007	0.0048	-0.0042 (-1.58)	-0.0042 (-1.46)
2	0.0075	0.0069	0.0051	-0.0007	0.0011	-0.0064*** (-2.61)	-0.0059** (-2.14)
3	0.0133	0.0164	0.0152	0.0083	-0.0015	-0.0148*** (-5.20)	-0.0131*** (-4.02)
4	0.0208	0.0251	0.0182	0.015	0.0038	-0.0170*** (-5.53)	-0.0172*** (-5.78)
Highest LAI	0.0212	0.0203	0.014	0.0104	0.0015	-0.0197*** (-6.93)	-0.0192*** (-5.21)
H_L	0.0122*** (3.14)	0.0105*** (3.23)	0.0058* (1.84)	0.0034 (1.02)	-0.0033 (-0.90)	-0.0155*** (-4.86)	
FF3 alpha	0.0098*** (4.35)	0.0095*** (4.60)	0.0041** (2.29)	0.0013 (0.59)	-0.0052** (-2.22)		

Appendix A8: The description of limit to arbitrage proxy (sources: Gu et al. (2018))

Proxies	Description
Pricing limit (LIMIT)	In the Chinese stock market, there has been a 10% limit of daily price up or down for regular stocks and a 5% limit for stocks under special treatment since December 1996. Stocks hitting the price limit are more likely to face higher limits of arbitrage. $LIMIT_{i,t}$ is assigned the value of one for stock i if it reaches at daily price limit for at least once in month t . The calculation period is from July 2000 to June 2020.
The margin trading and short selling (MTSS)	In the Chinese stock market, the margin trading and short selling (MTSS) policy, started from March 2010, is a pilot program. We expect that the stocks not included in MTSS are exposed to higher limits of arbitrage. $MTSS_{i,t}$ is assigned the value of one if stock i is excluded from this program in month t . The calculation period is from December 2011 to June 2020.
CSI 300 future (CSI300)	The CSI 300 future, listed on April 2010, is the only tradable index future in the Chinese stock market. We expect, for stocks that are not included the index, arbitrageurs will face a higher degree of limits of arbitrage. $CSI_{i,t}$ is assigned the value of one if stock i does not belong to the CSI 300. The calculation period is April 2010 to June 2020.
Illiquidity (AMIHU)	Stocks with higher illiquidity are more likely to have higher limits of arbitrage. We take log of the Amihud (2002) illiquidity measure and calculate the median in each month. $AMIHU_{i,t}$ is assigned the value of one if stock i has a value larger than the cross-sectional median in month t . The calculation period is from July 2000 to June 2020.
Trading volume (VOL)	Stocks that experience lower trading volume are more likely to be associated with higher limits of arbitrage. Volume is the average monthly volume over the past six months. $VOL_{i,t}$ is assigned the value of one if stock i 's volume is less than or equal to the cross-sectional median in month t . The calculation period is from July 2000 to June 2020.
Analyst Coverage (COV)	Stocks with less analyst coverage may have higher limits of arbitrage. Analyst coverage is the number of analysts covering firm i in month t . $COV_{i,t}$ is assigned the value of one if stock i 's number of following analyst is less than or equal to the cross-sectional median in month t . The calculation period is from January 2005 to June 2020.



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