Dutch Journal of Finance and Management, 1:1 (2016), 39
ISSN: 2468-211X

Looking for Psychological Barriers in nine European Stock Market Indices

Júlio Lobão*, Cristiano Pereira*,
Universidade do Porto, PORTUGAL
*Correspondence to: jlobao@fep.up.pt, pereiracristiano@outlook.com

ABSTRACT

In this paper we examine nine European stock market indices for indication of psychological barriers at round numbers. We test for uniformity in the trailing digits of the indices and use regression and GARCH analysis to assess the differential impact of being above or below a possible barrier. Despite having rejected uniformity for all data series, we only found significant psychological barriers in the stock markets of Germany, Finland and the Netherlands. Moreover, we document that the relationship between risk and return tends to be weaker at the proximity of round numbers which poses a challenge to the traditional equilibrium models.

Keywords

psychological barriers,
M-values,
stock market indices,
market psychology,
round numbers

Received: 10 June 2016
Accepted: 8 July 2016
Published Online: 8 August 16

DOI: 10.20897/lectito.201639

1. INTRODUCTION

Market practitioners and journalists often refer to the existence of psychological barriers in stock markets. Many investors believe that round numbers serve as barriers, and that prices may resist crossing these barriers. Moreover, the use of technical analysis is based on the assertion that traders will "jump on the bandwagon" of buying (selling) once the price breaks up (down) through a "psychologically important level" thus suggesting that the crossing of one of these barriers may push the prices up (down) more than otherwise warranted. Frequently used phrases by the business press such as "support level" and "resistance level" imply that, until such time as an important barrier is broken, increases and decreases in the prices may be restrained.

The impact of such kind of psychological barriers in investors' decisions has been studied since the 1990's for a variety of asset classes, from exchange rates with De Grauwe and Decupere (1992) to stock options with Jang (2013). The evidence of psychological barriers on stock market indices suggests some significant impacts of this phenomenon in the returns and variances in different geographies and periods (e.g., Donaldson and Kim, 1993; Koedijk and Stork, 1994; Cyree *et al.*, 1999; Bahng, 2003).

This article examines the existence of psychological barriers at round numbers in the nine stock market indices of the eurozone. Considering an extended sample period, we examined the major stock market indices of Austria (ATX), Belgium (BEL 20), Finland (OMXH25), France (CAC 40), Germany (DAX 30), Ireland (ISEQ 20), Luxembourg (LUXX) and the Netherlands (AEX). The European index EURO STOXX 50 was also included in the sample. The economic significance of these countries is not negligible: the eight national stock markets accounted in 2012, in aggregate, for more than two thirds of eurozone's GDP and for more than three quarters of eurozone's total stock market capitalization (World Bank, 2014).

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

Of course, behavioral biases are not the only reason why barriers could exist. For example, the fact that option exercise prices also are usually round numbers may be an additional explanation for the phenomenon.

The existence of psychological barriers contradicts the efficient market hypothesis as it points to some level of predictability in stock markets and thus may lead to abnormal risk-adjusted returns. Hence empirical evidence for the existence of psychological barriers represents a contribution to the literature on market anomalies.

This article offers several distinctive contributions. Firstly, our study focuses on some stock market indices that to the best of our knowledge have never been analysed with the purpose of detecting psychological barriers. This is the case of five of the series of our sample, i.e., the stock market indices of Austria, Finland, Ireland, Luxembourg and the Netherlands.

Second, the time period under scrutiny is much more extensive than those considered in the remaining studies on the subject. Moreover, the sample includes the period of the post-2008 financial crisis. This point is of particular importance. Given that the significance of market anomalies tends to be influenced by market-wide sentiment (e.g., Stambaugh *et al.*, 2012), a sample has to cover long periods for the results regarding the existence of psychological barriers to be considered representative. This assertion is highlighted by several authors that have found conflicting results in different sub-periods (see, e.g., Dorfleitner and Klein, 2003). The fact that the samples adopted in most studies on the subject do not usually include periods of crisis suggests that the results obtained therein may be biased.

Finally, in this study we use a set of tests that allows not only to test the existence of psychological barriers at round numbers but also to assess the differential impact on price returns and volatility of being above or below a possible barrier.

The results obtained reveal that psychological barriers at round numbers were a significant phenomenon in some of the markets of the sample, namely in the stock markets of Germany, Finland and the Netherlands. Moreover, we report that the relationship between risk and return tends to be weaker at the proximity of round numbers.

This article is organized in as follows. Section 2 reviews the empirical evidence regarding psychological barriers. Section 3 presents the data and methodologies used in this paper. Section 4 presents the empirical results. Section 5 offers conclusions.

2. PREVIOUS FINDINGS

Donaldson (1990a, 1990b) and De Grauwe and Decupere (1992) were the first to study the phenomenon of psychological barriers and showed that round numbers are indeed of special importance for investors in the stock and in the foreign exchange markets, respectively. From then on, several other studies followed, focusing not only on different geographies and periods, but also on different asset classes, such as bonds, commodities and derivatives.

To date, stock indices have been the target of most research concerning psychological barriers. Donaldson (1990a, 1990b) used both chi-squared tests and regression analysis to test for uniformity in the trailing digits of the Dow Jones Industrial Average (DJIA), the FTSE-100, the TSE, and the Nikkei 225. His findings rejected uniformity for all but the Nikkei index.

Donaldson and Kim (1993) examined the DJIA for the period 1974-1990 using a Monte Carlo experiment and found evidence confirming round numbers (100-levels) as support and resistance levels. Furthermore, they concluded that once such levels were crossed through, the DJIA moved up or down more than usual in what they called a “bandwagon effect”. The same was not true to the less important Wilshire 5000.

Ley and Varian (1994) also studied the DJIA considering a wider interval of time (1952-1993) and confirmed that there were in fact fewer observations around 100-levels. In 98.4% of the tested cases, uniformity in the trailing digits was rejected at the 95% significance level. Additionally, they emphasized the fact that non-uniform distribution of the final digits was not necessarily synonym of price barriers and found no evidence of stock price predictability due to these barriers.

Koedijk and Stork (1994) expanded the research to a number of indices. The authors studied the existence of psychological barriers on the Brussels Stock Index (Belgium), on the FAZ General (Germany), on the Nikkei 225 (Japan) and on the S&P 500 (U.S.) during the period January 1980 to February 1992, while the FTSE-100 (U.K.) was observed from January 1984 to February 1992. They discovered significant indications of psychological barriers' existence on the FAZ General, the FTSE-100 and the S&P 500, but weak indications on the Brussels Index, and none for the Nikkei 225. As in Ley and Varian (1994), they failed to find evidence supporting the significance of 100-levels in predicting returns. However, this may be due in part to the fact that they did not disaggregate the effects of upward and downward movements through barriers.

De Ceuster *et al.* (1998) compared the last digits of DJIA, FTSE-100, or the Nikkei 225 with the empirical distribution of a Monte Carlo simulation. They did not find any indication of the existence of psychological barriers on those three indices.

Cyree *et al.* (1999) showed that the last two digits of the DJIA, the S&P 500, the Financial Times U.K. Actuaries (London) and the DAX are not equally distributed. Prices next to barriers turn up less frequently than prices in a more distant position. The TSE 300, CAC 40, Hang Seng and Nikkei 225 exhibit some significant evidence. They also analysed the distribution of the returns with regard to expected returns and volatility in a modified GARCH model to conclude that upward movements through barriers tended to have a consistently positive impact on the conditional mean return and also that conditional variance tended to be higher in pre-crossing subperiods and lower in post-crossing subperiods.

More recently, Bahng (2003) applied the methodology of Donaldson and Kim (1993) to analyse seven major Asian indices including South Korea, Taiwan, Hong Kong, Thailand, Malaysia, Singapore, and Indonesia between 1990 and 1999. Their analysis showed that the Taiwanese index did possess price barrier effects and that the price level distributions of the Taiwanese, Indonesian, and Hong Kong indices were explained by quadratic functions.

Finally, Dorfleitner and Klein (2009) focused on the DAX 30, the CAC 40, the FTSE-50 and the Euro-zone-related DJ EURO STOXX 50 for different periods until 2003. They found fragile traces of psychological barriers in all indices at the 1000-level. There were also indications of barriers at the 100-level except in the CAC index.

Other studies concerning psychological barriers in stock markets are also related to our analysis. It is the case of those articles that address the presence of barriers in individual stock prices such as Cai *et al.* (2007) and Dorfleitner and Klein (2009).

Cai *et al.* (2007) assessed the existence of psychological barriers in a total of 1050 A-shares and 100 B-shares from both the Shanghai Stock Exchange and the Shenzhen Stock Exchange during June 2002. A range of measures for price resistance showed the digits 0 and 5 to be significant resistance points in the A-share market. No resistance point was found in the Shanghai B-share market, although digit 0 has had the highest level of resistance compared to others.

Dorfleitner and Klein (2009) analysed eight major stocks from the German DAX 30 over the period May 1996-June 2003. The prices were examined with respect to the frequency with which they lied within a certain band around the barrier. In addition, they studied barrier's influence on intraday variances and the daily trading volume. Overall, the authors were not able to identify a systematic and consistent pattern at barriers.

Different studies concluded that price barriers or at least significant deviations from uniformity also exist in other asset classes such as exchange rates (De Grauwe and Decupere, 1992), bonds (Burke, 2001), commodities (Aggarwal and Lucey, 2007) and derivatives (Schwartz *et al.*, 2004; Chen and Tai, 2011; Jang, 2013; Dowling *et al.*, 2016). Overall, evidence of price barriers in various asset classes seems to be fairly robust.

3. DATA AND METHODOLOGY

3.1. Data

The examination window for each of the stock market indices under study is presented in Table 1 below. Starting dates are different since we used the data pertaining each index since its inception. All the data were retrieved from Thomson Reuters Datastream. Summary statistics on the stock prices are presented in Table 2 where it can be seen that the measures of skewness and, especially, kurtosis are in general inconsistent with normality.

Table 1 - Data used in the study

Country	Stock index	Starting date	Ending date
Austria	ATX	January, 7th 1986	December, 31st 2013
Belgium	BEL 20	January, 2nd 1990	
Europe	EURO STOXX 50	December, 31st 1986	
Finland	OMXH25	May, 3rd 1988	
France	CAC 40	July, 9th 1987	
Germany	DAX 30	December, 31st 1964	
Ireland	ISEQ 20	January, 2nd 1998	
Luxembourg	LUXX	January, 4th 1999	
The Netherlands	AEX	January, 3rd 1983	

3.2. Methodology

3.2.1. Definition of Barriers

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

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

3.2.2. M-Values

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

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

, resulting, for instance, on 3400 being considered a barrier, whereas 340 would not. Additionally, the authors claimed that, as defined by equation (1), the gap between barriers would tend to zero as the price series increased, disrupting the intuitive appeal of a psychological barrier. Thus, one should also consider the possibility of barriers at the levels …, 10, 20, …, 100, 200, …, 1000, 2000, …, i.e. at:

$$k \text{ X } 10^l, k = 1, 2, \ldots, 9;\ l = \ldots, -1, 0, 1, \ldots; \tag{3}$$

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

$$k \text{ X } 10^l, k = 10, 11, \ldots, 99;\ l = \ldots, -1, 0, 1, \ldots; \tag{4}$$

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

$$M_t^a = [P_t] \text{mod } 100, \tag{5}$$

where P_t is the integer part of P_t and mod 100 refers to the reduction modulo 100. For barriers at the levels defined by equations (3) and (4), the *M*-values would be defined respectively as the second and third and the third and fourth significant digits. Formally,

$$M_t^b = \left[100 \text{ X } 10^{(\log P_t) \text{mod } 1}\right] \text{mod } 100, \tag{6}$$

$$M_t^c = \left[1000 \text{ X } 10^{(\log P_t) \text{mod } 1}\right] \text{mod } 100, \tag{7}$$

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

3.2.3. Uniformity Test

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

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

3.2.4. Barrier Tests

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

a) Barrier Proximity Test

This test examines the frequency of observations, f(M), near potential barriers and will be performed according to equation (8).

$$f(M) = \alpha + \beta D + \varepsilon \qquad (8)$$

The dummy variable will take the value of unity when the index is at the supposed barrier and zero elsewhere. As it was mentioned in section 3.2.1, this barrier will not be strictly considered as an exact number but also as a number of different specific intervals, namely with an absolute length of 2% and 5% of the corresponding power of ten as barriers. The null hypothesis of no barriers will thus imply that β equals zero, while β is expected to be negative and significant in the presence of barriers as a result of lower frequency of *M*-values at these levels.

b) Barrier Hump Test

The second barrier test will examine not just the tails of frequency distribution near the potential barriers, but the entire shape of the distribution. It is thus necessary to define the alternative shape that the distribution should have in the presence of barriers (Donaldson and Kim, 1993; Aggarwal and Lucey, 2007). Bertola and Caballero (1992), who analysed the behaviour of exchange rates in the presence of target zones imposed by forward-looking agents, suggest that a hump-shape is an appropriate alternative for the distribution of observations.
The test to examine this possibility will follow equation (9), in which the frequency of observation of each *M*-value is regressed on the *M*-value itself and on its square.

$$f(M) = \alpha + \Phi M + \gamma M^2 + \eta \qquad (9)$$

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

3.2.5. Conditional Effect Tests

The rejection of uniformity on the observations of *M*-values is not sufficient to prove the existence of psychological barriers (Ley and Varian, 1994). Therefore, it is necessary to analyse the dynamics of the returns series around these barriers, namely regarding mean and variance in order to examine the differential effect on returns due to prices being near a barrier, and whether these barriers were being approached on an upward or on a downward movement (Cyree *et al.*, 1999; Aggarwal and Lucey, 2007).

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

$$R_t = \beta_1 + \beta_2 BD_t + \beta_3 AD_t + \beta_4 BU_t + \beta_5 AU_t + \varepsilon_t \qquad (10)$$

Following Aggarwal and Lucey (2007), we started with an OLS estimation of Eq. (3.9) but heteroscedasticity and autocorrelation were clearly present across our data base. Therefore, the full analysis of the effects in the proximity of barriers required us to apply the former test also to the variances. Equation (11) represents this approach assuming autocorrelation similar to one as in Cyree *et al.* (1999) and Aggarwal and Lucey (2007). Besides the abovementioned dummy variables it includes a moving average parameter and a GARCH parameter.

$$\varepsilon_t = N(0, V_t)$$
$$V_t = \alpha_1 + \alpha_2 BD_t + \alpha_3 AD_t + \alpha_4 BU_t + \alpha_5 AU_t + \alpha_6 V_{t-1} + \alpha_7 \varepsilon_{t-1}^2 + \eta_t \qquad (11)$$

The four possible hypothesis to be tested are the following:

H1: There is no difference in the conditional mean return before and after a *downward* crossing of a barrier.
H2: There is no difference in the conditional mean return before and after an *upward* crossing of a barrier.
H3: There is no difference in conditional variance before and after a *downward* crossing of a barrier.
H4: There is no difference in the conditional variance before and after a *upward* crossing of a barrier.

4. Empirical Results

4.1. Uniformity Test

Table 3 provides the results of a uniformity test concerning the distribution of digits for the nine stock market indices under scrutiny. Overall, there is robust evidence that the *M*-values do not follow a uniform distribution. Uniformity is clearly rejected for all data series. Considering a statistical significance level of 5%, uniformity is never rejected. These findings are in line with the ones obtained by other authors (e.g., Cyree *et al*, 1999; Dorfleitner and Klein, 2003) although their results were more heterogeneous than ours.

Table 3 – Kolmogorov-Smirnov test for uniformity of digits

Country	Statistic	M0.1 (*I=0*)	M1 (*I=1*)	M10 (*I=2*)	M100 (*I=3*)
Austria	Kolmogorov (D) - Statistic value (adjusted)	2.283***	1.764***	1.777***	12.856***
	P-value	0.000	0.004	0.004	0.000
Belgium	Kolmogorov (D) - Statistic value (adjusted)	**1.503****	2.369***	2.362***	7.953***
	P-value	0.022	0.000	0.000	0.000
Europe	Kolmogorov (D) - Statistic value (adjusted)	1.832***	1.708***	2.173***	4.300***
	P-value	0.002	0.006	0.000	0.000
Finland	Kolmogorov (D) - Statistic value (adjusted)	1.502**	1.612**	1.681***	8.684***
	P-value	0.022	0.011	0.007	0.000
France	Kolmogorov (D) - Statistic value (adjusted)	1.598**	2.292***	1.583**	7.747***
	P-value	0.012	0.000	0.013	0.000
Germany	Kolmogorov (D) - Statistic value (adjusted)	2.732***	2.169***	2.282***	15.367***
	P-value	0.000	0.000	0.000	0.000
Ireland	Kolmogorov (D) - Statistic value (adjusted)	2.033***	1.966***	2.806***	–
	P-value	0.001	0.001	0.000	–
Luxembourg	Kolmogorov (D) - Statistic value (adjusted)	1.499**	1.365**	1.712***	12.643***
	P-value	0.022	0.048	0.006	0.000

The Netherlands	**Kolmogorov (D) - Statistic value (adjusted)**	2.133***	1.953***	7.254***	–
	P-value	0.000	0.001	0.000	–

Table 3 shows the results of a Kolmogorov-Smirnov test for uniformity. Each test was performed for the daily closing prices of each stock index. D stands for the value of the test statistic while P-value gives the marginal significance of this statistic. H0: uniformity in the distribution of digits, H1: non uniformity in the distribution of digits. ***: significant at the 1 percent level; **: significant at the 5 percent level.

4.2. Barrier Tests

4.2.1. Barrier Proximity Test

Results for the barrier proximity tests are shown in Tables 4 to 6 for the intervals mentioned in sections 3.2.1 and 3.2.4. As referred above, in the presence of a barrier we would expect β to be negative and significant, implying a lower frequency of *M*-values at these points. Considering a barrier in the exact zero modulo point, evidence in Table 4 shows that all the data series seem to reject the no barrier hypothesis at a statistical significance of 10%. All the significant results were detected on the two highest levels, i.e., the 100- and the 1000-barrier levels.

When we widen the barrier interval, evidence of psychological barriers appear to be weaker. In fact, if we assume a barrier to be in the interval 98-02, only Finland, Germany and the Netherlands seem to reject the no barrier hypothesis at a statistical significance of 1% (see Table 5). Considering the 95-05 interval, Table 6 shows that the no barrier hypothesis is again rejected for the same three countries and also for Belgium. All the other series are either not significant or β is not negative.

Overall, evidence suggests that psychological barriers are a relevant phenomenon for the all indices of the sample but only at 100- and 1000-barrier levels. R-squares are significantly low, which is in line with previous studies.

Table 4 – Barrier proximity test: strict barrier

Country	M0.1 (*l=0*)			M1 (*l=1*)			M10 (*l=2*)			M100 (*l=3*)		
	β	p-value	R-square	β	p-value	R-square	β	p-value	R-square	β	p-value	R-square
Austria	-4.10-3	0.289	0.011	-0.004	0.405	0.007	-0.009**	0.037	0.044	-0.01	0.138	0.002
Belgium	-6.10-3	0.361	0.009	-0.005	0.203	0.017	-0.009	0.149	0.021	-0.01*	0.062	0.003
Europe	-5.10-3	0.323	0.01	-0.004	0.276	0.012	-0.007	0.195	0.017	-0.01**	0.041	0.004
Finland	-1.10-3	0.677	0.002	-0.004	0.329	0.010	-0.01**	0.035	0.045	-0.02	0.108	0.003
France	-7.10-3	0.186	0.018	-0.007	0.113	0.025	-0.005	0.360	0.009	-0.01*	0.058	0.004
Germany	-4.10-3	0.156	0.02	-0.002	0.525	0.004	-0.008***	0.009	0.068	-0.01	0.201	0.002
Ireland	1.10-3	0.689	0.002	0.000	0.942	0.000	-0.01***	0.003	0.084	–	–	–
Luxembourg	1.10-3	0.657	0.002	-0.001	0.92	0.000	-0.01**	0.037	0.044	-0.01	0.211	0.002
The Netherlands	-2.10-3	0.673	0.002	-0.006	0.106	0.026	-0.01***	0.001	0.102	–	–	–

Table 4 shows the results of a regression *f(M)*=α+βD+ε, where *f(M)* stands for the frequency of appearance of the *M*-values, D is a dummy variable that takes the value of unity when M=00 and 0 otherwise. Refer to section 3.2.4 for details. *, **, *** indicates significance at the 10%, 5% and 1% level, respectively.

Table 5 – Barrier proximity test: 98-02 barrier

	M0.1 (*l=0*)			M1 (*l=1*)			M10 (*l=2*)			M100 (*l=3*)		
Country	β	p-value	R-square	β	p-value	R-square	β	p-value	R-square	β	p-value	R-square
Austria	0.002	0.122	0.024	-0.001	0.745	0.001	0.001	0.525	0.004	0.001	0.125	0.002

Belgium	0.001	0.683	0.002	-0.001	0.500	0.005	0.001	0.820	0.001	-0.001	0.170	0.002
Europe	0.001	0.807	0.001	-0.001	0.779	0.001	0.001	0.808	0.001	0.004**	0.000	0.032
Finland	0.002	0.295	0.011	-0.002	0.284	0.012	0.000	0.889	0.000	-0.007***	0.000	0.017
France	0.001	0.659	0.002	0.000	0.982	0.000	-0.001	0.665	0.002	0.003***	0.000	0.013
Germany	0.001	0.539	0.004	-0.001	0.364	0.008	0.000	0.993	0.000	-0.005***	0.006	0.008
Ireland	0.003**	0.016	0.058	-0.001	0.638	0.002	0.000	0.984	0.000	–	–	–
Luxembourg	0.001	0.291	0.011	-0.001	0.751	0.001	0.001	0.557	0.004	-0.001	0.307	0.001
The Netherlands	0.001	0.690	0.002	-0.001	0.583	0.003	-0.003**	0.020	0.054	–	–	–

Table 5 shows the results of a regression $f(M)=\alpha+\beta D+\varepsilon$, where $f(M)$ stands for the frequency of appearance of the *M*-values, D is a dummy variable that takes the value of unity when M=value is in the 98-02 interval and 0 otherwise. Refer to section 3.2.4 for details. *** significant at the 1% level; **: significant at the 5 percent level.

Table 6 – Barrier proximity test: 95-05 barrier

	M0.1 (l=0)			**M1 (l=1)**			**M10 (l=2)**			**M100 (l=3)**		
Country	**β**	**p-value**	**R-square**	**β**	**p-value**	**R-square**	**β**	**p-value**	**R-square**	**β**	**p-value**	**R-square**
Austria	0.001	0.394	0.007	0.000	0.836	0.000	0.000	0.777	0.001	0.002***	0.000	0.022
Belgium	0.001	0.731	0.001	-0.001	0.659	0.002	0.000	0.892	0.000	-0.001**	0.012	0.006
Europe	0.001	0.682	0.002	0.000	0.717	0.001	0.000	0.794	0.001	0.002***	0.000	0.026
Finland	0.001	0.501	0.005	0.000	0.752	0.001	0.000	0.870	0.000	-0.008***	0.000	0.048
France	0.000	1.000	0.000	0.000	0.868	0.000	0.000	0.816	0.001	0.003***	0.000	0.049
Germany	0.000	0.721	0.001	-0.001	0.527	0.004	0.000	0.823	0.001	-0.006***	0.000	0.025
Ireland	0.001	0.371	0.008	0.000	0.811	0.001	-0.001	0.370	0.008	–	–	–
Luxembourg	0.001	0.458	0.006	0.000	0.984	0.000	0.000	0.836	0.000	0.000	0.728	0.000
The Netherlands	-0.001	0.590	0.003	-0.002	0.204	0.016	-0.002**	0.020	0.054	–	–	–

Table 6 shows the results of a regression $f(M)=\alpha+\beta D+\varepsilon$, where $f(M)$ stands for the frequency of appearance of the *M*-values, D is a dummy variable that takes the value of unity when M=value is in the 95-05 interval and 0 otherwise. Refer to section 3.2.4 for details. ***: significant at the 1 % level; **: significant at the 5% level.

4.2.2. Barrier Hump Test

Table 7 shows the results for the barrier hump test, which is meant to test the entire shape of the distribution of M-values. Assuming it should follow a hump-shape distribution, we thus expected ϒ to be negative and significant in the presence of barriers. The results of the barrier hump test partially confirm the evidence presented previously with the barrier proximity tests. The stock market indices of Germany and Finland stand out again as they are the only ones that exhibited a persistent barrier, namely at the 1000-level barrier, at a statistically significant level of 1%. All the other series are either not significant or ϒ is not negative.

Table 7 – Barrier hump test
Table7 shows the results of a regression $f(M)=\alpha+\phi M+\Upsilon M^2+\eta$, where f(M), the frequency of appearance of each M-values, is regressed on M, the *M*-value itself, and M^2, its square. *** indicates significance at the 1% level.

Country	M0.1 (l=0)			M1 (l=1)			M10 (l=2)			M100 (l=3)		
	γ	P-value	R-square	γ	P-value	R-square	γ	P-value	R-square	γ	P-value	R-square
Austria	310.10^{-9}	0.496	0.012	-34.10^{-9}	0.956	0.001	49.10^{-9}	0.934	0.001	0.000000012***	0.000	0 .213
Belgium	-175.10^{-9}	0.836	0.001	43.10^{-9}	0.940	0.013	360.10^{-9}	0.663	0.003	-0.000000002	0.215	0.105
Europe	150.10^{-9}	0.826	0.002	170.10^{-9}	0.748	0.003	250.10^{-9}	0.718	0.003	0.000000010***	0.000	0.049
Finland	-17.10^{-9}	0.968	0.003	13.10^{-9}	0.982	0.002	-117.10^{-9}	0.857	0.000	-0.000000068***	0.000	0.226
France	-8.10^{-9}	0.991	0.000	75.10^{-9}	0.894	0.005	-291.10^{-9}	0.708	0.002	0.000000023***	0.000	0.218
Germany	-4.10^{-9}	0.991	0.010	-118.10^{-9}	0.806	0.003	-30.10^{-9}	0.943	0.008	-0.000000076***	0.000	0.256
Ireland	250.10^{-9}	0.552	0.016	-373.10^{-9}	0.630	0.009	-567.10^{-9}	0.227	0.028	–	–	–
Luxembourg	120.10^{-9}	0.756	0.004	-40.10^{-9}	0.956	0.001	160.10^{-9}	0.809	0.001	0.000000008***	0.000	0.171
The Netherlands	64.10^{-9}	0.900	0.007	-704.10^{-9}	0.174	0.020	-563.10^{-9}	0.168	0.105	–	–	–

4.2.3. Conditional Effects Test

Assuming the existence of psychological barriers, we expected the dynamics of return series to be different around these points. In fact, results in Table 8 provide some interesting evidence of mean effects around barriers as it is observed, on one hand, that stock market returns in all nine markets tend to be significantly higher when a barrier is to be crossed in an upward movement. On the other hand, the coefficients of BD and AD are negative and significant for all indices which means that stock market return tend to be significantly lower in the proximity of a barrier when that barrier is to be crossed on a downward movement. This pattern of conditional effects is similar to the one obtained by Cyree *et al.* (1999).

Table 8 shows the results of the mean equation of a GARCH estimation of the form $R_t=\beta_1+ \beta_2BD+ \beta_3AD+ \beta_4BU+ \beta_5AU+\varepsilon_t$; $\varepsilon_t \sim N(0,V_t)$; $V_t= \alpha_1+ \alpha_2BD+ \alpha_3AD+ \alpha_4BU+ \alpha_5AU+\alpha_6V_{t-1}+\alpha_7\varepsilon^2_{t-1}+\eta_t$. BD, AD, BU and AU are dummy variables. BD takes the value 1 in the 5 days before crossing a barrier on a downward movement and zero otherwise, whereas AD is for the 5 days after the same event. BU is for the 5 days before crossing a barrier from below, while AU is 1 in the 5 days after the same upward crossing. V_{t-1} refers to the moving average parameter and ε^2_{t-1} stands for the GARCH parameter. ***: significant at the 1 % level; **: significant at the 5% level.

Table 8 – GARCH analysis: mean equation

		C	BD	AD	BU	AU
Austria	**Coefficient**	0.0000158***	-0.00016***	-0.00013***	0.000105***	0.000138***
	P-value	0.000	0.000	0.000	0.000	0.000
Belgium	**Coefficient**	0.000011***	-0.0000628***	-0.0000746***	0.0000814***	0.0000286***
	P-value	0.000	0.000	0.000	0.000	0.005
Europe	**Coefficient**	0.00001***	-0.0000697***	-0.0000893***	0.0000671***	0.0000502***
	P-value	0.000	0.000	0.000	0.000	0.000
Finland	**Coefficient**	0.0000176***	-0.00016***	-0.00013***	0.000144***	0.000112***
	P-value	0.000	0.000	0.000	0.000	0.000
France	**Coefficient**	0.00000589***	-0.0000653***	-0.0000573***	0.0000554***	0.0000529***
	P-value	0.000	0.000	0.000	0.000	0.000

Germany	**Coefficient**	0.0000149***	-0.0000785***	-0.0000948***	0.0000788***	0.0000614***
	P-value	0.000	0.000	0.000	0.000	0.000
Ireland	**Coefficient**	0.0000319***	-0.00027***	-0.00026***	0.000262***	0.000186***
	P-value	0.001	0.000	0.000	0.000	0.000
Luxembourg	**Coefficient**	0.0000177***	-0.00015*	-0.00022***	0.000243***	0.00000963
	P-value	0.000	0.076	0.005	0.001	0.916
The Netherlands	**Coefficient**	0.0001***	-0.00026**	-0.00077***	0.000733***	0.00015
	P-value	0.000	0.016	0.000	0.000	0.117

Table 9 contains results for the conditional variance equation. The constant is positive and significant for all indices. All coefficients of the lagged squared residuals are positive and significant at the 1% level pointing out to an increase in conditional variance coincident with higher residuals from the previous period. The GARCH term in the conditional variance is positive and significant, suggesting significant GARCH effects around barriers. The GARCH term corresponding to the Finnish market is closer to one which indicates a higher level of volatility persistence. The variance effects are particularly evident before an upward movement through a barrier: the coefficient of BU in the variance equation is negative and statistically significant in most the markets under study. This indicates that the markets tend to calm before having risen through a barrier. This is in sharp contradiction with the results obtained by Cyree *et al.* (1999) according to which, in most cases, markets tend to be more volatile before crossing a barrier in an upward movement. In the pre-crossing period but in the case of a downward movement, the results are heterogeneous: Germany and the Netherlands have statistically significant results whereas the coefficient corresponding to the European market as a whole is negative.

The results in the post-crossing period are also somewhat heterogeneous. It is not possible to discern a clear trend in the volatility level after crossing a barrier in an upward movement. The volatility has increased after the crossing of a barrier in a downward movement for four of the indices but the markets of Germany and the Netherlands present important exceptions.

Table 9 – GARCH analysis: variance equation

		α_1	ε^2_{t-1}	V_{t-1}	**BD**	**AD**	**BU**	**AU**
Austria	**Coefficient**	0.0000000001***	0.0962***	0.9101***	-0.000000001	0.000000008***	-0.000000005**	0.000000001
	P-value	0.000	0.000	0.000	0.714	0.009	0.022	0.687
Belgium	**Coefficient**	0.000000003***	0.2339***	0.7198***	0.000000001	0.000000001*	-0.000000003***	-0.000000002***
	P-value	0.000	0.000	0.000	0.262	0.082	0.000	0.000
Europe	**Coefficient**	0.0000000003***	0.1147***	0.8891***	-0.0000000091***	0.0000000147***	-0.0000000011	-0.0000000004
	P-value	0.000	0.000	0.000	0.000	0.000	0.206	0.67
Finland	**Coefficient**	0.0000000003***	0.0780***	0.9269***	0.0000000004	0.0000000071**	0.0000000013	-0.0000000077***
	P-value	0.000	0.000	0.000	0.897	0.019	0.546	0.000
France	**Coefficient**	0.0000000002***	0.1029***	0.9001***	0.0000000006	0.0000000007**	-0.0000000004	-0.0000000007***

	P-value	0.000	0.000	0.000	0.115	0.047	0.153	0.003
Germany	**Coefficient**	0.0000000255***	0.1500***	0.5999***	0.0000000047***	-0.0000000017**	-0.0000000208***	-0.0000000068***
	P-value	0.000	0.000	0.000	0.000	0.016	0.000	0.000
Ireland	**Coefficient**	0.000000003***	0.0893***	0.9107***	-0.000000009	0.000000025***	-0.000000012***	-0.000000002
	P-value	0.000	0.000	0.000	0.131	0.000	0.007	0.693
Luxembourg	**Coefficient**	0.0000000018***	0.1096***	0.883***	0.0000000097	0.0000000120	-0.0000000393***	0.000000052***
	P-value	0.000	0.000	0.000	0.651	0.627	0.003	0.001
The Netherlands	**Coefficient**	0.000000301***	0.2569***	0.7141***	0.000000525***	-0.000000498***	-0.000000441***	0.000000434***
	P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 9 shows the results of the variance equation of a GARCH estimation of the form $R_t=\beta_1+\beta_2BD+\beta_3AD+\beta_4BU+\beta_5AU+\varepsilon_t$; $\varepsilon_t \sim N(0,V_t)$; $V_t=\alpha_1+\alpha_2BD+\alpha_3AD+\alpha_4BU+\alpha_5AU+\alpha_6V_{t-1}+\alpha_7\varepsilon^2_{t-1}+\eta_t$. BD, AD, BU and AU are dummy variables. BD takes the value 1 in the 5 days before crossing a barrier on a downward movement and zero otherwise, whereas AD is for the 5 days after the same event. BU is for the 5 days before crossing a barrier from below, while AU is 1 in the 5 days after the same upward crossing. V_{t-1} refers to the moving average parameter and ε^2_{t-1} stands for the GARCH parameter. *, **, *** indicates significance at the 10%, 5% and 1% level, respectively.

Table 10 shows the test results of the four barrier hypothesis mentioned in section 3.2.5. If some kind of barrier indeed existed, we would expect that the restraints in terms of mean and variance would be relaxed after the price crossed that barrier. With this test we are now able to examine the differences in returns and volatility before and after crossing a potential psychological barrier and thus we are also able to assess the relationship between these two parameters. In the time horizon of five days, the stock market indices of Austria and France did not show a statistically significant different behavior before and after crossing a barrier. In the markets of Luxembourg and the Netherlands, the differences in the variance were matched by a corresponding changes in the returns, over the same circumstances. However, in other markets important changes were observed in only one of the parameters (return or variance). In the case of the market of Belgium, for example, there was a statistically significant difference in the market return in the case of an upward crossing of a barrier with no statistically significant change in the variance. In the cases of Finland, Germany and of the European index, it was the volatility that has changed with no significant variation in the observed return. In Ireland, the two parameters showed significant changes but in different situations.

Table 10 – Barrier hypothesis tests

		H1	H2	H3	H4
Austria	**Chi-square**	0.937	0.589	1.754	2.416
	P-value	0.333	0.443	0.185	0.120
Belgium	**Chi-square**	10.819***	0.780	0.095	0.187
	P-value	0.001	0.377	0.758	0.665
Europe	**Chi-square**	0.663	0.619	0.153	142.942***
	P-value	0.416	0.431	0.696	0.000
Finland	**Chi-square**	0.766	0.713	5.040**	1.331
	P-value	0.381	0.398	0.025	0.249

France	**Chi-square**	0.048	0.449	0.556	0.011
	P-value	0.827	0.503	0.456	0.916
Germany	**Chi-square**	1.046	0.948	94.771***	22.164***
	P-value	0.307	0.330	0.000	0.000
Ireland	**Chi-square**	3.205*	0.121	1.156	7.557***
	P-value	0.073	0.728	0.282	0.006
Luxembourg	**Chi-square**	2.889*	0.327	10.252***	0.003
	P-value	0.089	0.567	0.001	0.959
The Netherlands	**Chi-square**	13.999***	19.349***	33.011***	248.986***
	P-value	0.000	0.000	0.000	0.000

Table 10 shows the results of a Chi-square test of four different null hypothesis. H1: There is no difference in the conditional mean return before and after a downward crossing of a barrier; H2: There is no difference in the conditional mean return before and after an upward crossing of a barrier. H3: There is no difference in conditional variance before and after a downward crossing of a barrier; H4: There is no difference in the conditional variance before and after an upward crossing of a barrier. *, **, *** indicates significance at the 10%, 5% and 1% level, respectively.

Overall, evidence suggests that the relationship between returns and volatility was significantly affected in most of the markets under analysis. A similar result was obtained by Cyree *et al.* (1999) for several indices representing developed stock markets. The authors noticed that their result – a simultaneous increase in conditional return and a decrease in conditional variance – appeared to represent an "aberration" in the equilibrium risk–return relationship. As pointed out also by Aggarwal and Lucey (2007), such findings pose some relevant implications for the positive risk-return relationship postulated by the standard financial models. As variance is normally used as a proxy for risk, changes in this parameter should be linked to changes in expected returns. However, our findings suggest that this relationship may be biased in the case of stock market indices near round numbers.

5. CONCLUSION

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

Following a complete set of methodologies for studying psychological barriers, we provide new evidence regarding this phenomenon in nine European stock market indices. Considering an extended sample period, we examined the existence of barriers at round numbers in the major stock market indices of Austria (ATX), Belgium (BEL 20), Finland (OMXH25), France (CAC 40), Germany (DAX 30), Ireland (ISEQ 20), Luxembourg (LUXX) and the Netherlands (AEX). The European index EURO STOXX 50 was also included in the sample.

Although a uniform distribution is rejected for every stock market index under analysis, barrier tests show some differences in the evidence of psychological barriers around round numbers across the stock indices. All the data series exhibit evidence of psychological barriers in the exact zero modulo point on one of the two highest levels, i.e., the 100- and the 1000-barrier levels. However, when the barrier interval is widened, only Finland, Germany and the Netherlands continue to show significant evidence of psychological barriers. The relevance of the phenomenon in the Finnish and in the German markets is confirmed by the results of the barrier hump test.

Regarding conditional effects, our results indicate that markets tended to be significantly more volatile after breaching through a barrier on an upward movement. Considering downward movements, we found a significant decrease of volatility before the breaching of a possible barrier.

These findings provide some evidence supporting the existence of psychological barriers with respect to index returns. Our results are thus in line with earlier studies (e.g., Koedijk and Stork, 1994; Cyree *et al.*, 1999; Bahng, 2003) and support the claim that technical analysis strategies based on price support and resistances can be profitable at least in some markets.

The implications of the results presented here are somewhat problematic for standard risk-return equilibrium models which predict a positive relationship between these two variables. The findings regarding the barrier hypothesis tests presented in Table 12 above, show that in the markets under analysis there were statistically significant changes in the volatility between the pre-crossing and the post-crossing periods. Changes in variance, as a proxy for risk, should of course be associated with changes in expected returns. However, the contemporaneous changes in the observed returns between those two periods do not seem to be significant in most cases. This has led us to conclude that the relationship between risk and return became weaker around psychological barriers.

The fragility in the relationship between risk and return, both in cross-sectional and in temporal frameworks, has been highlighted by several authors over the last decades. For example, Fama and French (1998, 2004) have shown that, after controlling the data for factors such as the book-to-market and the stock capitalization, the relationship between the observed returns and the beta risk parameter becomes statistically non-significant, if not negative. And more recently, Savor and Wilson (2014) have shown that beta is positively related to average stock returns only on days when macroeconomics news regarding employment, inflation, and interest rate are scheduled to be announced. On the remaining days, beta is unrelated or even negatively related to average returns. The results of our study suggest an additional circumstance where the relationship between risk and return tends to be weaker: in the proximity of psychological barriers (in our case, round numbers).

Psychological barriers continue to represent a fertile field for future research. It would be interesting to investigate why the incidence of psychological barriers, like other market anomalies (see, e.g., Stambaugh *et al.*, 2012), seem to vary both cross-sectionally and over time.

REFERENCES

Aggarwal, R. and B.M. Lucey (2007). Psychological barriers in gold prices? Review of Financial Economics 16(2): 217-230.

Bahng, S. (2003). Do Psychological Barriers Exist in the Stock Price Indices? Evidence from Asia's Emerging Markets. International Area Studies Review 6(1): 35-52.

Bertola G. and R.J. Caballero (1992). Target Zones and Realignments. American Economic Review 82(3): 520-536.

Brock,W., J. Lakonishok and B. LeBaron (1992). Simple technical trading rules and the stochastic properties of stock returns. Journal of Finance 47(5): 1731−1764.

Cai, B. M., C.X. Cai and K. Keasey, K. (2007). Influence of cultural factors on price clustering and price resistance in China's stock markets. Accounting and Finance 47(4): 623-64.

Chen, M. and V.W. Tai (2011). Psychological Barriers and Prices Behaviour of TAIFEX Futures. Global Economy and Finance Journal 4(2): 1-12.

Cyree, K.B., D.L. Domian, D.A. Louton, D.A. and E.J. Yobaccio (1999). Evidence of psychological barriers in the conditional moments of major world stock indices. Review of Financial Economics 8(1): 73-91. De Ceuster, M.J.K., G. Dhaene and T. Schatteman (1998). On the hypothesis of psychological barriers in stock markets and Benford's Law. Journal of Empirical Finance 5(3): 263-279.

De Grauwe, P. and D. Decupere (1992). Psychological barriers in the foreign exchange markets. Journal of International and Comparative Economics 1(2): 87−101.

Donaldson, R.G. (1990a). Psychological barriers in asset prices, rationality and the efficient market hypothesis. Princeton Financial Research Center Memorandum 114.

Donaldson, R. G. (1990b). International evidence on psychological barriers in asset prices and the efficient market hypothesis. Princeton Financial Research Center Memorandum 116.

Donaldson, R.G. and H.Y. Kim (1993). Price Barriers in the Dow Jones Industrial Average. Journal of Financial and Quantitative Analysis 28(3): 313-330.

Dorfleitner, G. and C. Klein (2009). Psychological barriers in European stock markets: Where are they? Global Finance Journal 19(3): 268-285.

Dowling, M., M. Cummins and B.M. Lucey (2016). Psychological barriers in oil futures markets. Energy Economics 53: 293-304.

Fama, E. and E.F. French (1998). Value versus Growth: The International Evidence. Journal of Finance 53(6): 1975-1999.

Fama, E. and E.F. French (2004). The Capital Asset Pricing Model: Theory and Evidence. Journal of Economic Perspectives 18(3): 25-46.

George, T.J. and C. Hwang (2004). The 52-Week High and Momentum Investing. Journal of Finance 59(5): 2145-2176.

Jang, B., C. Kim, K.T. Kim, S. Lee and D. Shin (2013). "Psychological Barriers and Option Pricing. Journal of Futures Markets 35(1): 52–74.

Koedijk, K.G. and P.A. Stork (1994). Should we care? Psychological barriers in stock markets. Economics Letters 44(4): 427-432.

Ley, E. and H.R. Varian (1994). Are there psychological barriers in the Dow-Jones index? Applied Financial Economics 4(3): 217-224.

Savor, P. and M. Wilson (2014). Asset pricing: A tale of two days. Journal of Financial Economics 113(2): 171-201.

Schwartz, A. L., B.F. Van Ness and R.A. Van Ness (2004). Clustering in the futures market: Evidence from S&P 500 futures contracts. Journal of Futures Markets 24(5): 413-428.

Shiller, R.J. (2015). Irrational Exuberance, third edition. Princeton University Press.

Stambaugh, R. F., J. Yu and Y. Yuan (2012). The short of it: investor sentiment and anomalies. Journal of Financial Economics 104: 288-302.

Tversky, A. and D. Kahneman (1974). Judgment under uncertainty: Heuristics and biases. Science, New Series 185(4157): 1124-1131.

Westerhoff, F. (2003). Anchoring and psychological barriers in foreign exchange markets. Journal of Behavioral Finance 4(2): 65-70.

World Bank (2014), World Development Indicators Database. World Bank. Washington, DC. Affairs.