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Psychological Barriers in the Stock Markets of the Baltic States

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PSYCHOLOGICAL BARRIERS IN THE STOCK MARKETS OF THE BALTIC STATES

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Abstract

Round numbers have been shown to be of special importance for individuals, impacting their behavior and expectations when investing in financial markets. In this sense, psychological barriers are defined as certain price levels at which the market tends to stick before breaking out either up or down. The impact of such kind of barriers in investors' decisions has been studied since the 1990's for a variety of asset classes and geographies.

This study examines for the first time, to the best of our knowledge, the Baltic States stock markets for indication of psychological barriers at round numbers. Therefore, it was considered the three major Baltic stock indices as well as the ten most actively traded stocks on the Nasdaq Baltic Market. It was collected a comprehensive set of data spanning from a variety of dates depending on each index available information and, for the case of individual stocks, the first trading day until December 31st, 2022.

It was conducted a uniformity test in the trailing digits of the indices and stocks under scrutiny, barriers proximity and hump tests to examine the frequency of observations near barriers and a generalized autoregressive conditional heteroskedasticity (GARCH) analysis to assess the differential impact of being above or below a possible barrier. The presence of psychological barriers may challenge the notion that Baltic States markets are efficient and may support the claim that technical analysis strategies can be useful in these markets. This research contributes to behavioral finance by applying investor psychology and its effects on stock prices levels, and gains its relevance by covering the lack of literature in this geographical area.

Findings suggest the existence of psychological barriers in OMX Tallinn index. Impacts in terms of returns and volatility around barriers were found for three stocks. Thus, results may suggest the possibility of creating profitable investment strategies based on this phenomenon, although evidence is not strong enough and more studies are required for clearer conclusions.

Key-words: psychological barriers; *M*-Values; stock indices; individual stocks; Baltic States.

JEL codes: G14; G15; G41

Resumo

Números redondos têm-se revelado de especial importância para os indivíduos, impactando o seu comportamento e expectativas quando investem nos mercados financeiros. Neste sentido, barreiras psicológicas são definidas como determinados níveis de preço para os quais o mercado tende a se manter antes de os passar, tanto para cima como para baixo. O impacto deste tipo de barreiras nas decisões dos investidores tem sido estudado desde os anos 90 para uma variedade de classes de ativos e áreas geográficas.

Este estudo examina pela primeira vez, dentro do meu conhecimento, a existência de barreiras psicológicas para números redondos nas bolsas de valores dos Países Bálticos. Portanto, foram considerados os três maiores índices de ações bálticos e também as dez ações mais transacionadas na Nasdaq Baltic Market. Foi recolhida uma amostra de dados para uma variedade de datas dependendo na informação disponível para cada índice e, para o caso das ações, o seu primeiro dia de transação até 31 de dezembro de 2022.

Foi conduzido um teste de uniformidade para os dígitos finais dos preços dos índices e ações sob escrutínio, testes de proximidade de barreiras e de toda a distribuição como um todo para examinar a frequência de observações perto de barreiras e uma análise de heteroscedasticidade condicional autorregressiva generalizada (GARCH) para avaliar o impacto diferencial de estar acima ou abaixo de uma possível barreira. A presença de barreiras psicológicas pode questionar a noção de que os mercados dos Países Bálticos são eficientes e pode apoiar a afirmação de que as estratégias de análise técnica podem ser úteis nestes mercados. Esta investigação contribui para as finanças comportamentais, aplicando a psicologia dos investidores e os seus efeitos nos níveis de preço das ações, e ganha a sua relevância cobrindo a falha na literatura nesta área geográfica.

Os resultados sugerem a existência de barreiras psicológicas no índice OMX Tallinn. Foram encontrados em três ações impactos em termos de rendibilidades e volatilidade perto de barreiras. Portanto, os resultados podem sugerir a possibilidade de criação de estratégias de investimento rentáveis baseadas neste fenómeno, embora não sejam suficientemente fortes e sejam precisos mais estudos para conclusões mais precisas.

Palavras-chave: barreiras psicológicas; *M*-Values; índices de ações; ações individuais; Países Bálticos.

Códigos JEL: G14; G15; G41

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1. Introduction

Psychological barriers are currently one of the most important topics of investigation in the field of Behavioral Finance. This subject has been studied since the 1990's for a variety of asset classes (stock indices, single stocks, bonds, derivatives, foreign exchange assets and commodities), periods and geographical areas. The phenomenon was first documented by Donaldson and Kim (1993) and De Grauwe and Decupere (1992), and then followed by several other studies, however, there is still existing a lack of empirical evidence in certain geographical areas.

The so-called psychological barriers are defined as certain price levels for which some investors find difficulty at crossing them, mainly at round numbers, reflecting investor's feelings and moods. The existence of these barriers seems to have a higher effect in the markets as technical analysis appears to be more and more vastly used, and thus suggesting that the crossing of one of these barriers may push the prices up (or down) more than otherwise warranted. The existence of this "resistance levels" and "support levels" on stock markets contradicts the efficient market hypothesis, as it suggests some level of predictability in stock markets and thus may potentially lead to abnormal risk-adjusted returns (Dorfleitner and Klein, 2009).

Our research extends the existing research about this topic, studying for the first time, to our best knowledge, if there are psychological barriers in the stock markets of the Baltic States, using empirical evidence of stock indices and individual stocks from these markets. Our study is also incentivized by few research on frontier markets – such as the stock markets of the Baltic States – on the field of psychological barriers. Moreover, this study assesses if barriers exist both in upward and downward price movements, and analysis the differential impact on price returns and variances of being above or below a possible barrier.

The dissertation starts with a thorough literature review which is concerned with defining the concept of psychological barriers in the field of Behavioral Finance and clarifying other related effects. Then follows by enumerating possible explanations for the existence of barriers. It also includes a description of the relationship between market efficiency and psychological barriers and how the phenomenon challenges the notion of efficiency. And concludes by presenting past empirical evidence about psychological barriers.

Following the literature review, this work analyzes the existence of psychological barriers in Baltic States stock markets, considering, for this purpose, a sample composed by the major stock indices of these markets – OMX Riga, OMX Tallinn and OMX Vilnius – and the ten individual stocks that compose the OMX Baltic 10 index, that is, the ten most actively traded stock on the Nasdaq Baltic Market – AS LHV Group, Coop Pank AS, Enefit Green AS, Ignitis Grupe AB, Merko Ehitus, Siauliu Bankas, Tallink Grupp, Tallinna Kuabamaja Grupp, Tallinna Sadam and Telia Lietuva. The time span is defined since the inception of each index (for stock indices) and since the first trading day of each stock (for individual stocks), until December 31st, 2022.

Then, the methodology is applied to the data sample as it was by Aggarwal and Lucey (2007), including a uniformity test, a barrier proximity test, a barrier hump test and a conditional effects test. The uniformity test examines the distribution of *M*-Values. The barrier proximity and barrier hump tests have the purpose to confirm the influence of round numbers in the non-uniform distribution of *M*-Values. Finally, the conditional effects test aims to analyze the impact of crossing a barrier on returns and variances, before and after crossing a barrier, either from above or from below.

The findings of this study suggest the existence of psychological barriers in OMX Tallinn index. When considering a 5-day period before and after crossing a round number, Siauliu Bankas and Telia Lietuva showed market turbulence before crossing barriers and calmed down afterwards both in downwards and upwards movements, and AS LHV Group behaved in the same way only in downwards movements.

The remainder of this dissertation is structured as follows: Chapter 2 presents the literature review of the topic. Chapter 3 addresses the data and methodological aspects of the study. Chapter 4 shows the empirical results and its analysis. Chapter 5 discusses the final results and conclusions. Finally, it is mentioned the bibliographic references.

2. Literature Review

Donaldson and Kim (1993) and De Grauwe de Decupere (1992) showed that there is clear evidence of certain price levels in the stock market and foreign exchange market, respectively, to which market participants attribute more significance than to other levels. From then on, several other studies on different asset classes, geographies and time spans, were encouraged by their findings. Despite this phenomenon being obvious to market practitioners and journalists, barriers are much less evident from an academic perspective, which makes psychological barriers being currently one of the most important topics of investigation on the field of behavioral finance.

Since the nature of this topic raises a broad discussion upon some controversial fields of market inefficiency and behavioral finance, a more extensively study about psychological barriers is required beyond simply analysing existing empirical evidence from previous studies. Therefore, this section starts by defining the concept of psychological barriers and clarify other related effects, followed by a discussion about the relationship between this phenomenon and market inefficiency, and then presenting a set of possible theoretical reasons for the existence of these barriers. Finally, the literature review closes referencing the most relevant existing studies that contributes for the psychological barriers research.

2.1. Psychological Barriers

According to Jang *et al.* (2015), "Psychological barriers, (…), are price levels that are perceived to be psychologically important to the extent that the market finds it difficult to reach these levels during upturns or downturns caused by the influx of selling or buying orders" (p. 54). These barriers are denominated "resistance levels" when investors do not cross a certain price from below, and "support levels" when investors do not break a barrier from above.

Usually, psychological barriers are found to exist mainly at round numbers, impacting asset's prices, returns and volatilities, however it does not imply that all round numbers can be seen as psychological barriers (Tschoegl, 1988).

When studying psychological barriers in the Dow Jones Industrial Average, Donaldson and Kim (1993), documented a phenomenon denominated bandwagon effect. It refers to upwards or downwards movements by more than usual after prices having crossed a barrier.

In addition, Dorfleitner and Klein (2009) observed the phenomenon, adding that "the bandwagon effect can be explained by the fact that the demand by some market participants increases because others are already purchasing the relevant asset. It is therefore a type of herding behavior" (p. 269). Therefore, according to Lobão and Pereira (2016) and based on Donaldson and Kim (1993), technical analysis may be used based on the assertion that traders will "jump on the bandwagon" after crossing a price barrier and producing a "breakout effect".

2.1.2. Clustering

It is important to distinguish the notion of psychological barriers from price clustering, and be aware that they may be not necessarily related with each other. Mitchell (2001) provides this distinction, and thus psychological barriers correspond to lower frequency of trades around certain prices or levels, whereas price clustering is the event in which particular prices or levels appear more frequently than others, due a concentration of the distribution of prices.

2.2. Possible Reasons for the Existence of Psychological Barriers

Psychological barriers are mainly consequences of behavioral biases. However, there are other possible explanations for their existence. This section approaches the most explanatory causes of the phenomenon under research.

2.2.1. Behavioral Biases

Number preferences by individuals is justified by investors bounded rationality and human biases. In fact, Yule (1927) analyzed the frequency of distributions of each final digits 0 to 9 in scale measurement readings by different observers, and confirmed this phenomenon. Likewise, Kendal and Smith (1938) reached the same conclusion after using a "randomizing" machine to yield likely fleeting observations of the digits 0 to 9, reporting an excessive frequency of even number observations and a human bias against the digits 1, 3 and 9.

Considering the existence of limits to arbitrage referred by Shleifer and Vishny (1997) and all the psychological aspects embedded in humans information processing and decision-making, the psychology-based asset-pricing theory, approached in the study of Hirshleifer (2001), considers that individuals are neither infinite in faculties nor in apprehension, and attempts to understand decision biases as well the importance of investors psychology for security prices, identifying a number of behavioral biases that have been shown to persist in asset price series. Some of these biases are closely related to the existence of psychological barriers, such as the anchoring effect and the heuristic simplification.

Slovic and Lichtenstein (1971) described anchoring as the phenomenon whereby individuals fixate on a recent number or a number which may be held out to be important by informed commentators, for instance. This effect is the main explanation for the issue of psychological barriers in financial markets. Nevertheless, Kahneman *et al.* (1982) described various judgmental heuristics and the biases they produce on the decision-making process that also may lead to the appearance of barriers.

Additionally, Avery and Zemsky (1998) and Welch (2000) pointed the tendency for certain individuals to follow a herding behavior, which refers to the tendency for a group of investors to trade in the same direction (buying and selling) over a period of time (Nofsinger and Sias, 1999), that is, the propensity of individuals to replicate the actions (rational or irrational) of a larger group.

Shiller (2000) found that in the absence of accurate agreement on fundamentals many investors tend to focus on the nearest round number as a reasonable proxy for the fundamental value. Also, based on both the heuristics and the herding behavior concepts, Westerhoff (2003) developed a formal model for which investors tend to cluster their expectations around round numbers.

2.2.2. Aspiration Levels

Simon (1955) in his study aimed to construct definitions of "rational choice" that are modelled more closely upon the actual decision processes in the behavior of economic agents than definitions heretofore propose. According to the author, an economic agent may choose rationally but within a given set of limits postulated by its model and thus may not pursue the optimal solution. Instead, individuals settle for a "good enough" solution and do

not pursue the maximization of the utility function due to information, time and calculation limitations.

Additionally, Sonnemans (2006) stated that some investors, when buying a stock, already have an idea for what price they will be able to sell the stock in the future. The target sell price may be considered an aspiration level in Simon's (1955) sense. Moreover, the target prices are typically round numbers, which may lead to many limit sell offers being posted at round whole numbers and, therefore leading to the origination of clustering effects, which makes harder for the prices to cross that numbers. In conformity, Cooney *et al.* (2003) presented empirical evidence that supports this idea, as investors submit more limit orders with even-eighth prices than odd-eighth prices on New York Stock Exchange (NYSE) stocks, thus leading to price clustering on even prices, which may explain the appearance of psychological barriers, as it is discussed in section 2.3.6.

2.2.3. Odd Pricing

Several studies in the marketing literature and cognitive psychology focus on odd pricing. Sonnemans (2006) defines it as the price being just below some round number (for example, €9.99 instead of €10.00). Odd pricing is very common in the marketing of consumer goods (e.g. Friedman, 1967; Holdershaw et al., 1997; Stiving and Winer, 1997; Schindler and Kirby, 1997) but also in real estate prices (Palmon et al., 2004). Likewise, Folkertsma (2002) investigated the prices of all consumer goods in the Dutch consumer price index (CPI) of January 2001 (more than 70 000 observations) and found that 31% of the observed prices had a 9 as the last significant digit (like 1.99 or 274.90) and 20% of the prices ended in 98 or 95 cents.

Brenner and Brenner (1982) explained the existence of the biological constraint that people have only a limited amount of memory and a limited capacity for storing directly accessible information, that is, when people are exposed to a continuous flow of information on prices, they tend to attach more significance to the first digits, treating them as more valuable information compared to the last digits. When comparing two numbers, a left-to-right comparison (i.e., first compare the hundreds, if these are the same the tens, etc.) is a very efficient procedure.

In financial markets, a stock quoted for 20€ is perceived as significantly higher than 19.90€. A current stock owner who wants to sell will probably be more satisfied if selling at a price of 20€ than 19.90€ despite the minimal difference. The same applies to a potential buyer who will be reluctant to purchase a stock that is already over 20€.

2.2.4. Cost Efficiency

Following the work of Yule (1927), Preece (1981) concluded that individuals when analyzing information tend to simplify it, and round numbers tend to predominate on their mental processing when it concerns to numerical information. By doing it, individuals are prone to produce a quicker and more cost-effective judgement over the precision of the analyzed data. In fact, Hornik *et al.* (1994) confirmed that rounding occurred more frequently than it was expected on a random process, when analysing data from seven different studies. The author also verified the increasing tendency for rounding with higher values. In accordance, Takayanagi *et al.* (1995) concluded that rounding numbers turn the numerical comparative judgements into a quicker process.

Sonnemans (2006) indicated that round numbers are more convenient for calculations, performing them easily, as round numbers limit informational load and decrease the probability of costly mistakes. Mitchell (2001) also pointed out the human habit for rounding to convenient numbers when reading scales, for example.

2.2.5. Option Exercise Prices

Dorfleitner and Klein (2009), besides pointing out behavioral factors as an explanation for the existence of psychological barriers, also claim that barriers may be originated by the fact of option exercise prices being usually round numbers. Delta hedgers are frequently most active when the option is at the money (i.e., the price of the underlying is close to the exercise price). Thus, additional trading activity in the underlying asset is also caused by purely technical reasons.

2.2.6. Price Clustering

Price clustering was first mentioned by Osborne (1962) and Niederhoffer (1965a, 1965b) who focused on the U.S. stock market and found that stock prices were clustered on whole numbers. Later, Mitchell (2001) defined price clustering as "a concentration of the distribution associated with a particular value or values when various values of price (digits) occur more frequently than other prices (digits)" (p. 402).

The clustering effect may be a possible reason for the appearance of barriers. For instance, considering a stock priced just below 20€, if the clustering effect is present at the 20€ level (i.e., due to limit orders established at this specific price), it may be difficult for prices to cross this level. However, the author stated that despite price clustering and psychological barriers may have similar behavioral interpretations and explanations for their existence, the two phenomena do not necessarily occur synonymously, nor must be related. Clustering does not necessarily imply that a barrier exists, that is, it is neither a necessary nor sufficient condition for a barrier (Mitchell, 2001).

2.3. Market Efficiency and Psychological Barriers

Fama (1970) claimed that a market is called "efficient" if prices always fully reflect available information. This efficiency may assume three forms. In weak form, all the available historical information is reflected in current prices; in semi-strong form, current prices reflect all the past and present publicly available information; and in strong form, all public and private information is reflected in market prices. If market conditions that characterizes an efficient market are verified, it is not possible for an investor to beat the market, that is, it is unlikely the investor to obtain abnormal returns – the returns (not prices) of an efficient market should follow a random walk (Pearson, 1905), and thus they are not possible to predict.

According to Tobin (1984), there are two different notions of market efficiency, informational efficiency and fundamental efficiency. Informational efficiency concerns to the rapid price reflection of all the available information, and it does not enable the prediction of how prices will evolve. Fundamental efficiency is a more demanding notion of efficiency and corresponds to the rapid and correct price reflection of all the available information.

Based on the last notion of market efficiency, the securities prices are the best estimate of their intrinsic value.

The efficient market hypothesis has been very controversial and disputed in financial literature, especially after several studies published in the 1990s suggested the existence of market inefficiencies. In fact, Simon (1955) had already addressed the limitations on knowledge and ability of the economic agents and the urge to have financial models which rely on limited rationality rather than relatively global rationality, which induce to eventual market inefficiencies.

Arbitrage may by a strategy of solving the inefficiencies caused by the investors' limited rationality and was defined by Sharpe and Alexander (1990) as "the simultaneous purchase and sale of the same, or essentially similar, security in two different markets for advantageously different prices". However, Shleifer and Vishny (1997) demonstrated that arbitrage faces several limitations, such as implementation costs or the noise trader risk, which opens the possibility of mispricing in financial markets. Additionally, Hirshleifer (2001) also pointed several psychological biases persisting in asset price series, confirming the existence of limits to arbitrage. Mitchell (2001), while providing a distinction between clustering and psychological barriers in his study, pointed outs that "a psychological barrier can be viewed as an impediment to an individual's mental outlook, that is, an obstacle created by the mind, barring advance or preventing access" (p. 402), which indicates that psychological barriers can also be seen as limits to arbitrage.

Despite Donaldson and Kim (1993) referred that the existence of barriers does not imply the rejection of market efficiency, Dorfleitner and Klein (2009) stated that the existence of psychological barriers contradicts the efficient market hypothesis as it suggests some level of predictability in stock prices and thus may lead to abnormal risk-adjusted returns, which may question the rationality of investors.

Nonetheless, it is important to have in consideration that there is a tendency for progressive disappearance of many anomalies after the publication of relevant studies on the subject (Marquering *et al.*, 2006).

2.3.1. Stock Markets of the Baltic States

The existence of psychological barriers may challenge the Efficient Market Hypothesis and suggest that investors can obtain abnormal returns based on historical information. Therefore, it is worth to be aware of the conclusions of studies conducted for testing the efficiency of Baltic States stock markets.

Kvedaras and Basdevant (2002) tested the efficiency of the financial markets in the three Baltic States. They found evidence suggesting that the Estonian and Lithuanian capital markets exhibit a certain degree of efficiency, although some deviations from market efficiency are also observed. In the Latvian market, they found a huge inefficiency indicating that the capital market structure was not developed enough to ensure even the nearly weak-form efficiency. In accordance, the study of Levišauskaitė and Jūras (2003) employed several statistical tests and also concluded that the Baltic markets are generally weak-form efficient.

Also, Lönnbark and Soultanaeva (2008) examined the profitability of technical trading rules in the Baltic stock markets. Their findings suggested that certain technical trading rules could generate excess returns, indicating the presence of short-term inefficiencies that could be exploited by investors using these strategies.

Norvaisiene, Stankeviciene, and Lakstutiene (2015) investigated seasonality in the Baltic stock markets. Their analysis revealed the presence of significant seasonal patterns in stock returns, such as month effect for Estonian and Lithuanian market but not for Latvian market. These findings suggest the existence of calendar anomalies that can be exploited by investors.

Gil-Alana, Gupta, Shittu, and Yaya (2018) employed a fractional integration approach to examine the market efficiency of the Baltic stock markets. Their findings revealed evidence of long memory and persistence in stock returns, indicating departures from market efficiency in the short run. However, they also highlight the existence of mean reversion and the convergence of returns towards equilibrium over the long run.

Finally, Aleknevičienė, Kviedaraitienė, and Aleknevičiūtė (2018) analyzed the semi-strong form efficiency in the Baltic stock markets under changing economic situations. They found evidence of market inefficiency during periods of economic instability, suggesting that the Baltic markets are not fully informationally efficient during such times.

2.4. Empirical Evidence about Psychological Barriers

Studies regarding psychological barriers have been conducted since the early 1990's in a wide range of assets, periods and geographies. The existence of this phenomenon was mostly studied on stock indices, however, the research was expanded to other asset classes, including, single stocks, bonds, derivatives, foreign exchange and commodities.

2.4.1. Stock Indices

The first study concerning the existence of psychological barriers using stock indices was conducted by Donaldson and Kim (1993). They examined the Dow Jones Industrial Average (DJIA) movements around key reference points for the period 1974-1990. Results showed that this movements are restrained by barrier support and resistance effects at round numbers (100-levels), but having crossed trough a 100-level, the DJIA moved more than warranted. However, the authors made it explicit that this phenomenon provoked by "investors sentiment" do not necessarily imply that the market is inefficient. Ley and Varian (1994) extended the previous study, they examined 41 years of closing values of the DJIA, and despite confirming the non-uniformity of the distribution (which is not necessarily synonym of psychological barriers), they concluded that there is little if any predictive power on the daily closing prices resulting from psychological barriers.

Koedijk and Stork (1994), using daily middle rates of five stock indices – from Belgium, Germany, Japan, USA and UK – between 1980 and 1992, found that round numbers are approached as well as transgressed relatively infrequently, and that the presence of psychological barriers does not lead to predictability.

De Ceuster *et al.* (1998) by virtue of Benford's Law[1], showed that previous studies unconsciously assumed incorrectly that deviations from uniformity in the trailing digit's distribution is considered evidence for the presence of psychological barriers. Therefore, they proposed a test based on the cyclical permutations of the actual returns applied to the DJIA, 100 FTSE and Nikkei Stock Average 225. Findings showed no support for the psychological barrier's hypothesis.

[1] Benford's Law states that, in a naturally occurring set of numbers, the smaller digits appear disproportionately more often as the leading digits.

Another study conducted by Cyree *et al.* (1999), investigated the presence of psychological barriers in the DJIA, S&P 500, and other six stock indices, most of them not included in previous studies. These barriers were found in seven of the eight indices tested, although the return dynamics did not appear to be uniform across the indices under study. The only indices for which these effects were consistently significant in the case of both upward and downward movement were the DJIA and the Nikkei. In a downward move through a barrier, the CAC was the only index that exhibited an increase in variance in the post-crossing period. The authors concluded that upward movements through barriers tend to have a consistently positive impact on the conditional mean return, while downward movements tend to have an indeterminate impact. Also, conditional variance tends to be higher in pre-crossing subperiods and lower in post-crossing subperiods.

Using the daily stock price indices of seven Asian stock markets including South Korea, Taiwan, Hong Kong, Thailand, Malaysia, Singapore, and Indonesia, Bahng (2003) tested for the existence of the possible price barriers. Results identified price barriers in the Taiwanese stock indice, while the same seemed not occur for the other markets included in the research. Contrary to positions taken by authors of previous studies, Bahng (2003) considers the presence of psychological barriers as evidence in favor of market inefficiency.

Dorfleitner and Klein (2009) examined the DAX 30, CAC 40, FTSE 50, and the DJ EURO STOXX 50, as well eight major German stocks for indications of psychological barriers, in different period between 1990 and 2003. Besides the methods used in existing literature to date, they pursue new approaches in estimating the intraday variance and in using open, high, low and closing prices for their calculations. Overall, results indicated for the inexistence of consistent barriers in European stock indices and stocks. Also, after some anomalies have been published, the authors noticed that some of them have disappeared, which is consistent with the literature findings about disappearing stock market anomalies.

Lim *et al.* (2013) investigated – during the period 2011-2011 – the presence of psychological barriers in the equity indexes of ten Asian markets, and found evidence for barriers for all of them, however, there was little evidence of the predictability of stock returns induced by the presence of these barriers.

The daily closing values of the NASDAQ Composite index, from 1990 to 2012, were analysed by Woodhouse *et al.* (2016) aiming to test whether there exist psychological barriers and to investigate the possible impact of the resultant psychological influences on market

activity. Conclusions confirmed the existence of barriers. Moreover, according to the authors, the lack of a formal rational explanation seemed to indicate a behavioural underpinning, however, they consider that these barriers are not enough to overrule efficient market hypothesis, since there were not sufficient arbitrage opportunities to investors.

A study conducted by Lobão and Pereira (2016) examined the existence of psychological barriers at round numbers in the nine stock market indices of the eurozone, during a time period more extensive than those considered in the remaining studies on the subject (post-2008 financial crisis), finding barriers in German, Finnish and Dutch stock markets. Moreover, the authors reported that the relationship between risk and return tended to be weaker at the proximity of round numbers.

Berk *et al.* (2016) published the first study of behavioral influences in frontier equities on the subject of psychological barriers. Using MSCI Frontier Markets 100 index (hereafter Frontier100), between 2008 and 2014, results showed existing psychological barriers in these markets, mainly in countries with higher cultural measures of individualism. Conclusions also showed that high bid-ask spreads act as a deterrent to the presence of psychological barriers, perhaps due to the high cost associated with trend following trading in markets with high spreads.

Lobão and Couto (2019) found psychological barriers in the markets of South Korea and Taiwan, after studying six major Asian stock markets, more extensively, for this purpose. Not so strong but still significative, Japan and Hong Kong also showed the existence of barriers, and Singapore and China stock markets exhibited weak signs of barriers. Results from this study 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. Finally, Lobão *et al.* (2020) extended the subject under research to the major markets of eight Latin America countries, presenting mild to strong evidence of barriers in all the markets with the exception of the Chilean stock market.

2.4.2. Single Stocks

Cai et al. (2007) were the firsts to focus on individual stock prices, examining 1050 A-shares and 100 B-shares from both Shanghai Stock Exchange (SHSE) and the Shenzhen Stock Exchange (SZSE) during June 2002. Although results have pointed a strong tendency for

price clustering due, for instance, to cultural factors, evidence on psychological price resistance was not found significant. The inexistence of psychological barriers on a consistent basis was also confirmed by Dorfleitner and Klein (2009), after focusing on prices of eight major German stocks, as already referred before.

Chen (2014) examined the effect of price clustering and price barriers based on the international stock market, using a total of 35,328 stocks traded on 68 countries over the period from 2000 to 2009. The last digit 0 in prices was found to be a significant resistance point for the global market. Also, these effects are detected for ending digit 5, however, this conclusion was not robust and persistent for several countries. The author pointed that the cross-country analysis indicated that price clustering and barriers become intensified in countries with a more transparent and open environment.

A more recent study conducted by Lobão and Fernandes (2018) examined the prices of the most widely traded stocks from Taiwan, Brazil and South Africa over the period 2000-2014. The 24 stocks under study revealed inexistence of psychological barriers at round numbers.

2.4.3. Bonds

Burke (2001) was the first studying the existence of psychological barriers on bonds, covering the 2, 5, 10 and 30-years U.S. benchmark bonds' yields, from 1983 to 2000. Evidence was found of yield barriers at integer multiples of 25% in the widely followed 30-year and 10-year benchmark bonds. Despite confirming deviation from uniformity, no significant effects were found in a GARCH framework regarding both mean and variance.

2.4.4. Derivatives

Schwartz *et al.* (2004) tested for trade price clustering in the open outcry futures markets. Their findings pointed that the S&P 500 Futures contract prices, in 1999 and 2000, tended to cluster at pricing increments of x.00 and x.50 during the trading day, which may increase the possibility of psychological barriers in these securities.

Chen and Tai (2011) focused on a time horizon from 2000 to 2009 for testing price barriers in TAIFEX futures prices. Conclusions refer that price in round numbers act as barriers with

important effects on the conditional mean and variance of the futures prices series around these levels.

Regarding options, Jang *et al.* (2013) proposed a threshold model to derive the pricing formulas of European Options, aiming to detect psychological barriers on the prices of stock options. For their analysis, 15-minute interval historical records of the S&P 500 and VIX indices from July 2011 and January 2012 was considered. They demonstrated the existence of such barriers in the S&P 500 Index and analysed the impacts of such barriers on the index's rate of return and volatility. Moreover, they examined the performance of the superior model proposed on option pricing and hedging relative to existing models such as the Black-Scholes and Constant Elasticity of Variance models. By performing a mean regression analysis, it was found that the VIX Index is not a simple mean-reverting process but is dependent on the barrier because it declines relatively by 0.5% on average when the S&P 500 Index is close to psychological barriers.

A paper focused on call options by Blyler (2013) proposed three different price barriers: Bollinger Bands, Round Numbers and Gann Levels. After examining the possibility in the stock market causing further systematic pricing differences between the market price and Black-Scholes predicted price, round numbers barriers were found to be present in the option market.

Dowling *et al.* (2014) tested for the presence of psychological barriers in the oil futures market, considering WTI and Brent futures over the time period 1990-2012. The study focused on $10 barrier regions and concluded that barriers are present in Brent prices but not in WTI prices. They also showed that psychological barriers only appeared to influence prices in the period 1990–2006, and then the phenomenon dissipated during the bust in oil prices over the following years, mainly because global recession took hold and markets reverted to wider economy focused fundamentals.

2.4.5. Foreign Exchange

One of the first studies about psychological barriers were taken regarding foreign exchange market and was conducted by Grauwe and Decupere (1992). The authors found that psychological barriers exist and are significant in the dollar-yen market and once these barriers have been crossed, exchange rates accelerate away from them.

Westerhoff (2003) developed a simple behavioral exchange rate model in which investor perception of the fundamental value is anchored to the nearest round number. He aimed to explore how traders think about fundamentals and how that influences exchange rate dynamics. According to the author, anchoring phenomenon leads to possible misalignments of exchange rates since they fluctuate between upper and down perceived fundamentals (resistance and support levels). It is referred the importance of central authorities in exploiting this property by reducing distortions despite the difficulty in breaking psychological barriers between anchors.

Mitchell and Izan (2006) extended the research on this phenomenon to the Australian dollar, covering the period 1978-1992, and found evidence of existing psychological barriers using a simulation analysis, despite being less pronounced and no longer significant compared to when used a uniformity test.

A more recent study extended this subject to the cryptocurrency market. Fonseca *et al.* (2019) confirmed the existence of psychological barriers in four cryptocurrencies under scrutiny, namely, Bitcoin, Dash, NEM and Ripple. Explanations for the existence of barriers are attributed to the fact that the cryptocurrency market has a high share of unexperienced investors which is consistent with the hypothesis that that class of investors is particularly prone to the behavioral biases. Also, Lee and Seong (2019) considered three Bitcoin markets, Coinbase of the US, Bitstamp of Europe and Bitfinex of Hong Kong for testing the existence of psychological barriers. Results are consistent with the previous study.

2.4.6. Commodities

The existence of psychological barriers in gold prices were examined for the first time by Aggarwal and Lucey (2007). The results from daily and intraday gold prices for the periods 1980-2000 and 2001-2003 respectively, indicated the existence of psychological barriers at the 100's digits in daily gold prices with significant effects on the conditional mean and variance of prices around these levels.

Lucey and O'Connor (2016) tried to find psychological barriers around key round numbers in gold and silver prices. The use of intra-day data from 1975-2015 composed of the London AM and PM fix allowed to conclude that there are some evidence to support the existence

of barriers at numbers ending in 0 and 00 in the price gold, but the same was not found for silver prices.

To conclude, Narayan *et al.* (2017) tried to understand how stock returns were affected when the oil price reached the psychological barrier of US $100 per barrel for the first time in history and found that this event had a statistically significant effect on some sectoral stock returns. It was a source of return drift and they found that there is a lack of robust evidence that the information contained in oil prices can be successfully exploited by investors.

2.5. Disappearing Stock Market Anomalies

Several studies have documented the disappearance of many anomalies found by empirical researchers. Marquering *et al.* (2006) showed that the weekend effect, the holiday effect, the time-of-the-month effect and the January effect in the Dow Jones Industrial Average (DJIA) have disappeared after these anomalies have been published. Dorfleitner and Klein (2009) complemented this idea, concluding that some of the barriers found in previous studies seem to have disappeared. It is consistent with Dimson and Marsh (1999) that examined the premier stock market anomaly ("small firm effect") and showed that out-of-sample small-firm premium turned negative – the effect reversed after it was found. Kohers *et al.* (2004) also showed that the weekend effect was existent in 12 indices during the 1980s but it appeared to have faded away in the 1990s.

An explanation for this tendency may be due to increases in market efficiency. For instance, the publication of certain anomalies is the initial point to statistical arbitrageurs' activities, such as those performed by hedge funds, which can eliminate the anomalies by trading on them.

3. Data and Methodology

In this section, it will be addressed the major methodological aspects of the present study, testing the presence of psychological barriers in the stock markets of the Baltic States as well their consistency over the period under analysis. Moreover, it tries to find whether these barriers exist both in upward and downward price movements and determine the differential impact on price returns and volatility of being above or below a possible barrier.

It will be first presented the data sample and its main features that will be considered followed by an explanation of how it will be defined the so-called psychological barriers for the purpose of being tested their existence. Then, theoretical foundations of all empirical tests to be conducted are presented, namely the uniformity test of the distribution of the digits of the stock indices considered, two barrier tests that examine the existence of barriers around round numbers and, finally, a conditional effect test which test the effects on returns and variances when prices get closer to certain levels.

3.1. Data

The research being conducted will focus on the main representative stock indices of the three Baltic States stock markets. Beyond testing the existence of barriers in these indices, it will be studied the existence of psychological barriers in the ten stocks included in the OMX Baltic 10 index. This research will analyse historical data in order to identify the presence of psychological barriers. Past studies have never considered stock markets of the Baltic States for the purpose of existence of psychological barriers, which justifies its relevance in the extension of existing research and finds its importance in the study of frontier markets, not only for academic purposes but also for the predictability of abnormal risk-adjusted returns concerning the investment activity.

Hence, the following indices will be under analysis: OMX Riga, OMX Tallinn and OMX Vilnius. The choice relies in gross indices as a full measure of the market's performance, thus tracking the gross return of the stocks they include, reflecting any payment of dividends besides changes in stock prices. Also, the individual stocks included in the OMX Baltic 10 that are going to be considered for the existence of psychological barriers are: AS LHV Group, Coop Pank AS, Enefit Green AS, Ignitis grupe AB, Merko Ehitus, Siauliu Bankas, Tallink Grupp, Tallina Kaubamaja Grupp, Tallinna Sadam and Telia Lietuva.

The time window under study ranges since the inception of each index (for stock indices) and since the first trading day of each stock (for individual stocks) until December 31st, 2022, covering the maximum past available data as possible for a complete and thorough analysis. The data was retrieved from Thomson Reuters Datastream.

Table 1 summarizes the data base of stock indices and individual stocks, as well the respective time range considered:

Table 1 – Data Included in the Sample

Stock Index	Company Name	Security Ticket	Starting Date	Ending Date
OMX Riga	-	OMXRGI	December 31st, 1999	December 31st, 2022
OMX Tallinn	-	OMXTGI	June 3rd, 1996	
OMX Vilnius	-	OMXVGI	December 31st, 1999	
OMX Baltic 10 (OMXB10)	AS LHV Group	LHV1T	May 23rd, 2016	December 31st, 2022
	Coop Pank AS	CPA1T	December 10th, 2019	
	Enefit Green AS	EGR1T	October 21st, 2021	
	Ignitis Grupe AB	IGN1L	October 7th, 2020	
	Merko Ehitus	MRK1T	August 11th, 2008	
	Siauliu Bankas	SAB1L	April 1st, 1998	
	Tallink Grupp	TAL1T	December 9th, 2005	
	Tallinna Kuabamaja Grupp	TKM1T	September 6th, 1996	
	Tallinna Sadam	TSM1T	June 13th, 2018	
	Telia Lietuva	TEL1T	June 12th, 2000	

Description of stock indices[2]:

- **OMX Baltic 10 index**: is a tradable index of the 10 most actively traded stocks on the Nasdaq Baltic Market. The limited number and excellent liquidity of the stocks which it includes make this index well-suited to derivative financial instruments. Stocks are weighted based on their free-float capitalization (the market value of shares considered available for trading), with a maximum weight of 15% for any one stock. The composition of the index is reviewed twice a year.
- **Local all-share indices** (OMX Tallinn, OMX Riga and OMX Vilnius): include all the stocks on the Main and Secondary lists of the respective market (Tallinn, Riga or Vilnius) except for those companies where a single shareholder controls 90% or

[2] Nasdaq Baltic. *About Indexes – Nasdaq Baltic*. https://nasdaqbaltic.com/market-information/about-indexes/

more of the outstanding shares. Their purpose is to show the current status and movements of stocks on each local market.

3.2. Methodology

Considering the previous studies conducted on the topic of psychological barriers so far, the methodologies used have been progressively harmonized. The present study follows as a guideline the methodology used by Aggarwal and Lucey (2007), since the authors combined the three most used types of tests applied to the most relevant studies on psychological barriers, and that are also applicable to the topic under research in the present study, intending to investigate whether the indices under analysis close more or less frequently around round numbers.

The first test that will be conducted is the uniformity test, introduced by Donaldson and Kim (1993) to examine the distribution of *M*-values in the Dow Jones Industries Average closing prices. Following this approach, a non-uniform distribution could indicate the presence of psychological barriers although it is not a sufficient condition in itself. The same authors also presented the second tests that will be used, denominated as barrier tests – barrier proximity and barrier hump tests – to confirm the influence of round numbers in the non-uniform distribution of *M*-values. Finally, the third test to conduct will be the conditional effects test presented first by Cyree et al. (1999) aiming to analyze the impact of crossing a barrier, on an upward or downward movement, on returns and variances.

A summary of the data series can be seen in Table 2:

Table 2 – Summary Statistics

Index/Stock	N	Return Series					Level Series	
		Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera (p-value)	Minimum Price	Maximum Price
OMX Riga	6000	0.000400	0.013489	-0.528779	23.96940	0.000000	104.48	1305.79
OMX Tallinn	6935	0.000414	0.013702	-1.145508	31.75744	0.000000	84.24	2141.55
OMX Vilnius	6001	0.000375	0.009726	-0.780030	35.93608	0.000000	63.18	1028.74
AS LHV Group	1725	0.000915	0.015235	0.163764	13.27351	0.000000	0.69	4.75
Coop Pank AS	799	0.001009	0.020148	-0.178783	15.13215	0.000000	0.93	4.20
Enefit Green AS	312	0.000730	0.015528	0.059241	5.973417	0.000000	3.31	4.86
Ignitis Grupe AB	583	-0.000273	0.010044	-0.805487	12.08054	0.000000	17.56	25.35
Merko Ehitus	3755	0.000197	0.018835	-0.406542	15.80392	0.000000	1.90	17.08
Siauliu Bankas	6458	0.000259	0.028462	0.010895	19.97869	0.000000	0.07	0.85
Tallink Grupp	4451	-0.000186	0.019239	0.182099	13.18209	0.000000	0.24	1.52
Tallinna Kuabamaja Grupp	6866	0.000511	0.021849	0.179289	22.19755	0.000000	0.12	11.72
Tallinna Sadam	1188	-0.000259	0.009500	-1.947504	26.02697	0.000000	1.37	2.17
Telia Lietuva	5885	9.84E-05	0.013825	0.603445	35.57401	0.000000	0.29	2.14

Table 2 indicates some aspects to consider. Stock indices provided positive mean returns in the period under analysis, while some individual stocks showed negative returns. Data does not follow a normal distribution based on the data's skewness and kurtosis (Jarque-Bera test). Also, one may observe that Coop Pank AS, Siauliu Bankas and Tallinna Kuabamaja Grupp are the most volatile assets. Finally, all the assets show a higher number of outliers that a normal distribution would predict, and there is no pattern in the asymmetry of the distributions (some are asymmetric on the left and others on the right).

3.2.1. Definition of Barriers

Following Brock *et al.* (1992), it will be used the so-called *band technique* and barriers will thus be defined as a certain range around the actual barrier number. This interpretation of a barrier corresponds to the insight that market participants will most certainly become active at a certain level before the index touches a round price level. For instance, considering a market index level of 100, the market participants will not become active at the very first touch of this price level, but instead the over-excitement is expected to begin, e.g. at 99 or 101, or even at 95 or 105.

Dorfleitner and Klein (2009) defined the barrier level l as the number of zeros that a barrier has. Barriers will thus be defined at multiples of 1000, 100, 10 and 1 and the intervals with

an absolute length of 2%, 5%, 10% and 25% of the corresponding barriers. However, it is also introduced the barrier level l = -1 for the 0.1-level barrier. Formally, the following possible barrier bands are considered:

Barrier level l = 3 (1000s)	980-20; 950-50; 900-100; 750-250
Barrier level l = 2 (100s)	98-02; 95-05; 90-10; 75-25
Barrier level l = 1 (10s)	9.8-0.2; 9.5-0.5; 9.0-1.0; 7.5-2.5
Barrier level l = 0 (1s)	0.98-0.02; 0.95-0.05; 0.90-0.10; 0.75-0.25
Barrier level = -1 (0.1s)	0.098-0.002; 0.095-0.005; 0.090-0.010; 0.075-0.025

For each index under consideration, it will be chosen the most appropriate barrier levels to examine for possible barrier phenomena.

3.2.2. *M*-Values

The concept of *M*-Values was first introduced by Donaldson and Kim (1993) and refers to the last digits in the integer portion of the indices under analysis. In their study, *M*-values considered potential barriers at the levels …, 300, 400, …, 3400, 3500, i.e. at:

$$k \times 100, k = 1, 2, \ldots \tag{3.1}$$

However, De Ceuster *et al.* (1998) identified two problems with this series of barriers. First, the series was not multiplicatively regenerative, resulting, for instance, on 3400 being considered a barrier, whereas 340 would not. Second, it was recognized that successive barriers should not be too close to each other, relatively speaking, but as defined by Eq. (3.1). 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:

$$k \times 10^l, k = 1, 2, \ldots, 9; l = \cdots, -1, 0, 1, \ldots; \tag{3.2}$$

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

$$k \times 10^l, k = 10, 11, \ldots, 99; l = \cdots, -1, 0, 1, \ldots \tag{3.3}$$

Considering it, the *M*-values which will be used can then be defined. Formally,

$$M_k = \left[P_t \times \frac{100}{k}\right] mod\ 100, k = 0.1, 1, 10, 100, 1000, \quad (3.4)$$

where, $\left[\mathrm{P_t} \times \frac{100}{\mathrm{k}}\right]$ is the integer part of $\mathrm{P_t} \times \frac{100}{\mathrm{k}}$, and *mod 100* denotes reduction modulo 100.

It means, in practice, that if P_t = 1234.56, then M0.1 is 60, the M1 is 56, the M10 is 45, the M100 is 34 and the M1000 is 23. At each level, barriers should appear when M = 00.

M1000 will only be considered for price levels whose integer part has 4 digits (e.g. 6543), M100 for 3 digits (e.g. 543), M10 for 2 digits (e.g. 43.21), etc. That is, a level 2 barrier (M100) will not be considered for a price level of 99.87, for example.

3.2.3. Uniformity Test

Having defined the *M*-values, it will be conducted a test that aims to examine the uniformity of their distribution. As was conducted by Aggarwal and Lucey (2007), a Kolmogorov-Smirnov Z-statistic test will be performed. Thus, it will be testing H0: uniformity of the *M*-values distribution, against H1: non-uniformity of the *M*-values distribution.

One can suggest that the rejection of uniformity may indicate the presence of psychological barriers. Nonetheless, it is important to emphasize that the rejection of the null hypothesis is not sufficient in itself to prove their existence. Ley and Varian (1994) showed that the digits of the American 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. Also, Dorfleitner and Klein (2009) pointed out that *M*-values can show a certain degree of autocorrelation, which may lead to potential deviations on the results.

3.2.4. Barrier Tests

As explained by Lobão and Pereira (2016): "Barrier tests are used to assess whether observations are less frequent near barriers than it would be expected considering a uniform distribution" (p. 4), examining the shape of the *M*-values distribution.

Barrier tests were first introduced by Donaldson and Kim (1993) on their study focused on the Dow Jones Industries Average index and have been used since then by other researchers who applied this approach to several other securities such as Burke (2001) and Aggarwal and Lucey (2007) on U.S. bond yields and gold prices, respectively.

Therefore, the observation of a significant lower closing price frequency within an interval around a certain price level, will indicate the existence of a psychological barrier. Two types of barrier tests will be used: the barrier proximity test and the barrier hump test.

3.2.4.1. Barrier Proximity Test

This test examines the frequency of observations, *f*(*M*), near potential barriers and will be performed according to the following equation:

$$f(M) = \alpha + \beta + \varepsilon, \quad M = 00, 01, \ldots, 99 \tag{3.5}$$

where, *D* is a dummy variable which takes the value of unity if the index is at the potential barrier and zero elsewhere. As it was mentioned in section 3.2.1., 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%, 10% and 25%, of the corresponding power of ten as barriers.

The results of this test are based in β coefficients. 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.

3.2.4.2. Barrier Hump Test

While the barrier proximity test examines the tails of frequency distribution near the potential barriers, the barrier hump test examines the entire shape of the distribution, not focusing solely on the proximity of the potential barriers, and thus, it is broader than the former. As stated by Donaldson and Kim (1993), in this case, the uniform distribution in the absence of barriers as a specification of the null hypothesis is not sufficient. The distribution has also to have a certain particular shape in the presence of barriers. When analysing the behavior of exchange rates in the presence of target zones imposed by forward-looking agents, Bertola and Caballero (1992) suggested that a hump-shape was an appropriate alternative for the

distribution of observations, which will be implemented in the present study as the following equation:

$$f(M) = \alpha + \Phi M + \gamma M^2 + \eta,\ M = 00, 01, \ldots, 99 \quad (3.6)$$

where the frequency of observation of each *M*-value is regressed on the *M*-value itself and on its square.

In the presence of psychological barriers, the *M*-values are expected to follow a hump-shape distribution, and γ will be negative and statistically significant, whereas under the null hypothesis of no existing barriers, γ is expected to be zero.

3.2.4. Conditional Effects Test

As mentioned in section 3.2.3., the rejection of uniformity on the observations of *M*-values are not sufficient to prove the existence of psychological barriers (Ley and Varian, 1994). Having this argument in consideration, Cyree *et al.* (1999) introduced a new approach in order to analyse the dynamics of the return series around these barriers, namely regarding mean and variance. Later, Aggarwal and Lucey (2007) used the same approach to study gold prices based on a GARCH (generalized autoregressive conditional heteroskedastic) framework. This way, the authors were able 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[3].

Accordingly, it will be adopted the method used by Aggarwal and Lucey (2007) for a 5-day analysis, and four regimes around barriers will be defined:

- *BD*: dummy variable which assumes the value 1 in the 5 days before the prices reach a barrier on a downwards movement and the value 0 otherwise.
- *AD*: dummy variable which assumes the value 1 in the 5 days after the prices reach a barrier on a downwards movement and the value 0 otherwise.
- *BU*: dummy variable which assumes the value 1 in the 5 days before the prices reach a barrier on an upwards movement and the value 0 otherwise.

[3] As previously illustrated by Brock *et al.* (1992).

- *AU*: dummy variable which assumes the value 1 in the 5 days after the prices reach a barrier on an upwards movement and the value 0 otherwise.

The Eq. (3.1) represents an OLS (ordinary least squares) estimation which results are consistent with the existence of psychological barriers.

$$R_t = \beta_1 + \beta_2 BD_t + \beta_3 AD_t + \beta_4 BU_t + \beta_5 AU_t + \varepsilon_t \quad (3.7)$$

However, the distributional shifts implied by barriers invalidate basic assumptions of OLS, such as the existence of heteroscedasticity and autocorrelation across the data base (Cyree *et al.*, 1999). Therefore, the full analysis of the effects in the proximity of barriers require the application of the former test also to the variances. The same mean equation is regressed but using a GARCH approach which implies that:

$$\varepsilon_t \sim N(0, V_t) \quad (3.8)$$

Besides the above-mentioned dummy variables, Eq. (3.2) includes a moving average parameter and a GARCH parameter.

$$V_t = \alpha_1 + \alpha_2 BD_t + \alpha_3 AD_t + \alpha_4 BU_t + \alpha_5 AU_t + \alpha_6 V_{t-1} + \alpha_7 \varepsilon^2_{t-1} + \eta_t \quad (3.9)$$

In the absence of barriers, it is expected that the coefficients on the indicator variables in the mean equation to be non-significantly different from zero, whereas any coefficient significantly different from zero (either positive or negative) might indicate the presence of psychological barriers.

Following Cyree *et al.* (1999) and Aggarwal and Lucey (2007), the four possible hypotheses to be tested are the following:

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

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

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

H4: There is no significant difference in the conditional variance before and after an upwards crossing of a barrier.

4. Empirical Study

In this section, it will be disclosed the results of the tests previously presented, as well as an analysis of each one of those tests' results, not only for the whole sample as a global analysis but also for the two sub-samples considered in this study: stock indices and single stocks. The analysis of the results for the different sub-samples will allow to make a comparison between them and understand if there are significant differences for each asset class.

There is no priori expectation concerning the results achieved as there is an absence of prior research in the geographical area considered.

4.1. Uniformity Test

Table 3 shows the results of the uniformity test performed for the different *M*-Values derived from the prices of the indices and stocks under consideration.

Table 3 – Kolmogorov-Smirnov Test for Uniformity

Stock Index	Statistic	M0.1 (*I*=-1)	M1 (*I*=0)	M10 (*I*=1)	M100 (*I*=2)	M1000 (*I*=3)
OMX Riga	Kolgomorov (D) - Stat. Value (adjusted)	-	1.963754	1.733919	6.293121	9.257250
	p-value		0.0009***	0.0049***	0.0000***	0.0000***
OMX Tallin	Kolgomorov (D) - Stat. Value (adjusted)	-	1.602693	0.987805	3.600812	14.42899
	p-value		0.0117**	0.2833	0.0000***	0.0000***
OMX Vilnius	Kolgomorov (D) - Stat. Value (adjusted)	-	1.771713	1.634939	6.074698	-
	p-value		0.0038***	0.0095***	0.0000***	

AS LHV Group	Kolgomorov (D) - Stat. Value (adjusted)	7.949816	13.83369	-	-	-
	p-value	0.0000***	0.0000***			
Coop Pank AS	Kolgomorov (D) - Stat. Value (adjusted)	8.088559	8.716047	-	-	-
	p-value	0.0000***	0.0000***			
Enefit Green AS	Kolgomorov (D) - Stat. Value (adjusted)	3.861759	2.896513	-	-	-
	p-value	0.0000***	0.0000***			
Ignitis Grupe AB	Kolgomorov (D) - Stat. Value (adjusted)	15.47580	1.971422	5.808890	-	-
	p-value	0.0000***	0.0008***	0.0000***		
Merko Ehitus	Kolgomorov (D) - Stat. Value (adjusted)	32.38141	4.803476	3.750073	-	-
	p-value	0.0000***	0.0000***	0.0000***		
Siauliu Bankas	Kolgomorov (D) - Stat. Value (adjusted)	24.99292	-	-	-	-
	p-value	0.0000***				
Tallink Grupp	Kolgomorov (D) - Stat. Value (adjusted)	6.472017	9.860832	-	-	-
	p-value	0.0000***	0.0000***			
Tallinna Kuabamaja Grupp	Kolgomorov (D) - Stat. Value (adjusted)	20.86714	7.605356	-	-	-
	p-value	0.0000***	0.0000***			
Tallinna Sadam	Kolgomorov (D) - Stat. Value (adjusted)	8.018323	10.29725	-	-	-
	p-value	0.0000***	0.0000***			
Telia Lietuva	Kolgomorov (D) - Stat. Value (adjusted)	17.11843	27.56851	-	-	-
	p-value	0.0000***	0.0000***			

This table presents the results of a Kolmogorov-Smirnov test for uniformity. The first line for each asset shows the value of the t-statistic; p-value shows the marginal significance of this statistic. H0: uniformity; H1: non-uniformity. Significance at the 10%, 5% and 1% levels are denoted respectively *, ** and ***.

Regarding stock indices, only OMX Tallinn does not reject uniformity at barrier level 1, considering a 10% significance level, and when considering a 1% significance level, uniformity is not rejected for barrier level 0. All remaining stock indices reject the null hypothesis for all significance levels. Therefore, evidence shows that the *M*-values do not follow a uniform distribution in the stock markets of Riga and Vilnius, however, evidence is not so clear for Tallinn stock market. Nevertheless, it is worth to point out that unlike M1 and M10, the highest *M*-values (M100 and M1000) show more statistically significant results.

The distribution of digits for the prices of individual stocks considered did not show uniformity for all significance levels.

When comparing the two sub-samples, one may conclude that there are no significant differences in results. Overall, uniformity is rejected by the vast majority of assets under consideration. Nonetheless, as mentioned in Section 3.2.3., rejecting uniformity is necessary but it is not in itself sufficient to prove the existence of psychological barriers.

Note that the analysis of uniformity regarding some *M*-Values did not include the total observations indicated in Table 2. Some prices assume very low values and cannot be studied for certain barrier levels[4]. Also, for barrier level 1 of Tallinna Kuamabaja Grupp, the number of observations is very low and, therefore, it was excluded from, not only the uniformity test, but also for the next tests.

4.2. Barrier Tests

4.2.1. Barrier Proximity Test

The results for the barrier proximity tests for all the intervals of barriers[5] mentioned in sections 3.2.1. and 3.2.4.1. are shown in Tables 4 to 8. As previously referred, in the presence of a psychological barrier, β is expected to be negative and statistically significant, implying lower frequency of *M*-Values at these points.

Considering a barrier in the exact zero modulo point (Table 4) and looking at the results for the stock indices, none of the analyzed indices present negative and significant estimates for β at any barrier level. Indeed, it was found negative β estimates for the three indices at two of the four barrier levels studied for these assets, however, all of them have *p*-values over 10% and, therefore, they are not statistically significant. OMX Vilnius is significant at a 10% level for M100, but β is positive, which do not support the theory of lower frequency of *M*-Values at barrier points. Curiously, OMX Tallinn seems perfectly uniform at M10 level.

The results for individual stocks show negative β estimates for AS LHV Group, Coop Pank AS, Enefit Green AS at the barrier level 0 and for Tallink Grupp at barrier level -1, but their respective *p*-values are also not statistically significant. Besides, Ignitis Grupe AB, Merko Ehitus, Siauliu Bankas Tallink Grupp, Tallinna Kuabamaja Grupp and Telia Lietuva seem to be significant at certain levels, however, β is positive.

[4] Example: Indices quoting lower than 1000 points cannot be studied for barrier levels M100 and M1000.

[5] Exceptions: M0.1 is not considered for stock indices because these barrier levels are not relevant for the purpose of psychological barriers in this class of assets. Also, M1000 is not considered for OMX Vilnius because there are few observations.

Table 4 – Barrier Proximity Test: Strict Barrier

Index/Stock	M0.1 (l=-1)			M1 (l=0)			M10 (l=1)			M100 (l=2)			M1000 (l=3)		
	β	*p*-value	R^2	β	*p*-value	R^2	β	*p*-value	R^2	β	*p*-value	R^2	β	*p*-value	R^2
OMX Riga	-	-	-	-0.168350	0.2615	0.012848	1.91E-15	1.0000	0.000000	-0.151515	0.5985	0.002840	0.487246	0.8866	0.000714
OMX Tallinn	-	-	-	0.096859	0.4338	0.006263	-0.048794	0.7040	0.001479	-0.202260	0.3061	0.010686	0.993701	0.4559	0.006057
OMX Vilnius	-	-	-	-0.151658	0.2626	0.012787	-0.134826	0.3815	0.007824	0.642966	0.0514*	0.038182	-	-	-
AS LHV Group	1.191626	0.6599	0.025429	-0.375356	0.7628	0.000953	-	-	-	-	-	-	-	-	-
Coop Pank AS	3.212349	0.2295	0.174644	-0.250766	0.8199	0.000543	-	-	-	-	-	-	-	-	-
Enefit Green AS	1.353276	0.5402	0.048679	-0.799481	0.3527	0.009822	-	-	-	-	-	-	-	-	-
Ignitis Grupe AB	37.86449	0.0039***	0.718086	4.262436	0.0116**	0.103105	1.967358	0.1167	0.037432	-	-	-	-	-	-
Merko Ehitus	29.57538	0.0001***	0.870041	4.558232	0.0000***	0.197599	2.421724	0.0698*	0.049699	-	-	-	-	-	-
Siauliu Bankas	17.15701	0.0056***	0.637394	-	-	-	-	-	-	-	-	-	-	-	-
Tallink Grupp	-0.476797	0.6130	0.033458	6.399119	0.0131**	0.134766	-	-	-	-	-	-	-	-	-
Tallinna Kuabamaja Grupp	5.249701	0.0033***	0.680890	1.007630	0.0232**	0.051512	-	-	-	-	-	-	-	-	-
Tallinna Sadam	0.018706	0.9931	0.000010	0.183267	0.8863	0.000264	-	-	-	-	-	-	-	-	-
Telia Lietuva	1.519872	0.3971	0.090935	4.988646	0.0065***	0.086869	-	-	-	-	-	-	-	-	-

This table shows the results of the regression $f(M) = \propto + \beta D + \varepsilon$, where the dependent variable is the frequency of appearance of *M*-values and D is a dummy variable that takes the value 1 if M=00 and 0 otherwise. H0 (no barriers): $\beta = 0$; H1 (barriers are present): $\beta < 0$. Significance at the 1%, 5% and 10% levels are denoted respectively ***, **, *.

Assuming a barrier in the 98-02 interval (Table 5), the findings are similar to those of the strict point barrier, just showing some differences for stock indices. OMX Tallinn and OMX Vilnius present a negative estimate for β, now significant at a 5% significance level for M100 and at a 10% significance level for M10.

Table 5 - Barrier Proximity Test: 98-02 Barrier

Index/Stock	M0.1 (l=-1)			M1 (l=0)			M10 (l=1)			M100 (l=2)			M1000 (l=3)		
	β	*p*-value	R^2	β	*p*-value	R^2	β	*p*-value	R^2	β	*p*-value	R^2	β	*p*-value	R^2
OMX Riga	-	-	-	-0.017544	0.7983	0.000669	0.021053	0.7610	0.000948	-0.157895	0.2279	0.014800	4.520329	0.0204**	0.171970
OMX Tallin	-	-	-	0.040223	0.4766	0.005182	-0.062991	0.2815	0.011826	-0.182714	0.0412**	0.041839	0.377057	0.5362	0.004173
OMX Vilnius	-	-	-	-0.021225	0.7321	0.001202	-0.119454	0.0877*	0.029468	0.449697	0.0025***	0.089614	-	-	-
AS LHV Group	1.191626	0.6599	0.025429	-0.330721	0.5602	0.003547	-	-	-	-	-	-	-	-	-
Coop Pank AS	3.212349	0.2295	0.174644	-0.044561	0.9294	0.000082	-	-	-	-	-	-	-	-	-
Enefit Green AS	1.353276	0.5402	0.048679	-0.158371	0.6881	0.001841	-	-	-	-	-	-	-	-	-
Ignitis Grupe AB	37.86449	0.0039	0.718086	1.763569	0.0796*	0.051186	1.352847	0.0180**	0.083136	-	-	-	-	-	-
Merko Ehitus	29.57538	0.0001	0.870041	0.887238	0.0589*	0.035920	4.044033	0.0000***	0.403165	-	-	-	-	-	-
Siauliu Bankas	17.15701	0.0056	0.637394	-	-	-	-	-	-	-	-	-	-	-	-
Tallink Grupp	-0.476797	0.6130	0.033458	6.319298	0.0000***	0.376354	-	-	-	-	-	-	-	-	-
Tallinna Kuabamaja Grupp	5.249701	0.0033	0.680890	0.183234	0.3710	0.008173	-	-	-	-	-	-	-	-	-
Tallinna Sadam	0.018706	0.9931	0.000010	1.791246	0.0017***	0.119586	-	-	-	-	-	-	-	-	-
Telia Lietuva	1.519872	0.3971	0.090935	2.827023	0.0007***	0.132764	-	-	-	-	-	-	-	-	-

This table shows the results of the regression $f(M) = \propto + \beta D + \varepsilon$, where the dependent variable is the frequency of appearance of *M*-values and D is a dummy variable that takes the value 1 when the M-value is in the 98-02 interval and 0 otherwise. H0 (no barriers): $\beta = 0$; H1 (barriers are present): $\beta < 0$. Significance at the 1%, 5% and 10% levels are denoted respectively ***, **, *.

Considering the 95-05 interval, Table 6 shows that the no barrier hypothesis is now rejected only for OMX Tallinn at a 5% significance level in M100. All the other series are either not significant or β is not negative.

Table 6 - Barrier Proximity Test: 95-05 Barrier

Index/Stock	M0.1 (l=-1)			M1 (l=0)			M10 (l=1)			M100 (l=2)			M1000 (l=3)		
	β	*p*-value	R^2	β	*p*-value	R^2	β	*p*-value	R^2	β	*p*-value	R^2	β	*p*-value	R^2
OMX Riga	-	-	-	-0.008512	0.8587	0.000325	-0.020429	0.6717	0.001840	-0.097038	0.2878	0.011521	5.738034	0.0000***	0.494823
OMX Tallinn	-	-	-	0.006113	0.8768	0.000247	-0.018927	0.6430	0.002201	-0.152370	0.0141**	0.059970	-0.045698	0.9146	0.000126
OMX Vilnius	-	-	-	0.006621	0.8782	0.000241	-0.044443	0.3643	0.008407	0.233155	0.0259**	0.049650	-	-	-
AS LHV Group	1.191626	0.6599	0.025429	-0.256072	0.5175	0.004377	-	-	-	-	-	-	-	-	-
Coop Pank AS	3.212349	0.2295	0.174644	0.524349	0.1325	0.023416	-	-	-	-	-	-	-	-	-
Enefit Green AS	1.353276	0.5402	0.048679	0.194742	0.4798	0.005691	-	-	-	-	-	-	-	-	-
Ignitis Grupe AB	37.86449	0.0039	0.718086	0.999210	0.1448	0.035696	0.919449	0.0236**	0.076308	-	-	-	-	-	-
Merko Ehitus	29.57538	0.0001	0.870041	0.424222	0.1970	0.016925	1.884943	0.0006***	0.166967	-	-	-	-	-	-
Siauliu Bankas	17.15701	0.0056	0.637394	-	-	-	-	-	-	-	-	-	-	-	-
Tallink Grupp	0.637394	0.6130	0.033458	6.339511	0.0000***	0.703422	-	-	-	-	-	-	-	-	-
Tallinna Kuabamaja Grupp	5.249701	0.0033	0.680890	0.111056	0.4366	0.006188	-	-	-	-	-	-	-	-	-
Tallinna Sadam	0.018706	0.9931	0.000010	1.673742	0.0000***	0.211329	-	-	-	-	-	-	-	-	-
Telia Lietuva	1.519872	0.3971	0.090935	3.060309	0.0000***	0.316278	-	-	-	-	-	-	-	-	-

This table shows the results of the regression $f(M) = \propto + \beta D + \varepsilon$, where the dependent variable is the frequency of appearance of *M*-values and D is a dummy variable that takes the value 1 when the M-value is in the 95-05 interval and 0 otherwise. H0 (no barriers): $\beta = 0$; H1 (barriers are present): $\beta < 0$. Significance at the 1%, 5% and 10% levels are denoted respectively ***, **, *.

Table 7 shows slightly different evidence for the 90-10 interval. Now, the no barrier hypothesis is still rejected for OMX Tallinn at a 1% significance level in M100 and, in addition, it is also rejected for OMX Vilnius at M1 and M10 at a 5% and 10% significance level, respectively. Therefore, one may claim that as we are going to widen the barrier intervals, the existence of barriers at different levels has the tendency to appear more significant. Regarding individual stocks, results show more negative β estimates for barrier level -1, yet *p*-values are not statistically significant at a 10% for those estimates. At barrier level 0, we may conclude that as widening the barrier interval, negative β estimates tended to become positive while *p*-values became more statistically significant, only not following this pattern for the 95-05 interval. For M10, β estimates tended to approximate to 0, yet remaining positive.

Table 7 – Barrier Proximity Test: 90-10 Barrier

Index/Stock	M0.1 (l=-1)			M1 (l=0)			M10 (l=1)			M100 (l=2)			M1000 (l=3)		
	β	*p*-value	R^2	β	*p*-value	R^2	β	*p*-value	R^2	β	*p*-value	R^2	β	*p*-value	R^2
OMX Riga	-	-	-	-0.015069	0.6816	0.001725	-0.025116	0.4973	0.004714	-0.032148	0.6474	0.002143	3.045025	0.0107**	0.204379
OMX Tallinn	-	-	-	0.017079	0.5724	0.003263	-0.033333	0.2869	0.011566	-0.188295	0.0001***	0.155193	-0.262379	0.4240	0.006961
OMX Vilnius	-	-	-	-0.065500	0.0461**	0.039969	-0.065500	0.0800*	0.030945	0.351512	0.0000***	0.191236	-	-	-
AS LHV Group	3.077985	0.0513*	0.395875	0.715342	0.0193**	0.055678	-	-	-	-	-	-	-	-	-
Coop Pank AS	1.031051	0.5701	0.041980	0.939901	0.0003***	0.127124	-	-	-	-	-	-	-	-	-
Enefit Green AS	2.503053	0.0542*	0.388581	0.561395	0.0073***	0.078853	-	-	-	-	-	-	-	-	-
Ignitis Grupe AB	5.889079	0.6101	0.039083	1.069017	0.0433**	0.067448	1.288047	0.0000***	0.234840	-	-	-	-	-	-
Merko Ehitus	7.830829	0.2825	0.142322	0.373141	0.1391	0.022190	0.956038	0.0278**	0.072291	-	-	-	-	-	-
Siauliu Bankas	7.709891	0.1010	0.300329	-	-	-	-	-	-	-	-	-	-	-	-
Tallink Grupp	-0.548833	0.3648	0.103442	4.265120	0.0000***	0.508888	-	-	-	-	-	-	-	-	-
Tallinna Kuabamaja Grupp	0.923807	0.5380	0.049198	0.163090	0.1353	0.022614	-	-	-	-	-	-	-	-	-
Tallinna Sadam	-2.100369	0.1034	0.296917	1.022602	0.0011***	0.128773	-	-	-	-	-	-	-	-	-
Telia Lietuva	-0.505725	0.6725	0.023492	2.695245	0.0000***	0.404185	-	-	-	-	-	-	-	-	-

This table shows the results of the regression $f(M) = \propto + \beta D + \varepsilon$, where the dependent variable is the frequency of appearance of *M*-values and D is a dummy variable that takes the value 1 when the M-value is in the 90-10 interval and 0 otherwise. H0 (no barriers): $\beta = 0$; H1 (barriers are present): $\beta < 0$. Significance at the 1%, 5% and 10% levels are denoted respectively ***, **, *.

Enlarging the barrier interval to 75-25 (Table 8), for stock indices, again only OMX Tallinn for M100 rejects the no barrier hypothesis at a 1% significance level. But interestingly, OMX Vilnius is still having negative β estimates, however, they are now not significant. The pattern referred above for individual stock at barrier levels -1 maintains, and the no barrier hypothesis is rejected for Telia Lietuva for M0.1 at a 10% significance level.

Table 8 – Barrier Proximity Test: 75-25 Barrier

Index/Stock	M0.1 (l=-1)			M1 (l=0)			M10 (l=1)			M100 (l=2)			M1000 (l=3)		
	β	*p*-value	R^2	β	*p*-value	R^2	β	*p*-value	R^2	β	*p*-value	R^2	β	*p*-value	R^2
OMX Riga	-	-	-	-0.002668	0.9290	0.000081	0.000667	0.9824	0.000005	0.075363	0.1865	0.017738	1.180634	0.4699	0.018155
OMX Tallinn	-	-	-	0.032399	0.1871	0.017688	-0.032803	0.1977	0.016873	-0.153806	0.0000***	0.155976	0.789195	0.0033***	0.090093
OMX Vilnius	-	-	-	-0.017677	0.5127	0.004385	-0.010342	0.7363	0.001162	0.290849	0.0000***	0.197217	-	-	-
AS LHV Group	3.257971	0.0173**	0.528008	0.466430	0.0597*	0.036433	-	-	-	-	-	-	-	-	-
Coop Pank AS	-0.025031	0.9881	0.000029	0.691441	0.0013***	0.102112	-	-	-	-	-	-	-	-	-
Enefit Green AS	1.666667	0.1887	0.205097	0.701923	0.0001***	0.170147	-	-	-	-	-	-	-	-	-
Ignitis Grupe AB	2.092624	0.8498	0.005483	0.633173	0.1473	0.035265	1.594390	0.0000***	0.316621	-	-	-	-	-	-
Merko Ehitus	5.533955	0.4148	0.084615	0.302598	0.1410	0.021981	-0.059589	0.8617	0.000471	-	-	-	-	-	-
Siauliu Bankas	3.871168	0.3993	0.090138	-	-	-	-	-	-	-	-	-	-	-	-
Tallink Grupp	-0.426870	0.4455	0.074495	3.220885	0.0000***	0.383324	-	-	-	-	-	-	-	-	-
Tallinna Kuabamaja Grupp	1.479755	0.2684	0.150275	0.079070	0.3760	0.008007	-	-	-	-	-	-	-	-	-
Tallinna Sadam	-0.875421	0.4900	0.061404	0.949999	0.0006***	0.142710	-	-	-	-	-	-	-	-	-
Telia Lietuva	-1.845370	0.0610*	0.372376	1.575006	0.0001***	0.181421	-	-	-	-	-	-	-	-	-

This table shows the results of the regression $f(M) = \propto + \beta D + \varepsilon$, where the dependent variable is the frequency of appearance of *M*-values and D is a dummy variable that takes the value 1 when the M-value is in the 75-25 interval and 0 otherwise. H0 (no barriers): $\beta = 0$; H1 (barriers are present): $\beta < 0$. Significance at the 1%, 5% and 10% levels are denoted respectively ***, **, *.

Overall, signs of the existence of psychological barriers clearly exist for OMX Tallinn at barrier level 2. The index rejects the no barrier hypothesis in all the scenarios, except the one considering a barrier for the zero modulo point, and results show that the wider the barrier interval, the more statistically significant are the barriers at this level. OMX Vilnius rejects the no barrier hypothesis for barrier level 1 in 98-02 and 90-10 interval scenarios, and therefore evidence is not consistent which does not allow to take clear conclusions. OMX Riga and all stocks do not reject the no barrier hypothesis at any potential barrier level, with the exception of Telia Lietuva for barrier level -1 in 75-25 interval, however, evidence is not sufficient to prove the existence of barriers at this level, as is the case of OMX Vilnius for barrier level 0 in 90-10 interval. Furthermore, in general, R-squared values are low, which is in line with previous studies. In the field of Behavioral Finance, it is perfectly normal to find low R-squared values, as it analyses human psychological behavioral.

It is important to refer that the β estimates may not be completely reliable for Tallink Grupp and Tallinna Kuabamaja Grupp at barrier levels M1 and M10, respectively, as it includes few observations. The same may apply for barrier levels 0.1 for all stocks.

4.2.2. Barrier Hump Test

The results for the barrier hump test, which focus mainly on the whole shape of the distribution of *M*-values, are shown in Table 9. As explained in Section 3.2.4., in the presence of barriers these values are assumed to follow a hump-shape distribution, and thus γ is expected to be negative and significant in the presence of such barriers.

The results seem to corroborate the results obtained from the barrier proximity test. The null hypothesis of no barriers is rejected just for OMX Tallinn for the M100 at 1% significance level, which provides strong evidence to conclude, so far, the existence of barriers at this level for the index. The doubts regarding the inconsistent evidence for possible barriers identified in the proximity test for OMX Vilnius and Telia Lietuva are now clarified, as despite γ estimates being negative, they are not significant at a 10% significance level.

Table 9 – Barrier Hump Test

Index/Stock	M0.1 (l=-1)			M1 (l=0)			M10 (l=1)			M100 (l=2)			M1000 (l=3)		
	γ	*p*-value	R^2	γ	*p*-value	R^2	γ	*p*-value	R^2	γ	*p*-value	R^2	γ	*p*-value	R^2
OMX Riga	-	-	-	-6.58E-06	0.7438	0.007477	-7.16E-06	0.7247	0.001512	9.25E-06	0.7974	0.130910	0.013135	0.0496**	0.436259
OMX Tallinn	-	-	-	1.29E-05	0.4312	0.029917	-1.77E-05	0.3029	0.011219	-0.000119	0.0000***	0.265480	0.000162	0.3396	0.169747
OMX Vilnius	-	-	-	-2.89E-05	0.1105	0.026148	-3.10E-05	0.1278	0.045673	0.000228	0.0000***	0.280555	-	-	-
AS LHV Group	0.002655	0.0005***	0.861549	0.000270	0.0380**	0.425213	-	-	-	-	-	-	-	-	-
Coop Pank AS	0.000479	0.6982	0.024121	0.000448	0.0001***	0.440469	-	-	-	-	-	-	-	-	-
Enefit Green AS	0.001918	0.0044***	0.764434	0.000397	0.0004***	0.196525	-	-	-	-	-	-	-	-	-
Ignitis Grupe AB	0.003475	0.6208	0.268885	0.000463	0.1103	0.075524	0.001072	0.0000***	0.423058	-	-	-	-	-	-
Merko Ehitus	0.005693	0.1869	0.381419	0.000209	0.1238	0.060148	0.000593	0.1755	0.035909	-	-	-	-	-	-
Siauliu Bankas	0.003092	0.0311**	0.882537	-	-	-	-	-	-	-	-	-	-	-	-
Tallink Grupp	-0.000490	0.2176	0.208525	0.004720	0.0001***	0.690778	-	-	-	-	-	-	-	-	-
Tallinna Kuabamaja Grupp	0.001112	0.2260	0.287648	7.34E-05	0.1519	0.286905	-	-	-	-	-	-	-	-	-
Tallinna Sadam	-0.000670	0.4487	0.175235	0.000796	0.0000***	0.331447	-	-	-	-	-	-	-	-	-
Telia Lietuva	-0.001025	0.1108	0.489508	0.001540	0.0000***	0.747213	-	-	-	-	-	-	-	-	-

This table shows the results of the regression $f(M) = \propto + \phi M + \gamma M^2 + \eta$, where the dependent variable is the frequency of appearance of *M*-values, regressed to the *M*-values and the respective squares.). H0 (no barriers): $\gamma = 0$; H1 (barriers are present): $\gamma < 0$. Significance at the 1%, 5% and 10% levels are denoted respectively ***, **, *.

4.3. Conditional Effects Test

If psychological barriers do exist, it is expected the dynamics of individual return series to be different around these levels. This test aims to identify if barriers are crossed in a downward movement, constituting possible support levels, or in an upward movement, as possible resistance levels. Therefore, the return series is assessed in order to determine a pattern significantly different from when prices are not in the proximity of any barrier, in the 5-days period before and after crossing it, that is, observing whether the markets calm down or are in turmoil after breaking a barrier.

The test is performed for one potential barrier level only for each asset, chosen as the most likely to constitute an actual barrier level, according to the results from the previous tests. Therefore, regarding stock indices, the conditional effects test is applied to the 10-level barrier for OMX Vilnius; and to the 100-level barrier for OMX Riga and OMX Tallinn. Concerning individual stocks, it is applied to the 0.1-level for Siauliu Bankas, Tallink Grupp, Tallina Sadam and Telia Lietuva; to 1-level barrier for AS LHV Group, Coop Pank AS, Enefit Green AS, Merko Ehitus and Tallina Kuabamaja Grupp; and to the 10-level barrier for Ignitis GrupeAB.

Table 10 shows the results of the mean return equation for stock indices. We may observe that the mean return before crossing a barrier from above (BD) is negative for the three indices – significant at a 10% level for OMX Riga, 1% level for OMX Tallinn, and 5% level for OMX Vilnius – meaning that the prices might be struggling to cross a barrier from above. After crossing a barrier in such movement (AD), mean returns are positive for OMX Riga but still negative for the other indices, however, being only significant at a 10% level for OMX Tallinn. Still on the downward movements, the results show that the magnitude of returns is lower before crossing barriers for all indices.

For the barrier crossing in an upward movement, the mean returns are positive for the three indices before crossing the barrier (BU) as well after crossing it (AU), except for OMX Tallinn after crossing the barrier from below (at 1% significance level for OMX Tallinn in both after and after crossing the barrier, and 5% significance level for the other indices only before crossing the barrier). The magnitude of returns is higher before than after an upward movement.

Table 10 – Conditional Effects Test – Return Equation: Stock Indices

Stock Index	Statistic	C	BD	AD	BU	AU
OMX Riga	Coefficient	0.000678	-0.003167	0.000237	0.001740	0.0000361
	p-value	0.0000***	0.0671*	0.8614	0.0343**	0.9666
OMX Tallinn	Coefficient	0.000516	-0.003370	-0.001616	0.003726	-0.002197
	p-value	0.0000***	0.0000***	0.0652*	0.0000***	0.0000***
OMX Vilnius	Coefficient	0.000503	-0.001535	-0.000297	0.001884	0.0000977
	p-value	0.0000***	0.0182**	0.5812	0.0106**	0.8557

This table shows the results of the mean equation of a GARCH estimation of the form $R_t = \beta_1 + \beta_2 UB_t + \beta_3 UA_t + \beta_4 DB_t + \beta_5 DA_t + \varepsilon_t; \varepsilon_t \sim N(0, V_t); V_t = \alpha_1 + \alpha_2 UB_t + \alpha_3 UA_t + \alpha_4 DB_t + \alpha_5 DA_t + \alpha_6 V_{t-1} + \alpha_7 \varepsilon^2_{t-1} + \eta_t$. BD, AD, BU and AU are dummy variables. BD takes the value 1 in the 5 days before crossing a barrier from above; AD takes the value 1 in the 5 days after crossing a barrier from above; BU takes the value 1 in the 5 days before crossing a barrier from below; AU takes the value 1 in the 5 days after crossing a barrier from below. Significance at the 10%, 5% and 1% levels are denoted respectively *, ** and ***.

Focusing on individual stocks, Table 11 shows that the mean returns in a downward movement are negative for all stocks before crossing the barrier (BD) – at a significance level of 1% for Coop Pank AS, Tallink Grupp and Telia Lietuva, and 10% for Merko Ehitus – which, again, may lead us to conclude that the prices might be struggling to cross a barrier from above, while, after crossing the barrier (AD), the mean returns are positive for all of them except for Ignitis Grupe AB and Tallink Grupp. However, the results are only significant at a 10% significance level for Telia Lietuva, showing a signal change of the mean returns.

Considering a barrier crossing from below, results show that the mean returns are positive for all stocks before the upward movement (BU) (significant at a significance level of 1% for Tallink Grupp and Telia Lietuva, and 5% for Coop Pank AS, Merko Ehitus, Siauliu Bankas and Tallinna Sadam). After the upward movement (AU), the signal of the mean return changes for AS LHV Group, Ignitis Grupe AB, Merko Ehitus, Tallina Sadam and Telia Lietuva but still positive for the other stocks (the results are only significant at a 5% level for Tallina Kuabamaja Grupp after an upwards movement). For the stocks that did not show changes in the signal, overall, no patterns can be observed clearly in the magnitude of the mean returns.

Enefit Green AS was not considered in this test neither in all the tests that follow because there are no possible psychological barriers for downwards movements and there is only one possible barrier when crossing it from below. It is explained by the few number observations as the stock started being traded only on October 21st, 2021.

Table 11 – Conditional Effects Test – Return Equation: Individual Stocks

Stock	Statistic	C	BD	AD	BU	AU
AS LHV Group	Coefficient	0.000444	-0.007147	0.001758	0.004828	-0.001889
	p-value	0.1489	0.3423	0.5712	0.8598	0.8543
Coop Pank AS	Coefficient	-0.000535	-0.021507	0.014824	0.013082	0.015752
	p-value	0.2979	0.0000***	0.2183	0.0416**	0.3657
Ignitis Grupe AB	Coefficient	-0.000246	-0.001604	-0.000956	0.010944	-0.016825
	p-value	0.4971	0.1861	0.8836	0.6587	0.2535
Merko Ehitus	Coefficient	0.000255	-0.002988	0.000670	0.002789	-0.000242
	p-value	0.2359	0.0598*	0.6983	0.0103**	0.8160
Siauliu Bankas	Coefficient	0.0000679	-0.002402	0.000706	0.004930	0.002527
	p-value	0.7827	0.2502	0.5505	0.0355**	0.1984
Tallink Grupp	Coefficient	-0.0000349	-0.004001	-0.000765	0.003652	0.000549
	p-value	0.8830	0.0009***	0.5208	0.0050***	0.6243
Tallinna Kuabamaja Grupp	Coefficient	0.0000281	-0.002375	0.000997	0.001888	0.002114
	p-value	0.8548	0.1893	0.4767	0.1971	0.0110**
Tallinna Sadam	Coefficient	-0.000275	-0.000693	0.000148	0.002724	-0.000355
	p-value	0.2879	0.4849	0.8627	0.0105**	0.6760
Telia Lietuva	Coefficient	-0.0000129	-0.002433	0.001213	0.004352	-0.0000182
	p-value	0.9331	0.0096***	0.1000*	0.0000***	0.9814

This table shows the results of the mean equation of a GARCH estimation of the form $R_t = \beta_1 + \beta_2 UB_t + \beta_3 UA_t + \beta_4 DB_t + \beta_5 DA_t + \varepsilon_t$; $\varepsilon_t \sim N(0, V_t)$; $V_t = \alpha_1 + \alpha_2 UB_t + \alpha_3 UA_t + \alpha_4 DB_t + \alpha_5 DA_t + \alpha_6 V_{t-1} + \alpha_7 \varepsilon^2_{t-1} + \eta_t$. BD, AD, BU and AU are dummy variables. BD takes the value 1 in the 5 days before crossing a barrier from above; AD takes the value 1 in the 5 days after crossing a barrier from above; BU takes the value 1 in the 5 days before crossing a barrier from below; AU takes the value 1 in the 5 days after crossing a barrier from below. Significance at the 10%, 5% and 1% levels are denoted respectively *, ** and ***.

Table 12 shows the results of the variance equation for stock indices. In the presence of psychological barriers, it is expected to find positive variance indicators before crossing a barrier, meaning that the markets are turbulent, and negative indicators after crossing a barrier, meaning that the markets are calmer. Regarding downward movements, results show statistically significant negative variance indicators before crossing a barrier (BD) for the three stock indices and only a positive variance indicator after crossing a barrier (AD) for

OMX Riga, despite not being statistically significant in this case. For upward movements, results show negative variance indicators both before (BU) and after (AU) crossing a barrier for all stock indices, only not being significant for OMX Tallinn before crossing the barriers.

Table 12 – Conditional Effects Test – Variance Equation: Stock Indices

Stock Index	Statistic	C	RESID(-1)^2	GARCH(-1)	BD	AD	BU	AU
OMX Riga	Coefficient	0.00000860	0.178718	0.780644	-0.0000121	0.00000661	-0.0000129	-0.00000561
	p-value	0.0000***	0.0000***	0.0000***	0.0087***	0.5141	0.0000***	0.0695*
OMX Tallinn	Coefficient	0.0000487	0.593928	0.269191	-0.0000281	-0.0000318	-0.00000569	-0.0000418
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.2952	0.0000***
OMX Vilnius	Coefficient	0.00000101	0.119970	0.889330	-0.00000180	-0.00000179	-0.00000365	-0.00000145
	p-value	0.0000***	0.0000***	0.0000***	0.0251**	0.0084***	0.0000***	0.0335**

This table shows the results of the mean equation of a GARCH estimation of the form $R_t = \beta_1 + \beta_2\, UB_t + \beta_3\, UA_t + \beta_4\, DB_t + \beta_5\, DA_t + \varepsilon_t$; $\varepsilon_t \sim N(0, V_t)$; $V_t = \alpha_1 + \alpha_2\, UB_t + \alpha_3\, UA_t + \alpha_4\, DB_t + \alpha_5\, DA_t + \alpha_6\, V_{t-1} + \alpha_7\, \varepsilon^2_{t-1} + \eta_t$. BD, AD, BU and AU are dummy variables. BD takes the value 1 in the 5 days before crossing a barrier from above; AD takes the value 1 in the 5 days after crossing a barrier from above; BU takes the value 1 in the 5 days before crossing a barrier from below; AU takes the value 1 in the 5 days after crossing a barrier from below. V_{t-1} refers to the moving average parameter and ε^2_{t-1} stands for the GARCH parameter. Significance at the 10%, 5% and 1% levels are denoted respectively *, ** and ***.

Table 13 shows the results of the variance equation for individual stocks. Regarding downward movements, results show that AS LHV Group, Siauliu Bankas and Telia Lietuva present market turbulence right before crossing a barrier (BD) and the market calms down after (AD) it with statistical significance at 1% level. For upward movements, significant (at 1% level) changes in the signal of variance indicators, from positive to negative, may be seen for Siauliu Bankas and Telia Lietuva. Tallink Grupp, Tallina Kuabamaja Grupp, Tallina Sadam, also show the same pattern, however not statistically significant.

Table 13 – Conditional Effects Test – Variance Equation: Individual Stocks

Stock	Statistic	C	RESID(-1)^2	GARCH(-1)	BD	AD	BU	AU
AS LHV Group	Coefficient	0.0000307	0.228889	0.616397	0.000414	-0.0000708	0.0000376	0.0000475
	p-value	0.0000***	0.0000***	0.0000***	0.0089***	0.0002***	0.8959	0.7569
Coop Pank AS	Coefficient	0.0000427	0.456358	0.511191	-0.000165	0.000473	0.0000308	0.000250
	p-value	0.0000***	0.0000***	0.0000***	0.0648*	0.2690	0.9214	0.6453
Ignitis Grupe AB	Coefficient	0.0000205	0.339097	0.414877	-0.0000135	0.000115	0.000261	0.0000784
	p-value	0.0000***	0.0000***	0.0000***	0.1764	0.0000***	0.0824*	0.8718
Merko Ehitus	Coefficient	0.00000417	0.111531	0.876749	0.0000187	0.0000283	-0.00000176	0.0000118
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.5720	0.0000***
Siauliu Bankas	Coefficient	0.0000172	0.078328	0.886390	0.000162	-0.000113	0.0000770	-0.0000663
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
Tallink Grupp	Coefficient	0.00000828	0.093788	0.880004	0.0000158	-0.0000000968	0.00000762	-0.00000123
	p-value	0.0000***	0.0000***	0.0000***	0.0001***	0.9747	0.1469	0.7766
Tallinna Kuabamaja Grupp	Coefficient	0.00000266	0.074550	0.925872	-0.00000524	-0.000000126	0.000000953	-0.0000118
	p-value	0.0000***	0.0000***	0.0000***	0.0022***	0.9452	0.8071	0.0001***
Tallinna Sadam	Coefficient	0.00000276	0.060680	0.910239	-0.00000469	-0.00000184	0.00000259	-0.00000274
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0478**	0.2202	0.1639
Telia Lietuva	Coefficient	0.000000960	0.033598	0.957734	0.0000180	-0.0000120	0.0000215	-0.0000159
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***

This table shows the results of the mean equation of a GARCH estimation of the form $R_t = \beta_1 + \beta_2\, UB_t + \beta_3\, UA_t + \beta_4\, DB_t + \beta_5\, DA_t + \varepsilon_t$; $\varepsilon_t \sim N(0, V_t)$; $V_t = \alpha_1 + \alpha_2\, UB_t + \alpha_3\, UA_t + \alpha_4\, DB_t + \alpha_5\, DA_t + \alpha_6\, V_{t-1} + \alpha_7\, \varepsilon^2_{t-1} + \eta_t$. BD, AD, BU and AU are dummy variables. BD takes the value 1 in the 5 days before crossing a barrier from above; AD takes the value 1 in the 5 days after crossing a barrier from above; BU takes the value 1 in the 5 days before crossing a barrier from below; AU takes the value 1 in the 5 days after crossing a barrier from below. V_{t-1} refers to the moving average parameter and ε^2_{t-1} stands for the GARCH parameter. Significance at the 10%, 5% and 1% levels are denoted respectively *, ** and ***.

Summing up, the pattern verified in the mean return of OMX Tallinn for M100 in upward movements is not consistent with the existence of psychological barriers as suggested in the barrier tests. Telia Lietuva suggests possible barriers at level -1 in downward movements. Concerning variance patterns, indices do not exhibit signs of psychological barriers, however, Siauliu Bankas and Telia Lietuva suggest their existence in both movements (for M01). AS LHV Group shows signs of barriers for downward movements (for M1).

The GARCH terms are positive and significant at a 1% level for all assets, indicating significant GARCH effects. Interestingly, considering the indices, OMX Riga and OMX Vilnius exhibit a GARCH term closer to one when compared to OMX Tallinn, indicating a higher degree of volatility persistence. Regarding individual stocks, AS LHV Group, Coop Pank AS and Ignitis Grupe AB show a GARCH term much lower than the other stocks, which indicates a lower degree of volatility persistence.

4.3.1. Conditional Effects Difference Tests

If some kind of barrier indeed exists, it is expected that the restraints in terms of mean and variance would be relaxed after the price crossed the barrier.

Table 14 exhibits the results of the Wald test to the hypotheses listed in Section 3.2.4.. One may conclude that there are significant changes in the conditional mean returns before and after crossing a barrier in a downwards movement (H1) for OMX Tallinn (at a significance level of 10%), while for upwards movements (H2), significant differences in the conditional mean returns, before and after crossing a barrier, are also exhibited for OMX Tallinn (but at 1% significance level) and for OMX Vilnius (at 10% significance level). Regarding changes in the conditional variances before and after crossing a barrier, results are not statistically significant for all indices in downwards movements (H3), but significant for OMX Riga and OMX Tallinn in upwards movements (H4), at a significance level of 10% and 1%, respectively.

Table 14 – Barrier Hypothesis Tests: Stock Indices

Stock Index	Statistic	H1	H2	H3	H4
OMX Riga	Chi-square	2.009976	1.993867	2.406406	3.008838
	p-value	0.1563	0.1579	0.1208	0.0828*
OMX Tallinn	Chi-square	3.208537	28.67037	0.257109	38.52778
	p-value	0.0733*	0.0000***	0.6121	0.0000***
OMX Vilnius	Chi-square	2.004083	3.749294	0.0000416	2.478887
	p-value	0.1569	0.0528*	0.9949	0.1154

This table shows the results of a Wald test to four hypotheses. H1: There is no significant difference in the conditional mean return before and after a downwards crossing of a barrier; H2: There is no significant difference in the conditional mean return before and after an upwards crossing of a barrier; H3: There is no significant difference in conditional variance before and after a downwards crossing of a barrier; H4: There is no significant difference in the conditional variance before and after an upwards crossing of a barrier. Significance at the 10%, 5% and 1% levels are denoted respectively *, ** and ***.

The results of the same test for individual stocks are exhibited in Table 15. For changes in the conditional mean returns before and after a downwards crossing of a barrier (H1), results are significant for Coop Pank AS and Telia Lietuva, at 1% level, and for Tallink Grupp, at a 10% level. In upwards movements (H2), the hypothesis is rejected for Telia Lietuva (1% significance level), Merko Ehitus and Tallina Sadam (5% significance level) and Tallink Grupp (10% significance level). Regarding significant differences in the conditional variance before and after a downwards movements (H3), seven out of the nine stocks tested show significant changes at 1% significance level (AS LHV Group, Ignitis Grupe AB, Merko Ehitus, Siauliu Bankas and Telia Lietuva), whereas Tallink Grupp changes are significant for a 5% level and Tallinna Kuabamaja Grupp for a 10% level. Finally, these changes in upwards movements (H4) keep significant at the same percentage levels (as in downwards movements) for Merko Ehitus, Siauliu Bankas, Tallina Kuabamaja Grupp and Telua Lietuva.

Note that Siauliu Bankas and Telia Lietuva present extremely high chi-square values statistically significance at 1% for the hypotheses of no significant differences in conditional variance before and after both upwards and downwards moments. It suggests an enormous volume of trading activity as the stock prices advance until finding a barrier.

Table 15 – Barrier Hypothesis Tests: Individual Stocks

Stock	Statistic	H1	H2	H3	H4
AS LHV Group	Chi-square	1.122730	0.066573	7.862592	0.000668
	p-value	0.2893	0.7964	0.0050***	0.9794
Coop Pank AS	Chi-square	8.845482	0.021203	2.079524	0.121012
	p-value	0.0029***	0.8842	0.1493	0.7279
Enefit Green AS	Chi-square	-	-	-	-
	p-value				
Ignitis Grupe AB	Chi-square	0.009565	0.928075	21.00681	0.130172
	p-value	0.9221	0.3354	0.0000***	0.7183
Merko Ehitus	Chi-square	2.429538	4.118034	7.546555	6.979007
	p-value	0.1191	0.0424**	0.0060***	0.0082***
Siauliu Bankas	Chi-square	1.664397	0.637279	1048.757	273.6896
	p-value	0.1970	0.4247	0.0000***	0.0000***
Tallink Grupp	Chi-square	3.641625	3.497781	6.415634	1.049921
	p-value	0.0564*	0.0615*	0.0113**	0.3055
Tallinna Kuabamaja Grupp	Chi-square	2.190337	0.018325	2.783959	3.552720
	p-value	0.1389	0.8923	0.0952*	0.0594*
Tallinna Sadam	Chi-square	0.434292	5.514424	2.247058	1.778544
	p-value	0.5099	0.0189**	0.1339	0.1823
Telia Lietuva	Chi-square	7.898919	14.21954	176.4746	169.4934
	p-value	0.0049***	0.0002***	0.0000***	0.0000***

This table shows the results of a Wald test to four hypotheses. H1: There is no significant difference in the conditional mean return before and after a downwards crossing of a barrier; H2: There is no significant difference in the conditional mean return before and after an upwards crossing of a barrier; H3: There is no significant difference in conditional variance before and after a downwards crossing of a barrier; H4: There is no significant difference in the conditional variance before and after an upwards crossing of a barrier. Significance at the 10%, 5% and 1% levels are denoted respectively *, ** and ***.

Overall, evidence suggests that there are significant effects in terms of returns and volatility both in stock market indices and individual stocks around barrier points, although not so evident for some assets. Telia Lietuva presents the stronger case of existence of psychological barriers as it rejects the four null hypothesis at 1% significance level.

5. Conclusion

Behavioral biases do not enable market participants to take fully rational investment decisions. Psychological barriers are a phenomenon that affects individuals and impact financial markets in different geographies and asset classes, and it has been subject of research in several previous studies.

This dissertation aims to extend the existing literature on the topic of psychological barriers, and it covers for the first time, to the best of our knowledge, the stock markets of the Baltic States. The phenomenon is studied considering the major stock indices and the ten most traded stocks of the Baltic stock markets covering a time span widening between the inception of each index or the first trading day of each stock until December 31st, 2022.

Firstly, a uniformity test was conducted, observing that all the assets rejected the null hypothesis. It was followed by a barrier proximity test for different barrier intervals, showing signs of the existence of psychological barriers only for one stock index. It was also performed a barrier hump test to assess the whole shape of the *M*-values distribution. The results were in conformity with the previous test indicating the presence of psychological barriers for the same index, as it follows a hump-shape distribution. Assuming the existence of barriers, it was also conducted a conditional effects test in order to verify if the markets behavior is different around round numbers for a 5-day period. The mean return equation showed that the returns before crossing a barrier in a downward movement tend to be negative while in an upward movement tend to be positive. Regarding the variance equation, results from some individual stocks suggest that markets may be turbulent before crossing a barrier and calmer afterwards. Finally, the barrier hypothesis test showed signs of possible psychological barriers for all assets considered, although evidence is not so strong for some of them.

Overall, the findings of this study suggest the existence of psychological barriers in OMX Tallinn index. When considering a 5-day period before and after crossing a round number, the markets does not behave in a random way, registering some impacts in terms of returns and volatility around barriers. Siauliu Bankas and Telia Lietuva showed market turbulence before crossing barriers and calmed down afterwards both in downwards and upwards movements, and AS LHV Group behaved in the same way only in downwards movements.

Telia Lietuva rejected all 4 null hypothesis at a 1 percent significance level, showing strong evidence of existence of psychological barriers.

Despite some evidence suggesting psychological barriers in the stock markets of the Baltic States, the results do not allow to take clear conclusions because those barriers were found for few assets in the entire data sample. Also, the number of statistically non-significant results far exceeds those that are statistically significant. Therefore, although round numbers seem to appear to be of special importance for investors in Baltic stock markets, evidence is not sufficient to challenge the market efficiency notion. And the conclusions of this dissertation are not strong enough to be used by investors to take advantage in their trading strategies when in the presence of psychological barriers.

Being aware of the limitations of this study, for future research, some suggestions follow: the time span of some stocks considered in the sample is not sufficiently broader, as their start trading dates are close to the present date, therefore, results concerning to these stocks are not strong enough to take clear conclusions; the use of other methodologies like Benford's Law, firstly explored by De Ceuster et al. (1998) would be fruitful; it would be interesting to consider other stocks for the purpose of psychological barriers in Baltic States stock markets to strengthen the results achieved; finally, the study of the phenomenon for other asset classes would enrich the research on this topic for Baltic markets.

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