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Statistical Arbitrage in Emerging Markets: A Global Test of Efficiency

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Abstract: In this paper, we use a statistical arbitrage method in different developed and emerging countries to show that the profitability of the strategy is based on the degree of market efficiency. We will show that our strategy is more profitable in emerging ones and in periods with greater uncertainty. Our method consists of a Pairs Trading strategy based on the concept of mean reversion by selecting pair series that have the lower Hurst exponent. We also show that the pair selection with the lowest Hurst exponent has sense, and the lower the Hurst exponent of the pair series, the better the profitability that is obtained. The sample is composed by the 50 largest capitalized companies of 39 countries, and the performance of the strategy is analyzed during the period from 1 January 2000 to 10 April 2020. For a deeper analysis, this period is divided into three different subperiods and different portfolios are also considered.

Keywords: emerging markets; pairs trading; Hurst exponent; financial markets; long memory; co-movement; efficiency

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1. Introduction

The Efficient Market Hypothesis (EMH) was introduced by Cootner [1] and Samuelson [2]. Recently, Fama [3] developed three states of efficiency:

- Strong form efficiency states all information in a market, whether public or private, is contained in the stock price.
- Semi-strong efficiency means that all public information is calculated into a stock's current share price.
- Weak form efficiency implies that all past prices of a stock are reflected in today's stock price.

When markets are fully efficient, neither technical analysis, fundamental analysis nor insider information enable an investor to obtain returns greater than those that could be obtained by holding random portfolios or individual stocks with the same risk.

Today, many financial economists and investors accept that the presence of the first two scenarios are almost impossible even in high capitalized markets (Campbell et al. [4] and Grossman and Stiglitz [5]); this is why the weak-form version of market efficiency is the most tested criterion in the financial literature. To test the level of market efficiency has been a quite popular topic in financial literature because, if a market is not efficient, this means that future stock prices are somewhat predictable based on past stock price which enable investors to earn excess risk adjusted rates of return.

One of the most interesting works is the one by Markiel and Fama [6], where authors considered that the weak and the semi strong forms of efficiency were strongly supported

by their results. After this work, some researchers have tested whether technical analysis is able to provide abnormal returns to the investors (see, for example, Fama and Blume [7], Fama and French [8], Olson [9], Rosillo et al. [10], Shynkevich [11], Metghalchi et al. [12] or Bobo and Dinica [13]).

Other researchers decided to analyze price adjustments after market events (see, for example, Pettit [14], Asquith and Mullins [15] and Michaely, Thaler and Womack [16], Aharony and Swary [17] and Kalay and Loewenstein [18], among others).

Another part of the financial literature has tested the EMH based on the statistical implication of this hypothesis: that stock returns follow a random walk. Interesting contributions are Lo and MacKinlay [19], Lima and Tabak [20], Fifield and Jetty [21], Charles and Darné [22], Al-Ajmi and Kim [23] or Mlambo and Biekpe [24] between others.

Recent contributions have come from some mathematicians and physicians that have focused their attention on Mandelbrot's critics to the EMH [25]. Mandelbrot proposed that stock prices follow a fractional Brownian motion and not a random walk. One of the implications of this assumption is that stock prices exhibit long memory, which is against the EMH. On this basis, to explore the presence of market memory is an alternative method to test the market efficiency. Relevant contributions are Beben and Orłowski [26], DiMatteo et al. [27], Zunino et al. [28], Cajueiro [29], Kristoufek [30], Ferreira et al. [31], Kristoufek [32] and Dimitrova et al. [33].

This paper goes along a similar line, and it is based on the recent novel approach introduced by Sanchez et al. [34], where the authors analyzed the relationship between market efficiency and a statistical arbitrage technique based on Hurst exponent [35]. We propose to extend the analysis to the 50 largest capitalized companies in 39 so-called advanced and emerging countries to see if a Pairs Trading strategy based on Hurst Exponent, which is a market memory indicator, can obtain a significant profit during different periods.

Our results will show that emerging markets are not efficient while the developed ones are, for most of the period, under study. We will prove that the method used is robust by studying the return of the trades with each pair, considering the estimated Hurst exponent of the pair selection. We will show that, as expected, the lower the Hurst exponent of the pair series, the higher the return of the pair in the Pairs Trading strategy. The paper is structured as follows: Section 2 introduces the Pairs Trading technique based on Hurst exponent. In this section, we present the fundamentals of the Pairs Trading technique as well as the main contributions done by the financial literature. This section also introduces some relevant questions about Hurst Exponent and the Pairs Trading strategy. Section 3 contains the results of the different strategies developed. Finally, Section 4 presents the conclusions.

2. A Pairs Trading Technique Based on Hurst Exponent

2.1. Fundamentals of Pairs Trading

The strategy of statistical arbitrage arose in the 1980s. Since its birth, there have been different studies in this area.

The pioneer in investigating this strategy was Gatev et al. [36] who found statistically significant results using US market values during the period 1962–1997. Gatev et al. [37] carried out the study again extending the period until 2002 and obtaining average annualized higher returns of up to 11%. The authors concluded that these higher returns from this strategy are due to a reward for the application of the Law of One Price.

Elliott et al. [38] used a Gaussian Markov chain model to measure dispersion, while Do et al. [39] employed theoretical pricing methods. The cointegration approach was used by Vidyamurthy [40], Burgess [41], and Haque and Haque [42].

Perlin [43] used a Pairs Trading strategy in the Brazilian market, concluding that it works significantly, pointing out that positive superior returns are significant.

Do and Faff ([44,45]) used the distance method introduced by Gatev et al. during the period 2000–2009 and concluded that the Pairs Trading strategy was still profitable, but the profitability decreases over the time. This decline was attributed to a worsening

of arbitrage risks and an increase in market efficiency. This is the first contribution where transaction costs are considered, showing that, from 2002 onwards, it generated losses.

Bowen et al. [46] developed their study taking intraday values and concluded that this strategy may be affected by transaction costs and speed of execution. They showed that the highest profitability is achieved at the first and last minute. Similar results are obtained by Liu et al. [47], where authors introduced an intraday trading strategy based on a conditional modeling to model spreads between pairs of stocks. The authors found remarkable returns including transaction costs during specific periods.

Huck [48] introduced a forecasting methodology using a combination of Neural Networks techniques and multi-criteria decision-making methods; Xie and Wu [49] proposed an alternative approach using the copula technique that is able to capture the structure of dependence of co-movement between two assets. Göncü and Akyildirim [50] supported the strategy of statistical arbitrage by assuming that the dispersion of two assets follows an Ornstein–Uhlenbeck process around a long-term equilibrium level.

Avellaneda et al. [51] studied the strategy of statistical arbitrage employing US actions. To do this, they used Principal Component Analysis and sectorial ETFs. In both cases, they detected opposite trading signals, considering the waste the returns of the shares and modeling the investment process.

Krauss [52] examined the literature on pairs trading strategy. It did so by dividing it into five groups; firstly, it studied the distance method; secondly, it used the co-integration method, it used the stochastic approach to identify the optimal portfolio trends, and, finally, it selected other approaches with some limitations in the literature.

Rad et al. [53] studied the performance of Pairs Trading based on the distance, cointegration, and copula methods on the entire US equity market from 1962 to 2014 including trading costs. The authors found that all strategies show positive results and mainly during periods of significant volatility.

Ramos-Requena et al. [35] introduced the Hurst exponent as a selection method in Pairs Trading. The authors found that this new methodology gives better results than the classical methodologies such as the distance or the correlation method. In a recent contribution [54], these authors proposed an alternative method to correlation and cointegration called the HP method.

Finally, all of these contributions are focused on the methodology for pairs selection. In a different line, Ramos-Requena et al. [55] introduced different models to calculate the amount of money that must be allocated to each stock. The authors showed these new alternatives perform better than the usual Equal Weight method.

2.2. Notes on Hurst Exponent

The hypothesis that price variations are well-described by means of a fractional Brownian motion was introduced by Mandelbrot [25]. This process is a long memory generalization of the Brownian motion process with a self-similarity exponent (called Hurst exponent) different to 0.5. Thus, when the process is a Brownian motion, the Hurst exponent (H) is equal to 0.5; when it is persistent, H will be greater than 0.5, and, finally, when it is anti-persistent, then H will be less than 0.5.

The Hurst exponent was introduced by Hurst in 1951 [56] to deal with the problem of reservoir control near the Nile River Dam, but, in recent decades, its application has been widely extended in economics in general and in finance in particular (see López-García and Ramos-Requena [57] for a literature and methodological review). There is also some novel applications, like Trinidad-Segovia et al. [58] and Nikolova et al. [59], where it was used to study volatility clusters.

Ramos-Requena et al. [35] used the Hurst exponent as a management tool for statistical arbitrage strategies based on the concept of reversion to the mean.

Since the first method introduced by Hurst [56], the R/S analysis, different methodologies have been proposed. In this paper, we use the Generalized Hurst exponent (GHE) introduced by Barabasi and Vicsek [60].

This algorithm is calculated as follows:

$$K_q(\tau) = \frac{< |X(t+\tau) - X(t)|^q >}{< |X(t)|^q >} \quad (1)$$

where X is the series (in this paper, X will be the pair series as defined in Section 2.3), τ can vary between 1, and τ_{max}, τ_{max} is usually chosen as a quarter of the length of the series, and $< \cdot >$ denotes the sample average over the time window.

Therefore, the GHE is defined on the basis of the behavior on the scale of the statistic given in (1), given by the power law:

$$K_q(\tau) \propto \tau^{qH(q)}. \quad (2)$$

where $H(q)$ is the Hurst exponent, which characterizes the power law scaling.

The GHE is calculated by linear regression after taking logarithms in Equation (2), for different values of τ [27,61].

2.3. Methodology

Our trading methodology is developed as follows:

Firstly, we normalize the stock prices. If we consider shares A and B, and their share prices are P_A and P_B, respectively, the pair series is defined as:

$$log(P_A) - b * log(P_B)$$

where b is a constant, and it is used to normalize the stock prices.

To calculate the value of b, we will use the method described by Ramos-Requena et al. [55], called minimizing distance.

The function $f(b) = \sum_t x_A(t) - bx_B(t)$ will be minimized, looking for the value of b, such that x_A and bx_B have the minimal distance, where $x_A(t) = \log P_A(t) - \log P_A(0)$ and $x_B(t) = \log P_B(t) - \log P_B(0)$.

Now, the pairs will be selected, using the Hurst exponent approach as developed in Section 2.2. Here, we look for pairs such that the Hurst exponent of their pair series is as low as possible.

Finally, the trading strategy will be developed. If s is the pair series, m the average of the series s, and σ the standard deviation of $m - s$ [62], then:

- If $m + 2\sigma > s > m + \sigma$, the pair will be sold at s_0. The position will be closed when $s < m$ or $s > s_0 + \sigma$.
- If $m - 2\sigma < s < m - \sigma$, the pair will be bought at s_0. The position will be closed when $s > m$ or $s < s_0 - \sigma$.

3. Experimental Results

This section shows the main results obtained by applying the Pairs Trading strategy. This will be done by taking the 50 largest capitalized companies in 39 countries. Three sub-periods (From 1 January 2000 to 31 December 2007, the second period is from 1 January 2007 to 31 December 2014 and the last period is from 1 January 2014 to 10 April 2020) and different portfolios (of 30, 40, and 50 pairs) are also considered. In this study, we considered transaction costs of 0.01%. Table A1 includes the classification of the countries studied between emerging and advanced.

Tables A2–A4 show the results obtained for the period 2000–2007 for the portfolios composed of 30, 40, and 50 pairs. It can be seen that the highest profits after transaction costs are obtained for emerging countries, especially in South Africa (71.21%, 65.84%, and 65.68%), Japan (32.61%, 28.99%, and 28.87%) and Israel (28.99%, 23.54%, 25.76%). Japan is not an emerging country, but the long-lasting negative bias in its stock market has caused many investors to forget about it. Regarding Israel, the country cannot be considered an emerging country, but its stock market posseses a very low capitalization, even below

emerging countries such as South Africa or Indonesia. For the same period, developed markets, especially the United States, show significantly negative returns after transaction costs (−12.87%, −11.61%, and −10.05%) as well as other European countries such as Norway, Russia, and Portugal.

If we look at the Sharpe ratio values, we can see that a value above 1 is obtained for countries such as South Africa (1.98, 1.6 and 1.45), Lebanon (1.11), Namibia (1.1), Israel, and Japan. Against these values, we find Norway with a negative Sharpe ratio (−0.74), and the United States (−0.35, −0.31, and −0.26).

Tables A5–A7 show results obtained for the period 2007–2014. During this period, we are faced with the subprime crisis, which led to a large drop in the values of the main world stock market indexes as a consequence of the volatility increase. Despite this, it can be seen that the greatest benefits are obtained for emerging countries such as Israel (54.25%, 51.59% and 47.32%) and South Africa (33.80%, 32.73% and 29.88%). In this ranking, we find some European countries with significant benefits, such as Portugal (36.82%, 24.75% and 10.91%), Netherlands (26.26%, 31.27% and 27.94%), and Greece (19.85%, 19.88% and 19.89%). It is not like in the previous period, when it is clear that the developed countries are at a disadvantage in this strategy; for example, the United States is making positive gains in this period (1.30%, 4.13%, and 4.66%). The positive results could be attributed to the high volatility and correlation during financial crisis. These results are congruent with previous finding of Ramos Requena et al. [35] and Lopez García et al. [63].

The Sharpe ratio will indicate that the best investment options will be in countries such as Lebanon (2.53), Israel (1.44, 1.35, and 1.23), and South Africa (1.31, 1.28, and 1.08).

Finally, Tables A8–A10 present the main results obtained for the period 2014–2020 for the portfolios composed of 30, 40, and 50 pairs. In this period, the highest profitability after transaction costs is for Greece (59.71%, 47.70%, 42.39%). Two other emerging countries (Colombia and South Africa) are among the most profitable to apply the Pairs Trading strategy during this period. France, Spain, or Dubai are the least profitable to invest in, with negative returns during this period.

If we look at the risk, the values of the Sharpe ratio indicate that Lebanon (3.85) and Colombia (2.11, 1.9 and 1.84) are the most appropriate countries. However, according to this ratio, it is not advisable to invest in countries such as Mexico or Dubai with a negative Sharpe ratio value.

One of the main features of Pairs Trading's strategy is its market neutrality. As presented by Ramos-Requena et al. [35], to comply with this property, investors must consider pairs with a value of the Hurst exponent (H) below 0.5.

Figures 1–3 show the relationship between the H value and the average return obtained for each of the periods studied (2000–07, 2007–14, 2014–20), in which all the countries considered in this paper are included. It can be seen that, as the value of H decreases, the average profitability increases for the three periods studied, it being significant that pairs with a value of 0.5 give negative average profitability. Therefore, those countries that select their pairs with an H close to 0 get a higher average return.

It is also important to note that the selection of the pairs based on the Hurst exponent is refreshed each six months with data from the previous year; therefore, the selected pairs are used for the next six months, without refreshing the calculation of the Hurst exponent. Consequently, these results are a kind of robustness check of the pair selection method, since we can see that the pairs with the lowest Hurst exponent in the past are the one for which the mean reversion strategy best work in the future.

Figure 4 gives the relationship between the value of H and the average return for the period 2000–2007, for Brazil, Colombia, Israel, and Saudi Arabia. We can see that, in all cases, if only pairs with small values of H are selected, they would obtain their highest returns. The case of Brazil (a) is significant, as pairs with values between 0.1 and 0.2 would obtain an average return of around 1%. In the case of Brazil (a), Colombia (b), and Saudi Arabia (d), when the value of H of a pair is between 0.4 and 0.5, the strategy get negative returns.

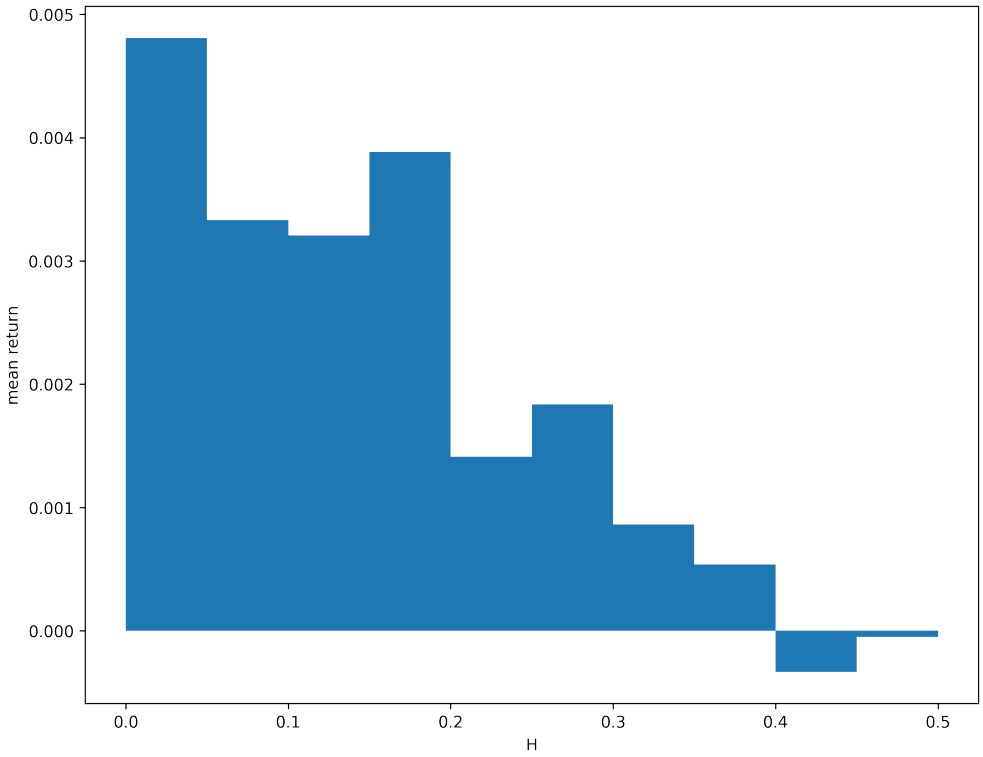


Figure 1. Comparison between the value of H and the mean return of the portfolios for the period 2000–2007.

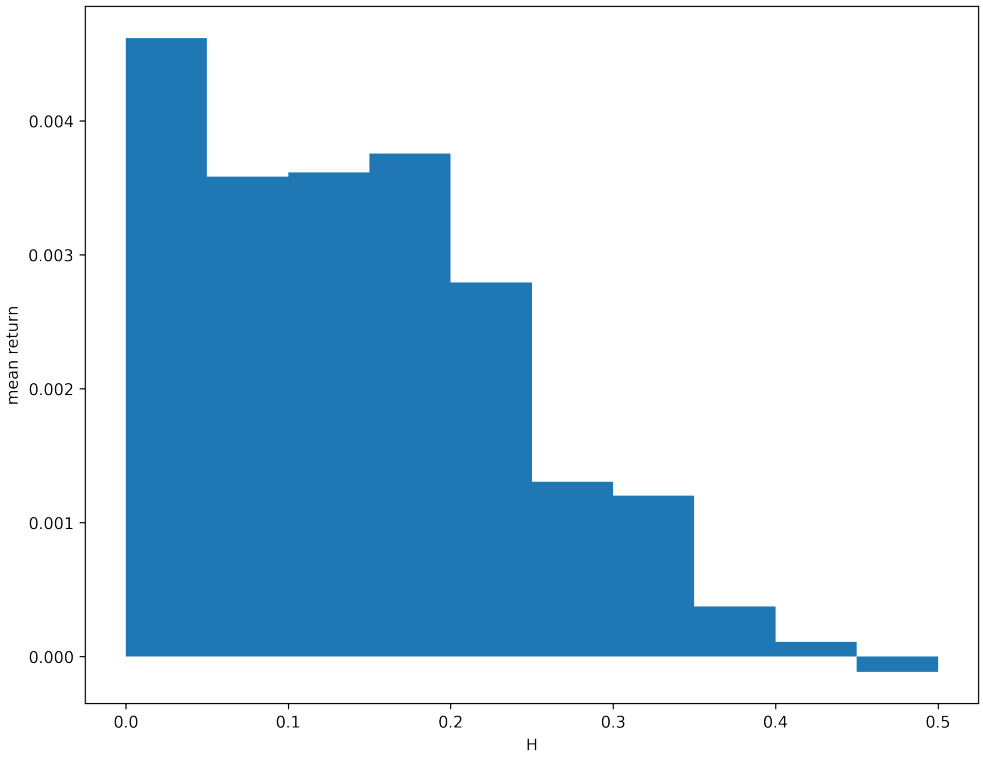


Figure 2. Comparison between the value of H and the mean return of the portfolios for the period 2007–2014.

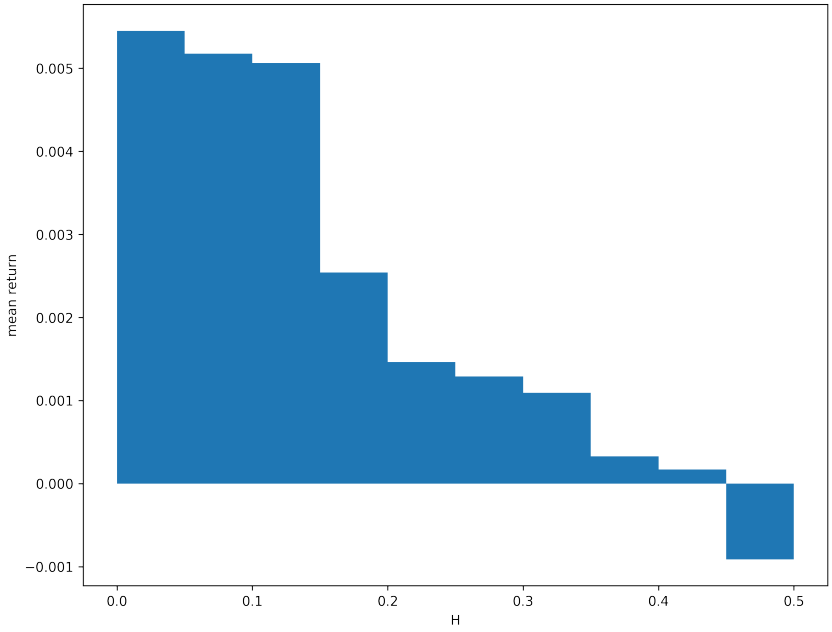
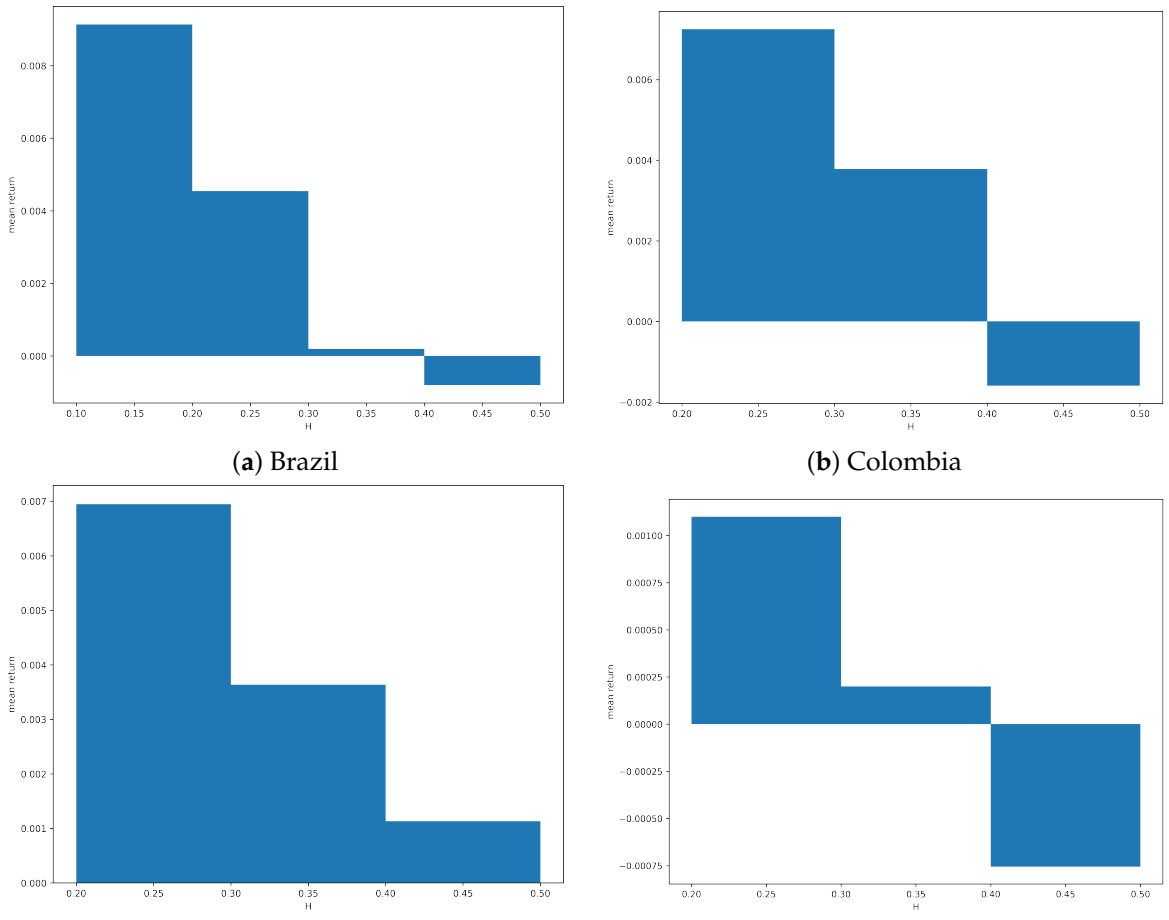


Figure 3. Comparison between the value of H and the mean return of the portfolios for the period 2014–2020.

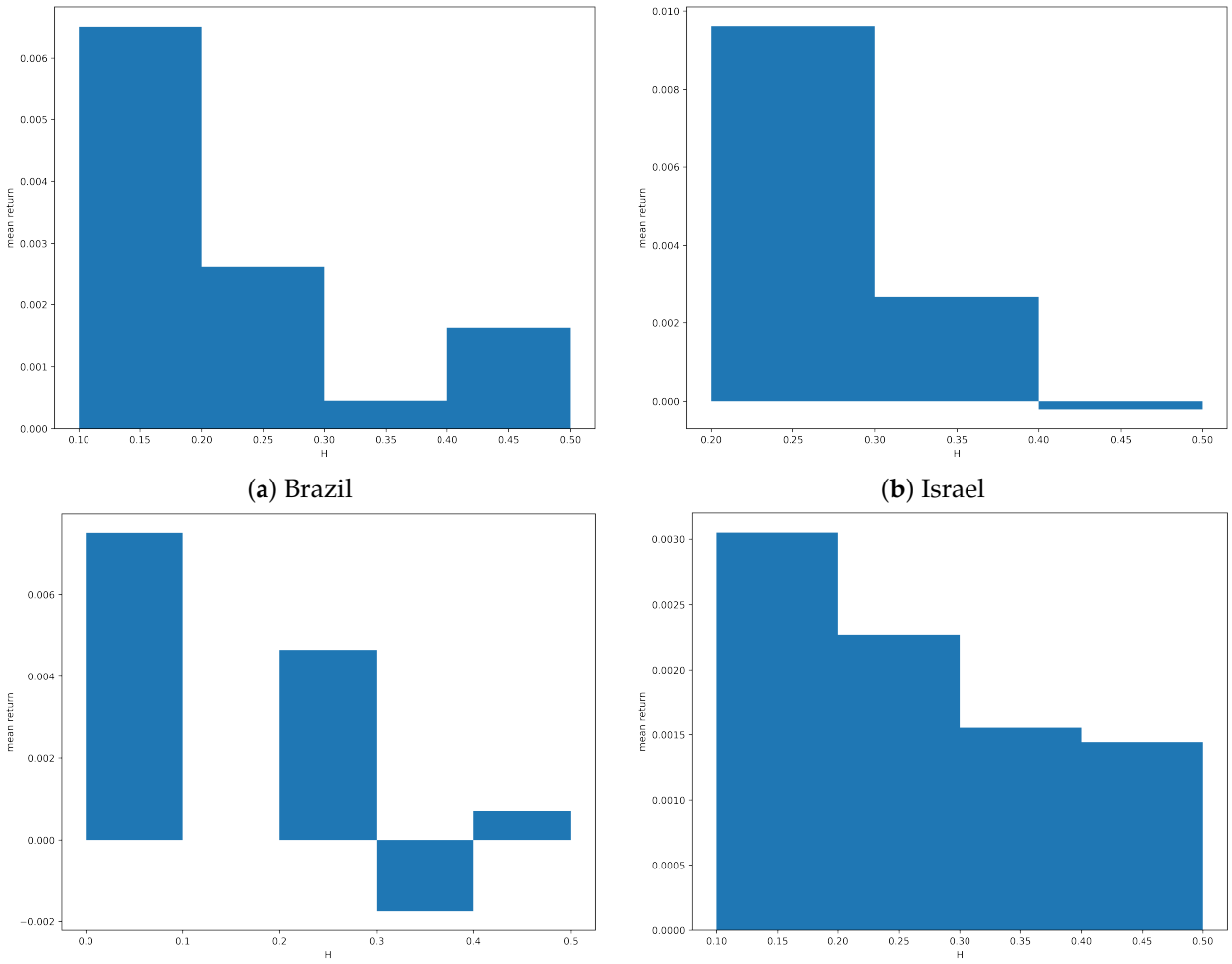


(**a**) Brazil (**b**) Colombia

(**c**) Israel (**d**) Saudi Arabia

Figure 4. Comparison between the value of H and the mean return between countries for the period 2000–2007.

Figure 5 shows the comparison between average returns and the value of H, for the countries Brazil (a), Israel (b), Mexico (c), and South Africa (d) for the period 2007–2014. As in the previous period, as the value of H decreases, the average return increases. It is significant in the case of Brazil and South Africa that, for all the values of H, it obtains a positive profitability.



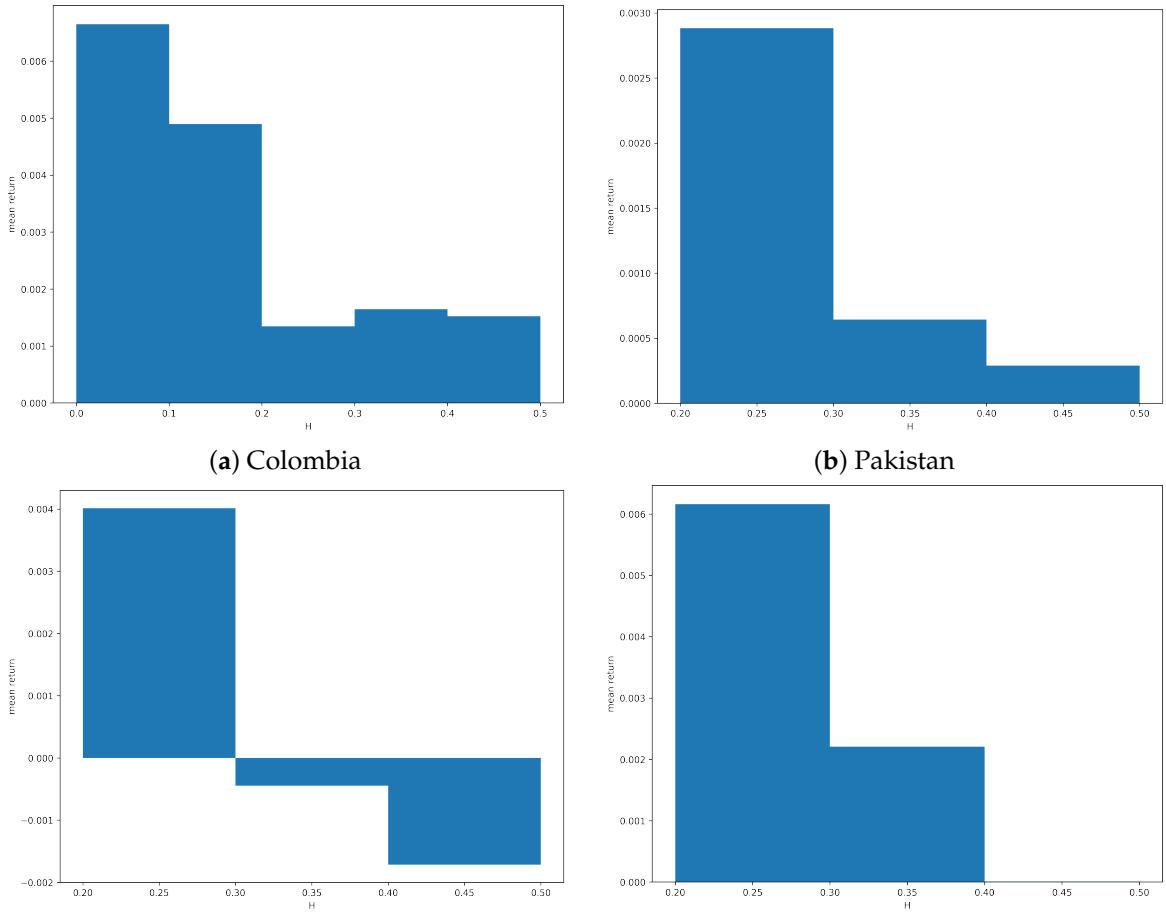
(**a**) Brazil (**b**) Israel

(**c**) Mexico (**d**) South Africa

Figure 5. Comparison between the value of H and the mean return between countries for the period 2007–2014.

Finally, Figure 6 shows for Colombia (a), Pakistan (b), Thailand (c), and Hong Kong (d) the average profitability vs. the H value of the pair series for the period 2014–2020. As we have been seeing, as the value of the Hurst exponent (H) decreases, the average return increases. If we observe what happens in the case of Thailand, we would only obtain a positive average return if the value if H is between 0.2 and 0.3.

Therefore, we can also conclude that it is interesting to form the pairs of shares that make up the portfolios with the lowest possible value of the Hurst exponent of the pair series, as this would mean an increase in the profitability of the strategy.



(**a**) Colombia (**b**) Pakistan

(**c**) Thailand (**d**) Hong Kong

Figure 6. Comparison between the value of H and the mean return between countries for the period 2014–2020.

4. Conclusions

According with the EMH, arbitrage strategies cannot over perform random portfolios with the same class of risk. In this paper, we look at market efficiency by comparing the performance of an arbitrage technique based on the Hurst exponent in emerging and developed markets.

We found that our statistical arbitrage strategy is consistent in emerging markets and it can obtain a significant profit during the period considered. This is the case of South Africa, Colombia, or Lebanon where the strategy obtains important results. However, in the case of the developed markets, only during high volatility periods, such as after the financial crisis, does the strategy performance properly. After the financial crisis, there are several markets where the Pairs Trading give significant results. The cases of Portugal and Greece are interesting, which are countries seriously affected by the financial crisis in Europe. These results are consistent with the previous findings of Ramos-Requena [35].

These results are also consistent with previous works of DiMatteo et al. [27], Zunino et al. [28], and Kristoufek [30], and they are a clear proof of the degree of inefficiency of emerging markets. Again, we consider that the performance of arbitrage methods in developed markets during specific periods could be considered a proof of the Adaptative Markets hypothesis [64].

On the other hand, we have studied the degree of incidence that the value of the Hurst exponent of the pair series has on the strategy performance, as proposed by Ramos-Requena et al. [35]. We have proved that the main characteristics of the Pairs Trading strategy, the mean reversion, are achieved with a low H. Another interesting result is that, when the value of H is around 0.1 or 0.2, the performance of the strategy is greater.

To conclude, we would like to remark that the selection methodology shows that the strategy is robust because the pairs with the lowest Hurst exponent in the past are the one for which the mean reversion strategy best works in the future.

Next, we highlight some possible limitations of this study (we thank the anonymous referees for pointing these out). The main issue is that the inefficiency of some markets may be due to various market frictions. For example, short selling banning on some countries is not taken into consideration for the difficulties to short sell some stocks in some countries. We have considered transaction fees, but we have not considered any cost or revenue incurring by the short selling positions, as well as any revenue for interest on cash not used. We have used daily closing prices to open or close positions. Though we have considered the most capitalized stocks in each country, it is still possible that the scale of the strategy may impact those prices. Therefore, the real implementation of this strategy may suffer some difficulties and the profitability of the strategy may be lower due to market frictions. However, we are mainly interested in the inefficiency of the markets, and it is beyond the scope of this paper (though very interesting) to determine the origin of this inefficiency.

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Informed Consent Statement: Not applicable.

Data Availability Statement: Publicly available datasets were analyzed in this study. This data can be found here: Investing.com.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Classification of Emerging and Advanced Countries

Table A1. Classification of emerging and advanced countries (following MSCI).

Country	Classification
Argentina	Emerging
Bahrain	Emerging
Belgium	Advanced
Brazil	Emerging
Colombia	Emerging
Czech Republic	Emerging
Denmark	Advanced
Dubai	Emerging
Finland	Advanced
France	Advanced
Greece	Emerging
Hong Kong	Advanced

Table A1. *Cont.*

Country	Classification
India	Emerging
Israel	Advanced
Italy	Advanced
Japan	Advanced
Jordan	Emerging
Kuwait	Emerging
Lebanon	Emerging
Mauritius	Emerging
Mexico	Emerging
Morocco	Emerging
Namibia	Emerging
Netherlands	Advanced
Norway	Advanced
Oman	Emerging
Pakistan	Emerging
Palestine	Emerging
Poland	Emerging
Portugal	Advanced
Romania	Emerging
Russia	Emerging
Saudi Arabia	Emerging
South Africa	Emerging
Spain	Advanced
Sweden	Advanced
Switzerland	Advanced
Thailand	Emerging
United States	Advanced

Appendix B. Results

Below is a comparison between the main results obtained.

Appendix B.1. Period 2000–2007

Table A2. Results obtained for the period 2000–2007 (30 Pairs), where N is the number of pairs; AAV Average annualized return; and Profit is the profitability for the full period with transaction costs.

Country	N	Operations	AAV	Sharpe Ratio	Profits
Argentina	30	1666	0.80%	0.31	4.14%
Bahrain	30	6	−0.10%	−0.53	−0.20%
Belgium	30	3617	1.50%	0.57	10.99%
Brazil	30	3127	1.10%	0.26	7.06%
Colombia	30	1612	−0.80%	−0.25	−4.34%
Czech Republic	30	1224	−0.40%	−0.26	−3.31%
Denmark	30	2710	−0.30%	−0.11	−2.60%
Dubai	30	509	−0.50%	−0.30	−2.67%
Finland	30	2591	2.00%	0.72	14.64%
France	30	3284	1.50%	0.54	11.71%
Greece	30	2644	0.20%	0.05	0.32%
Hong Kong	30	63	0.20%	0.78	1.28%
India	30	3116	0.80%	0.22	5.46%
Israel	30	3628	3.60%	0.96	28.99%
Italy	30	3249	1.80%	0.68	13.22%
Japan	30	2983	4.00%	1.04	32.61%
Jordan	30	1980	0.50%	0.16	2.14%

Table A2. *Cont.*

Country	N	Operations	AAV	Sharpe Ratio	Profits
Kuwait	30	2452	0.20%	0.07	0.58%
Lebanon	30	171	0.60%	1.11	2.64%
Mauritius	30	1855	−0.50%	−0.23	−3.92%
Mexico	30	2362	1.40%	0.48	7.91%
Morocco	30	882	0.60%	0.35	3.91%
Namibia	30	1590	3.00%	1.06	12.07%
Netherlands	30	3322	3.20%	0.80	27.59%
Norway	30	679	−1.10%	−0.74	−8.63%
Oman	30	740	−0.10%	−0.08	−0.85%
Pakistan	30	2116	1.90%	0.51	14.19%
Palestine	30	264	0.50%	0.42	2.51%
Poland	30	4	0.90%	1.37	0.20%
Portugal	30	2772	−0.50%	−0.16	−4.72%
Romania	30	34	−0.30%	−0.71	−1.21%
Russia	30	2887	−0.90%	−0.27	−7.86%
Saudi Arabia	30	2530	0.30%	0.12	1.86%
South Africa	30	4682	6.90%	1.45	65.84%
Spain	30	304	0.00%	−0.07	−0.40%
Sweden	30	4057	0.00%	−0.01	−1.55%
Switzerland	30	3552	0.60%	0.19	3.32%
Thailand	30	2779	0.80%	0.21	4.77%
United States	30	2736	−1.50%	−0.26	−11.61%

Table A3. Results obtained for the period 2000–2007 (40 Pairs), where N is the number of pairs; AAV Average annualized return; and Profit is the profitability for the full period with transaction costs.

Country	N	Operations	AAV	Sharpe Ratio	Profits
Argentina	40	1776	0.50%	0.27	2.66%
Bahrain	40	6	−0.10%	−0.53	−0.20%
Belgium	40	4714	1.40%	0.61	10.12%
Brazil	40	3923	0.40%	0.12	2.32%
Colombia	40	1851	−0.50%	−0.18	−2.76%
Czech Republic	40	1224	−0.30%	−0.26	−2.51%
Denmark	40	3477	−0.20%	−0.10	−2.27%
Dubai	40	509	−0.40%	−0.30	−2.03%
Finland	40	3393	2.10%	0.78	15.15%
France	40	4158	1.70%	0.67	12.96%
Greece	40	3499	−0.20%	−0.04	−1.87%
Hong Kong	40	63	0.10%	0.78	0.98%
India	40	4084	0.90%	0.25	6.18%
Israel	40	4658	3.00%	0.91	23.54%
Italy	40	4124	1.80%	0.77	13.47%
Japan	40	3795	3.60%	1.02	29.45%
Jordan	40	2539	−0.10%	−0.03	−1.13%
Kuwait	40	3204	0.20%	0.09	1.00%
Lebanon	40	171	0.40%	1.11	2.06%
Mauritius	40	2335	−0.50%	−0.28	−4.08%
Mexico	40	3032	0.50%	0.19	2.24%
Morocco	40	1018	0.40%	0.32	3.15%
Namibia	40	1706	2.50%	1.10	10.17%
Netherlands	40	4486	3.40%	0.95	28.78%
Norway	40	679	−0.80%	−0.74	−6.47%
Oman	40	809	0.10%	0.07	0.20%
Pakistan	40	2620	2.00%	0.65	15.54%

Table A3. *Cont.*

Country	N	Operations	AAV	Sharpe Ratio	Profits
Palestine	40	264	0.40%	0.42	1.83%
Poland	40	4	0.70%	1.37	0.10%
Portugal	40	3710	−0.30%	−0.11	−3.43%
Romania	40	34	−0.20%	−0.71	−0.91%
Russia	40	3503	−1.00%	−0.33	−8.58%
Saudi Arabia	40	3320	0.00%	0.00	−0.73%
South Africa	40	6073	6.90%	1.60	65.68%
Spain	40	304	0.00%	−0.07	−0.28%
Sweden	40	5049	−0.40%	−0.16	−4.26%
Switzerland	40	4734	0.30%	0.12	1.32%
Thailand	40	3589	0.00%	0.00	−0.90%
United States	40	3461	−1.70%	−0.35	−12.87%

Table A4. Results obtained for the period 2000–2007 (50 Pairs), where N is the number of pairs; AAV Average annualized return; and Profit is the profitability for the full period with transaction costs.

Country	N	Operations	AAV	Sharpe Ratio	Profits
Argentina	50	1776	0.40%	0.27	2.14%
Bahrain	50	6	−0.10%	−0.53	−0.10%
Belgium	50	5735	1.40%	0.66	10.25%
Brazil	50	4747	0.90%	0.24	5.65%
Colombia	50	2080	−0.50%	−0.20	−2.72%
Czech Republic	50	1224	−0.20%	−0.26	−2.04%
Denmark	50	4307	−0.20%	−0.09	−2.06%
Dubai	50	509	−0.30%	−0.30	−1.60%
Finland	50	4213	1.90%	0.76	13.96%
France	50	4987	1.80%	0.77	13.80%
Greece	50	4315	−0.40%	−0.14	−3.66%
Hong Kong	50	63	0.10%	0.78	0.79%
India	50	4870	0.90%	0.28	6.23%
Israel	50	5710	3.30%	1.09	25.76%
Italy	50	4973	1.60%	0.75	12.21%
Japan	50	4637	3.60%	1.08	28.87%
Jordan	50	3071	0.20%	0.08	0.59%
Kuwait	50	3904	0.20%	0.09	0.82%
Lebanon	50	171	0.30%	1.11	1.57%
Mauritius	50	2782	−0.50%	−0.34	−4.16%
Mexico	50	3573	0.50%	0.23	2.59%
Morocco	50	1144	0.40%	0.28	2.47%
Namibia	50	1706	2.00%	1.10	8.16%
Netherlands	50	5586	3.10%	0.96	26.08%
Norway	50	679	−0.70%	−0.74	−5.24%
Oman	50	828	0.00%	0.03	−0.07%
Pakistan	50	2989	1.90%	0.69	14.50%
Palestine	50	264	0.30%	0.42	1.55%
Poland	50	4	0.50%	1.37	0.10%
Portugal	50	4643	−0.60%	−0.23	−5.43%
Romania	50	34	−0.20%	−0.71	−0.71%
Russia	50	4114	−0.60%	−0.21	−5.52%
Saudi Arabia	50	4075	0.00%	−0.01	−1.12%
South Africa	50	7458	7.40%	1.98	71.21%
Spain	50	304	0.00%	−0.07	−0.26%
Sweden	50	5989	−0.50%	−0.21	−4.90%
Switzerland	50	5847	0.50%	0.19	2.63%
Thailand	50	4179	0.10%	0.05	0.16%
United States	50	4180	−1.30%	−0.31	−10.04%

Appendix B.2. Period 2007–2014

Table A5. Results obtained for the period 2007–2014 (30 Pairs), where N is the number of pairs; AAV Average annualized return; and Profit is the profitability for the full period with transaction costs.

Country	N	Operations	AAV	Sharpe Ratio	Profits
Argentina	30	2877	0.10%	0.03	−0.06%
Bahrain	30	186	0.90%	1.04	4.94%
Belgium	30	4076	2.90%	0.92	23.64%
Brazil	30	3756	2.00%	0.53	14.55%
Colombia	30	3844	1.00%	0.41	6.62%
Czech Republic	30	506	1.30%	0.52	9.93%
Denmark	30	3024	1.70%	0.40	12.69%
Dubai	30	2836	−2.00%	−0.56	−15.25%
Finland	30	4103	2.00%	0.48	15.03%
France	30	3470	1.50%	0.48	10.94%
Greece	30	3739	2.50%	0.48	19.85%
Hong Kong	30	1425	1.70%	0.55	5.72%
India	30	4051	3.20%	0.51	25.75%
Israel	30	3735	6.10%	1.23	54.25%
Italy	30	3817	1.80%	0.52	13.83%
Japan	30	3010	3.70%	0.84	30.30%
Jordan	30	2359	0.60%	0.15	3.41%
Kuwait	30	2862	−0.10%	−0.03	−1.85%
Lebanon	30	318	0.70%	2.53	5.39%
Mauritius	30	1153	0.40%	0.28	2.72%
Mexico	30	2535	1.00%	0.34	7.35%
Morocco	30	2635	0.60%	0.23	3.82%
Namibia	30	2537	1.60%	0.50	11.95%
Netherlands	30	3415	3.10%	0.71	26.26%
Norway	30	2091	−0.90%	−0.41	−7.50%
Oman	30	1816	−1.30%	−0.57	−10.11%
Pakistan	30	2805	0.80%	0.16	5.06%
Palestine	30	492	−0.60%	−0.69	−4.56%
Poland	30	1886	1.80%	0.88	13.37%
Portugal	30	3836	4.20%	0.73	36.82%
Romania	30	723	2.50%	0.83	19.76%
Russia	30	3081	0.70%	0.15	4.27%
Saudi Arabia	30	3508	0.50%	0.14	2.33%
South Africa	30	4557	3.60%	1.08	29.88%
Spain	30	2087	0.20%	0.07	0.80%
Sweden	30	4072	2.50%	0.55	19.14%
Switzerland	30	4033	2.90%	0.79	22.86%
Thailand	30	3217	−1.10%	−0.27	−8.67%
United States	30	2996	0.30%	0.11	1.30%

Table A6. Results obtained for the period 2007–2014 (40 Pairs), where N is the number of pairs; AAV Average annualized return; and Profit is the profitability for the full period with transaction costs.

Country	N	Operations	AAV	Sharpe Ratio	Profits
Argentina	40	3660	0.20%	0.05	0.48%
Bahrain	40	186	0.70%	1.04	3.65%
Belgium	40	5243	2.50%	0.87	20.29%
Brazil	40	4796	2.20%	0.67	16.60%
Colombia	40	4846	0.70%	0.32	4.19%
Czech Republic	40	506	1.00%	0.52	7.37%
Denmark	40	4008	0.90%	0.23	6.20%
Dubai	40	3524	−1.40%	−0.43	−11.28%
Finland	40	5308	1.80%	0.46	13.47%

Table A6. *Cont.*

Country	N	Operations	AAV	Sharpe Ratio	Profits
France	40	4551	1.20%	0.42	8.56%
Greece	40	4873	2.50%	0.53	19.88%
Hong Kong	40	1831	1.00%	0.35	3.34%
India	40	5287	3.60%	0.63	29.78%
Israel	40	4858	5.90%	1.35	51.59%
Italy	40	4841	2.30%	0.77	18.49%
Japan	40	3919	3.00%	0.72	23.12%
Jordan	40	3023	0.70%	0.18	4.14%
Kuwait	40	3839	−0.10%	−0.02	−1.36%
Lebanon	40	318	0.50%	2.53	4.02%
Mauritius	40	1317	0.30%	0.20	1.67%
Mexico	40	3283	0.70%	0.25	4.48%
Morocco	40	3307	0.60%	0.27	3.97%
Namibia	40	3004	1.50%	0.57	10.95%
Netherlands	40	4517	3.60%	0.91	31.27%
Norway	40	2536	−0.80%	−0.40	−6.43%
Oman	40	2395	−1.10%	−0.52	−8.50%
Pakistan	40	3607	1.40%	0.31	9.70%
Palestine	40	492	−0.50%	−0.69	−3.42%
Poland	40	2435	1.60%	0.82	11.59%
Portugal	40	4981	3.00%	0.62	24.75%
Romania	40	889	2.10%	0.90	16.88%
Russia	40	3996	1.20%	0.30	8.70%
Saudi Arabia	40	4594	0.80%	0.27	4.85%
South Africa	40	6004	4.00%	1.28	33.80%
Spain	40	2678	0.50%	0.20	3.33%
Sweden	40	5126	2.00%	0.49	15.12%
Switzerland	40	5175	1.70%	0.55	12.71%
Thailand	40	4267	−0.90%	−0.27	−7.87%
United States	40	3882	0.70%	0.28	4.13%

Table A7. Results obtained for the period 2007–2014 (50 Pairs), where N is the number of pairs; AAV Average annualized return; and Profit is the profitability for the full period with transaction costs.

Country	N	Operations	AAV	Sharpe Ratio	Profits
Argentina	50	4279	−0.20%	−0.06	−2.16%
Bahrain	50	186	0.50%	1.04	2.96%
Belgium	50	6496	3.10%	1.14	25.60%
Brazil	50	5854	2.40%	0.79	18.43%
Colombia	50	5762	0.70%	0.34	4.05%
Czech Republic	50	506	0.80%	0.52	5.90%
Denmark	50	4884	0.90%	0.25	6.32%
Dubai	50	4144	−1.20%	−0.40	−10.03%
Finland	50	6471	1.80%	0.51	13.51%
France	50	5527	1.30%	0.49	9.89%
Greece	50	6049	2.50%	0.57	19.89%
Hong Kong	50	2218	1.10%	0.41	3.76%
India	50	6529	3.20%	0.60	25.79%
Israel	50	5917	5.50%	1.44	47.32%
Italy	50	5987	2.80%	0.99	23.10%
Japan	50	4813	2.50%	0.64	18.94%
Jordan	50	3703	0.60%	0.22	4.06%
Kuwait	50	4698	0.60%	0.23	4.16%
Lebanon	50	318	0.40%	2.53	3.14%
Mauritius	50	1493	0.20%	0.14	1.10%
Mexico	50	3921	0.60%	0.23	3.72%
Morocco	50	3965	0.40%	0.20	2.31%

Table A7. *Cont.*

Country	N	Operations	AAV	Sharpe Ratio	Profits
Namibia	50	3395	1.30%	0.59	9.62%
Netherlands	50	5798	3.30%	0.92	27.94%
Norway	50	2941	−0.80%	−0.48	−6.59%
Oman	50	2805	−1.00%	−0.49	−7.46%
Pakistan	50	4395	1.40%	0.37	9.92%
Palestine	50	492	−0.40%	−0.69	−2.80%
Poland	50	2935	1.50%	0.84	10.91%
Portugal	50	6108	3.00%	0.70	24.88%
Romania	50	1045	1.80%	0.88	14.09%
Russia	50	4998	1.20%	0.33	8.40%
Saudi Arabia	50	5611	0.90%	0.34	6.08%
South Africa	50	7346	3.90%	1.31	32.73%
Spain	50	3100	0.30%	0.15	1.98%
Sweden	50	6263	2.30%	0.62	17.45%
Switzerland	50	6294	2.00%	0.73	15.54%
Thailand	50	5249	−1.40%	−0.45	−11.05%
United States	50	4723	0.70%	0.32	4.66%

Appendix B.3. Period 2014–2020

Table A8. Results obtained for the period 2014–2020 (30 Pairs), where N is the number of pairs; AAV Average annualized return; and Profit is the profitability for the full period with transaction costs.

Country	N	Operations	AAV	Sharpe Ratio	Profits
Argentina	30	2514	0.00%	0.00	−0.94%
Bahrain	30	5	0.00%	0.16	0.00%
Belgium	30	3048	3.90%	1.82	24.98%
Brazil	30	2375	2.40%	0.70	13.61%
Colombia	30	3543	5.00%	2.11	31.02%
Czech Republic	30	1009	−0.70%	−0.48	−4.44%
Denmark	30	2089	1.30%	0.56	7.10%
Dubai	30	2307	−1.30%	−0.35	−7.87%
Finland	30	3001	0.90%	0.30	4.30%
France	30	2411	−0.60%	−0.31	−4.20%
Greece	30	2978	8.60%	1.35	59.71%
Hong Kong	30	1997	2.20%	0.57	11.43%
India	30	2760	2.50%	0.47	14.38%
Israel	30	2590	1.40%	0.71	7.64%
Italy	30	2687	1.40%	0.55	7.60%
Japan	30	2108	1.90%	0.60	10.60%
Jordan	30	1682	−0.30%	−0.17	−2.46%
Kuwait	30	2834	2.70%	0.85	15.36%
Lebanon	30	182	1.30%	3.85	7.04%
Mauritius	30	233	0.00%	0.08	0.12%
Mexico	30	1808	−1.40%	−0.67	−8.90%
Morocco	30	1606	0.20%	0.12	0.76%
Namibia	30	2260	2.00%	0.71	11.55%
Netherlands	30	2467	1.70%	0.59	9.58%
Norway	30	2381	0.80%	0.29	4.41%
Oman	30	1005	−0.20%	−0.12	−1.44%
Pakistan	30	2149	1.00%	0.25	5.28%
Palestine	30	358	0.00%	0.04	−0.02%
Poland	30	2804	2.00%	0.65	11.47%
Portugal	30	2243	0.00%	0.01	−0.55%
Romania	30	2036	0.50%	0.15	2.22%
Russia	30	2095	0.00%	−0.01	−0.90%
Saudi Arabia	30	2780	2.60%	0.82	14.77%

Table A8. *Cont.*

Country	N	Operations	AAV	Sharpe Ratio	Profits
South Africa	30	3036	3.90%	1.27	23.79%
Spain	30	2321	−0.80%	−0.28	−5.37%
Sweden	30	2653	2.60%	1.05	15.82%
Switzerland	30	2259	0.80%	0.32	4.35%
Thailand	30	1869	0.00%	0.01	−0.52%
United States	30	2090	0.80%	0.41	4.20%

Table A9. Results obtained for the period 2014–2020 (40 Pairs), where N is the number of pairs; AAV Average annualized return; and Profit is the profitability for the full period with transaction costs.

Country	N	Operations	AAV	Sharpe Ratio	Profits
Argentina	40	3177	−0.40%	−0.10	−3.19%
Bahrain	40	5	0.00%	0.16	0.00%
Belgium	40	3860	3.70%	1.88	23.03%
Brazil	40	3062	1.70%	0.56	9.63%
Colombia	40	4505	4.00%	1.84	24.47%
Czech Republic	40	1087	−0.60%	−0.48	−3.47%
Denmark	40	2634	1.00%	0.49	5.64%
Dubai	40	3107	−1.60%	−0.48	−9.68%
Finland	40	3774	0.30%	0.11	0.76%
France	40	3017	−0.10%	−0.04	−1.15%
Greece	40	4008	7.10%	1.28	47.70%
Hong Kong	40	2593	1.70%	0.46	8.65%
India	40	3436	2.40%	0.51	13.84%
Israel	40	3276	1.30%	0.71	6.88%
Italy	40	3441	1.20%	0.51	6.44%
Japan	40	2677	2.30%	0.83	13.63%
Jordan	40	2276	−0.20%	−0.14	−1.97%
Kuwait	40	3753	3.20%	1.14	18.86%
Lebanon	40	182	0.90%	3.85	5.15%
Mauritius	40	233	0.00%	0.08	0.04%
Mexico	40	2230	−1.10%	−0.60	−7.16%
Morocco	40	2078	−0.10%	−0.06	−1.12%
Namibia	40	2847	2.00%	0.74	11.39%
Netherlands	40	3245	1.20%	0.51	6.79%
Norway	40	3031	0.40%	0.16	1.74%
Oman	40	1088	−0.10%	−0.05	−0.67%
Pakistan	40	2851	0.90%	0.27	4.89%
Palestine	40	358	0.00%	0.04	0.01%
Poland	40	3669	1.50%	0.51	7.78%
Portugal	40	2961	0.30%	0.09	1.06%
Romania	40	2664	0.10%	0.03	−0.27%
Russia	40	2747	0.30%	0.09	1.11%
Saudi Arabia	40	3571	2.40%	0.84	13.51%
South Africa	40	3818	3.40%	1.18	20.05%
Spain	40	2901	−0.70%	−0.30	−5.03%
Sweden	40	3239	2.10%	0.98	12.69%
Switzerland	40	2878	1.10%	0.48	6.08%
Thailand	40	2525	−0.70%	−0.32	−4.53%
United States	40	2643	0.90%	0.51	4.64%

Table A10. Results obtained for the period 2014–2020 (50 Pairs), where N is the number of pairs; AAV Average annualized return; and Profit is the profitability for the full period with transaction costs.

Country	N	Operations	AAV	Sharpe Ratio	Profits
Argentina	50	3799	−1.40%	−0.38	−8.56%
Bahrain	50	5	0.00%	0.16	0.00%
Belgium	50	4687	3.30%	1.83	20.36%
Brazil	50	3817	1.20%	0.43	6.64%
Colombia	50	5354	3.80%	1.90	22.83%
Czech Republic	50	1112	−0.40%	−0.47	−2.82%
Denmark	50	3128	1.00%	0.48	5.27%
Dubai	50	3821	−1.70%	−0.57	−10.36%
Finland	50	4485	0.40%	0.15	1.40%
France	50	3692	−0.20%	−0.12	−1.84%
Greece	50	5026	6.50%	1.28	42.39%
Hong Kong	50	3221	1.90%	0.48	9.66%
India	50	4085	2.00%	0.48	11.38%
Israel	50	3962	1.50%	0.89	8.21%
Italy	50	4296	0.90%	0.40	4.64%
Japan	50	3224	2.30%	0.85	13.46%
Jordan	50	2757	0.20%	0.12	0.55%
Kuwait	50	4597	3.30%	1.29	19.38%
Lebanon	50	182	0.70%	3.85	4.16%
Mauritius	50	233	0.00%	0.08	0.05%
Mexico	50	2731	−0.90%	−0.54	−6.05%
Morocco	50	2496	0.20%	0.15	0.90%
Namibia	50	3386	1.70%	0.72	9.72%
Netherlands	50	3871	1.40%	0.65	7.73%
Norway	50	3640	0.50%	0.23	2.47%
Oman	50	1172	0.00%	0.02	−0.13%
Pakistan	50	3583	1.80%	0.55	9.88%
Palestine	50	358	0.00%	0.04	0.03%
Poland	50	4355	1.30%	0.50	6.83%
Portugal	50	3636	0.30%	0.08	0.87%
Romania	50	3263	−0.10%	−0.04	−1.15%
Russia	50	3452	−0.10%	−0.04	−1.29%
Saudi Arabia	50	4358	1.90%	0.75	10.83%
South Africa	50	4587	2.50%	0.90	14.38%
Spain	50	3468	−0.50%	−0.23	−3.59%
Sweden	50	3935	1.80%	0.85	10.51%
Switzerland	50	3511	1.00%	0.50	5.60%
Thailand	50	3215	−0.40%	−0.22	−3.14%
United States	50	3102	0.60%	0.38	2.98%

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