Exploring the psychology of price barriers in Baltic stock markets

Júlio Lobão and João G. Lopes
School of Economics and Management, University of Porto, Porto, Portugal

Received 3 November 2023
Revised 19 January 2024
17 April 2024
Accepted 18 June 2024

Abstract

Purpose – The purpose of this study is to investigate the presence of psychological barriers both in the main stock market indices of the Baltic states and the most actively traded individual stocks. A psychological barrier refers to a specific price point, often at round numbers (i.e. powers of 10), that investors believe is challenging to breach, influencing their behavior and trading decisions.

Design/methodology/approach – We conduct uniformity tests and barrier tests, such as barrier proximity tests and barrier hump tests, to evaluate the presence of psychological barriers. Additionally, we explore variations in means and variances near these potential barriers using regression and GARCH analysis.

Findings – The findings reveal that psychological barriers do exist in the Baltic stock markets, particularly within market indices. The Estonian market index stands out with the most pronounced indications of psychological barriers. Individual stocks also display significant changes in means and variances related to potential barriers, albeit with less uniformity.

Practical implications – Collectively, our findings challenge the traditional assumption of random returns within the Baltic stock markets. For practitioners, the finding that psychological barriers exist opens up opportunities for investment strategies that can capitalize on them.

Originality/value – This study is the first to comprehensively investigate psychological barriers in the Baltic stock markets. Our results provide a valuable contribution to understanding the impact of that phenomenon on pricing dynamics, which is particularly pertinent in less-researched frontier markets like the Baltic states.

Keywords Baltic stock markets, Psychological barriers, Stock market indices, Individual stocks, Market psychology

Paper type Research paper

1. Introduction

Market observers often allude to the presence of psychological barriers within stock markets. Round numbers, in particular, are often perceived as barriers that influence price movements. Phrases like "support levels" and "resistance levels" are commonly used by various market participants, including the business press, security analysts, and investment advisors, when discussing round price levels. The use of these terms suggests that reaching these levels can influence the behavior of market participants and impact stock prices. Specifically, a resistance level signifies a price point above which investors perceive it challenging for a stock price to rise. On the other hand, a support level indicates a price level below which investors believe it is improbable for a stock to fall (Mitchell, 2001; Aggarwal and Lucey, 2007; Lucey and O'Connor, 2016).

The influence of psychological barriers on investors' decision-making has been studied since the 1990s across different asset classes, ranging from exchange rates (Mitchell and Izan, 2006) to cryptocurrencies (Fonseca *et al.*, 2020). Evidence of psychological barriers in stock

JEL Classification — G11, G12, G14, G15

Funding: This research has been funded by Portuguese public funds through Fundação para a Ciência e a Tecnologia (FCT) (No. UIDB/04105/2020).

Baltic Journal of Management
Vol. 19 No. 6, 2024
pp. 94-110
Emerald Publishing Limited
1746-5265
DOI 10.1108/BJM-10-2023-0407

markets suggests significant effects on returns and variances in various geographies and time periods (e.g. Cyree *et al.*, 1999; Woodhouse *et al.*, 2016; Berk *et al.*, 2017; Lobão and Couto, 2019).

This paper investigates whether detectable barriers exist at round price levels perceived as psychologically significant (psychological barriers) in three stock indices representing the performance of the Estonian (OMX Tallinn), Latvian (OMX Riga), and Lithuanian (OMX Vilnius) stock markets, as well as in the ten individual stocks that make up the OMX Baltic 10 index. This index includes the most liquid stocks traded in these three national stock markets.

The existence of psychological barriers challenges the efficient market hypothesis (Fama, 1970), implying some level of predictability in stock markets that may lead to abnormal risk-adjusted returns. Therefore, empirical evidence for the existence of psychological barriers not only interests practitioners seeking profitable strategies but also contributes to the literature on market efficiency and market anomalies.

Our paper provides several notable contributions. First, we explore the presence of psychological barriers in the Baltic equity markets for the first time. Second, our study, focusing on three frontier stock markets [1], is only the second in the literature to address the topic of psychological barriers in such markets. To the best of our knowledge, Berk *et al.* (2017) are the only authors who have explored this issue in the context of frontier stock markets, although they did not include the Baltic countries in their analysis. The understudy of this topic in frontier stock markets is surprising as there are compelling reasons to suspect that behavioral biases and opportunities may be prevalent in these markets, where less-informed individual investors dominate and levels of liquidity, stability, and transparency are lower (Speidell, 2009). Additionally, our empirical study covers a much more extensive time period than Berk *et al.* (2017), spanning over 22 years for some assets. A larger sample size is essential for obtaining more robust results that are less sensitive to specific data features in different periods. Finally, unlike Berk *et al.* (2017), who focused solely on individual stocks in frontier markets, our paper investigates the presence of psychological barriers in both stock market indices and individual stocks. This distinction is significant because it allows us to test Cyree *et al.*'s (1999) hypothesis that stock market indices, receiving more media and investment community attention, are more likely to exhibit signs of psychological barriers than individual stocks.

The motivation to investigate the presence of psychological barriers in the stock markets of the Baltic states arises from both the scarcity of studies on the subject and the literature suggesting that frontier stock markets, such as those under analysis, have significantly different structures compared to developed and emerging markets (e.g. Balcilar *et al.*, 2013; Dimic *et al.*, 2015). This implies that the results obtained in these two categories of markets cannot be directly extrapolated to frontier markets. Moreover, investors in frontier stock markets appear to be significantly affected by several behavioral effects, which, as we will see, constitute the primary explanation for the occurrence of psychological barriers (Almudhaf, 2017; Shrotryia and Kalra, 2023). Lastly, there is evidence suggesting that the stock markets of the Baltic countries display distinct behavior even when compared to other frontier markets (e.g. Kivihao *et al.*, 2014; Lee and Choi, 2023).

Our findings reveal that the stock market indices of the Baltic countries exhibited stronger signs of psychological barriers than the individual stocks analyzed, with the OMX Tallinn index showing the most significant evidence of the phenomenon. As for individual stocks, the results were less homogeneous: while positional effects of psychological barriers were practically non-existent, transgressional effects were observed in all single stocks, with varying degrees of significance. Collectively, these findings are difficult to reconcile with the market efficiency hypothesis and provide evidence supporting the argument that trading strategies based on price support and resistance levels may have practical utility.

The structure of this paper is as follows: In Section 2, we review the literature on psychological barriers. Section 3 provides an overview of the data and methodologies employed in this study. Section 4 presents the empirical results, and Section 5 offers our conclusions.

2. Literature review

2.1 Explanations for psychological barriers

In modern financial markets, investors must make decisions in highly uncertain environments with vast amounts of information beyond human processing capabilities. Consequently, their decisions are expected to reflect cognitive limitations and emotional influences (Hirshleifer, 2015). For example, investors tend to attribute symbolic importance to numbers linked to financial asset prices (Mitchell, 2001). Additionally, Psychology has shown that there are significant differences in the cognitive load associated with forming internal representations of each number. For example, Shepard *et al.* (1975) and Krueger (1986) show that the time and energy spent by an individual on interpreting a number depends on whether the number is odd or even. Among the numbers investors deal with, round numbers stand out, as Mitchell (2001, p. 405) states, "Number counting and number representation (ciphers) of the decimal system suggest a natural tendency to think in terms of 10s or powers of 10."

The emergence of behavioral biases in individual decision-making is commonly associated with heightened cognitive load, influencing the process. The anchoring bias, a behavioral effect identified by Tversky and Kahneman (1974), is the primary explanation for the presence of psychological barriers in financial markets. The authors suggest that in ambiguous situations, individuals tend to anchor their estimates on salient numbers like round numbers, even if those numbers are clearly uninformative. This occurs when cognitive resources are scarce to thoroughly process all available information. Westerhoff (2003) developed a formal model within the context of the exchange rate market, wherein investors' perception of the fundamental value is anchored to the nearest round number. The model predicts that, due to anchoring, exchange rates will persistently misalign, establishing support and resistance levels at the limits of the fluctuation band, with the perceived fundamental value acting as a psychological barrier. More recently, Shiller (2015) supports the relationship between anchoring and psychological barriers, suggesting that market participants, lacking better knowledge, use the nearest round number as a proxy for the fundamental value of financial securities.

Sonnemans (2006) proposes the odd-pricing effect as an alternative explanation for psychological barriers. This effect, commonly observed in marketing studies, causes consumers to perceive odd prices, such as 19.95 euros, as significantly lower than round prices like 20.00 euros.

Herding behavior, that is, the tendency that individuals' have to imitate the actions of the group, is another effect to consider in connection with psychological barriers. According to Dorfleitner and Klein (2009), herding is often observed when prices breach a potential barrier, resulting in rapid movements away from the barrier or increased fluctuations in the nearby region.

Less informed investors are more susceptible to the influence of behavioral factors (Wilson *et al.*, 1996; Kaustia *et al.*, 2008). In frontier markets like the Baltic markets, this category of investors tends to have a disproportionate impact on prices compared to institutional and other professional investors (Speidell, 2009). Therefore, we anticipate psychological barriers to be a prevalent phenomenon in the assets within our sample.

2.2 Empirical evidence

Most existing studies on psychological barriers focus on indices representing emerging and developed stock markets. Concerning emerging markets, Bahng (2003) examined seven Asian stock market indices and found the most significant price barrier effects in the Taiwanese index. Moreover, the price level distributions of the Indonesian and Hong Kong indices were found to be non-uniform, consistent with the idea that psychological barriers exist, as this phenomenon implies that values representing a barrier occur less often than others. Expanding on this research, Lobão and Couto (2019) identified the strongest evidence of psychological barriers in the South Korean and Taiwanese markets. In contrast, the stock markets of Singapore and China displayed weak signs of psychological barriers at round numbers.

Regarding developed market indices, Donaldson (1990) assessed the trailing digits of the Dow Jones Industrial Average (DJIA), the FTSE-100, the TSE, and the Nikkei 225, concluding that the Nikkei index was the only one to exhibit uniformity. Ley and Varian (1994) later confirmed the lack of uniformity in the DJIA's results. De Ceuster *et al.* (1998) compared the last digits of DJIA, FTSE-100, and Nikkei 225 with a Monte Carlo simulation's empirical distribution, finding no indications of psychological barriers. Cyree *et al.* (1999) revealed non-uniform distribution in the last two digits of DJIA, S&P 500, Financial Times U.K. Actuaries, and DAX. They observed that prices near barriers occurred less frequently than those further away. Dorfleitner and Klein (2009) explored the indices DAX 30, CAC40, FTSE-50, and DJ EURO STOXX 50 until 2003, detecting weak traces of psychological barriers at the 1000-level across all indices.

More recently, Woodhouse *et al.* (2016) investigated the evidence of barriers in the NASDAQ Composite index from 1971 to 2012, identifying statistically significant effects at certain index levels. Lastly, Lobão and Pereira (2017) explored stock markets in four Southern European countries (Greece, Italy, Portugal, and Spain). Their findings indicated weak evidence of barriers in the Iberian stock markets, strong indications of psychological barriers in the Greek stock market, and no evidence of barriers in the Italian stock market.

Studies focusing on barriers in individual stocks are relatively scarce. Cai *et al.* (2007) analyzed the price behavior of 1,050 Chinese stocks and found that the digits zero and five constituted significant resistance points. They suggested that these findings might be influenced by cultural factors. Berk *et al.* (2017) were the only researchers to investigate signs of psychological barriers in frontier stock markets. They analyzed the prices of 77 individual stocks from 15 markets and found that psychological barriers were indeed a characteristic of frontier market stock pricing. Finally, in a related study, Lobão (2023) examined the preference of Baltic investors for stock prices ending in specific digits, reporting that in eight out of nine analyzed stocks, investors exhibited a significant preference for prices ending in zero or five.

Various studies have found evidence of price barriers or notable departures from uniformity in other asset categories, including foreign exchange rates (Mitchell and Izan, 2006), commodities (Aggarwal and Lucey, 2007; Lucey and O'Connor, 2016), derivatives (Palao and Pardo, 2018) and cryptocurrencies (Fonseca *et al.*, 2020).

The literature on psychological barriers remains very active in recent times, showing potential to explain phenomena as diverse as the impact of oil prices on the banking sector's stock prices (Alqahtani *et al.*, 2020), the preference for lottery-like stocks (Byun *et al.*, 2020), or the cross-country predictability of stocks resulting from the delayed price response to news in the case of economically linked firms (Huang *et al.*, 2021).

We make a unique contribution to the literature by analyzing the phenomenon of psychological barriers in the stock market exchanges of the three Baltic states for the first time.

3. Data and methodology

3.1 Data

Table 1 provides details about the period of analysis of each asset as well as summary statistics. All the data were sourced from Thomson Reuters Datastream.

Table 1.
Summary statistics on asset prices data series

Series	Sample period	Obs	Mean	Return series Std. Dev	Skewness	Kurtosis	Level series Min	Max
Stock market indices								
OMX Riga	12/31/1999–12/31/2022	6,000	0.000400	0.013	−0.52	23.96	104.48	1305.79
OMX Tallinn	6/3/1996–12/31/2022	6,935	0.000414	0.013	−1.14	31.75	84.24	2141.55
OMX Riga	12/31/1999–12/31/2022	6,001	0.000375	0.009	−0.78	35.93	63.18	1028.74
Individual stocks								
AS LHV Group	5/23/2016–12/31/2022	1,725	0.000915	0.015	0.16	13.27	0.69	4.75
Coop Pank AS	12/10/2019–12/31/2022	799	0.001009	0.020	−0.17	15.13	0.93	4.2
Enefit Green AS	10/21/2021–12/31/2022	312	0.000730	0.015	0.05	5.97	3.31	4.86
Ignitis Grupe AB	10/7/2020–12/31/2022	583	−0.000273	0.010	−0.80	12.08	17.56	25.35
Merko Ehitus	8/11/2008–12/31/2022	3,755	0.000197	0.018	−0.40	15.80	1.90	17.08
Siauliu Bankas	4/1/1998–12/31/2022	6,458	0.000259	0.028	0.01	19.97	0.07	0.85
Tallink Grupp	12/9/2005–12/31/2022	4,451	−0.000186	0.019	0.18	13.18	0.24	1.52
Tallinna Kuabamaja Grupp	9/6/1996–12/31/2022	6,866	0.000511	0.021	0.17	22.19	0.12	11.72
Tallinna Sadam	6/13/2018–12/31/2022	1,188	−0.000259	0.009	−1.94	26.02	1.37	2.17
Telia Lietuva	6/12/2000–12/31/2022	5,885	9.84E−05	0.013	0.60	35.57	0.29	2.14

Source(s): Authors' own creation

All the stock market indices under examination exhibit a positive average return and negative skewness. However, the individual stocks in our sample display more diverse range of behaviors. Specifically, stocks from Ignitis Group AB, Tallink Grupp, and Tallinna Sadam companies show negative average returns during their respective analysis periods, and stocks from Coop Pank AS, Ignitis Grupe AB, Merko Ehitus, and Tallinna Sadam present returns with negative skewness. It is noteworthy that all series in our sample are leptokurtic, which deviates from normal distribution characteristics.

3.2 Methodology

In our methodology, we investigate both positional and transgressional effects of psychological barriers. The positional effects refer to the tendency of prices to close less frequently near round numbers due to investors' expectations that these price levels serve as significant barriers. The investigation of positional effects involves conducting several uniformity tests and barrier tests on the *M*-values derived from closing prices, as detailed in the upcoming sections. The transgressional effects of psychological barriers concern the possibility of observing significant changes in conditional mean returns and conditional variance before and after crossing a barrier. To assess the differing impact of being above or below a potential barrier, we employ regression and GARCH analysis.

3.2.1 Definition of barriers. Following Dorfleitner and Klein (2009), we adopt the "band technique" to define barriers. In this approach, barriers are delineated as specific ranges around the actual barrier level. The rationale behind this choice lies in the expectation that market participants will likely spring into action at levels preceding the index's touch of a round price level. For example, when an index reaches the value of 100, heightened activity is anticipated at levels like 99 or 101, or even at 95 or 105.

As a result, we will define barriers as multiples of the lth power of ten, with intervals equivalent to 2 and 5% of the corresponding power of ten serving as the barrier ranges. Formally, the possible barrier bands we consider are the following:

M100: Barrier level $l = 3$ (1000s)	980-20; 950-50
M10: Barrier level $l = 2$ (100s)	98-02; 95-05
M1: Barrier level $l = 1$ (10s)	9.8-0.2; 9.5-0.5
M0.1: Barrier level $l = 0$ (1s)	0.98-0.02; 0.95-0.05
M0.01: Barrier level $l = -1$ (0.1s)	0.098-0.002; 0.095-0.005

For each asset under scrutiny, we select different barrier levels to examine for possible psychological barriers.

3.2.2 M*-values.* *M*-values pertain to the final digits within the whole number portion of the examined assets. *M*-values consider potential barriers at specific levels, such as 300, 400, all the way to 3,400, 3,500, denoted as:

$$k \times 100, k = 1, 2, \ldots \tag{1}$$

Subsequently, De Ceuster *et al.* (1998) argued that this definition was overly restrictive because it did not exhibit multiplicative regenerativity. This resulted in, for instance, 3,400 being deemed a barrier while 340 would not. Consequently, it was proposed to also consider potential barriers at different levels, such as 10, 20, all the way to 100, 200, and beyond, as expressed by:

$$k \times 10^l, k = 1, 2, \ldots, 9;\ l = \ldots, -1, 0, 1, \ldots; \tag{2}$$

and, on the other hand, at levels like 10, 11, all the way to 100, 110, and so forth, as indicated by:

$$k \times 10^l, k = 10, 11, \ldots, 99; \; l = \ldots, -1, 0, 1, \ldots; \tag{3}$$

M-values would then be defined based on these different barrier levels. For barriers at the levels outlined in Equation (1), M-values would comprise the pair of digits just before the decimal point:

$$M_t^a = [P_t] \bmod 100; \tag{4}$$

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

$$M_t^b = \left[100 \times 10^{(\log P_t) \bmod 1}\right] \bmod 100; \tag{5}$$

$$M_t^c = \left[1000 \times 10^{(\log P_t) \bmod 1}\right] \bmod 100; \tag{6}$$

where logarithms are to base 10. In practical terms, for example if $P_t = 1234.56$, then $M_t^a = 34$. At this level, barriers should manifest when $M_t^a = 00$. Additionally, $M_t^b = 23$ and $M_t^c = 12$.

3.2.3 Uniformity test. After calculating the M-values, the subsequent step involves assessing the uniformity of their distribution. The lack of uniformity in prices aligns with the notion of the existence of psychological barriers, suggesting that values representing a barrier should occur significantly less frequently than others. In line with Aggarwal and Lucey (2007), we assess price uniformity using the Kolmogorov-Smirnov Z-statistic test. Consequently, we will evaluate H0, which posits that the M-values are uniformly distributed, against H1, which suggests non-uniformity in the distribution of M-values.

It is crucial to highlight that the rejection of uniformity, while suggestive of potential psychological barriers, does not alone provide conclusive evidence of their existence (Ley and Varian, 1994). Furthermore, as a series extends indefinitely, and the intervals between barriers widen, the theoretical distribution of digits and their respective frequencies cease to be uniform (De Ceuster *et al.*, 1998).

3.2.4 Barrier tests. Barrier tests are employed to determine if observations deviate from what would be expected under a uniform distribution. When a psychological barrier exists, it suggests that we should observe a notably lower frequency of closing prices within a certain interval surrounding the barrier (Ley and Varian, 1994). Hence, the primary goal of barrier tests is to explore how round numbers influence the non-uniform distribution of M-values. Two types of barrier tests will be utilized: the barrier proximity test and the barrier hump test.

3.2.4.1 Barrier proximity test. The barrier proximity test evaluates the frequency of observations, denoted as f(M), in proximity to potential barriers, and it will be conducted following Eq. (7).

$$f(M) = \alpha + \beta D + \varepsilon \tag{7}$$

In this equation, the dummy variable D takes the value of one when the price is at the presumed barrier and zero elsewhere. As mentioned in section 3.2.1, these barriers are not strictly considered as exact numbers; they are defined as intervals, specifically with absolute lengths of 2 and 5% of the corresponding power of ten. The null hypothesis, suggesting the absence of barriers, implies that β equals zero. Conversely, if barriers exist, β is expected to be significantly negative due to the lower frequency of M-values observed at these levels.

3.2.4.2 Barrier hump test. The barrier hump test does not solely examine the tails of frequency distribution near the potential barriers but the entire shape of the distribution. We consider that a hump-shaped distribution is an appropriate alternative for the distribution of observations. Thus, the test follows Eq. (8), where the frequency of observation for each M-value is regressed on the M-value itself and its square:

$$f(M) = \alpha + \Phi M + \gamma M^2 + \eta \tag{8}$$

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

3.2.5 Conditional effects tests. In addition to studying positional effects, we investigate transgressional effects resulting from psychological barriers. Therefore, we analyze the dynamics of the returns series around these barriers, specifically focusing on mean and variance. This examination aims to understand the differential impact on returns when prices are near a barrier and whether these barriers are approached during an upward or downward movement (Cyree *et al.*, 1999; Aggarwal and Lucey, 2007).

To facilitate this analysis, we define four regimes around barriers: BD represents the five days before prices reach a barrier during a downward movement, AD for the five days after prices cross a barrier during a downward movement, BU for the five days before prices breach a barrier during an upward movement, and AU for the five days after prices breach a barrier during an upward movement. These dummy variables are assigned a value of one for the specified days and zero otherwise. The names of the dummy variables are indicative of their meaning. The first letter signifies whether the period under analysis pertains to before or after the crossing of a barrier (A: After crossing a barrier; B: Before crossing a barrier), while the second letter denotes the direction of price movement associated with the barrier crossing (D: Downward movement; U: Upward movement). In the absence of barriers, we anticipate that the coefficients on the indicator variables in the mean equation will not be statistically different from zero:

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

Considering that the distributional shifts associated with psychological barriers challenge the basic assumptions of OLS, we perform regressions using a GARCH (1,1) model:

$$\varepsilon_t = N(0, V_t)$$

$$V_t = \alpha_1 + \alpha_2 BD_t + \alpha_3 AD_t + \alpha_4 BU_t + \alpha_5 AU_t + \alpha_6 V_{t-1} + \alpha_7 \varepsilon_{t-1}^2 + \eta_t \tag{10}$$

The four hypotheses to be tested are as follows:

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 an *upward* crossing of a barrier.

4. Empirical findings

4.1 Uniformity test

In Table 2, we present the results of the uniformity test regarding the digit distribution for the assets under analysis. Overall, there is compelling evidence indicating that M-values

Table 2.
Kolmogorov-Smirnov test for uniformity of digits

Series	M0.1 (l = 0) (1's digits)	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)
Stock market indices					
OMX Riga	–	1.963***	1.733***	6.293***	9.257***
OMX Tallinn	–	1.602**	0.987	3.600***	14.428***
OMX Vilnius	–	1.771***	1.634***	6.074***	–
Individual stocks					
AS LHV Group	7.949***	13.833***	–	–	–
Coop Pank AS	8.088***	8.716***	–	–	–
Enefit Green AS	3.861***	2.896***	–	–	–
Ignitis Grupe AB	15.475***	1.971***	5.808***	–	–
Merko Ehitus	32.381***	4.803***	3.750***	–	–
Siauliu Bankas	24.992***	–	–	–	–
Tallink Grupp	6.472***	9.860***	–	–	–
Tallinna Kuabamaja Grupp	20.867***	7.605***	–	–	–
Tallinna Sadam	8.018***	10.297***	–	–	–
Telia Lietuva	17.118***	27.568***	–	–	–

Note(s): Table 2 displays the outcomes of Kolmogorov-Smirnov tests for assessing uniformity. The null hypothesis (H0) posits a uniform distribution of digits, while the alternative hypothesis (H1) suggests non-uniformity. **, *** indicates significance at the 5 and 1% level, respectively
Source(s): Authors' own creation

significantly deviate from a uniform distribution for all the assets in our sample. With the exception of the Estonian stock market index at the two lowest barrier levels, we reject the uniformity assumption at a 1% significance level across all barrier levels.

4.2 Barrier tests

4.2.1 Barrier proximity test. In Table 3, we present the results of the barrier proximity tests, focusing on the intervals outlined in sections 3.2.1 and 3.2.4. As noted earlier, when a barrier is present, we expect β to be significantly negative. Starting with the exact zero modulo point, III reveals that none of the analyzed assets reject the no-barrier hypothesis at conventional significance levels. In all cases, the results either lack significance at standard thresholds, or β is not negative.

However, as we widen the barrier interval, evidence of psychological barriers in stock market indices begins to emerge. For example, assuming a barrier within the 98-02 interval, one market index rejects the no-barrier hypothesis at a 5% significance level (OMX Tallinn at the 100-level barrier), while another index rejects it at a 10% significance level (OMX Vilnius at the 10-level barrier).

Expanding the interval to 95-05, Table 3 shows that the no-barrier hypothesis is rejected for the same two stock market indices, now at a 5% significance level, again at the 100-level barrier.

Overall, the evidence suggests that positional effects related to psychological barriers appear to manifest in only two of the stock market indices (OMX Tallinn and OMX Vilnius) under scrutiny. This implies that individual stocks included in the analysis do not exhibit any psychological barriers, regardless of the considered interval.

4.2.2 Barrier hump test. Table 4 presents the results of the barrier hump test, which assesses the overall shape of the distribution of *M*-values. We expected ϒ to be significantly negative in the presence of barriers. The findings of the barrier hump test generally align with

Table 3. Barrier proximity tests

Series	Strict barrier (00)					98–02 barrier					95–05 barrier				
	M0.01 ($l = -1$) (0.1's digits)	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)	M0.01 ($l = -1$) (0.1's digits)	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)	M0.01 ($l = -1$) (0.1's digits)	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)
Stock market indices															
OMX Riga	–	−0.168	1.91E−15	−0.151	0.487	–	−0.017	0.021	−0.157	4.520**	–	–	−0.020	−0.097	5.738***
OMX Tallinn	–	0.096	−0.048	−0.202	0.993	–	0.040	−0.062	−0.182**	0.377	–	–	−0.018	−0.152**	−0.045
OMX Vilnius	–	−0.151	−0.134	0.642*	–	–	−0.021	−0.119*	0.449***	–	–	–	−0.044	0.233**	–
Individual stocks															
AS LHV Group	1.191	−0.375	–	–	–	1.153	−0.330	–	–	–	0.731	−0.256	–	–	–
Coop Pank AS	3.212	−0.250	–	–	–	2.322	−0.044	–	–	–	3.323	0.524	–	–	–
Enefit Green AS	1.353	−0.799	–	–	–	1.533	−0.158	–	–	–	1.634	0.194	–	–	–
Ignitis Grupe AB	37.864***	4.262**	1.967	–	–	33.266***	1.763*	1.352**	–	–	33.654**	0.999	0.919**	–	–
Merko Ehitus	29.575***	4.558***	2.421*	–	–	31.545***	0.887*	4.044***	–	–	24.486***	0.424	1.884***	–	–
Siauliu Bankas	17.157***	–	–	–	–	16.177***	–	–	–	–	19.438***	–	–	–	–
Tallink Grupp	−0.476	6.399**	–	–	–	−0.321	6.319***	–	–	–	0.547	6.339***	–	–	–
Tallinna Kuabamaja Grupp	5.249***	1.007**	–	–	–	5.311***	0.183	–	–	–	5.494**	0.111	–	–	–
Tallinna Sadam	0.018	0.183	–	–	–	0.027	1.791***	–	–	–	0.034	1.673***	–	–	–
Telia Lietuva	1.519	4.988***	–	–	–	1.633	2.827***	–	–	–	1.572	3.060***	–	–	–

Note(s): Table 3 shows the estimates of β in 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 1 when M equals 00, falls within the considered level or interval, and 0 otherwise. *, **, *** indicates significance at the 10, 5, and 1% level, respectively
Source(s): Authors' own creation

Series	M0.01 (l = −1) (0.1's digits)	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)
Stock market indices					
OMX Riga	–	−6.5E−06	−7.1E−06	9.2E−06	0.013**
OMX Tallinn	–	1.2E−05	−1.7E−05	−0.0001***	0.0001
OMX Vilnius	–	−2.8E−05	−3.1E−05	0.0002***	–
Individual stocks					
AS LHV Group	0.002***	0.0002**	–	–	–
Coop Pank AS	0.0004	0.0004***	–	–	–
Enefit Green AS	0.001***	0.0003***	–	–	–
Ignitis Grupe AB	0.003	0.0004	0.001***	–	–
Merko Ehitus	0.005	0.0002	0.0005	–	–
Siauliu Bankas	0.003**	–	–	–	–
Tallink Grupp	−0.0004	0.004***	–	–	–
Tallinna Kuabamaja Grupp	0.001	7.3E−05	–	–	–
Tallinna Sadam	−0.0006	0.0007***	–	–	–
Telia Lietuva	−0.001	0.001***	–	–	–

Note(s): Table 4 shows the estimates of γ in 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*-value itself and its square. ** and *** indicates significance at the 5 and 1% level, respectively
Source(s): Authors' own creation

Table 4.
Barrier hump test

the evidence presented in the barrier proximity tests. In our sample, the OMX Tallinn and OMX Vilnius stock market indices remain the only assets that reject the null hypothesis of no psychological barriers at statistically significant levels. Both markets exhibit barriers at the 100-level barrier, with statistical significance at the 1% level. Furthermore, the OMX Riga index and the individual stocks in our sample continue to show no evidence of psychological barriers at round numbers.

4.2.3 Conditional effects test. Assuming the presence of psychological barriers, we expected variations in the return and variance series dynamics near these points. Tables 5 and 6 present the results of the conditional effects test. Here, we examine the behavior of the assets' prices during the five-day periods before and after crossing a barrier from below, potentially indicating a resistance level, and before and after crossing a barrier from above, potentially indicating a support level. Due to the limited number of observations, Enefit Green AS stocks were not included in the conditional mean return effects test.

The outcomes of the mean return equation are presented in Table 5. We observe that BU is positive and statistically significant, at least at the 5% level, for most of the assets under analysis. This includes the three stock market indices and six individual stocks. This implies an increase in mean returns, corresponding to an acceleration in prices as they approach barrier levels during an upward movement. After surpassing the barrier in this upward price movement, mean returns generally return to normal for most assets (exceptions include the OMX Tallinn index and Tallinna Kuabamaja Grupp stocks).

A similar pattern seems to apply to price movements in a downward direction. BD is negative and statistically significant, at least at the 10% level, for all indices and four individual stocks. This indicates a decrease in mean returns just before crossing a barrier in a downward movement, consistent with an acceleration of prices towards the barrier. Again, the effects after breaking the barrier were distinct. AD is only statistically significant at conventional significance levels for the OMX Tallinn index (negative) and Telia Lietuva stocks (positive), indicating that for most of the assets analyzed, mean returns did not appear to be affected after breaking a barrier following a downward movement.

Table 5. GARCH analysis: mean equation

Series	BU	AU	BD	AD
Stock market indices				
OMX Riga	0.0017**	0.00003	−0.0031*	0.0002
OMX Tallinn	0.0037***	−0.0021***	−0.0033***	−0.0016*
OMX Vilnius	0.0018**	0.00009	−0.0015**	−0.0002
Individual stocks				
AS LHV Group	0.0048	−0.0018	−0.0071	0.0017
Coop Pank AS	0.0130**	0.0157	−0.0215***	0.0148
Ignitis Grupe AB	0.0100	−0.0168	−0.0016	−0.0009
Merko Ehitus	0.0027**	−0.0002	−0.0029*	0.0006
Siauliu Bankas	0.0049**	0.0025	−0.0024	0.0007
Tallink Grupp	0.0036***	0.0005	−0.0040***	−0.0007
Tallinna Kuabamaja Grupp	0.0018	0.0021**	−0.0023	0.0009
Tallinna Sadam	0.0027**	−0.0003	−0.0006	0.0001
Telia Lietuva	0.0043***	−0.00001	−0.0024***	0.0012*

Note(s): Table 5 displays the results of the mean equation within a GARCH estimation framework, specified as $R_t = \beta_1 + \beta_2 BD + \beta_3 AD + \beta_4 BU + \beta_5 AU + \varepsilon_t$; $\varepsilon_t \sim N(0,V_t)$; $V_t = \alpha_1 + \alpha_2 BD + \alpha_3 AD + \alpha_4 BU + \alpha_5 AU + \alpha_6 V_{t-1} + \alpha_7 \varepsilon^2_{t-1} + \eta_t$. BD, AD, BU, and AU represent dummy variables. BD equals 1 for the five days preceding a barrier crossing during a downward movement, and 0 otherwise. AD is applicable for the five days following the same event. BU corresponds to the five days before crossing a barrier from below, while AU is set to 1 for the five days following the same upward crossing. *, **, *** indicates significance at the 10, 5 and 1% level, respectively
Source(s): Authors' own creation

Table 6. GARCH analysis: variance equation

Series	BU	AU	BD	AD
Stock market indices				
OMX Riga	−0.00001***	−0.000005*	−0.00001***	0.000006
OMX Tallin	−0.000005	−0.00004***	−0.00002***	−0.0000318***
OMX Vilnius	−0.000003***	−0.000001**	−0.000001**	−0.000001***
Individual stocks				
AS LHV Group	0.00003	0.00004	0.0004***	−0.00007***
Coop Pank AS	0.00003	0.0002	−0.0001*	0.0004
Ignitis Grupe AB	0.0002*	0.00007	−0.00001	0.0001***
Merko Ehitus	−0.000001	0.00001***	0.00001***	0.00002***
Siauliu Bankas	0.00007***	−0.00006***	0.0001***	−0.0001***
Tallink Grupp	0.000007	−0.000001	0.00001***	−0.00000009
Tallinna Kuabamaja Grupp	0.0000009	−0.00001***	−0.000005***	−0.0000001
Tallinna Sadam	0.000002	−0.000002	−0.000004***	−0.000001**
Telia Lietuva	0.00002***	−0.00001***	0.00001***	−0.00001***

Note(s): Table 6 displays the results of the variance equation within a GARCH estimation framework, specified as $R_t = \beta_1 + \beta_2 BD + \beta_3 AD + \beta_4 BU + \beta_5 AU + \varepsilon_t$; $\varepsilon_t \sim N(0,V_t)$; $V_t = \alpha_1 + \alpha_2 BD + \alpha_3 AD + \alpha_4 BU + \alpha_5 AU + \alpha_6 V_{t-1} + \alpha_7 \varepsilon^2_{t-1} + \eta_t$. BD, AD, BU and AU represent dummy variables. BD equals 1 for the five days preceding a barrier crossing during a downward movement, and 0 otherwise. AD is applicable for the five days following the same event. BU corresponds to the five days before crossing a barrier from below, while AU is set to 1 for the five days following the same upward crossing. *, **, *** indicates significance at the 10, 5 and 1% level, respectively
Source(s): Authors' own creation

Table 6 presents the outcomes related to the equations for conditional variance. Regarding the stock market indices, the negative values of the coefficients associated with BU, AU, BD, and AD in most cases suggest that the observed volatility in these indices was generally lower in the vicinity of psychological barriers, regardless of whether prices were rising or falling. However, concerning individual stocks, the picture is less homogeneous. During price declines, the stocks of Ignitis Grupe AB, Siauliu Bankas, and Telia Lietuva exhibit higher volatility before crossing the psychological barrier. After crossing the barrier following an upward price movement, three stocks show lower volatility. These effects are also not uniform across all individual stocks during price declines. Thus, before crossing a psychological barrier with falling prices, significantly lower volatility is observed in three different stocks. On the other hand, the stocks of five other companies exhibit significantly higher volatility in these circumstances. After crossing the barrier in a downward direction, four stocks experience a significant decrease in volatility, while other two stocks undergo the opposite effect.

In conclusion, the GARCH model allows us to conclude that significant transgressional effects are observed for both stock market indices and individual stocks. While these effects appear to be similar for the stock market indices, they exhibit substantial variations among individual stocks.

In Table 7, we present the results for the four barrier hypotheses described in section 3.2.5. The results are consistent with the evidence from the tests mentioned earlier, as all analyzed assets (stock market indices and individual stocks) show significant differences at conventional levels of statistical significance in returns and/or variances before and after

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
Stock market indices				
OMX Riga	2.009	1.993	2.406	3.008*
OMX Tallin	3.208*	28.670***	0.257	38.527***
OMX Vilnius	2.004	3.749*	0.00004	2.478
Individual stocks				
AS LHV Group	1.122	0.066	7.862***	0.0006
Coop Pank AS	8.845***	0.021	2.079	0.121
Ignitis Grupe AB	0.009	0.928	21.006***	0.130
Merko Ehitus	2.429	4.118**	7.546***	6.979***
Siauliu Bankas	1.664	0.637	1048.757***	273.689***
Tallink Grupp	3.641*	3.497*	6.415**	1.049
Tallinna Kuabamaja Grupp	2.190	0.018	2.783*	3.552*
Tallinna Sadam	0.434	5.514**	2.247	1.778
Telia Lietuva	7.898***	14.219***	176.474***	169.493***

Note(s): Table 7 shows the results of a Chi-square test based on the likelihood ratio test of the four different null hypotheses. *, **, *** indicates significance at the 10, 5, and 1% level, respectively
Source(s): Authors' own creation

Table 7.
Barrier hypotheses tests

crossing a potential barrier. Concerning the stock market indices, the evidence is more significant for the OMX Tallin index. In this index, the return changed significantly before and after crossing a possible barrier in an upward direction. Volatility also varied significantly prior to and following the barrier's upward crossing. In the case of the OMX Riga and OMX Vilnius indices, differences are observed in volatility and returns during an upward price movement, respectively.

For individual stocks, the results are not uniform, consistent with the findings presented in Tables 5 and 6. Some stocks show significant variations in average returns before and after crossing a potential psychological barrier while others exhibit differences only in volatility. In the case of four stocks, differences are observed in both mean returns and volatility. Notably, Telia Lietuva stocks stand out as the asset that exhibited more significant differences in a greater number of circumstances and variables.

These findings collectively suggest that the presence of psychological barriers has significant effects on both returns and volatility for a range of assets. The extent and nature of these effects, however, vary across different assets and barrier scenarios.

5. Conclusion

The aim of this study was to investigate the presence of psychological barriers in both the stock market indices of the Baltic states and the main individual stocks traded within these markets. The recognition of psychological barriers offers valuable insights into the underlying human behaviors that influence asset prices. The Baltic stock markets, as frontier markets, have garnered attention from international investors due to their diversification potential and unique characteristics, making them an ideal setting for the examination of psychological barriers.

Our findings revealed substantial disparities in the incidence of psychological barriers among the assets of the sample. When we account for both positional and transgressional effects, several distinct patterns emerge. Concerning stock market indices, the OMX Tallin index exhibited the most pronounced signs of psychological barriers. The OMX Vilnius index displayed some positional effects, while the OMX Riga index exhibited the least impact from psychological barriers. In contrast, for individual stocks, positional effects were largely absent, while transgressional effects were observed in all stocks, albeit with varying degrees of significance. Telia Lietuva's stocks, in particular, displayed the most significant transgressional effects.

The observation that psychological barriers appear to exert a more substantial influence on indices than on individual stocks is in line with the findings of Cyree *et al.* (1999) and Dorfleitner and Klein (2009), derived from studies of developed markets. These authors proposed a plausible explanation: indications of barriers are more likely to manifest in assets that are widely monitored by the media and investment community.

In contrast, our results concerning the existence of psychological barriers in individual stocks exhibited greater heterogeneity compared to the findings reported by Berk *et al.* (2017) for a set of stocks traded in other frontier stock markets. Our conjecture is that the local conditions of each market may explain these differences. As for the stock indices of the three markets under examination, our results strongly indicate the presence of significant psychological barriers.

While the empirical strategy employed in this study does not allow us to establish a specific causal relationship for the observed barriers, the authors believe that the absence of a formal rational explanation suggests an underlying behavioral influence. Herding behavior, usually associated with psychological barriers, and which results in an acceleration of prices following the break of a barrier, seems to be absent in the majority of the assets under scrutiny. The stocks of Tallinna Kuabamaja Grupp are an exception in this regard as the prices of this asset experience a significantly higher return after breaking a price barrier in an upward direction (Table 5).

The presence of obstacles that impede smooth price movement, unrelated to economic fundamentals, challenges to the efficient market hypothesis, and is of great interest from an academic perspective. In light of the existence of price barriers, it becomes evident that prices near specific psychological reference points may not accurately reflect intrinsic values. Consequently, from a practical standpoint, the existence of these barriers opens up opportunities for investment strategies that can capitalize on them. For instance, based on our findings regarding Merko Ehitus stocks, an investor could consider adopting a buying position in this asset when prices approach a barrier during an upward movement. This is because, in such scenario, the stock price tends to accelerate (as indicated in Table 5) without a concomitant increase in the risk of the stock (Table 6).

If our conjecture about the presence of psychological barriers in the Baltic stock markets, stemming from behavioral factors influencing investor behavior around round numbers is accurate, our findings hold significant implications for regulators and policymakers. Investing in financial literacy programs and implementing policies to encourage market participation among investors less susceptible to behavioral biases, such as institutional investors, could help mitigate the prevalence of phenomena like psychological barriers in prices.

Our paper suffers from some limitations. For instance, while it is plausible to consider that overall market conditions, as well as specific stock characteristics related to liquidity or transaction costs, may have a significant impact on the formation of psychological barriers, this was not the focus of our study in the current paper.

Future research directions for the exploration of psychological barriers within the Baltic stock markets could involve analyzing the occurrence of barriers in distinct time periods corresponding to the prevailing market price trends, employing statistical tests based on the assumption that prices follow specific statistical distributions (e.g. Benford's law), and investigating factors that account for variations in the prevalence of price barriers across different assets.

Note

1. The frontier equity indices provided by Morgan Stanley Capital International (MSCI), Standard and Poor, Russell and FTSE consistently classify the Baltic stock markets as frontier markets.

References

Aggarwal, R. and Lucey, B.M. (2007), "Psychological barriers in gold prices?", *Review of Financial Economics*, Vol. 16 No. 2, pp. 217-230, doi: 10.1016/j.rfe.2006.04.001.

Almudhaf, F. (2017), "Speculative bubbles and irrational exuberance in African stock markets", *Journal of Behavioral and Experimental Finance*, Vol. 13, pp. 28-32, doi: 10.1016/j.jbef.2016.11.002.

Alqahtani, F., Samargandi, N. and Kuran, A.M. (2020), "The influence of oil prices n the banking sector in oil-exporting economies: is there a psychological barrier?", *International Review of Financial Analysis*, Vol. 69, 101470, doi: 10.1016/j.irfa.2020.101470.

Bahng, S. (2003), "Do psychological barriers exist in the stock price indices? Evidence from Asia's emerging markets", *International Area Studies Review*, Vol. 6 No. 1, pp. 35-52, doi: 10.1177/223386590300600103.

Balcilar, M., Demirer, R. and Hammoudeh, S. (2013), "Investor herds and regime-switching: evidence from Gulf Arab stock markets", *Journal of International Financial Markets, Institutions and Money*, Vol. 23, pp. 295-321, doi: 10.1016/j.intfin.2012.09.007.

Berk, A.S., Cummins, M., Dowling, M. and Lucey, B.M. (2017), "Psychological price barriers in frontier equities", *Journal of International Financial Markets, Institutions and Money*, Vol. 49, pp. 1-14, doi: 10.1016/j.intfin.2016.11.007.

Byun, S., Goh, J. and Kim, D. (2020), "The role of psychological barriers in lottery-related anomalies", *Journal of Banking and Finance*, Vol. 114, 105786, doi: 10.1016/j.jbankfin.2020.105786.

Cai, B.M., Cai, C.X. and Keasey, K. (2007), "Influence of cultural factors on price clustering and price resistance in China's stock markets", *Accounting and Finance*, Vol. 47 No. 4, pp. 623-664, doi: 10.1111/j.1467-629x.2007.00221.x.

Cyree, K.B., Domian, D.L., Louton, D.A. and Yobaccio, E.J. (1999), "Evidence of psychological barriers in the conditional moments of major world stock indices", *Review of Financial Economics*, Vol. 8 No. 1, pp. 73-91, doi: 10.1016/s1058-3300(99)00002-6.

De Ceuster, M.J.K., Dhaene, G. and Schatteman, T. (1998), "On the hypothesis of psychological barriers in stock markets and Benford's Law", *Journal of Empirical Finance*, Vol. 5 No. 3, pp. 263-279, doi: 10.1016/s0927-5398(97)00024-8.

Dimic, N., Orlov, V. and Pilak, V. (2015), "The political risk factor in emerging, Frontier, and developed stock markets", *Finance Research Letters*, Vol. 15, pp. 239-245, doi: 10.1016/j.frl.2015.10.007.

Donaldson, R.G. (1990), *International Evidence on Psychological Barriers in Asset Prices and the Efficient Market Hypothesis*, Princeton Financial Research Center Memorandum, University of Princeton, Princeton, New Jersey.

Dorfleitner, G. and Klein, C. (2009), "Psychological barriers in European stock markets: where are they?", *Global Finance Journal*, Vol. 19 No. 3, pp. 268-285, doi: 10.1016/j.gfj.2008.09.001.

Fama, E.F. (1970), "Efficient capital markets-a review of theory and empirical work", *Journal of Finance*, Vol. 25 No. 2, pp. 383-417, doi: 10.1111/j.1540-6261.1970.tb00518.x.

Fonseca, V., Pacheco, L. and Lobão, J. (2020), "Psychological barriers in the cryptocurrency market", *Review of Behavioral Finance*, Vol. 12 No. 2, pp. 151-169, doi: 10.1108/rbf-03-2019-0041.

Hirshleifer, D. (2015), "Behavioral finance", *Annual Review of Financial Economics*, Vol. 7 No. 1, pp. 133-159, doi: 10.1146/annurev-financial-092214-043752.

Huang, S., Lin, T. and Xiang, H. (2021), "Psychological barrier and cross-firm return predictability", *Journal of Financial Economics*, Vol. 142 No. 1, pp. 338-356, doi: 10.1016/j.jfineco.2021.06.006.

Kaustia, M., Alho, E. and Puttonen, V. (2008), "How much does expertise reduce behavioral biases? The case of anchoring effects in stock returns estimates", *Financial Management*, Vol. 37 No. 3, pp. 391-412, doi: 10.1111/j.1755-053x.2008.00018.x.

Kivihao, J., Nikkinen, J., Pilkak, V. and Rothovius, T. (2014), "The Co-movement dynamics of European frontier stock markets", *European Financial Management*, Vol. 20 No. 3, pp. 574-595, doi: 10.1111/j.1468-036x.2012.00646.x.

Krueger, L.E. (1986), "Why $2 \times 2 = 5$ looks so wrong: on the odd–even rule in product verification", *Memory and Cognition*, Vol. 14, pp. 141-149, doi: 10.3758/bf03198374.

Lee, M. and Choi, S. (2023), "Comparing market efficiency in developed, emerging, and frontier equity markets: a multifractal detrended fluctuation analysis", *Fractal and Fractional*, Vol. 7 No. 6, pp. 478-509, doi: 10.3390/fractalfract7060478.

Ley, E. and Varian, H.R. (1994), "Are there psychological barriers in the Dow-Jones index?", *Applied Financial Economics*, Vol. 4 No. 3, pp. 217-224, doi: 10.1080/758526902.

Lobão, J. (2023), "Efficiency and price clustering in the Baltic stock exchanges: evidence from a micro-level analysis", *Journal of Baltic Studies*, pp. 1-19, doi: 10.1080/01629778.2023.2251459.

Lobão, J. and Couto, M. (2019), "Are there psychological barriers in Asian stock markets?", *Asian Academy of Management Journal of Accounting and Finance*, Vol. 15 No. 1, pp. 83-106, doi: 10.21315/aamjaf2019.15.1.4.

Lobão, J. and Pereira, C. (2017), "Psychological barriers in stock market indices: evidence from four southern European countries", *Cuadernos de Economía*, Vol. 40 No. 114, pp. 268-278, doi: 10.1016/j.cesjef.2016.10.005.

Lucey, M.E. and O'Connor, F.A. (2016), "Mind the gap: psychological barriers in gold and silver prices", *Finance Research Letters*, Vol. 17, pp. 135-140, doi: 10.1016/j.frl.2016.03.009.

Mitchell, J. (2001), "Clustering and psychological barriers: the importance of numbers", *Journal of Futures Markets*, Vol. 21 No. 5, pp. 395-428, doi: 10.1002/fut.2.

Mitchell, J. and Izan, H.Y. (2006), "Clustering and psychological barriers in exchange rates", *Journal of International Financial Markets, Institutions and Money*, Vol. 16 No. 4, pp. 318-344, doi: 10.1016/j.intfin.2005.03.003.

Palao, F. and Pardo, A. (2018), "Do price barriers exist in the European carbon market?", *Journal of Behavioral Finance*, Vol. 19 No. 1, pp. 111-124, doi: 10.1080/15427560.2017.1366492.

Shepard, R.N., Kilpatric, D.W. and Cunningham, J.P. (1975), "The internal representation of numbers", *Cognitive Psychology*, Vol. 7 No. 1, pp. 82-138, doi: 10.1016/0010-0285(75)90006-7.

Shiller, R.J. (2015), *Irrational Exuberance*, 3rd ed., Princeton University Press, Princeton, NJ.

Shrotryia, V.K. and Kalra, H. (2023), "COVID-19 and overconfidence bias: the case of developed, emerging and Frontier markets", *International Journal of Emerging Markets*, Vol. 18 No. 3, pp. 633-665, doi: 10.1108/ijoem-09-2020-1019.

Sonnemans, J. (2006), "Price clustering and natural resistance points in the Dutch stock market: a natural experiment", *European Economic Review*, Vol. 50 No. 8, pp. 1937-1950, doi: 10.1016/j.euroecorev.2005.09.001.

Speidell, L.S. (2009), "Investing in the unknown and the unknowable – behavioral finance in frontier markets", *Journal of Behavioral Finance*, Vol. 10, pp. 1-8, doi: 10.1080/15427560902719323.

Tversky, A. and Kahneman, D. (1974), "Judgment under uncertainty: heuristics and biases", *Science*, Vol. 185 No. 4157, pp. 1124-1131, doi: 10.1126/science.185.4157.1124.

Westerhoff, F. (2003), "Anchoring and psychological barriers in foreign exchange markets", *Journal of Behavioral Finance*, Vol. 4 No. 2, pp. 65-70, doi: 10.1207/s15327760jpfm0402_03.

Wilson, T.D., Houston, C.E., Etling, K.M. and Brekke, N. (1996), "A new look at anchoring effects: basic anchoring and its antecedents", *Journal of Experimental Psychology*, Vol. 125 No. 4, pp. 387-402, doi: 10.1037//0096-3445.125.4.387.

Woodhouse, S.A., Singh, H., Bhattacharya, S. and Kumar, K. (2016), "Invisible walls: do psychological barriers really exist in stock index levels?", *North American Journal of Economics and Finance*, Vol. 36, pp. 267-278, doi: 10.1016/j.najef.2016.01.006.

Corresponding author
Júlio Lobão can be contacted at: jlobao@fep.up.pt