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ARE THERE PSYCHOLOGICAL BARRIERS IN ASIAN STOCK MARKETS?

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ABSTRACT

We examine six major Asian stock markets for indication of psychological barriers at round numbers. We test for uniformity in the trailing digits of the indices and use regression and generalized autoregressive conditional heteroskedasticity (GARCH) analysis to assess the differential impact of being above or below a possible barrier. The strongest indication of barriers was found in the markets of South Korea and Taiwan. There is mild evidence of barriers in Japan and Hong Kong and the stock markets of Singapore and China exhibit only weak signs of psychological barriers. These findings challenge the notion that Asian markets are efficient and support the claim that technical analysis strategies can be useful in some of these markets.

Keywords: Asian markets, psychological barriers, stock market indices, market psychology, round numbers

INTRODUCTION

Market observers frequently refer to the existence of psychological barriers in stock markets. Many investors believe that round numbers serve as barriers, and that prices may resist crossing these barriers. Moreover, the use of technical analysis is based on the assertion that traders will jump on the bandwagon of buying (selling) once the price breaks up (down) through a psychologically

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important level thus suggesting that the breaching of one of these barriers may push the prices up (down) more than otherwise warranted. Frequently used phrases by the business press such as “support levels” and “resistance levels” imply that, until such time as an important barrier is crossed, increases and decreases in the prices may be restrained.[1]

The impact of such kind of psychological barriers in investors’ decisions has been studied since the 1990’s for a variety of asset classes, from exchange rates with De Grauwe and Decupere (1992) to the European Carbon Market with Palao and Pardo (2018). The evidence of psychological barriers on stock market indices suggests some significant impacts of this phenomenon in the returns and variances in different geographies and periods (e.g., Cyree, Domian, Louton, & Yobaccio, 1999; Woodhouse, Singh, Bhattarcharya, & Kumar, 2016; Berk, Cummins, Dowling, & Lucey, 2017).

This paper examines the existence of psychological barriers at round numbers in six major Asian stock market indices: Shanghai SE Composite (China), KOSPI (South Korea), Taiwan SE Weighted DS (Taiwan), Hang Seng (Hong Kong), Nikkei 225 (Japan), and Straits Times Index (Singapore). To the best of our knowledge, this is the most extensive analysis ever conducted of these markets with this purpose.

The anchoring effect, a well-known behavioural bias firstly identified by Tversky and Kahneman (1974), is the main explanation for the existence of psychological barriers in financial markets. Individuals, when performing an estimation in an ambiguous situation, tend to fixate (“to anchor”) on a salient number even if that number is irrelevant for the estimation. The anchoring on round numbers is important due to its great explanatory power of some of the features commonly associated to financial markets. It may help to understand, for example, the excessive price volatility (Westerhoff, 2003), the momentum effect (George & Hwang, 2004), or even the emergence of speculative bubbles (Shiller, 2015).

The existence of psychological barriers contradicts the efficient market hypothesis as it points to some level of predictability in stock markets and thus may lead to abnormal risk-adjusted returns. Hence, empirical evidence for the existence of psychological barriers is not only of interest to practitioners who are looking for profitable strategies but it also represents a contribution to the literature on market efficiency and on market anomalies.

To investigate the existence of psychological barriers, we conduct tests for positional and transgressional effects. We test for uniformity in the trailing digits of the stock indices and use regression and GARCH analysis to assess the differential impact of being above or below a possible barrier.

We extend the existing research in several important directions. First, we add at least more 30 years of observations to the sample period considered in previous studies on the Asian markets. For example, our sample of more than 66 years of data referring to the Nikkei 225 index compares with samples ranging from 13 to 16 years considered by Koedijk and Stork (1994), De Ceuster, Dhaene and Schatteman (1998), and Cyree et al. (1999). Having a larger sample is important since it will likely lead to more robust results, i.e., results less sensitive to period-specific features in the data. Second, we address for the first time in most of the markets of the sample (the Nikkei 225 and the Hang Seng are the exceptions) the separate effects of crossing barriers from below and above, and we control for potential changes in variance. By ignoring these effects, previous work might have understated the importance of psychological barriers. Third, we are the first to examine the existence of barriers on China's most important stock market barometer, the Shanghai SE Composite index.

The results obtained reveal substantial differences in the incidence of psychological barriers on the markets of the sample. The strongest indication of psychological barriers was found in the South Korean and in the Taiwanese markets. There is mild evidence of barriers in the stock markets of Japan and Hong Kong. The stock markets of Singapore and China exhibit only weak signs of psychological barriers at round numbers. Overall, these results are difficult to reconcile with the market efficiency hypothesis and lend support to the claim that trading strategies based on price support and resistance levels can be useful at least in some Asian stock markets.

PREVIOUS FINDINGS

Donaldson (1990a, 1990b) and De Grauwe and Decupere (1992) were the first to study the phenomenon of psychological barriers and showed that round numbers are indeed of special importance for investors in the stock market and in the foreign exchange markets, respectively. From then on, several other studies followed, focusing on different asset classes such as bonds, commodities and derivatives.

However, to date, little research has been conducted on the existence of psychological barriers in Asian markets with the exception of the Nikkei 225. Most of the studies conclude that the Nikkei 225 do not exhibit significant psychological barriers. For example, Donaldson (1990a, 1990b) failed to reject the hypothesis of uniformity in the trailing digits of the Japanese index. Koedijk and Stork (1994) studied the Nikkei 225 during the period 1980–1992, among other stock market indices. They discovered no significant indications of psychological barriers' existence on the Japanese market. De Ceuster et al. (1998) compared the last digits of the Nikkei 225, the DJIA, and the FTSE-100 with the empirical distribution of a Monte Carlo simulation and did not find any indication of the existence of barriers on those three indices. However, Cyree et al. (1999) showed that the Nikkei 225 and the Hang Seng exhibited some significant evidence of psychological barriers in the period 1981–1994. They analysed the distribution of the returns with regard to expected returns and volatility in a modified GARCH model to conclude that upward movements through barriers tended to have a consistently positive impact on the conditional mean return and also that conditional variance tended to be higher in the vicinity of a possible barrier.

Bahng (2003) expanded the research considering seven major Asian stock market indices (South Korea, Taiwan, Hong Kong, Thailand, Malaysia, Singapore and Indonesia) between 1990 and 1999. The analysis showed that the price level distributions of the Taiwanese, Indonesian, and Hong Kong indices were not uniform and that only the Taiwanese index did possess significant price barrier effects. However, these findings might be affected in part by the fact that they did not disaggregate the effects of upward and downward movements through barriers.

Other studies concerning psychological barriers in stock markets are also related to our analysis. It is the case of those papers that consider single stock prices. For example, Cai, Cai and Keasey (2007) studied the price behaviour of 1,050 stocks in June 2002 to conclude that the digits 0 and 5 constituted significant resistance points in the Chinese A-share market.

More recently, Berk et al. (2017) and Lobão and Fernandes (2018) conducted studies on individual stock prices and found conflicting results. Berk et al. (2017) examined the prices of 77 individual stocks belonging to 15 frontier equity markets, i.e., markets that are not developed enough to be considered as "emerging". Overall, psychological barriers were found to be a feature of frontier market equity pricing. A large number of securities exhibited predictable pricing patterns after passing through a psychologically important price point, including round numbers. Lobão and Fernandes (2018) analysed the prices of 24 major stocks from Taiwan, Brazil and South Africa, having found no consistent signs of psychological barriers.

Most of the literature on psychological barriers consider developed market indices. For example, Donaldson and Kim (1993) examined the DJIA using a Monte Carlo experiment and found evidence confirming round numbers

(100-levels) as support and resistance levels. Furthermore, they concluded that once such levels were crossed through, the DJIA moved up or down more than usual in what they called a "bandwagon effect". Ley and Varian (1994) also studied the DJIA considering a wider interval of time (1952–1993) and confirmed that there were in fact fewer observations around 100-levels. In 98.4% of the tested cases, uniformity in the trailing digits was rejected at the 95% significance level. More recently, Dorfleitner and Klein (2009) focused on the DAX 30, the CAC 40, the FTSE-50 and the DJ EURO STOXX 50 for different periods until 2003. They found fragile traces of psychological barriers in all indices at the 1000-level.

The literature on psychological barriers in stock indices continues to be active nowadays. For example, Shawn and Kalaichelvan (2012) examined five European indices (FTSE-100, CAC 40, DAX 30, ATX, SMI) finding evidence for barriers in the SMI at the 1000-level but no significant evidence of barriers in the remaining indices. Woodhouse et al. (2016) investigated the existence of barriers in the NASDAQ Composite index. Statistically significant barrier effects were detected in certain index levels (usually in multiples of 100).

Different studies concluded that price barriers or at least significant deviations from uniformity also exist in other asset classes such as exchange rates (De Grauwe & Decupere, 1992; Mitchell & Izan, 2006), bonds (Burke, 2001), commodities (Aggarwal & Lucey, 2007; Lucey & O'Connor, 2016) and derivatives (Schwartz, Van Ness, & Van Ness, 2004; Chen & Tai, 2011; Jang, Kim, Kim, Lee, & Shin, 2015; Dowling, Cummins, & Lucey, 2016; Palao & Pardo, 2018). Overall, evidence of price barriers in various asset classes seems to be fairly robust.

DATA AND METHODOLOGY

Data

The examination window for each of the stock market indices under study is presented in Table 1. Starting dates are different since we used the data pertaining to each index since its inception. The daily data were retrieved from Thomson Reuters Datastream. Summary statistics on the stock prices are presented in Table 2. China and Hong Kong present the most volatile markets in the region. There is no pattern in the asymmetry of the returns distributions. Moreover, all the stock markets show a number of outliers inconsistent with normality.

Table 1
Data used in the study

Series	Stock index	Starting date	Ending date
China	Shanghai SE Composite	2 January 1991	31 December 2016
South Korea	KOSPI	31 December 1974	31 December 2016
Taiwan	Taiwan SE Weighted DS	31 December 1974	31 December 2016
Hong Kong	Hang Seng	31 July 1964	31 December 2016
Japan	Nikkei 225	3 April 1950	31 December 2016
Singapore	Straits Times Index	31 August 1999	31 December 2016

Table 2
Summary statistics on stock prices data series

Series	Obs.	Return series				Level series	
		Mean	S. D.	Skewness	Kurtosis	Min	Max
China	6,783	0.00046	0.022	5.41	161.64	105.77	6092.05
South Korea	10,959	0.00031	0.014	-0.31	11.364	65.35	2228.96
Taiwan	7,175	-3.26×10^{-5}	0.016	-0.11	7.4451	30.73	145.04
Hong Kong	13,676	-0.00039	0.017	1.09	37.273	58.61	31638.22
Japan	17,415	0.00030	0.011	-0.4	13.551	85.25	38915.87
Singapore	4,524	6.11×10^{-5}	0.011	-0.25	8.4553	1170.85	3831.31

Methodology

Regarding the existence of positional effects, we investigate if the indices close more or less frequently around round numbers by performing a number of uniformity tests and barrier tests on the *M*-values of the closing prices, as it will be described in the following sections. The presence of transgressional effects is captured by investigating the dynamics of the conditional mean return and conditional variance before and after the crossing of a barrier. We use regression and GARCH analysis to assess the differential impact of being above or below a possible barrier.

Definition of barriers

Following Brock, Lakonishok and Le Bron (1992) and Dorfleitner and Klein (2009), we will use the so-called *band technique* and barriers will thus be defined as a certain range around the actual barrier. The main reason is that market participants will most certainly become active at a certain level before the index touches a round price level. Considering an index level of 100, for instance, over-excitement is expected to begin for instance at 99 or 101, or even at 95 or 105. Barriers will thus be defined as multiples of the *l*th power of ten, with intervals with an absolute length of 2%, 5%, and 10% of the corresponding power of ten as barriers. These intervals are conventionally used in the literature about psychological barriers. Formally, we may consider as possible barrier bands:

M100: Barrier level $l = 3$ (1,000's)	980-20; 950-50; 900-100
M10: Barrier level $l = 2$ (100's)	98-02; 95-05; 90-10
M1: Barrier level $l = 1$ (10's)	9.8-0.2; 9.5-0.5; 9.0-1.0
M0.1: Barrier level $l = 0$ (1's)	0.98-0.02; 0.95-0.05; 0.9-0.1

M-values

M-values refer to the last digits in the integer portion of the indices under analysis. Initially used by Donaldson and Kim (1993), *M*-values consider potential barriers at the levels …, 300, 400, …, 3400, 3500, i.e. at:

$$k \times 100,\ k = 1, 2, \ldots \qquad (1)$$

Later, De Ceuster et al. (1998) claimed that this definition was too narrow because the series was not multiplicatively regenerative, resulting, for instance, on 3400 being considered a barrier, whereas 340 would not. Additionally, the authors claimed that, as defined by Equation (1), the gap between barriers would tend to zero as the price series increased, disrupting the intuitive appeal of a psychological barrier. Thus, one should also consider the possibility of barriers at the levels …, 10, 20, …, 100, 200, …, 1000, 2000, …, i.e. at:

$$k \times 10^l, k = 1,2,...,9; l = ..., -1,0,1,...; \qquad (2)$$

and, on the other hand, at the levels …, 10, 11, …, 100, 110, …, 1000, 1100, …, i.e. at:

$$k \times 10^l, k = 10,11,...,99; l = ..., -1,0,1,...; \qquad (3)$$

M-values would then be defined according to these barriers. For barriers at the levels defined in Equation (1), *M*-values would be the pair of digits preceding the decimal point:

$$M_t^a = [P_t] \mathrm{mod} 100; \qquad (4)$$

where P_t is the integer part of P_t and mod 100 refers to the reduction modulo 100. For barriers at the levels defined by Equation (2) and Equation (3), the *M*-values would be defined respectively as the second and third and the third and fourth significant digits. Formally,

$$M_t^b = [100 \times 10^{(\log P_t) \mathrm{mod} 1}] \mathrm{mod} 100; \quad (5)$$

$$M_t^c = [1000 \times 10^{(\log P_t) \mathrm{mod} 1}] \mathrm{mod} 100; \quad (6)$$

where logarithms are to base 10. In practical terms, for example if P_t = 1234.56, then = 34. At this level, barriers should appear when = 00. Additionally, = 23 and = 12.

Uniformity test

Having computed the *M*-values, the next step consists in examining the uniformity of their distribution. Following Aggarwal and Lucey (2007), this will be done through a Kolmogrov-Smirnov Z-statistic test. Thus we will be testing H0: uniformity of the *M*-values distribution, against H1: non-uniformity of the *M*-values distribution.

It is important to emphasize that the rejection of uniformity might suggest the existence of significant psychological barriers but it is not in itself sufficient to prove their existence. Ley and Varian (1994) showed that the last digits of the Dow Jones Industrial Average were in fact not uniformly distributed and even appeared to exhibit certain patterns, but the returns conditional on the digit realization were still significantly random. Additionally, De Ceuster et al. (1998) noted that as a series grows without limit and the intervals between barriers become wider, the theoretical distribution of digits and the respective frequency of occurrence is no longer uniform.

Barrier tests

Barrier tests are used to assess whether observations are less frequent near barriers than it would be expected considering a uniform distribution. The existence of a psychological barrier implies we will observe a significantly lower closing price frequency within an interval around the barrier (Donaldson & Kim, 1993; Ley & Varian, 1994). Therefore, the objective of the barrier tests is to investigate the influence of round numbers in the non-uniform distribution of *M*-values. We will use two types of barrier tests: the barrier proximity test and the barrier hump test.

a) Barrier Proximity Test

This test examines the frequency of observations, *f*(*M*), near potential barriers and will be performed according to Equation (7).

$$f(M) = \alpha + \beta D + \varepsilon \qquad (7)$$

The dummy variable will take the value of unity when the index is at the supposed barrier and zero elsewhere. As it was mentioned in "Definition of Barriers", this barrier will not only be strictly considered as an exact number but also as a number of different specific intervals, namely with an absolute length of 2%, 5%, and 10% of the corresponding power of ten as barriers. The null hypothesis of no barriers will thus imply that β equals zero, while β is expected to be negative and significant in the presence of barriers as a result of lower frequency of *M*-values at these levels.

b) Barrier Hump Test

The second barrier test will examine not just the tails of frequency distribution near the potential barriers, but the entire shape of the distribution. It is thus necessary to define the alternative shape that the distribution should have in the presence of barriers (Donaldson & Kim, 1993; Aggarwal & Lucey, 2007). Bertola and Caballero (1992), who analysed the behaviour of exchange rates in the presence of target zones imposed by forward-looking agents, suggest that a hump-shape is an appropriate alternative for the distribution of observations.

The test to examine this possibility will follow Equation (8), in which the frequency of observation of each *M*-value is regressed on the *M*-value itself and on its square.

$$f(m) = \alpha + \Phi M + \gamma M^2 + \eta \qquad (8)$$

Under the null hypothesis of no barriers Υ is expected to be zero, whereas the presence of barriers should result in Υ being negative and significant.

Conditional effect tests

The study of positional effects should to be complemented with the investigation regarding transgressional effects that result from psychological barriers (Ley & Varian, 1994). Therefore, it is necessary to analyse the dynamics of the returns series around these barriers, namely regarding mean and variance in order to examine the differential effect on returns due to prices being near a barrier, and whether these barriers were being approached on an upward or on a downward movement (Cyree et al., 1999; Aggarwal & Lucey, 2007).

Accordingly, we will define four regimes around barriers: BD for the ten days before prices reaching a barrier on a downward movement, AD for the ten days after prices crossing a barrier on a downward movement, and BU and AU for the ten days respectively before and after prices breaching a barrier on an upward movement. These dummy variables will take the value of unity for the days noted and zero otherwise. In the absence of barriers, we expect the coefficients on the indicator variables in the mean equation to be non-significantly different from zero.

$$R_t = \beta_1 + \beta_2 BD_t + \beta_3 AD_t + \beta_4 BU_t + \beta_5 AU_t + \varepsilon_t \tag{9}$$

Following Aggarwal and Lucey (2007), we started with an OLS estimation of Equation (9) but heteroscedasticity and autocorrelation were present across our database. Therefore, the full analysis of the effects in the proximity of barriers required us to apply the former test also to the variances. Equation (10) represents this approach assuming autocorrelation similar to one as in Cyree et al. (1999) and Aggarwal and Lucey (2007). Besides the abovementioned dummy variables it includes a moving average parameter and a GARCH parameter.

$$\begin{aligned} \varepsilon_t &= N(0, V_t) \\ V_t &= \alpha_1 + \alpha_2 BD_t + \alpha_3 AD_t + \alpha_4 BU_t + \alpha_5 AU_t + \alpha_6 V_{t-1} + \alpha_7 \varepsilon_{t-1}^2 + \eta_t \end{aligned} \tag{10}$$

The four possible hypothesis to be tested are the following:

H1: There is no difference in the conditional mean return before and after a *downward* crossing of a barrier.

H2: There is no difference in the conditional mean return before and after an *upward* crossing of a barrier.

H3: There is no difference in conditional variance before and after a *downward* crossing of a barrier.

H4: There is no difference in the conditional variance before and after a *upward* crossing of a barrier.

EMPIRICAL FINDINGS

Uniformity Test

Table 3 provides the results of a uniformity test concerning the distribution of digits for the six stock market indices under scrutiny. Overall, there is robust evidence that the *M*-values do not follow a uniform distribution in each one of the stock markets included in the sample. Moreover, uniformity is more clearly rejected in the highest barrier levels. In the case of the markets of Taiwan, Hong Kong and Japan, uniformity is rejected at 1% in all the barrier levels. The rejection of uniformity of the trailing digits is not so strong in the Singaporean and Chinese markets: from the four barrier levels under test, uniformity is rejected at a significance level of 5% only in the two highest barrier levels.

Table 3
Kolmogorov-Smirnov test for uniformity of digits

Series	Statistic	M0.1 ($l = 0$) (1's digits)	M1 ($l = 1$) (10's digits)	M10 ($l = 2$) (100's digits)	M100 ($l = 3$) (1,000's digits)
China	Kolmogorov (D) stat.	1.235	1.196	1.817	6.861
	p-value	0.094*	0.114	0.002**	0.000***
South Korea	Kolmogorov (D) stat.	1.466	2.074	9.788	19.219
	p-value	0.027**	0.000***	0.000***	0.000***
Taiwan	Kolmogorov (D) stat.	1.675	2.148	25.034	-
	p-value	0.007***	0.000***	0.000***	-
Hong Kong	Kolmogorov (D) stat.	3.524	3.064	4.210	10.434
	p-value	0.000***	0.000***	0.000***	0.000***
Japan	Kolmogorov (D) stat.	1.869	2.136	1.861	10.360
	p-value	0.001***	0.000***	0.002**	0.000***
Singapore	Kolmogorov (D) stat.	1.059	1.162	1.386	4.891
	p-value	0.211	0.134	0.042**	0.000***

Note: Table 3 shows the results of a Kolmogorov-Smirnov test for uniformity. Each test was performed for the daily closing prices of each stock index. H0: uniformity in the distribution of digits, H1: non uniformity in the distribution of digits. ***: significant at the 1% level; **: significant at the 5% level; *: significant at the 10% level.

Barrier Tests

Barrier Proximity Test

Results for the barrier proximity tests are shown in Tables 4 to 7 for the intervals mentioned in "Definition of Barriers" and "Barrier Tests". As referred above, in the presence of a barrier we would expect β to be negative and significant, implying a lower frequency of M-values at these points. Considering a barrier in the exact zero modulo point, evidence in Table 4 shows that no market seems to reject the no barrier hypothesis at a statistical significance of 10%. All the series are either not significant at the conventional levels or β is not negative. If we assume a barrier to be in the interval 98-02, there are two markets that reject the no barrier hypothesis at a statistical significance of 5%: Hong Kong and Japan at the 1000-level barrier. As we keep widening the barrier interval, evidence on psychological barriers appear to strengthen. In fact, considering the 95-05 interval, Table 6 shows that the no barrier hypothesis is rejected for all the markets of the sample at some barrier level at a statistical significance of 10%. Hong Kong and Japan continue to reject the no barrier hypothesis at the 1000-level, but now they are joined by Taiwan at the 100-level. In all these three markets, the no barrier hypothesis is rejected at a significance level of 1%. South Korea and Singapore exhibit signs of barriers at the 10- and 100-levels, respectively, with a significance of 5%. The results for China in the 1's digits are only significant at the 10% level. Finally, Table 7 contains the results considering the 90-10 interval. The evidence only confirms the previous results for the markets of Taiwan and Japan at a statistical significance of 1%. In fact, the evidence of barriers in the markets of South Korea and Singapore is weaker, being only significant at the 10% level. The barriers detected previously in the markets of China and Hong Kong seem to have vanished.

Overall, evidence suggests that positional effects related to psychological barriers are a relevant phenomenon for the market of Taiwan at the 100-barrier level and for the markets of Hong Kong and Japan at the 1000-level barrier. There is weaker evidence of barriers in the markets of South Korea and Singapore and practically no evidence at all of psychological barriers around round numbers in the Chinese stock market.

Table 4
Barrier Proximity Test: Strict Barrier (00)

Series	M0.1 (l = 0) (1's digits)			M1 (l = 1) (10's digits)			M10 (l = 2) (100's digits)			M100 (l = 3) (1,000's digits)		
	β	p-value	R^2	β	p -value	R^2	β	p -value	R^2	β	p -value	R^2
China	-0.026	0.859	0.000	-0.116	0.448	0.005	-0.057	0.707	0.001	-0.011	0.824	0.000
South Korea	0.040	0.715	0.001	0.040	0.733	0.001	0.059	0.813	0.000	0.073	0.490	0.000
Taiwan	0.355	0.014**	0.059	-0.010	0.950	0.000	-0.559	0.538	0.003	-	-	-
Hong Kong	1.70	0.000***	0.604	0.570	0.000***	0.118	0.245	0.250	0.013	-0.026	0.697	0.000
Japan	0.051	0.505	0.004	0.091	0.250	0.013	0.057	0.477	0.005	-0.025	0.479	0.000
Singapore	-0.228	0.152	0.020	0.136	0.338	0.009	-0.183	0.215	0.015	0.054	0.306	0.001

Note: Table 4 shows the results of the regression $f(M) = \alpha + \beta D + \varepsilon$, where $f(M)$ stands for the frequency of appearance of M-values, D is a dummy variable that takes the value of unity when M = 00 and 0 otherwise. Refer to "Barrier Tests" for details. *, **, *** indicates significance at the 10%, 5% and 1

Table 5
Barrier Proximity Test: 98-02 Barrier

Series	M0.1 (l = 0) (1's digits)			M1 (l = 1) (10's digits)			M10 (l = 2) (100's digits)			M100 (l=3) (1,000's digits)		
	β	p-value	R^2	β	p-value	R^2	β	p-value	R^2	β	p-value	R^2
China	-0.102	0.139	0.022	0.030	0.639	0.002	0.039	0.564	0.003	-0.009	0.237	0.001
South Korea	-0.044	0.385	0.007	-0.030	0.573	0.003	0.000	0.999	0.000	0.025	0.127	0.002
Taiwan	0.121	0.070*	0.033	0.027	0.723	0.001	-0.65	0.115	0.025	-	-	-
Hong Kong	0.338	0.000***	0.115	0.172	0.022**	0.052	0.266	0.005***	0.076	-0.024	0.027**	0.004
Japan	0.06	0.05**	0.03	0.049	0.171	0.018	0.014	0.686	0.001	-0.021	0.000***	0.013
Singapore	-0.010	0.889	0.000	0.008	0.905	0.000	-0.121	0.071*	0.032	0.020	0.016**	0.005

Table 5 shows the results of the regression $f(M) = \alpha + \beta D + \varepsilon$, where $f(M)$ stands for the frequency of appearance of M-values, D is a dummy variable that takes the value of unity when M = value is in the 98-02 interval and 0 otherwise. Refer to "Barrier Tests" for details. *, **, *** indicates significance at the 10%, 5% and 1% level, respectively.

Table 6
Barrier Proximity Test: 95-05 Barrier

Series	M0.1 ($l = 0$) (1's digits)			M1 ($l = 1$) (10's digits)			M10 ($l = 2$) (100's digits)			M100 ($l = 3$) (1,000's digits)		
	β	*p*-value	R²	β	p-value	R²	β	*p*-value	R²	β	*p*-value	R²
China	-0.082	0.086*	0.029	0.046	0.304	0.010	0.034	0.475	0.005	-0.006	0.269	0.001
South Korea	0.020	0.553	0.003	-0.083	0.026**	0.049	0.150	0.057*	0.036	0.014	0.183	0.001
Taiwan	0.048	0.304	0.010	0.069	0.192	0.017	-0.747	0.008***	0.068	-	-	-
Hong Kong	0.131	0.060*	0.035	0.95	0.071*	0.032	0.081	0.227	0.014	-0.027	0.000***	0.014
Japan	0.057	0.017**	0.056	0.035	0.163	0.019	-0.009	0.702	0.001	-0.020	0.000***	0.029
Singapore	-0.012	0.803	0.000	0.021	0.668	0.001	-0.091	0.050**	0.038	0.009	0.107	0.002

Table 6 shows the results of the regression $f(M) = \alpha + \beta D + \varepsilon$, where $f(M)$ stands for the frequency of appearance of *M*-values, *D* is a dummy variable that takes the value of unity when M=value is in the 95-05 interval and 0 otherwise. Refer to "Barrier Tests" for details. *, **, *** indicates significance at the 10%, 5% and 1% level, respectively.

Table 7
Barrier Proximity Test: 90-10 Barrier

Series	M0.1 ($l = 0$) (1's digits)			M1 ($l = 1$) (10's digits)			M10 ($l = 2$) (100's digits)			M100 ($l = 3$) (1,000's digits)		
	β	*p*-value	R²	β	*p*-value	R²	β	*p*-value	R²	β	*p*-value	R²
China	-0.033	0.379	0.007	0.020	0.561	0.003	0.036	0.335	0.009	-0.00	0.112	0.002
South Korea	-0.011	0.683	0.001	-0.052	0.075*	0.031	0.040	0.521	0.004	0.026	0.001***	0.009
Taiwan	0.023	0.521	0.004	0.062	0.131	0.023	-0.885	0.000***	0.156	-	-	-
Hong Kong	0.062	0.258	0.01	0.021	0.600	0.002	0.035	0.509	0.004	0.016	0.003***	0.008
Japan	0.038	0.043**	0.041	0.022	0.256	0.013	0.013	0.484	0.005	-0.024	0.000***	0.073
Singapore	0.025	0.528	0.004	0.036	0.346	0.009	-0.060	0.100*	0.027	0.010	0.011**	0.006

Table 7 shows the results of the regression $f(M) = \alpha + \beta D + \varepsilon$, where $f(M)$ stands for the frequency of appearance of *M*-values, *D* is a dummy variable that takes the value of unity when M = value is in the 90-10 interval and 0 otherwise. Refer to "Barrier Tests" for details. *, **, *** indicates significance at the 10%, 5% and 1% level, respectively.

Table 8
Barrier Hump Test

Series	M0.1 ($l = 0$) (1's digits)			M1 ($l = 1$) (10's digits)			M10 ($l = 2$) (100's digits)			M100 ($l = 3$) (1,000's digits)		
	γ	*p*-value	R^2	γ	*p*-value	R^2	γ	*p*-value	R^2	γ	*p*-value	R^2
China	$-2.98x10^{-5}$	0.143	0.024	$2.65x10^{-6}$	0.890	0.004	$1.58x10^{-5}$	0.435	0.009	$3.76x10^{-8}$	0.072^{*}	0.105
South Korea	$-1.78x10^{-6}$	0.905	0.002	$-4.56x10^{-5}$	0.003^{***}	0.116	$6.30x10^{-5}$	0.023^{**}	0.335	$4.96x10^{-7}$	0.000^{***}	0.120
Taiwan	$1.84x10^{-5}$	0.346	0.035	$4.14x10^{-5}$	0.063^{*}	0.042	-0.000683	0.000^{***}	0.471	-	-	-
Hong Kong	$5.73x10^{-5}$	0.048^{**}	0.066	$5.13x10^{-5}$	0.019^{**}	0.070	$6.93x10^{-5}$	0.014^{**}	0.067	$3.61x10^{-6}$	0.204	0.062
Japan	$2.39x10^{-5}$	0.018^{**}	0.057	$7.66x10^{-6}$	0.464	0.058	$-8.30x10^{-7}$	0.937	0.031	$-1.70x10^{-7}$	0.000^{***}	0.183
Singapore	$-5.60x10^{-6}$	0.794	0.003	$3.38x10^{-6}$	0.871	0.000	$-3.16x10^{-5}$	0.103	0.069	$1.60x10^{-7}$	0.000^{***}	0.060

Table 8 shows the results of the regression $f(M) = \alpha + \phi M + \Upsilon M^2 + \eta$, where f(M), the frequency of appearance of each M-values, is regressed on M, the *M*-value itself, and M^2, its square. *, **, *** indicates significance at the 10%, 5% and 1% level, respectively.

Barrier Hump Test

Table 8 shows the results for the barrier hump test, which is meant to test the entire shape of the distribution of *M*-values. Assuming it should follow a hump-shape distribution, we thus expected Υ to be negative and significant in the presence of barriers. The results of the barrier hump test partially confirm the evidence presented previously with the barrier proximity tests. The relevance of the psychological barrier of the markets of South Korea (at the 10-level barrier), Taiwan (at the 100-level barrier) and Japan (at the 1000-level barrier) is corroborated by the rejection of the no barrier hypothesis at a statistically significant level of 1%. All the other series are either not significant at the conventional levels or Υ is not negative.

Overall, from the results presented so far it is possible to discern substantial differences in the incidence of psychological barriers on the markets under study. In the Chinese stock market, it was not detected practically any evidence of psychological barriers. In the case of the stock markets of Hong Kong and Singapore there is weak to mild evidence of barriers. Lastly, the stock markets of South Korea, Taiwan and Japan exhibit the strongest indications of psychological barriers nearby round numbers. In the case of the South Korean market the positional effect is noticeable at the 10-level barrier. In the cases of Taiwan and Japan the barrier is especially salient at the 100-level and at the 1000-level, respectively.

Conditional Effects Test

Assuming the existence of psychological barriers, we expected the dynamics of return series to be different around these points. In fact, results in Table 9 provide some interesting evidence of mean effects after both upward and downward movements through potential psychological barriers. The coefficient of BD is negative and statistically significant only for the South Korean index in the 10-day window around the potential barrier. This suggests that the stock market returns in this market tend to be significantly lower when a barrier is to be crossed on a downward movement. AD is negative and significant for South Korea and Taiwan. This indicates that stock returns in these countries experienced lower returns after the barrier was breached on a downward movement. Cyree et al. (1999) also found negative coefficients for BD and AD in most of the countries under scrutiny, including in the Hang Seng. BU is negative and significant for two markets of the sample (Taiwan and Hong Kong). This means that stock markets returns in these countries showed lower returns in the proximity of a barrier when the barrier was to be crossed in an upward movement. The results regarding BU are at variance with what was found by Cyree et al. (1999) for most of the countries in their sample. Finally, the coefficient of AU is positive and significant for the indices of South Korea, Taiwan and Singapore. This suggests that the stock market returns in this market tend to be higher after a barrier was crossed on an upward movement. The values we found for AU and BU indicate that prices tend to slow down as they approach a possible barrier in an upward movement and also that, once that level is crossed, they tend to move away from the barrier more quickly. These observations are consistent with increased technical trading when indices are in the vicinity of a barrier point (Osler, 2003) and support the anecdotal evidence reported by notorious traders such as Jesse Livermore (1940, pp. 49–50): "Frequently I had observed that when a stock sold at 50, 100, 200 and even 300, a fast and straight movement almost invariably occurred after such points were passed".

Overall, the return dynamics seem to be significantly different around possible barriers in the markets of South Korea and Taiwan. The returns in the Chinese and the Japanese indices appear not to be affected at all.

Table 9
GARCH analysis: Mean equation

Series	c	BU	AU	BD	AD
China	0.037	0.202	0.231	-0.097	-0.155
	(0.589)	(0.372)	(0.392)	(0.441)	(0.298)
South Korea	0.038	-0.043	0.265	-0.122	-0.250
	(0.013)**	(0.497)	(0.000)***	(0.064)**	(0.000)***
Taiwan	-0.0001	-0.247	0.341	-0.090	-0.676
	(0.995)	(0.003)***	(0.003)***	(0.401)	(0.000)***
Hong Kong	-0.072	-0.205	-0.010	0.038	0.102
	(0.035)**	(0.011)**	(0.943)	(0.733)	(0.572)
Japan	0.032	0.087	0.034	0.026	-0.200
	(0.126)	(0.779)	(0.872)	(0.923)	(0.191)
Singapore	0.011	-0.005	0.262	-0.148	-0.126
	(0.776)	(0.666)	(0.013)**	(0.130)	(0.198)

Table 9 shows the results of the mean equation of a GARCH estimation of the form $R_t=\beta_1 + \beta_2 BD + \beta_3 AD + \beta_4 BU + \beta_5 AU + \varepsilon_t$; $\varepsilon_t \sim N(0,V_t)$; $V_t = \alpha_1 + \alpha_2 BD + \alpha_3 AD + \alpha_4 BU + \alpha_5 AU + \alpha_6 V_{t-1} + \alpha_7 \varepsilon^2_{t-1} + \eta_t$. BD, AD, BU and AU are dummy variables. BD takes the value 1 in the 10 days before crossing a barrier on a downward movement and zero otherwise, whereas AD is for the 10 days after the same event. BU is for the 10 days before crossing a barrier from below, while AU is 1 in the 10 days after the same upward crossing. V_{t-1} refers to the moving average parameter and ε^2_{t-1} stands for the GARCH parameter. $l = 3$ is tested for Hong Kong and Japan; $l = 2$ is tested for China, Taiwan and Singapore; $l = 1$ is tested for South Korea. Robust standard error t statistics are in parentheses. *, **, *** indicates significance at the 10%, 5% and 1% level, respectively.

Table 10 contains the results for the conditional variance equations. The constant is positive and significant for all indices. All coefficients of the lagged squared residuals are positive and significant at the 1% level with the exception of South Korea, which points out to an increase in conditional variance coincident with higher residuals from the previous period. The GARCH term in the conditional variance is positive and significant, suggesting significant GARCH effects around barriers. The GARCH term corresponding to the South Korean market is closer to one which indicates a higher level of volatility persistence. The variance effects are shown to exist in all circumstances. The coefficient of BU in the variance equation is negative and statistically significant in all the markets under study. This result indicates that in general the markets tend to calm before having risen through a barrier. This is in sharp contradiction with the results obtained by Cyree et al. (1999) according to which, in most cases, markets tend to be more volatile before crossing a barrier in an upward movement. In the post-crossing period, all the markets with the exception of South Korea present negative and significant results. The volatility effects around a possible barrier when prices move on a downward movement are also clear across the markets. Before crossing the barrier prices seem to be less volatile in the cases of Taiwan, Hong Kong, Japan and Singapore. However, the volatility increases significantly in the case of the South Korean market. After crossing the barrier prices show less volatility in the markets of Hong Kong, Japan and Singapore.

In general, our findings suggest that the markets tend to calm in the vicinity of a possible barrier. A market by market analysis reveals that the conditional effects were felt, albeit with different intensities, in all the markets that make up our sample. The evidence regarding the mean effects lacks only in the cases of China and Japan. The volatility effects were felt in all the markets under study.

Table 11 contains the test results of the four barrier hypothesis mentioned in “Conditional Effect Tests”, considering a 10-day period. If some kind of barrier indeed existed, we would expect that the restraints in terms of mean and variance would be relaxed after the price crossed that barrier.

The results corroborate previous findings showing that the conditional differences in the variances tend to be more pervasive in the markets of the sample. In fact, with the exception of the Singaporean market, all the indices of the sample exhibited significant differences in the volatility before and/or after breaching possible barriers. The effects are especially salient in the context of an upward movement in prices.

Table 10
GARCH analysis: Variance equation

Series	c	ε_{t-1}^2	V_{t-1}	BU	AU	BD	AD
China	4.145	0.130	0.568	-1.161	-1.281	-0.097	-0.155
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.001)***	(0.441)	(0.298)
South Korea	0.008	0.046	0.948	-0.019	0.007	0.090	-0.005
	(0.000)***	(0.673)	(0.000)***	(0.000)***	(0.125)	(0.000)***	(0.159)
Taiwan	1.720	0.140	0.364	-0.747	-0.607	-0.582	0.107
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.115)
Hong Kong	2.542	0.114	0.531	-1.539	-2.235	-2.325	-0.455
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.013)**
Japan	1.201	0.084	0.111	-0.373	-0.087	-0.461	-0.809
	(0.000)***	(0.000)***	(0.000)***	(0.016)**	(0.000)***	(0.006)***	(0.000)***
Singapore	1.050	0.090	0.585	-0.376	-0.372	-0.362	-0.397
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***

Table 10 shows the results of the variance equation of a GARCH estimation of the form $R_t = \beta_1 + \beta_2 BD + \beta_3 AD + \beta_4 BU + \beta_5 AU + \varepsilon_t$; $\varepsilon_t \sim N(0,V_t)$; $V_t = \alpha_1 + \alpha_2 BD + \alpha_3 AD + \alpha_4 BU + \alpha_5 AU + \alpha_6 V_{t-1} + \alpha_7 \varepsilon^2_{t-1} + \eta_t$. BD, AD, BU and AU are dummy variables. BD takes the value 1 in the 10 days before crossing a barrier on a downward movement and zero otherwise, whereas AD is for the 10 days after the same event. BU is for the 10 days before crossing a barrier from below, while AU is 1 in the 10 days after the same upward crossing. V_{t-1} refers to the moving average parameter and ε^2_{t-1} stands for the GARCH parameter. $l = 3$ is tested for Hong Kong and Japan; $l = 2$ is tested for China, Taiwan and Singapore; $l = 1$ is tested for South Korea. Robust standard error t statistics are in parentheses. *, **, *** indicates significance at the 10%, 5% and 1% level, respectively.

Table 11
Barrier hypothesis tests

Series	H1: There is no difference in the conditional mean return before and after a downwards crossing of a barrier	H2: There is no difference in the conditional mean return before and after an upwards crossing of a barrier	H3: There is no difference in conditional variance before and after a downwards crossing of a barrier	H4: There is no difference in conditional variance before and after an upwards crossing of a barrier
China	0.004 (0.944)	0.096 (0.756)	0.055 (0.813)	14.606 (0.000***)
South Korea	8.540 (0.003***)	0.910 (0.339)	7.987 (0.004***)	161.063 (0.000***)
Taiwan	37.151 (0.000***)	4.532 (0.033**)	0.939 (0.332)	18.627 (0.000***)
Hong Kong	1.688 (0.193)	0.060 (0.805)	2.171 (0.000***)	40.135 (0.000***)
Japan	0.019 (0.888)	0.439 (0.507)	2.237 (0.072*)	3.285 (0.069*)
Singapore	0.042 (0.837)	1.502 (0.220)	0.337 (0.561)	2.025 (0.154)

Note: Table 11 shows the results of a Chi-square test based on the likelihood ratio test of the four different null hypothesis. *p*-values are in parenthesis. *, **, *** indicates significance at the 10%, 5% and 1% level, respectively.

The conditional differences in the returns are not uniform across the series under test. The case of Taiwan is worth noting since it is the only market with significant differences in the mean return after crossing a barrier both as part of an upward move and as part of a downward move. The South Korean stock market also shows a significant variation in returns after breaching a barrier in an downward movement. All the remaining four markets show no statistically significant differences in returns. Interestingly, the market of Singapore is the only one that does not exhibit any significant differences in mean returns and variance effects between pre-crossing and post-crossing periods. In general, all these findings are in line with our previous analysis (see Tables 9 and 10).

Overall, the results obtained reveal substantial differences in the incidence of psychological barriers on the markets of the sample. In fact, when we consider the combination of positional and transgressional effects it is possible to distinguish several different situations. Of all the stock markets under analysis, only China and Singapore have revealed weak signs of psychological barriers. In these two markets, either the positional effects were almost non-existent (case of China) or the transgressional effects were not significant (case of Singapore). Second, there are markets that have shown moderate signs of psychological barriers. We may include in this group the markets of Japan and Hong Kong. In these two cases, the results show that there were some mild positional effects or some relevant transgressional effects, especially when it comes to volatility. Third, the strongest indication of psychological barriers was found in the South Korean and in the Taiwanese markets. In this instance, the detected positional and transgressional effects were strong.

CONCLUSION

Psychological barriers have been found to impact financial markets in different geographies and asset classes. Due to several behavioural biases and the consequent inability to make fully rational decisions, the average market practitioner is often affected, directly or indirectly, by such phenomenon.

Following the most widely used methodologies for studying psychological barriers, we provide new evidence regarding this phenomenon in six Asian stock markets. Considering an extended sample period, we examined the existence of barriers at round numbers in the major stock market indices of China (Shanghai SE Composite), South Korea (KOSPI), Taiwan (Taiwan SE Weighted DS), Hong Kong (Hang Seng), Japan (Nikkei 225), and Singapore (Straits Times Index).

In summary, it was possible to distinguish three types of situations regarding the presence of positional effects and transgressional effects in the stock markets under scrutiny. Firstly, the stock markets of China and Singapore showed weak signs of psychological barriers. Secondly, there is mild evidence of barriers in the cases of the markets of Japan and Hong Kong. Lastly, the markets of South Korea and Taiwan exhibited the strongest indications of psychological barriers nearby round numbers. Interestingly, our findings about the Taiwanese market confirm the conclusion of Bahng (2003) according to which this market presented the most significant signs of psychological barriers among the Asian markets under analysis.

The markets of South Korea and Taiwan seem to present important psychological barriers at the 10- and 100-level barrier, respectively, while the markets of Hong Kong and Japan tend to reject the no barrier hypothesis at the 1000-level barrier.

Overall, these findings provide evidence supporting the existence of psychological barriers with respect to index returns. Our results are thus in line with earlier studies (e.g., Cyree et al., 1999; Woodhouse et al., 2016; Berk et al., 2017) and can be regarded as evidence against market efficiency. In fact, under the presence of price barriers, prices tend to exhibit some pockets of predictability thus contradicting the random walk usually associated with efficient capital markets.

Moreover, our results support the claim that technical analysis strategies based on price support and resistances around round numbers can be profitable, at least in some stock markets.

There is much to be investigated about psychological barriers in financial markets. For example, it would be interesting to understand if the prices ending in 4 and 8, which are digits especially significant in the context of the Chinese culture, constitute more important barriers than round numbers, as suggested by several authors (e.g., Cai et al., 2007). Further avenues for research may also include the adoption of statistical tests based on the assumption that prices follow specific distributions (e.g., the Benford's Law) and the study of the impact of salient events (e.g., a financial crisis) on the prevalence of price barriers.

NOTE

1. There are numerous quotations from financial press about potential psychological thresholds in Asian stock markets. Consider the following recent examples: "Trading is inactive, and the [Shanghai Composite] Index is hovering below the important 3,000 psychological level" (South China Morning Post, 20 June 2018); "The Shanghai Composite Index opened sharply lower and slumped 3 percent by midday, to 2,932.08 points, falling past the psychologically key 3,000-point level" (Reuters, Asian Market Report, 19 June 2018); "The Nikkei 225 has stumbled away from the major 23,000.00 psychological handle twice this week (…)" (FX Street, 14 June 2018); "The key date, if you are keeping track, is the week ending April 13 as the PSEi [Philippine Stock Exchange Composite Index] broke below a key price and psychological level at 7,900" (John Mangun, Business Mirror, 28 May 2018).

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