THE IMPACT OF COVID-19 ON THE SECURITIES AND EQUITY MARKETS OF PORTUGAL AND EDP: AN ECONOPHYSICS APPROACH

Maria Manuel[1]
Paula Heliodoro[2]
Rui Dias[3]
Paulo Alexandre[4]

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Abstract: *The Efficient Market Hypothesis (EMH), is one of the most important hypotheses in the financial economy, which argues that yields have no memory (correlation), which implies that agents cannot have abnormal returns in the financial markets, base arbitration operations. This essay intends to investigate the efficiency, in its weak form, in the stock and bond markets of Portugal and EDP, in the period from December 31, 2019, to August 10, 2020. With the purpose of achieving such an analysis, whether: (i) with the evolution of the global pandemic (Covid-19) the Portuguese and EDP stock and bond markets show signs of (in) efficiency? (ii) Does the increased integration between the Portuguese and EDP stock and bond markets result in risk transmission? The model DFA shows the existence of long memories in these markets, suggesting that they are not efficient, which validates the first research question. This situation has implications for investors, since some returns can be expected, creating opportunities for arbitrage and abnormal earnings. However, to confirm the inefficiency of these markets, based on our results, we must prove the existence of anomalous returns. In order to answer the second investigation question, we carried out the integration test that shows that these markets are mostly integrated. To validate whether financial integration results in risk transmission between the analyzed markets, we estimate the trendless cross-correlation coefficients (λ_{DCCA}), which shows 4 pairs of markets showing risk transmission (4 out of 10 possible). In conclusion, the authors suggest that these results are of interest, among others, to international investors interested in expanding the geographical scope, regarding the implementation of portfolio diversification strategies.*

Keywords: *Covid-19, Long memories, Financial integration, Portfolio diversification.*

1. INTRODUCTION

Globalization has reduced barriers to trade and increased international investment exponentially, which has created numerous opportunities for investors to invest in different markets. The stock, bond, and foreign exchange markets are the relevant sources for investing and maximizing investor profitability (Rehan, Zehra, Chhapra, and Makhija, 2019).

[1] Escola Superior de Ciências Empresarias - Instituto Politécnico de Setúbal, Portugal
[2] Escola Superior de Ciências Empresarias – Instituto Politécnico de Setúbal, Portugal
[3] Escola Superior de Ciências Empresarias - Instituto Politécnico de Setúbal, Portugal & CEFAGE, Universidade de Évora, Portugal
[4] Escola Superior de Ciências Empresarias – Instituto Politécnico de Setúbal, Portugal

Financial instability is a very important factor for society since a financial crisis or stock market crash can affect, directly or indirectly, the level of the economic well-being of the inhabitants of a country. If a given stock market is strongly linked to the stock market of another country, the financial stability of the first depends, in part, on the financial stability of the second. Thus, the occurrence of integration between markets can have significant implications for the international diversification of risk (Dias, da Silva and Dionísio, 2019).

The Market Efficiency Hypothesis is an important concept for investors to maintain their diversified portfolios efficiently. With the increase in investments, due to the globalization of the economy, there was a marked integration of world economies, in view of this understanding the synchronizations between companies and the financial markets have gained international relevance (Gupta and Basu, 2011).

This investigation differs from studies carried out so far on the impact of the global pandemic on financial markets, as far as is known; the authors He, Liu, Wang, and Yu (2020), Kanno (2020) Wang and Enilov (2020) analyzed the Covid-19 pandemic shocks, but the research questions, the markets analyzed, and the approach was essentially different from that followed in this essay.

In terms of structure, this essay is organized into 5 sections. In addition to the current introduction, section 2 presents a Literature Review on market efficiency, in its weak form, section 3 describes the methodology and data, section 4 contains the results. Section 5 presents the general discussions of the work.

2. LITERATURE REVIEW

The topic of the efficient market hypothesis (EMH) has motivated other studies to analyze the implications for the market efficiency hypothesis, according to which the current asset price reflects all the information available, at a given moment, and the price adjusts up quickly, as new and unforeseen information hits the market. The mean reversion hypothesis, also known as negative series correlation, has been interpreted as an efficient correction mechanism in developed markets and a sign of a speculative bubble in emerging financial markets (Summers, 1986; Fama and French, 1988).

Ferreira and Dionísio (2014), Sensoy and Tabak (2015), Ferreira and Dionísio (2016), Rounaghi and Nassir Zadeh (2016), analyzed the presence of long memories in the financial markets, testing the efficient market hypothesis. Ferreira and Dionísio (2014) analyzed the stock indexes of 10 markets, using the methodology, the authors show that the series of returns have long-term dependence, being more accentuated in the markets of Spain, Greece and Portugal. Sensoy and Tabak (2015) show that the 2008 global financial crisis caused persistent profitability in almost all EU equity markets. However, during the eurozone sovereign debt crisis, this long-term dependency was seen only in the markets of France, Spain and Greece. Ferreira and Dionísio (2016) tested the Efficient Market Hypothesis (HME) in Africa's stock markets; using the methodology, the authors show that the long-term correlation only ends at the 149th lag, which corresponds to about seven months. Does this result harm HME?

Rounaghi and Nassir Zadeh (2016), Shirvani and Delcoure (2016), Mensi, Tiwari and Yoon (2017), Ali, Shahzad, Raza and Al-Yahyaee (2018), tested the random walk hypothesis in several financial markets. Rounaghi and Nassir Zadeh (2016) investigated the presence of long memory in the profitability of the S&P 500 and the London Stock Exchange (LSE). Recently,

multifractal analysis has evolved as an important way of explaining the complexity of financial markets that can hardly be described by linear methods of efficient market theory. A comparison between the S&P 500 and the London Stock Exchange shows that both markets are efficient and have financial stability during periods of high and low volatility. Shirvani and Delcoure (2016) analyzed 16 OECD markets, the authors show that the markets are efficient, as the hypothesis of reversion to the mean was not rejected. Mensi Tiwari, and Yoon (2017) show high efficiency in the long term, but moderate in the short term, and that these markets became less efficient after the beginning of the global financial crisis. Ali, Shahzad, Raza and Al-Yahyaee (2018) demonstrate that developed markets are relatively more efficient, followed by the BRICS stock markets. The authors show that almost all Islamic stock markets, except for Russia, Jordan and Pakistan, are more efficient than their conventional peers.

Guedes, Ferreira, Dionísio and Zebende (2019), Bashir et al. (2019), da Silva, Guedes, Ferreira, Dionísio and Zebende (2019) tested the market efficiency, in its weak form, through the cross-correlation coefficient. Guedes, Ferreira, Dionísio and Zebende (2019) show a decrease in the cross-correlation coefficient which means that the United Kingdom is more segmented, in the post BREXIT. Bashir et al. (2019) show through the model that most European financial markets tend to be negatively correlated in the long run after the Brexit referendum. Da Silva, Guedes, Ferreira, Dionísio and Zebende (2019) analyzed the main indices in the World: North America, South America, Asia and Europe. The authors show a perfect long-term cross-correlation between opening and closing prices; however, in the short term, there are differences between the different stock markets.

In summary, this work aims to contribute to the provision of information to international investors interested in expanding, in the geographical scope, strategies for diversifying efficient portfolios.

3. METHODOLOGY

DATA

The data used for the preparation of the test were the prices index (daily) of the stock markets of EDP, PSI 20, and the Portuguese energy sector. The yields of EDP's 10-year bonds, and Portugal's 10-year sovereign bonds, from December 31, 2019 to August 10, 2020. The source of information used was the Thomson Reuters platform, with prices in local currency, to mitigate exchange rate distortions.

Table 1. The name of countries and their indices used in this paper

Index	Country
EDP (PRICE INDEX)	PORTUGAL
EDP (BOND 10YR)	PORTUGAL
PSI 20	PORTUGAL
PORTUGAL (BOND 10YR)	PORTUGAL
ENERGY SECTOR PORTUGAL	PORTUGAL

Source: Own elaboration

METHODOLOGY MODELS

The development of the research took place over several stages. The characterization of the sample used was carried out through descriptive statistics, the Jarque and Bera (1980) adherence

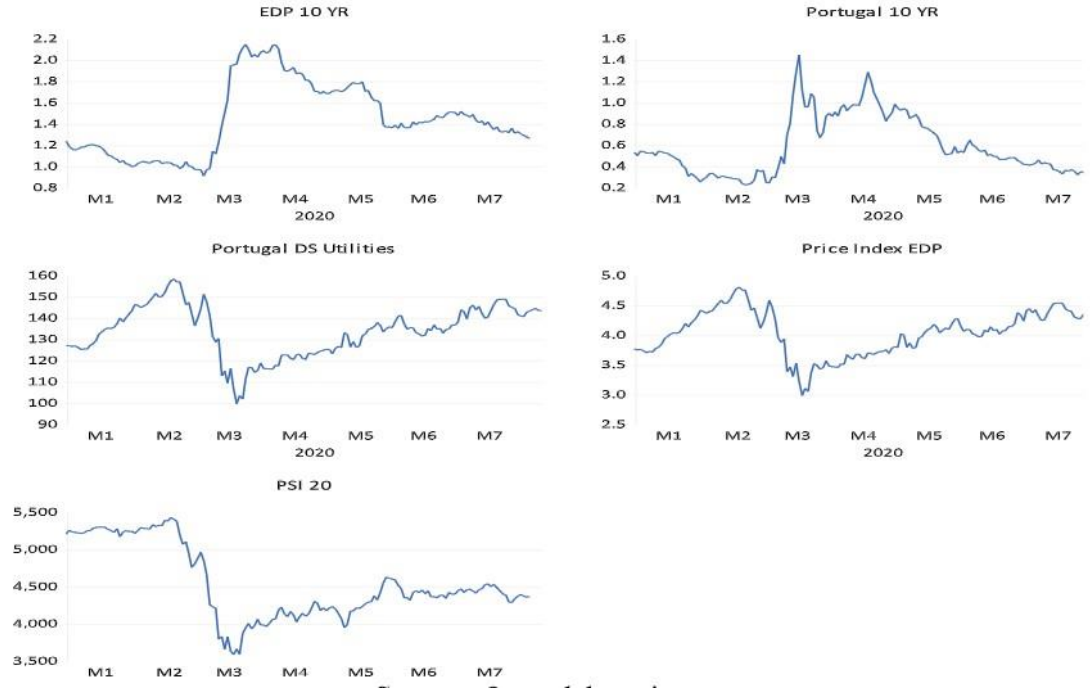
test, as well as the quantile graphs. To estimate the breakdowns in the financial markets, we used the unit root test by Clemente et al. (1998). In order to test efficiency, in its weak form, in the stock and bond markets under analysis, we will use the Detrended Fluctuation Analysis (DFA) methodology. DFA is an analysis method that examines time dependency on non-stationary data series. This technique, assuming that the time series are non-stationary, avoids spurious results when the analysis focuses on the relationships of the data series in the long run. The DFA has the following interpretation: $0 < \alpha < 0{,}5$: anti-persistent series; $\alpha = 0{,}5$ series features random walk; $0{,}5 < \alpha < 1$ persistent series. The function of this technique is to examine the relationship between values x_k and x_{k+t} at different times (Guedes et al., 2018). To test the integration between the financial markets we will use the methodology of Gregory and Hansen (1996). In this empirical study, the authors were concerned with a general test model, in which the cointegration vector varies with time. The method developed by Gregory and Hansen (1996) is considered a complement to the ADF test. Also, it can also be affirmed, in the econometric perspective, as a multivariate version of the model by Zivot and Andrews (1992). According to the authors, the existence of structural breaks can lead to erroneous conclusions regarding the acceptance of the null hypothesis of non-cointegration and, therefore, the absence of any type of long-term relationship between variables $I(1)$. In order to validate whether the integration causes risk between the stock and bond markets under analysis, we will use Zebende's (2011) cross-correlation coefficient without trend, being the same, a method to quantify the level of cross-correlation between two series non-stationary storms. The coefficient is based on the DFA methods of Peng et al. (1994) and the DCCA of Podobnik and Stanley (2008). The cross-correlation coefficient depends on the length of the box s (time scale). One of the advantages of this cross-correlation coefficient is centered on the possibility of measuring the correlations between two non-stationary time series at different time scales. The DCCA cross-correlation coefficient varies within the range $-1 \leq \rho DCCA \leq 1$ logically 1 means perfect cross-correlation, -1 means perfect anti-cross-correlation and 0 means that there is no correlation (Podobnik and Stanley, 2008).

4. RESULTS

Figure 1 shows the evolution of the Portuguese and EDP stock and bond markets, in levels, in the period from December 31, 2019 to August 10, 2020, being a very complex period, due to the understanding the outbreak of the global pandemic (Covid-19). Most markets show structure breaks in February and March 2020. These findings are corroborated by authors Dias, Heliodoro, Alexandre, and Vasco, (2020), Alexandre, Dias, and Heliodoro (2020b), Heliodoro, Dias, and Alexandre (2020), Dias, Teixeira, Machova, et al. (2020), Dias, Heliodoro, and Alexandre (2019), Dias, Heliodoro, Alexandre, and Vasco (2020b) who evidence that the 2020 global pandemic had significant impacts on international financial markets.

Figure 2 shows the evolution, in% of the differences, of the Portuguese and EDP stock and bond markets. In all series, there is a relatively high dispersion around the average, as well as a relatively synchronized behavior between the data series. Through graphical analysis, there is high volatility, especially in February and March 2020.

Figure 1. Evolution, in levels, of the 5 financial markets, in the period from 12/31/2019 to 10/08/2020



Source: Own elaboration

Figure 2. Evolution, in% of the differences, of the 5 financial markets, in the period from 12/31/2019 to 10/08/2020.

Source: Own elaboration

Table 2 shows the main descriptive statistics on the profitability of the five financial markets, as well as the Jarque-Bera adherence test. The analysis of descriptive statistics allows us to verify that the returns have positive daily averages, except for the stock market PSI 20 and the sovereign yields of Portugal. The Portuguese sovereign debt market has the largest standard

deviation, while EDP 10-year bonds have the highest level of kurtosis and asymmetry. Additionally, the coefficients of asymmetry and kurtosis are statistically different from those of a normal distribution, this evidence is corroborated by the Jarque-Bera test where the rejection of the null hypothesis is rejected with a significance of 1%. The authors Alexandre, Dias, and Heliodoro (2020), Heliodoro et al. (2020), Dias, Heliodoro, Alexandre, et al. (2020), Dias, Heliodoro, Teixeira, and Godinho (2020), Dias and Pereira (2021) also show that the financial series do not follow normal distributions.

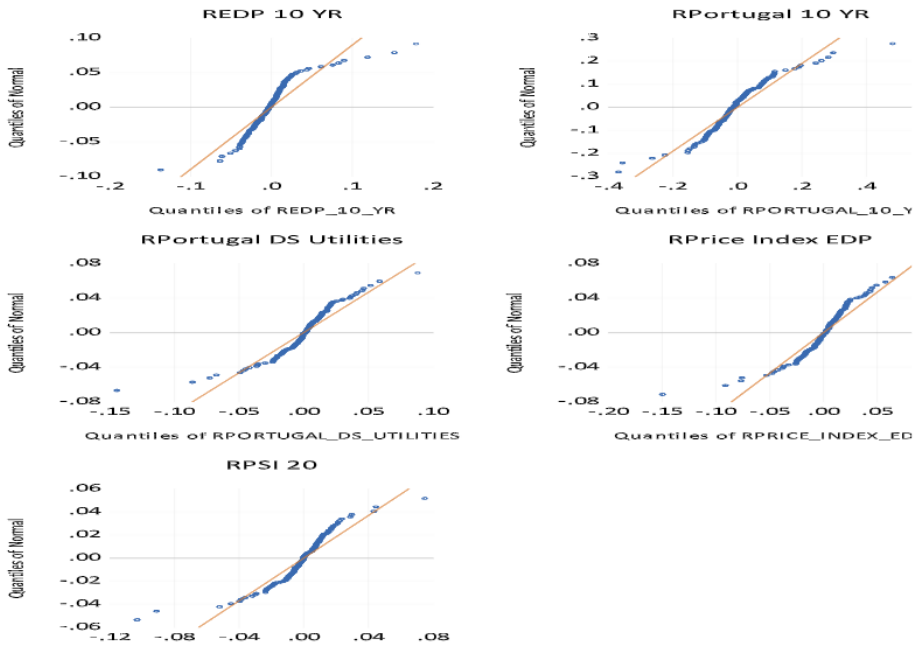
Table 2. Descriptive statistics, on returns, of the 5 financial markets, in the period from 12/31/2019 to 10/08/2020

	EDP 10YR	PORTUGAL 10YR	PORTUGAL DS UTILITIES	PRICE INDEX EDP	PSI 20
Mean	0.000135	-0.004008	0.000774	0.000940	-0.001132
Std. Dev.	0.033473	0.102220	0.025194	0.026729	0.019343
Skewness	1.669289	0.608094	-1.377193	-1.282833	-1.298431
Kurtosis	12.51146	7.801034	10.94610	10.37153	11.09842
Jarque-Bera	656.2572***	158.4168***	456.7794***	393.4557***	467.1192***
Sum	0.020954	-0.621174	0.119989	0.145749	-0.175456
Sum Sq. Dev.	0.172552	1.609121	0.097750	0.110023	0.057621
Observations	155	155	155	155	155

Source: Own elaboration

The quantile plots show that the profitability rate distribution is leptokurtic and asymmetric or skewed. The distribution is leptokurtic because the graph has the shape of "S", on the 45º line, and is asymmetric because the "S" is not symmetric on the line, showing the existence of non-linear relations (see figure 3).

Figure 3. Graphs of yield rate quantiles, from the 5 financial markets, in the period from 12/31/2019 to 10/08/2020



Source: Own elaboration

Table 3 shows the results of the unit root tests with structure breaks, by Clemente et al. (1998), and we can easily see that the financial markets showed structural breaks in February 2020, with the execution of the securities market in Portugal and EDP that broke in March and January 2020, respectively. The results are in line with the findings of the authors G.Sudha and V. Sornaganesh (2020), Lahmiri and Bekiros (2020), which indicate sharp declines in the international financial markets, resulting from the global pandemic (Covid-19). These findings are corroborated by authors Heliodoro, Dias, and Alexandre (2020), Dias, Heliodoro, Alexandre, and Vasco (2020), Dias, Heliodoro, Alexandre, Santos, and Farinha (2021), Dias and Pereira (2021) who evidence stock market crashes in the first quarter of 2020 due to the 2020 global pandemic.

Table 3. Unit root tests with structural breaks by Clemente et al. (1998), in returns, referring to the 5 financial markets, in the period from 12/31/2019 to 8/10/2020

Index	t-stat	Break Date
EDP (BOND 10 YR)	-9.77(0)***	09/01/2020
PORTUGAL (BOND 10 YR)	-11.13(0)***	07/03/2020
ENERGY SECTOR PT	-13.74(0)***	27/02/2020
EDP (PRICE INDEX)	-13.59(0)***	26/02/2020
PSI 20	-13.39(0)***	23/02/2020

Note: Lag Length (Automatic Length based on SIC). Break Selection: Minimize Dickey-Fuller t-statistic. The lateral values in parentheses refer to lags. ***. **. *. represent significance at 1%. 5% and 10%. respectively.

Source: Own elaboration.

The results of the exponents DFA, we can see in table 4, and verify that the securities markets: EDP (10YR), Portugal (10YR) and the stock markets: Portuguese energy sector, EDP and PSI 20 show long memories, or that is, they show signs of (in) market efficiency, in its weak form. These findings imply that prices do not fully reflect the information available and that changes in prices are not i.i.d. This situation has implications for investors, since some returns can be expected, creating opportunities for arbitrage and abnormal earnings. These findings are in line with the evidence suggested by the authors Aggarwal (2018), Rehman, Chhapra, Kashif, and Rehan (2018), which show accentuated levels of arbitrage which may create anomalous returns for investors, without incurring increased risk.

Table 4. DFA exponent for index and return. The values of the linear adjustments for αDFA always had $R2 > 0.99$.

Stock market	DFA exponent (Covid-19 period)
EDP (BOND 10 YR)	0.80 ≅ 0.0011***
PORTUGAL (BOND 10 YR)	0.61 ≅ 0.0011***
ENERGY SECTOR PT	0.57 ≅ 0.0034***
EDP (PRICE INDEX)	0.54 ≅ 0.0039***
PSI 20	0.67 ≅ 0.0061***

Source: Own elaboration.

Note: The hypotheses are H_0: α = 0.5 and H_1: α ≠ 0.5. ***. **. *. represent significance at 1%. 5% and 10%. respectively.

Source: Own elaboration.

The results of the Gregory-Hansen test can be seen in Table 5 which shows the integrations between the stock, Portuguese securities and EDP markets and we verify that all markets are integrated, except for EDP (PRICE INDEX) / PSI 20, which causes us some surprise. These findings call into question the implementation of efficient portfolio diversification strategies,

with important implications for the individual, institutional investors, portfolio managers, and policy makers.

Table 5. Gregory-Hansen tests, Covid period (31/12/2019 to 10/08/2020)

Markets	t-statistic	Method	Lags	Break Date	Results
EDP (BOND 10 YR) / EDP (PRICE INDEX)	-5.07**	Regime	0	56	Integration
EDP (BOND 10 YR) / ENERGY SECTOR (PT)	-5.56***	Regime	0	56	Integration
EDP (BOND 10 YR) / PSI 20	-4.75*	Regime	0	56	Integration
EDP (BOND 10 YR) / PORTUGAL (10 YR)	-4.88**	Trend	5	49	Integration
EDP (PRICE INDEX) / EDP (BOND 10 YR)	-4.73*	Regime	0	55	Integration
EDP (PRICE INDEX) / ENERGY SECTOR (PT)	-8.96***	Regime	0	127	Integration
EDP (PRICE INDEX) / PORTUGAL (10 YR)	-5.18**	Trend	0	70	Integration
ENERGY SECTOR (PT) / EDP (BOND 10 YR)	-5.12**	Regime	0	56	Integration
ENERGY SECTOR (PT) / EDP (PRICE INDEX)	-8.51***	Regime	0	55	Integration
ENERGY SECTOR (PT) / PSI 20	-5.05**	Trend	0	24	Integration
ENERGY SECTOR (PT) / EDP (BOND 10 YR)	-5.14**	Trend	0	115	Integration
PSI 20 / EDP (BOND 10 YR)	-5.32**	Trend	1	44	Integration
PSI 20 / EDP (PRICE INDEX)	-5.18**	Regime	1	44	Integration
PSI 20 / ENERGY SECTOR (PT)	-6.29***	Regime	0	43	Integration
PSI 20 / PORTUGAL (10 YR)	-5.22**	Regime	1	43	Integration
PORTUGAL (10 YR) / EDP (BOND 10 YR)	-4.87*	Regime	5	110	Integration
PORTUGAL (10 YR) / EDP (PRICE INDEX)	-5.92**	Regime	1	70	Integration
PORTUGAL (10 YR) / ENERGY SECTOR (PT)	-6.14***	Regime	1	71	Integration
PORTUGAL (10 YR) / PSI 20	-6.16***	Trend	1	68	Integration

Notes: The asterisks ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

Source: Own elaboration.

Table 6 shows the trendless cross-correlation coefficients (λ_{DCCA}), referring to the Portuguese and EDP stock and bond markets, from December 31, 2019, to August 10, 2020. The EDP financial market pairs (BOND 10 YR) / PORTUGAL (10 YR), EDP (PRICE INDEX) / ENERGY SECTOR (PT), EDP (PRICE INDEX) / PSI 20, ENERGY SECTOR (PT) / PSI 20 present the λ_{DCCA} strong coefficients, which indicates the presence of risk transmission. Regarding the remaining pairs, the λ_{DCCA} coefficients are anti-correlated, that is, there is no risk transmission between these markets. This evidence is relevant because the Gregory-Hansen integration test shows that these markets are integrated, however, the integration ratio is not equal to the identified risk. These findings are relevant for institutional investors, risk managers who seek to diversify their portfolios in these geographic markets.

Table 6. Summary table of the λ_{DCCA} coefficient peaks, in the financial markets under analysis, in the period from 12/31/2019 to 10/08/2020

Index	λ_{DCCA}	Time scale (days)	Trend
EDP (BOND 10 YR) / EDP (PRICE INDEX)	-0.51	n > 35 days	anti-correlation
EDP (BOND 10 YR) / ENERGY SECTOR (PT)	-0.60	n > 29 days	anti-correlation
EDP (BOND 10 YR) / PSI 20	-0.48	n > 35 days	anti-correlation
EDP (BOND 10 YR) / PORTUGAL (10 YR)	0.57	n > 35 days	**Strong correlation**

EDP (PRICE INDEX) / ENERGY SECTOR (PT)	0.76	n > 35 days	**Strong correlation**
EDP (PRICE INDEX) / PSI 20	0.87	n > 29 days	**Strong correlation**
EDP (PRICE INDEX) / PORTUGAL (10 YR)	-0.72	n > 35 days	anti-correlation
ENERGY SECTOR (PT) / PSI 20	0.71	n > 35 days	**Strong correlation**
ENERGY SECTOR (PT) / PORTUGAL (10 YR)	-0.63	n > 29 days	anti-correlation
PSI 20 / PORTUGAL (10 YR)	-0.73	n > 35 days	anti-correlation

Source: Own elaboration

5. CONCLUSION

The general conclusion to be kept and sustained by the results obtained, through tests carried out with econometric and mathematical models, suggests that the global pandemic has an adverse effect on the properties of memories in these financial markets. The model shows the existence of long memories in these markets, suggesting that they are not efficient, which validates the first research question. This situation has implications for investors, since some returns can be expected, creating opportunities for arbitrage and abnormal earnings, contrary to the assumptions of the random walk and information efficiency. However, to confirm the inefficiency of these markets, based on our results, we must prove the existence of anomalous returns. In order to answer the second investigation question, we carried out the integration test that shows that these markets are mostly integrated. To validate whether financial integration results in risk transmission between the analyzed markets, we estimate the trendless cross-correlation coefficients, which show 4 pairs of markets showing risk transmission (4 out of 10 possible). In conclusion, the authors suggest that the implementation of efficient portfolio diversification strategies in these regional markets may be questionable. These conclusions also open space for regulators in these regional markets to take steps to ensure better information between these markets and international markets.

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