

INSTITUTO POLITÉCNICO DE LISBOA
INSTITUTO SUPERIOR DE CONTABILIDADE E
ADMINISTRAÇÃO DE LISBOA



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DID THE COVID19 PANDEMIC
CREATE PRICING INEFFICIENCIES
IN THE MSCI WORLD INDEX ETFs?

Vânia Monteiro

Lisbon, February 2022

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Dissertação submetida ao Instituto Superior de Contabilidade e Administração de Lisboa para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Análise Financeira, realizada sob a orientação científica de Mestre Especialista José Nuno Sacadura, professor adjunto de Finanças.

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Resumo

A dissertação proposta pretende aferir os efeitos que a pandemia de Covid19 provocou na eficiência de preços (pricing efficiency), estratégia de replicação (replication strategy) e no erro de seguimento (tracking error) dos Exchange Traded Funds que seguem o Índice MSCI World, especificamente de que forma foi afetada a capacidade dos Exchange Traded Funds acompanharem o Índice e os efeitos nas oportunidades de arbitragem. A amostra conta com os 17 ETFs que seguem o Índice MSCI World e cobre um período de 6 anos (2015-2020), dividido em dois sub-períodos: 2015 a 2019 e 2020. Dando assim a possibilidade de analisar um período representativo anterior à crise pandémica (2015-2019), permitindo aferir as mudanças no funcionamento do mercado após o início da crise.

Os resultados indicam que, no geral, os ETFs melhoram a sua eficiência de preços e que a persistência do desvio de preços diminuiu, minimizando consequentemente as oportunidades de arbitragem. A estratégia de replicação dos ETFs permaneceu a mesma antes e durante a pandemia, sendo uma estratégia de replicação seletiva. O tracking error aumentou durante a pandemia em relação ao período anterior em todos os ETFs, refletindo as dificuldades introduzidas pela pandemia na incerteza dos mercados.

Palavras-Chave: Exchange Traded Funds, MSCI World Index, Replication Strategy, Pricing Efficiency, Tracking Error, Covid19, pandemic

Abstract

The proposed thesis aims to assess the effects of the Covid19 pandemic on the pricing efficiency, replication strategy and tracking error of Exchange Traded Funds that follow the MSCI World Index, specifically how the ability of Exchange Traded Funds to track the Index has been affected and the effects on arbitrage opportunities. The sample includes the 17 ETFs that follow the MSCI World Index and covers a period of 6 years (2015-2020), divided into two sub-periods: 2015 to 2019, and 2020. Giving the possibility to analyze a representative period prior to the pandemic crisis (2015-2019), allowing to assess changes in the functioning of the market after the beginning of the crisis.

The results indicate that, overall, ETFs improve their pricing efficiency, and the persistence of price deviation has decreased, consequently minimizing arbitrage opportunities. The replication strategy of the ETFs remained the same before and during the pandemic, consisting of a selective replication strategy. Tracking error increased during the pandemic relative to the previous period in all ETFs, reflecting the difficulties introduced by the pandemic in the uncertainty of the markets.

Keywords: Exchange Traded Funds, MSCI World Index, Replication Strategy, Pricing Efficiency, Tracking Error, Covid19, pandemic

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List of Abbreviations

CAPM – Capital Asset Pricing Model

ETF – Exchange Traded Fund

NAV – Net Asset Value

OLS – Ordinary Least Squares

TE – Tracking Error

TIPs – Toronto Index Participation Units

US – United States

VECM – Vector Error Correction Model

1. Introduction

Over the past few years the number of Exchange Traded Funds available on the market has increased exponentially, with around 7000 ETFs now being traded on the markets (Statista, 2021).

According to Ku, Liew and Pua (2019), the Exchange Traded Funds were invented to replicate the performance of an underlying index and are traded on the exchange markets like stocks, being transitioned according to supply and demand, thus justifying their price fluctuation on a daily basis. Because of this index replication objective, intrinsic to the ETF, it makes sense to analyze the ETFs' pricing efficiency, replication strategy and tracking errors relative to a broadly representative index.

This dissertation contributes to the literature on Exchange Traded Funds by providing a detailed analysis of the pricing efficiency, through price deviation persistence, replication strategy and three calculation methods for tracking error, while taking into consideration a period before the pandemic crisis hit and the period of the beginning of the pandemic crisis (2020), on the MSCI World Index on which there is still little to no literature on these matters.

This dissertation aims to assess the effects that the Covid19 pandemic of the Exchanges Traded Funds that follow the MSCI World Index, specifically how the Exchange Traded Funds ability to follow the Index was affected and the effects on the arbitrage opportunities.

The five years prior to the pandemic crisis will be analyzed, in order to establish what the 'normal' behaviour of these indicators is in a period of some economic and financial stability in the financial markets. After, the same indicators will be analyzed for the year of 2020, allowing a comparison of the period before and during the pandemic crisis.

This comparison allows us to assess if the replication strategy has remained the same, if the tracking error has increased due to the instability that occurred in financial markets during the pandemic and if the pricing efficiency has changed, increasing price deviation persistence and therefore creating arbitrage opportunities in the markets.

The methodology used is the same as a significant number of investigations have used before. Pricing efficiency is calculated using price deviation between the market price and Net Asset Value (NAV) of the ETFs and autoregression on price deviations lagged days. The replication strategy is analyzed through a Capital Asset Pricing Model (CAPM), that regresses the ETF returns on the benchmark index returns. The tracking error is calculated with three different

methods: standard deviation and absolute value of the tracking difference and standard deviation of the residuals from the same regression used to determine replication strategy.

The dissertation is introduced with Section 2 on the characteristics of ETFs and an explanation of the concepts of each indicator that will later be calculated/tested. Section three presents the literature review of these indicators, where we go through some of the scientific research made on ETFs and these indicators of performance. We then have a Section 4 dedicated to the sample and methodology used in the research, describing the calculations made for each performance indicator. Section 5 analyses the results of the research, and the last Section concludes the dissertation with the most important conclusions taken from the research.

2. Exchange Traded Funds

For a better understanding of the concept and functioning of an ETF, we start this dissertation with a section on the main characteristics of the ETFs, as well as the three performance indicators that will later be analyzed, pricing efficiency, replication strategy and tracking error.

The first Exchange Traded Fund (ETF) was created in 1990 in Canada, the Toronto Index Participation Units (TIPs) with the goal of replicating the TSE 35 Composite Index. In 1993, the first ETF is created in the United States of America, the Standard & Poor's Depository Receipts (as known as "Spider") that replicated the S&P 500 Index, according to Afonso and Cardoso (2019).

The Exchange Traded Fund is a basket of securities, that tracks an underlying index while being listed on a stock exchange and trading daily on the financial markets. According to Kumar (2018), an ETF trades like a common stock, acquiring the possibility of short selling, placing limit orders and trading on margin. They function as passive funds with a low expense ratio, taxes and minimal brokerage fees while providing high liquidity. ETFs are a way for individual investors to diversify their portfolio and invest in foreign exchange markets (Johnson, 2009), as they provide instant diversification, cost efficiency and a reduced tax burden (Nyukorong, 2020). Kumar (2018) claims that like stocks, ETF's also have a bid price, the highest price any investor is willing to pay for it, and an ask price, the lowest price any seller is willing to accept.

ETFs have intrinsically in them the structure of a fund, with the advantages of being traded as if they were stocks. According to Reddy & Dhabolkar (2020), the main difference between an Exchange Traded Fund and a Mutual Fund is that the ETF trades in real time in the markets, just like stocks, whereas a Mutual Fund trades only at the end of the day at their Net Asset Value (NAV).

Nyukorong (2020) also states that ETFs have become a valuable investment instrument for all investors and its fundamental benefit is liquidity, as they are highly liquid and enable investors to broadly diversify their portfolio.

Reddy and Dhabolkar (2020, p. 246) state that «the key to understanding how ETFs work is the creation/redemption mechanism». According to Diaw (2019), in the primary market, ETFs mechanism is based on unit creation, that increases the supply of ETFs shares, and redemption, decreasing the shares available of the ETFs, by Authorized Participants (APs). They regulate supply and demand in the secondary market either by buying or selling the ETF shares.

2.1 Pricing Efficiency

According to Kumar (2018), ETFs usually have two prices, the Net Asset Value (NAV) and market price. The NAVs are determined by the market values of the securities held and the market prices are based on the supply and demand of the market participants. These values tend to differ from each other and this enables cost and arbitrage opportunities. This discrepancy between the NAV and market price results in ETFs trading either at a premium or discount. If the market price is higher than the NAV, it means that the ETF is trading at premium. On the other hand, if the market price is lower than the NAV, it means that the ETF is trading at discount. These market dynamics allow arbitrage opportunities to exist.

According to a conclusion made by Diaw (2019), there is a consensus in the literature that price deviations are small and usually short-lived since the creation and redemption process favors the mechanism of arbitrage, therefore keeping ETF market price close to its NAV.

According to Poterba and Shoven (2002)¹, cited by Afonso and Cardoso (2019), these differences have made ETFs a very relevant investment option for investors that demand short-term liquidity and buy in large quantities.

2.2 Replication Strategy

According to Kumar (2018), the classic method of replication is the physical replication or full replication, where the ETF holds all the securities of the index. There is also synthetic or selective replication which allows ETF investors to invest in new asset classes and replicate some indices more efficiently.

Replication strategy is often associated with investment strategy which can be passive or active. Passive investing means the use of index tracking funds that try to match as closely as possible the returns from the underlying index, while active investing tries to achieve higher returns than the underlying index.

¹ Poterba, J. M., & Shoven, J. B. (2002). Exchange-Traded Funds: A new investment option for taxable investors. *American Economic Review*, 92(2), 422-427.

2.3 Tracking Error

The tracking error of an ETF measures the difference between the return of the ETF and that of its underlying benchmark index. For Diaw (2019), the tracking error reflects the ability of the ETF to mimic accurately the underlying benchmark. Theoretically, the smaller the tracking error, the better the replication strategy.

Kumar (2018) states that a small tracking error means the ETF is following its index closely and a large tracking error means that the ETF is moving above the index and trying to generate higher returns to investors. It shows the quality of replication.

These are the main performance indicators of ETFs, as they are the most specific to the main objective of an ETF: to track the performance of an underlying benchmark index.

3. Literature Review

The three indicators explained before have been broadly used in the literature of Exchange Traded Funds. Our literature review will cover scientific research that studies either one or more than one of these indicators, as they often go hand-in-hand in the literature.

Pricing efficiency has been studied through a number of different methods, the most common being the Capital Asset Pricing Model (CAPM) and a regression of price deviations on lagged days. This method was used by Kumar (2018) and Afonso & Cardoso (2019), using the CAPM and assuming a linear relation between the closing price and NAV of the ETFs. After, they regress the premium/discount on a one day lagged premium/discount (autoregression), to calculate the persistence of the premium/discount.

Kumar (2018) studies the pricing efficiency of selected Equity and Gold ETFs, over the period of 2012 to 2017, and through the analysis of the beta of the CAPM, concluded that except for one, all the ETFs delivered premiums to investors. The results of autoregression show that ETFs with premium persistence, that creates arbitrage opportunities, usually vanish after a few days.

Afonso and Cardoso (2019) use the same regression methods to analyse the price efficiency and its persistence, on the Exchange Traded Fund that tracks PSI20, and find that the ETF is priced at a low average discount and that the deviation persistence is of at least two days.

A similar analysis is used by Purohit and Malhotra (2015), only instead of using a CAPM to establish if the ETFs in India are trading at a premium or discount, they use a simple price deviation (difference between market closing price and NAV of the ETF). If the result is positive, the ETF is trading at a premium and vice-versa. Then, the autoregression used by the previous researchers, is used to determine the persistence of the premium/discount.

They analyse the period of January 2002 to December 2013, and given that there is a financial crisis during this period, the authors chose to divide the data into three panels. The first one covers the period before the financial crisis, the middle one covers the events of the financial crisis and the last one covers the remaining time after the critical period of the crisis.

The results show that ETFs in India show pricing inefficiencies. The price deviation reveals the ETFs are trading at a discount and these price deviations tend to last for an average period of three days.

Reddy and Dhabolkar (2020), Engle and Sarkar (2006) and Charteris (2013) use the same method as the previous research, applying the price deviation and autoregression analysis.

The first analyses the pricing efficiency of selected ETFs in India is studied from April 2017 to March 2019, using the daily price deviations of the ETFs and testing for its persistence. The results indicate that the selected Indian ETFs have a minimum of 1 day and a maximum of 4 days of price deviation persistence.

Additionally, these authors also use the vector error correction model (VECM) to understand the lead-lag relationship between the market price and the NAV. The results indicate that NAV is the lead variable and the market price is the lag variable, meaning that the market price corrects itself based on the movements of the NAV. Overall, they consider that the ETF market in India is partially efficient despite the still existing arbitrage opportunities.

The second, Engle and Sarkar (2006), examines the magnitude and properties of premiums and discounts for a wide range of Exchange Traded Funds, using data from 21 domestic (US) ETFs and 16 international ETFs from an end-of-day and from a minute-by-minute intra-daily perspective.

The overall finding is that premiums and discounts for the domestic ETFs are generally small and highly transient, typically lasting only several minutes. Premiums and discounts are much larger and more persistent for the analyzed international ETFs, frequently lasting several days. The authors believe an explanation for this difference is related with the higher cost of creation and redemption for the international products.

Charteris (2013) studies the price deviations of four domestic and three foreign South African ETFs, during the period of 30th of June 2008 to the 7th of December 2012. The results show that five of these ETFs trade at a premium to their NAV and the remaining two trade at a discount. These price deviations do not persist for more than two trading days, indicating that the opportunity for arbitrage opportunities for investors is limited.

Diaw (2019) on the other hand uses a different analysis of the premium/discount of three domestic Saudi Arabian ETFs, during July 2010 to June 2018, by using a direct analysis of the descriptive statistics of the premium/discount values. The results show that two are trading at a slight premium and the other at a discount.

This direct analysis of descriptive statistics of premium/discount values is also used by Bas and Sarioglu (2015), when studying the pricing efficiency of 16 ETFs operating in the Turkish Capital Markets, during the period of between 14/01/2005 and 30/04/2013. The results find that Turkish ETFs are priced efficiently and there exists no arbitrage opportunities in the market.

To determine the replication strategy of ETFs, the analysed literature uses the CAPM model, by analysing mainly the beta values, that represent the measure value of the systematic risk.

$$R_{ETF_t} = \alpha_{ETF} + \beta_{ETF} \times R_{index_t} + \varepsilon_{ETF_t} \quad (3.1)$$

Kumar (2018) studies the replication strategy on selected Equity and Gold ETFs and concludes that all ETFs analyzed use selective replication. Purohit and Malhotra (2015) study ETFs in India, during the period of January 2002 to December 2013 and the results show that ETFs do not make use of full replication strategies, being also selective.

Milonas and Rompotis (2006) study the performance and the trading characteristics of a sample of 36 Swiss ETFs during the period of August 2001 to April 2006, using daily ETFs closing values. They find that Swiss ETFs also do not adopt full replication strategies.

At last we have the indicator that seems to have more research available. The tracking error is calculated through a few different methods. The ones present on the analysed literature are the following:

Tracking Error 1 (TE1):

$$R_{ETF_t} = \alpha_{ETF} + \beta_{ETF} \times R_{index_t} + \varepsilon_{ETF_t} \quad (3.2)$$

- R_{ETF_t} – Daily return of the ETF
- R_{index_t} – Daily return of the benchmark index
- ε_{ETF_t} – regression residuals

Tracking Error 2 (TE2):

$$TE2 = \sqrt{\frac{1}{N-1} \sum_{t=1}^N (R_{ETF} - \overline{R_{ETF}})^2} \quad (3.3)$$

- N – number of observations

Tracking Error 3 (TE3):

$$TE3 = \frac{\sum_{t=1}^N |R_{ETF} - R_{INDEX}|}{N} \quad (3.4)$$

Tracking Error 4 (TE4):

$$TE4 = \sqrt{\frac{1}{N-1} \sum_{t=1}^N (TD - \overline{TD})^2} \quad (3.5)$$

- Tracking Difference (TD_{ETF}) = $R_{ETF_t} - R_{index_t}$

Tracking Error 5 (TE5):

$$TE5 = \sqrt{\frac{1}{N-1} \sum_{t=1}^N (R_{ETF} - R_{index})^2} \quad (3.6)$$

Kumar (2018) studies the tracking errors on selected Equity and Gold ETFs, over the period of 2012 to 2017, using two methods to calculate the tracking error of the ETFs: TE1 and TE3. The results conclude that all ETFs analyzed are closely tracking its underlying index.

Afonso and Cardoso (2019) use methods TE1, TE2, TE3 and TE4 to calculate the tracking error of the ETF that tracks the PSI20, Comstage PSI20, and the results indicate a good tracking ability when compared to the tracking error of Mutual Funds.

Milonas and Rompotis (2006) and Purohit and Malhotra (2015) use methods TE1, TE3 and TE4. The first studies the performance of a sample of 36 Swiss ETFs during the period of August 2001 to April 2006, and find that Swiss ETFs underperform their underlying indexes and the magnitude of tracking error is substantial. The latter studies the performance of ETFs in India and the results show that ETFs have significant tracking errors.

Chu (2011) also uses these three methods and presents the first study on the magnitude of the tracking error and its determinants, using data from the ETFs traded in the Hong Kong stock market. He finds that tracking errors are higher than those found in ETFs traded in the US and Australia stock market.

Ku et al. (2019) also measures the tracking error of seven ETFs listed on the Bursa Malaysia (Malaysia stock market), covering the period from June 2007 to May 2016, through methods TE1, TE3 and TE4 and the results show high tracking errors. The results intend to provide information to help passive institutional and retail investors select the best ETF to replicate the desired underlying index and motivate improvement in the tracking ability of the ETFs in Malaysia.

Through the same methods, Rompotis (2009) makes a comparison between active and passive managed ETFs listed in the US market, three active ETFs and three corresponding passive ETFs that in pairs have the same index of reference. Tracking error results reveal that the difference between ETF and index returns is greater for active ETFs.

Miziolek and Feder-Sempach (2019) study the tracking efficiency of 14 ETFs listed on European exchanges that replicate the performance of the MSCI Emerging Markets Index, covering the period of 2012 to 2017. The results indicate that the observed ETFs are effectively managed as they present lower tracking errors than those in existing literature. Shin and Soydemir (2010) calculate the tracking error of 26 ETFs through TE1, TE3 and TE4 and results are statistically significantly different from zero and display persistence.

Bas and Sarioglu (2015) use methods TE3 and TE5, to study the performance of 16 ETFs operating in the Turkish Capital Markets and conclude that Turkish ETFs underperform their underlying indexes and are significantly different from zero.

Svetina and Wahal (2008) study a sample of 584 US domestic equity, international equity, and fixed income ETFs from their inception to the end of 2007. Results for tracking error using method TE4 indicate that ETFs are not immune from tracking error, as they estimate a tracking error of 0,47% for domestic equity ETFs and 1,13% for international equity ETFs.

Diaw (2019) calculates tracking errors of the domestic Saudi Arabian ETFs using TE1, TE3 and TE5. The author concludes that all 3 ETFs have minimum tracking errors which suggest a good tracking ability.

Johnson (2009) and Saunders (2018) use a multiple regression analysis to determine the explanatory variables of the tracking error. Johnson (2009) studies the returns of 20 foreign country ETFs and their underlying indexes, in the period of 1997 to 2003. It explains that ETFs and underlying indexes that originate from different countries tend to have tracking errors, caused by different trading hours and trading momentum.

Saunders (2018) does an analysis on the tracking error of ETFs traded in the United States that track a country-specific stock market index outside the US (United States), using a sample of 93 country-specific ETFs from 47 different countries. Saunders (2018) uses the tracking error as the dependent variable and retrieves 7 relevant independent variables from the existing literature. The results show that the Heritage Foundation Economic Freedom Index, the ETF return relative to the total US equity market return and the ETF expense ratio are statistically significant explanatory variables for tracking error.

Another method used to test the performance of ETFs is Jensen's model, used by Shin and Soydemir (2010) and Pinheiro and Varela (2018).

Shin and Soydemir (2010) test the performance of 26 ETFs and Jensen's alpha indicates significantly lower risk adjusted returns compared to the benchmark, on all ETFs analyzed except for two, indicating a passive investment strategy that does not outperform the market returns. The negative alpha values imply that investing in these ETFs does not provide a significant benefit compared to investing in their benchmarks.

Pinheiro and Varela (2018) investigate the performance of the ETF and Mutual Funds that track the Portuguese stock index, PSI20. They test the hypothesis that ETFs generate significant abnormal returns when compared to the market and the results do not show evidence that the Funds tracking the PSI20 index outperform the market.

As seen above, throughout literature on ETFs, several different ways to evaluate performance can be found. Based on this analysis we have selected the methods that will be used in this dissertation, as presented in the next section.

4. Sample and methodology

4.1 Sample

This research focuses on the MSCI World Index and the 17 ETFs that track it. The MSCI World is an Equity Index that tracks stocks from 23 developed countries, being the countries with the largest representation in its constitution the United States of America, Japan and the United Kingdom. The industries with the largest representation are Information Technology, Financial Services and Healthcare.

Our sample is composed by the MSCI World Index and the 17² ETFs that use it as its underlying benchmark. We retrieved all daily closing prices of the index and ETFs from the Bloomberg Database and the Eikon Datastream, as well as the Net Asset Values for all ETFs.

Data used in the following analyses is divided in two periods:

- 1st of January 2015 to 31st of December 2019 – pre-covid pandemic;
- 1st of January 2020 to 31st of December 2020 – covid pandemic.

Table 4.1 Characteristics of the MSCI World Exchange Traded Funds

NAME	ISIN	FUND DOMICILE	INCEPTION DATE	INDEX TYPE
AMUNDI INDEX MSCI WORLD UCITS ETF DR EUR (D)	LU1737652237	Luxembourg	6 February 2018	Total return index
AMUNDI MSCI WORLD UCITS ETF EUR (C)	LU1681043599	Luxembourg	18 April 2018	Total return index
DEKA MSCI WORLD UCITS ETF	DE000ETF508	Germany	04 September 2018	Price index
HSBC MSCI WORLD UCITS ETF USD	IE00B4X9L533	Ireland	08 December 2010	Total return index
INVESCO MSCI WORLD UCITS ETF	IE00B60SX394	Ireland	02 April 2009	Total return index
ISHARES CORE MSCI WORLD UCITS ETF USD (ACC)	IE00B4L5Y983	Ireland	25 September 2009	Total return index

² On the 3rd of March 2021, another MSCI tracking ETF was listed on the market. This ETF was not included in our research as it was non-existent at the beginning of the research as well as at the period analysed.

ISHARES MSCI WORLD UCITS ETF (DIST)	IE00B0M62Q58	Ireland	28 October 2005	Total return index
LYXOR CORE MSCI WORLD (DR) UCITS ETF - ACC	LU1781541179	Luxembourg	28 February 2018	Total return index
LYXOR MSCI WORLD UCITS ETF - DIST	FR0010315770	France	26 April 2006	Total return index
LYXOR MSCI WORLD (LUX) UCITS ETF	LU0392494562	Luxembourg	27 November 2008	Total return index
SPDR MSCI WORLD UCITS ETF	IE00BFY0GT14	Ireland	28 February 2019	Total return index
UBS ETF (IE) MSCI WORLD UCITS ETF (USD) A-ACC	IE00BD4TXV59	Ireland	7 June 2019	Total return index
UBS ETF (IE) MSCI WORLD UCITS ETF (USD) A-DIS	IE00B7KQ7B66	Ireland	11 April 2012	Total return index
UBS ETF (LU) MSCI WORLD UCITS ETF (USD) A-DIS	LU0340285161	Luxembourg	25 June 2008	Total return index
XTRACKERS MSCI WORLD SWAP UCITS ETF 1C	LU0274208692	Luxembourg	19 December 2006	Total return index
XTRACKERS MSCI WORLD UCITS ETF 1C	IE00BJ0KDQ92	Ireland	22 July 2014	Total return index
XTRACKERS MSCI WORLD UCITS ETF 1D	IE00BK1PV551	Ireland	23 February 2015	Total return index

4.2 Methodology

Our methodology for calculations was chosen based on the existing methods found on the reviewed literature for the same indicators. For consistency reasons, days with missing values have been deleted from the data series and all data was retrieved in US dollars.

4.2.1 Pricing Efficiency

As we have stated earlier, ETFs have two different prices, the Net Asset Value (NAV) and the market price. According to Gallagher & Segara (2006), the NAV is calculated with reference to the market value of the securities held by the ETF. On the other hand, the market price of an ETF is determined by the supply and demand from the market participants. This can lead to differences between the two, representing both a cost and an arbitrage opportunity to the investor.

$$PD = P_t - NAV_t \quad (4.1)$$

- PD – Price deviation
- P_t – Closing price of the ETF on moment t
- NAV_t – Net Asset Value of the ETF on moment t

$$PD_t = \alpha + \beta_1 PD_{t-1} + \varepsilon_t \quad (4.2)$$

- PD_t – Price deviation on day t
- α – intercept value (constant)
- β_1 – Coefficient of PD_{t-1}
- PD_{t-1} – Price deviation on day t-1
- ε_t – Regression residuals

4.2.2 Replication Strategy

To determine the replication strategy of the MSCI World ETFs, we have used a widely know model, the Capital Asset Pricing Model (CAPM model). This analysis is based on market price daily returns.

$$R_{ETF_t} = \ln\left(\frac{P_t}{P_{t-1}}\right) \quad (4.3)$$

R_{ETF_t} – Return of the ETF on day t

P_t – Closing market price of the ETF on day t

P_{t-1} – Closing market price of the ETF on day t-1

$$R_{Benchmark_t} = \ln\left(\frac{P_t}{P_{t-1}}\right) \quad (4.4)$$

$R_{Benchmark_t}$ – Return of the Benchmark Index on day t

P_t – Closing market price of the Benchmark Index on day t

P_{t-1} – Closing market price of the Benchmark Index on day t-1

$$\text{CAPM: } R_{ETF_t} = \alpha_{ETF} + \beta_{ETF} \times R_{benchmark_t} + \varepsilon_{ETF_t} \quad (4.5)$$

Where:

- R_{ETF_t} – Daily return of the ETF
- α_{ETF} – Alpha coefficient is the return generated by the ETF regardless of the benchmark index return;
- β_{ETF} – Beta coefficient measures the sensitivity of the ETF to fluctuations in the benchmark index return and reflects the replication strategies adopted by fund managers. It measures the systematic risk and, in this case, it will be used to determine the ETFs replication strategy.

If the value of beta is close to 1, it indicates a full replication strategy which means the fund manager invested in all securities held by the ETF in the same weight as the benchmark index. If the value of beta is less than 1, it indicates a selective replication strategy, meaning that the fund manager deviated from a passive investment strategy and selected the securities to optimize its returns.

- $R_{benchmark_t}$ – Daily return of the benchmark index
- ε_{ETF_t} – Regression residuals

4.2.3 Tracking Error

The following methods to calculate the tracking error of the ETFs were taken from existing literature, such as Purohit and Malhotra (2015) and Miziolek and Feder-Sempach (2019).

$$R_{ETF_t} = \ln\left(\frac{P_t}{P_{t-1}}\right) \quad (4.6)$$

$$R_{Benchmark_t} = \ln\left(\frac{P_t}{P_{t-1}}\right) \quad (4.7)$$

$$\text{Tracking Difference } (TD_{ETF}) = R_{ETF_t} - R_{Benchmark_t} \quad (4.8)$$

Tracking Error 1 (TE1) – Standard deviation of the difference between the return of the fund and the underlying benchmark.

$$TE1 = \sqrt{\frac{1}{N-1} \sum_{t=1}^N (TD_{ETF} - \overline{TD_{ETF}})^2} \quad (4.9)$$

- N – number of observations

Tracking Error 2 (TE2) – Absolute value of the difference between fund (ETF) and benchmark returns.

$$TE2 = \frac{\sum_{t=1}^N |TD_{ETF}|}{N} \quad (4.10)$$

- N – number of observations

Tracking Error 3 (TE3) – Standard deviation of residuals from the regression of ETF's return on the benchmark return.

$$R_{ETF_t} = \alpha_{ETF} + \beta_{ETF} \times R_{benchmark_t} + \varepsilon_{ETF_t} \quad (4.11)$$

- R_{ETF_t} - Daily return of the ETF
- α_{ETF} – intercept term (constant)
- β_{ETF} – Beta coefficient (measures the sensitivity of the ETF to fluctuations in the benchmark index return)
- $R_{benchmark_t}$ – Daily return of the benchmark index
- ε_{ETF_t} – regression residuals

When using regression, we perform tests to address possible problems with long time series data, as heteroscedasticity and autocorrelation. We use the Breusch-Pagan and Durbin Watson tests, to test for heteroscedasticity and autocorrelation, respectively.

When the null hypothesis is rejected in the Breusch-Pagan test, we are in the presence of heteroscedasticity and OLS (Ordinary Least Squares) estimators are no longer BLUE (Best Linear Unbiased Estimator) and will produce biased coefficient estimates. When the null hypothesis is rejected in the Durbin-Watson test, we are in the presence of autocorrelation and in violation an important OLS assumption that errors in the regression model are uncorrelated at all times.

In cases where the null hypothesis is rejected, we will use robust standard errors estimates, which are meant to obtain unbiased standard errors of OLS coefficients under heteroscedasticity.

5. Results

Our results were obtained through the methods explained in the previous section and were performed using Stata software.

5.1 Pricing Efficiency

The following tables show the results of the summary statistics of the price deviations calculations and the results for regression on lagged days of the price deviations, to determine its persistence.

Table 5.1 Summary statistics of the ETF's price deviation (from 01/01/2015 to 31/12/2019)

PERIOD: 01/01/2015 (OR INITIAL TRADING DATE) TO 31/12/2019	AVERAGE	STANDARD DEVIATION	MEDIAN	MINIMUM	MAXIMUM
AMUNDI INDEX MSCI WORLD UCITS ETF DR EUR (D)	2,3230	0,5851	2,2037	0,5814	3,6175
AMUNDI MSCI WORLD UCITS ETF EUR (C)	0,0005	1,0180	-0,0068	-5,2934	7,1467
DEKA MSCI WORLD UCITS ETF	0,6201	0,1184	0,6202	0,3260	1,0208
HSBC MSCI WORLD UCITS ETF USD	1,3059	0,4019	1,3716	0,4174	2,2034
INVESCO MSCI WORLD UCITS ETF	0,0048	0,2014	-0,0001	-1,0627	1,4586
ISHARES CORE MSCI WORLD UCITS ETF USD (ACC)	0,0265	0,1937	0,0228	-1,0150	1,3361
ISHARES MSCI WORLD UCITS ETF (DIST)	2,2629	0,7814	2,3350	0,5350	4,2016
LYXOR CORE MSCI WORLD (DR) UCITS ETF - ACC	0,0124	0,0375	0,0118	-0,1460	0,1635
LYXOR MSCI WORLD UCITS ETF - DIST	12,2433	4,8176	12,5907	1,7048	22,7018
LYXOR MSCI WORLD (LUX) UCITS ETF	2,4061	0,5576	2,4205	0,7128	4,1418
SPDR MSCI WORLD UCITS ETF	0,0148	0,0614	0,0108	-0,2507	0,3302
UBS ETF (IE) MSCI WORLD UCITS ETF (USD) A-ACC	0,0023	0,0530	-0,0008	-0,1632	0,2707
UBS ETF (IE) MSCI WORLD UCITS ETF (USD) A-DIS	2,9442	1,0148	2,9837	0,6420	5,1857

UBS ETF (LU) MSCI WORLD UCITS ETF (USD) A-DIS	10,8089	3,8105	11,0168	1,6466	19,3215
XTRACKERS MSCI WORLD SWAP UCITS ETF 1C	0,0015	0,2117	-0,0042	-1,0693	1,4085
XTRACKERS MSCI WORLD UCITS ETF 1C	0,0355	0,2083	0,0325	-1,0397	1,4989
XTRACKERS MSCI WORLD UCITS ETF 1D	3,1249	0,5733	3,2050	1,1906	4,9430

In Table 5.1, for the time period from 01/01/2015 to 31/12/2019, the lowest average price deviation is 0,0005, from the Amundi MSCI World UCITS ETF EUR (C), and the highest is 12,2433, from the Lyxor MSCI World UCITS ETF – Dist.

The standard deviation has a minimum in the Lyxor Core MSCI World (DR) UCITS ETF - Acc of 0,0375 and a maximum in the Lyxor MSCI World UCITS ETF - Dist of 4,8176. The minimum price deviation is -5,2934 from the Amundi MSCI World UCITS ETF EUR (C) and the maximum price deviation is 22,7018 from the Lyxor MSCI World UCITS ETF - Dist.

Table 5.2 Summary statistics of the ETF's price deviation (from 01/01/2020 to 31/12/2020)

PERIOD: 01/01/2020 TO 31/12/2020	AVERAGE	STANDARD DEVIATION	MEDIAN	MINIMUM	MAXIMUM
AMUNDI INDEX MSCI WORLD UCITS ETF DR EUR (D)	0,8831	0,4772	0,9562	-1,5023	2,6502
AMUNDI MSCI WORLD UCITS ETF EUR (C)	0,1599	2,1400	0,1456	-11,7201	10,8995
DEKA MSCI WORLD UCITS ETF	0,2575	0,1767	0,2304	-0,5613	0,9431
HSBC MSCI WORLD UCITS ETF USD	0,3274	0,1777	0,3070	-0,4601	1,1092
INVESCO MSCI WORLD UCITS ETF	0,0148	0,4222	0,0151	-2,3174	1,9933
ISHARES CORE MSCI WORLD UCITS ETF USD (ACC)	0,0319	0,3900	0,0363	-2,0399	1,6769
ISHARES MSCI WORLD UCITS ETF (DIST)	0,4352	0,3814	0,4070	-1,1021	2,0989
LYXOR CORE MSCI WORLD (DR) UCITS ETF - ACC	0,0129	0,0715	0,0132	-0,4041	0,3411
LYXOR MSCI WORLD UCITS ETF - DIST	2,4686	1,8876	2,2518	-5,7767	9,6306

LYXOR MSCI WORLD (LUX) UCITS ETF	0,6928	0,6117	0,7544	-1,4492	2,7165
SPDR MSCI WORLD UCITS ETF	0,0271	0,1445	0,0250	-0,7687	0,7051
UBS ETF (IE) MSCI WORLD UCITS ETF (USD) A-ACC	0,0054	0,1232	0,0026	-0,6325	0,6158
UBS ETF (IE) MSCI WORLD UCITS ETF (USD) A-DIS	0,6390	0,4465	0,5706	-1,3742	2,3892
UBS ETF (LU) MSCI WORLD UCITS ETF (USD) A-DIS	2,3034	1,7229	2,0478	-5,4728	9,1891
XTRACKERS MSCI WORLD SWAP UCITS ETF 1C	0,0351	0,4380	0,0196	-2,3735	2,0969
XTRACKERS MSCI WORLD UCITS ETF 1C	0,0282	0,4309	0,0210	-2,3130	2,0746
XTRACKERS MSCI WORLD UCITS ETF 1D	1,2463	0,7091	0,9937	-0,5266	3,4323

In Table 5.2, for the time period from 01/01/2020 to 31/12/2020, the lowest average price deviation is 0,0054, from the UBS ETF (IE) MSCI World UCITS ETF (USD) A-acc, and the highest is 2,4686, from the Lyxor MSCI World UCITS ETF - Dist.

The standard deviation has a minimum in the Lyxor Core MSCI World (DR) UCITS ETF - Acc of 0,0715 and a maximum in the Amundi MSCI World UCITS ETF EUR (C) of 2,1400. The minimum price deviation is -11,7201 from the Amundi MSCI World UCITS ETF EUR (C) and the maximum price deviation is 10,8995, also from the Amundi MSCI World UCITS ETF EUR (C).

The results of the regressions to test the persistence of price deviations are shown in Table 5.3 and Table 5.4 below. During the period shown in Table 5.3, the price deviation captured by the intercept (constant) in the regression is positive on all ETFs, which means that these ETFs trade at a premium (market price higher than the NAV). On the other hand, only five ETFs have a statistically significant intercept value.

During the period shown in Table 5.4, the price deviation captured by the intercept (constant) in the regression is also positive on all ETFs, which again means that these ETFs trade at a premium. On the other hand, nine ETFs have a statistically significant intercept value, a higher number than in the pre-pandemic period results.

Table 5.3 Persistence of the price deviations (from 01/01/2015 to 31/12/2019)

PERIOD: 01/01/2015 (OR INITIAL TRADING DATE) TO 31/12/2019	α	β_1	β_2	β_3	β_4	β_5	β_6
AMUNDI INDEX MSCI WORLD UCITS ETF DR EUR (D)	0,0526646	0,3579838*	0,2246236*	0,1282145*	0,0542845	0,1151711*	0,0933397
AMUNDI MSCI WORLD UCITS ETF EUR (C)	0,0021806	-0,042016	-0,0347069	0,0161346	-0,0314341	-0,0057794	0,0094311
DEKA MSCI WORLD UCITS ETF	0,0882255*	0,2002963*	0,2284776*	0,1473783	0,0143763	0,0932711	0,1681244*
HSBC MSCI WORLD UCITS ETF USD	0,0043106	0,1820474*	0,2160038*	0,1736398*	0,1473576*	0,1316985*	0,1432225*
INVESCO MSCI WORLD UCITS ETF	0,1094204	-0,0094038	0,006462	0,0021904	-0,0014449	-0,0001063	0,0050061
ISHARES CORE MSCI WORLD UCITS ETF USD (ACC)	0,0291971*	-0,0520942	0,0062298	0,0024585	-0,0284466	0,0063287	-0,0374437
ISHARES MSCI WORLD UCITS ETF (DIST)	0,0104505	0,1754471*	0,1829964*	0,1914729*	0,1246262*	0,1842468*	0,1334773*
LYXOR CORE MSCI WORLD (DR) UCITS ETF - ACC	0,0088715*	0,0991312	0,0934928	0,0685203	-0,0398734	0,0459001	-0,0014204
LYXOR MSCI WORLD UCITS ETF - DIST	0,014106	0,232597*	0,1909792*	0,2067355*	0,1196061*	0,1169922*	0,128884*
LYXOR MSCI WORLD (LUX) UCITS ETF	0,0599126	0,2100707*	0,2002273*	0,1894201*	0,1134654*	0,1682583*	0,0923931*
SPDR MSCI WORLD UCITS ETF	0,0132719*	0,1967598	0,0340197	0,0098729	-0,1402678	0,0278452	-0,0335814
UBS ETF (IE) MSCI WORLD UCITS ETF (USD) A-ACC	0,0029735	0,1684649	-0,0078823	0,0097156	-0,1261475	-0,0078339	-0,0052401

UBS ETF (IE) MSCI WORLD UCITS ETF (USD) A-DIS	0,0166434	0,2398311*	0,2324389*	0,1590945*	0,1271359*	0,1255072*	0,1075884*
UBS ETF (LU) MSCI WORLD UCITS ETF (USD) A-DIS	0,0832378	0,222235*	0,2400246*	0,1878956*	0,1035619*	0,1374399*	0,0983098*
XTRACKERS MSCI WORLD SWAP UCITS ETF 1C	0,0018149	-0,0160671	0,0369588	0,0177798	-0,0511331	-0,0577342	-0,0135085
XTRACKERS MSCI WORLD UCITS ETF 1C	0,0354112*	-0,0174639	0,0185439	0,0078783	0,0117668	-0,0507052	0,0315561
XTRACKERS MSCI WORLD UCITS ETF 1D	0,0829555	0,2367994*	0,1713069*	0,1707291*	0,162966*	0,0854176*	0,1454061*

Note: * statistically significant at 5% confidence level (p-value<0,05)

Table 5.4 Persistence of the price deviations (from 01/01/2020 to 31/12/2020)

PERIOD: 01/01/2020 TO 31/12/2020	α	β_1	β_2	β_3	β_4	β_5	β_6
AMUNDI INDEX MSCI WORLD UCITS ETF DR EUR (D)	0,2753879*	-0,0623382	0,1911463*	0,2155847*	0,1754589	0,1326174	0,0273409
AMUNDI MSCI WORLD UCITS ETF EUR (C)	0,2043571	-0,2726381*	-0,0363176	0,0031518	0,0191389	0,0506725	-0,0378693
DEKA MSCI WORLD UCITS ETF	0,0619917*	-0,1215582	0,1351244*	0,2113657	0,194896*	0,2102118*	0,1156012
HSBC MSCI WORLD UCITS ETF USD	0,0806659*	-0,1649899	0,1385977	0,2090547	0,2182876*	0,2266623*	0,1094204
INVESCO MSCI WORLD UCITS ETF	0,0186391	-0,3198619*	-0,0382882	0,0432777	0,0416729	0,0762103	-0,0436546
ISHARES CORE MSCI WORLD UCITS ETF USD (ACC)	0,0406312	-0,2832175*	-0,0123828	0,0096699	0,0213998	0,0431101	-0,0489335
ISHARES MSCI WORLD UCITS ETF (DIST)	0,1485778*	-0,1391412	0,1765294*	0,1578795	0,1818382	0,1687509	0,0949349
LYXOR CORE MSCI WORLD (DR) UCITS ETF - ACC	0,0158748*	-0,2468836*	-0,0056343	0,0368618	0,0185933	0,018326	-0,0536042

LYXOR MSCI WORLD UCITS ETF - DIST	0,4052136*	-0,0727386	0,1692038*	0,2384318*	0,2157973*	0,181406*	0,0849654
LYXOR MSCI WORLD (LUX) UCITS ETF	0,0669987	-0,069988	0,2390467*	0,2179709	0,148384	0,2311265*	0,1142667
SPDR MSCI WORLD UCITS ETF	0,0333765*	-0,3046942*	-0,0187016	0,0623431	0,0490544	0,049762	-0,0664528
UBS ETF (IE) MSCI WORLD UCITS ETF (USD) A-ACC	0,0078429	-0,3092936*	-0,0771707	0,028734	-0,104438	0,0343333	-0,0231466
UBS ETF (IE) MSCI WORLD UCITS ETF (USD) A-DIS	0,150302*	-0,1225226	0,164997*	0,2399526*	0,0940058	0,2502682*	0,1190936
UBS ETF (LU) MSCI WORLD UCITS ETF (USD) A-DIS	0,6473808*	-0,14563	0,1491591*	0,2039862	0,2244582*	0,2055876*	0,063797
XTRACKERS MSCI WORLD SWAP UCITS ETF 1C	0,0414868	-0,28026*	0,0146057	0,1025263	0,0426547	-0,0063182	-0,0497217
XTRACKERS MSCI WORLD UCITS ETF 1C	0,0358646	-0,2695628*	-0,0222425	0,0305703	0,0302351	0,015798	-0,0487663
XTRACKERS MSCI WORLD UCITS ETF 1D	0,1012439	-0,0241578	0,2397329*	0,2307901	0,1997714*	0,1764572	0,0819361

Note: * statistically significant at 5% confidence level (p-value<0,05)

The results of the regressions shown in Table 5.3, referring to the pre-pandemic period, show that four of the ETFs do not have any statistically significant intercept and coefficient values, meaning that they do not have persistence of price deviation and it disappears within the next day. These are the Amundi MSCI World UCITS ETF EUR (C, Invesco MSCI World UCITS ET, UBS ETF (IE) MSCI World UCITS ETF (USD) A-acc and Xtrackers MSCI World Swap UCITS ETF 1C.

There are four of the ETFs that only have the intercept statistically significant which means that they also do not have persistence of price deviation. These are the iShares Core MSCI World UCITS ETF USD (Acc), Lyxor Core MSCI World (DR) UCITS ETF – Acc, SPDR MSCI World UCITS ETF and Xtrackers MSCI World UCITS ETF 1C.

The Deka MSCI World UCITS ETF is the only one that presents a two day persistence of the price deviation and the Amundi Index MSCI World UCITS ETF DR EUR (D) is the only one to present a three day persistence of the price deviation.

The remaining seven ETFs have all of the coefficients statistically significant and this translates into having price deviations for at least six days until it disappears. These are the HSBC MSCI World UCITS ETF USD, iShares MSCI World UCITS ETF (Dist), Lyxor MSCI World UCITS ETF – Dist, Lyxor MSCI World (LUX) UCITS ETF, UBS ETF (IE) MSCI World UCITS ETF (USD) A-dis, UBS ETF (LU) MSCI World UCITS ETF (USD) A-dis and Xtrackers MSCI World UCITS ETF 1D.

The results of the regressions shown in Table 5.4, referring to the pandemic period, show that seven ETFs have a statistically significant intercept value and do not have a persistent price deviation, indicating that the premium disappears within the next day. These are the Amundi Index MSCI World UCITS ETF DR EUR (D), Deka MSCI World UCITS ETF, HSBC MSCI World UCITS ETF USD, iShares MSCI World UCITS ETF (Dist), Lyxor MSCI World UCITS ETF – Dist, UBS ETF (IE) MSCI World UCITS ETF (USD) A-dis and UBS ETF (LU) MSCI World UCITS ETF (USD) A-dis.

There are two ETFs, Lyxor MSCI World (LUX) UCITS ETF and Xtrackers MSCI World UCITS ETF 1D that do not have a statistically significant intercept value or coefficient, so there is not persistence of the price deviation.

The remaining eight ETFs have a persistence of one day in price deviation. These are the Amundi MSCI World UCITS ETF EUR (C), Invesco MSCI World UCITS ETF, iShares Core MSCI World UCITS ETF USD (Acc), Lyxor Core MSCI World (DR) UCITS ETF – Acc, SPDR MSCI World UCITS ETF, UBS ETF (IE) MSCI World UCITS ETF (USD) A-acc, Xtrackers MSCI World Swap UCITS ETF 1C and Xtrackers MSCI World UCITS ETF 1C.

This results indicate that during the pandemic the correction process of the price deviations in the markets occurred much faster than in the pre-pandemic analysed period.

5.2 Replication Strategy

The following table show the results of the replication strategy regressions for both periods in analysis.

Table 5.5 Regression Results for Replication Strategy (from 01/01/2015 to 31/12/2019)

PERIOD: 01/01/2015 (OR INITIAL TRADING DATE) TO 31/12/2019	α	β	R^2	DW STATS	BREUSCH- PAGAN TEST
AMUNDI INDEX MSCI WORLD UCITS ETF DR EUR (D)	0,0000969	0,8494257*	0,5666	2,13719	10,84
AMUNDI MSCI WORLD UCITS ETF EUR (C)	0,0001385	0,8997573*	0,5478	2,563814	12,89
DEKA MSCI WORLD UCITS ETF	0,0001154	0,8702762*	0,6338	2,214165	22,91
HSBC MSCI WORLD UCITS ETF USD	0,0000619	0,8935521*	0,5451	2,557695	16,51
INVESCO MSCI WORLD UCITS ETF	0,0001415	0,8968608*	0,5465	2,561668	15,76
ISHARES CORE MSCI WORLD UCITS ETF USD (ACC)	0,000142	0,9011476*	0,5427	2,562102	12,09
ISHARES MSCI WORLD UCITS ETF (DIST)	0,0000652	0,8974481*	0,5396	2,547283	14,80
LYXOR CORE MSCI WORLD (DR) UCITS ETF - ACC	0,0001489	0,8561947*	0,5700	2,127254	29,75
LYXOR MSCI WORLD UCITS ETF - DIST	0,0000538	0,9002001*	0,5420	2,543854	10,91
LYXOR MSCI WORLD (LUX) UCITS ETF	0,0001128	0,8987872*	0,5409	2,542951	13,82
SPDR MSCI WORLD UCITS ETF	0,0002047	0,9485956*	0,7185	1,95482	24,64
UBS ETF (IE) MSCI WORLD UCITS ETF (USD) A-ACC	0,0001839	0,9333698*	0,6812	2,046426	18,10
UBS ETF (IE) MSCI WORLD UCITS ETF (USD) A-DIS	0,0000645	0,8840039*	0,5409	2,497635	16,85
UBS ETF (LU) MSCI WORLD UCITS ETF (USD) A-DIS	0,0000596	0,8963817*	0,5444	2,540545	15,11
XTRACKERS MSCI WORLD SWAP UCITS ETF 1C	0,0001414	0,9001543*	0,5455	2,563366	13,29

XTRACKERS MSCI WORLD UCITS ETF 1C	0,0001412	0,8958242*	0,5478	2,554014	15,83
XTRACKERS MSCI WORLD UCITS ETF 1D	0,0000725	0,873751*	0,5266	2,412079	19,80

Note: * statistically significant at 5% confidence level (p -value<0,05)

For the period of 01/01/2015 to 31/12/2019, results displayed in Table 5.5 above, we have all ETFs with an alpha (constant value) that is not statistically significant at 5% level of confidence. According to similar results obtained by Purohit and Malhotra (2015), since ETFs are designed to imitate the performance of the underlying benchmark index, these findings for the alpha values are in line with a passive investment strategy.

On the other hand, all beta value are statistically significant at 5% confidence level. All estimated betas are below one, indicating that they do not perform a full replication strategy. The highest beta is 0,9485956 from the SPDR MSCI World UCITS ETF and the lowest is 0,8494257 from the Amundi Index MSCI World UCITS ETF DR EUR (D).

According to Rompotis (2012)³, cited in the analysis made by Purohit and Malhotra (2015), R^2 is also an indicator of the ETFs replication strategy and a signification deviation from one confirms that the ETF does not have a full replication strategy. In our results all ETFs deviate from one in the r-squared estimate, confirming the absence of a full replication strategy. The highest R^2 is 0,7185 from the SPDR MSCI World UCITS ETF, the same one with the highest beta. The lowest R^2 is 0,5266 from the Xtrackers MSCI World UCITS ETF 1D.

Table 5.6 Regression Results for Replication Strategy (from 01/01/2020 to 31/12/2020)

PERIOD: 01/01/2020 TO 31/12/2020	α	β	R^2	DW STATS	BREUSCH- PAGAN TEST
AMUNDI INDEX MSCI WORLD UCITS ETF DR EUR (D)	0,0000856	0,7368946*	0,6059	2,188391	44,63
AMUNDI MSCI WORLD UCITS ETF EUR (C)	0,0001473	0,7180041*	0,5975	2,152842	37,46
DEKA MSCI WORLD UCITS ETF	0,0000946	0,7177366*	0,5943	2,138593	24,24

³ Rompotis, G. G. (2012). The German Exchange Traded Funds. *The IUP Journal of Applied Finance*, 18(4), 62-82.

HSBC MSCI WORLD UCITS ETF USD	0,0000974	0,7125301*	0,5900	2,109468	41,74
INVESCO MSCI WORLD UCITS ETF	0,0001546	0,7253284*	0,5998	2,182525	28,32
ISHARES CORE MSCI WORLD UCITS ETF USD (ACC)	0,0001336	0,7510603*	0,6331	2,253206	48,51
ISHARES MSCI WORLD UCITS ETF (DIST)	0,0000807	0,7293758*	0,6018	2,144277	45,00
LYXOR CORE MSCI WORLD (DR) UCITS ETF - ACC	0,0001436	0,7243893*	0,5971	2,171688	43,90
LYXOR MSCI WORLD UCITS ETF - DIST	0,0000832	0,7258614*	0,5890	2,117748	46,48
LYXOR MSCI WORLD (LUX) UCITS ETF	0,0000808	0,7417218*	0,6101	2,202383	67,87
SPDR MSCI WORLD UCITS ETF	0,0001386	0,72932*	0,5991	2,176323	45,05
UBS ETF (IE) MSCI WORLD UCITS ETF (USD) A-ACC	0,0001511	0,7243991*	0,6080	2,184573	46,39
UBS ETF (IE) MSCI WORLD UCITS ETF (USD) A-DIS	0,0000736	0,7389632*	0,6121	2,194802	59,11
UBS ETF (LU) MSCI WORLD UCITS ETF (USD) A-DIS	0,0000696	0,7419001*	0,6172	2,183795	56,90
XTRACKERS MSCI WORLD SWAP UCITS ETF 1C	0,0001405	0,7358186*	0,6061	2,142237	46,98
XTRACKERS MSCI WORLD UCITS ETF 1C	0,000134	0,7501255*	0,6219	2,202584	91,99
XTRACKERS MSCI WORLD UCITS ETF 1D	0,0000506	0,7393517*	0,6026	2,175861	56,07

Note: * statistically significant at 5% confidence level (p-value<0,05)

For the period of 01/01/2020 to 31/12/2020, results displayed in Table 5.6 above, we have again all ETFs with an alpha estimate that is not statistically significant, which as in the previous analysed period means that the alpha values are in line with a passive investment strategy.

On the other hand, all beta value are statistically significant at 5% confidence level. As in the previous analysed period, all estimated betas are below one, indicating that they do not perform a full replication strategy. The highest beta is 0,7510603 from the iShares Core MSCI World

UCITS ETF USD (Acc) and the lowest is 0,7125301 from the HSBC MSCI World UCITS ETF USD.

In our results all ETFs deviate from one in the r-squared (R^2) estimate, confirming the absence of a full replication strategy. The highest R^2 is 0,6331 from the iShares Core MSCI World UCITS ETF USD (Acc), the same one with the highest beta as in the previous analysed period. The lowest R^2 is 0,5890 from the Lyxor MSCI World UCITS ETF – Dist.

5.3 Tracking Error

The following tables display the results from the three methods of calculating the tracking error and its average value for each ETF, during the two analysed periods.

Table 5.7 Tracking error results for TE1, TE2 and TE3 (from 01/01/2015 to 31/12/2019)

PERIOD: 01/01/2015 (OR INITIAL TRADING DATE) TO 31/12/2019	TE1	TE2	TE3	AVERAGE
AMUNDI INDEX MSCI WORLD UCITS ETF DR EUR (D)	0,005369003	0,003724676	0,0060164	0,00503669
AMUNDI MSCI WORLD UCITS ETF EUR (C)	0,005818869	0,003915241	0,0063569	0,00536367
DEKA MSCI WORLD UCITS ETF	0,005016189	0,00355555	0,0064757	0,00501581
HSBC MSCI WORLD UCITS ETF USD	0,00581654	0,003958986	0,0063131	0,00536288
INVESCO MSCI WORLD UCITS ETF	0,005818114	0,003924283	0,0063365	0,00535963
ISHARES CORE MSCI WORLD UCITS ETF USD (ACC)	0,005888338	0,003954112	0,0063692	0,00540388
ISHARES MSCI WORLD UCITS ETF (DIST)	0,005901497	0,003980214	0,0063406	0,00540744
LYXOR CORE MSCI WORLD (DR) UCITS ETF - ACC	0,005275685	0,003658765	0,0059637	0,00496605
LYXOR MSCI WORLD UCITS ETF - DIST	0,00588864	0,003964261	0,0063601	0,00540433
LYXOR MSCI WORLD (LUX) UCITS ETF	0,005893606	0,003982848	0,0063501	0,00540885

SPDR MSCI WORLD UCITS ETF	0,003757693	0,002781633	0,0059813	0,00417354
UBS ETF (IE) MSCI WORLD UCITS ETF (USD) A-ACC	0,003990687	0,002842811	0,0058014	0,00421163
UBS ETF (IE) MSCI WORLD UCITS ETF (USD) A-DIS	0,005811839	0,003945298	0,0062456	0,00533425
UBS ETF (LU) MSCI WORLD UCITS ETF (USD) A-DIS	0,005839929	0,003951518	0,0063331	0,00537485
XTRACKERS MSCI WORLD SWAP UCITS ETF 1C	0,005847444	0,003948404	0,0063597	0,00538518
XTRACKERS MSCI WORLD UCITS ETF 1C	0,00579707	0,003904562	0,0063291	0,00534358
XTRACKERS MSCI WORLD UCITS ETF 1D	0,005926244	0,00400014	0,0061791	0,00536849

On Table 4.8 for the period of 01/01/2015 to 31/12/2019, the TE1 method has a minimum tracking error of 0,003757693 (SPDR MSCI World UCITS ETF) and a maximum of 0,005926244 (Xtrackers MSCI World UCITS ETF 1D).

The TE2 method has a minimum tracking error of 0,002781633 (SPDR MSCI World UCITS ETF) and a maximum of 0,00400014 (Xtrackers MSCI World UCITS ETF 1D).

The TE3 method has a minimum tracking error of 0,0058014 (UBS ETF (IE) MSCI World UCITS ETF (USD) A-acc) and a maximum of 0,0064757 (Deka MSCI World UCITS ETF).

We then calculated the average of the results from the three methods used. The minimum average tracking error is 0,00417354 (SPDR MSCI World UCITS ETF) and the maximum average tracking error is 0,00540885 (Lyxor MSCI World (LUX) UCITS ETF).

Table 5.8 Tracking error results for TE1, TE2 and TE3 (from 01/01/2020 to 31/12/2020)

PERIOD: 01/01/2020 TO 31/12/2020	TE1	TE2	TE3	AVERAGE
AMUNDI INDEX MSCI WORLD UCITS ETF DR EUR (D)	0,01195887	0,007375468	0,0135594	0,01096458
AMUNDI MSCI WORLD UCITS ETF EUR (C)	0,012021021	0,007433573	0,0132118	0,0108888
DEKA MSCI WORLD UCITS ETF	0,01208455	0,00733377	0,0132068	0,01087635
HSBC MSCI WORLD UCITS ETF USD	0,01214162	0,007352267	0,013111	0,0108683

INVESCO MSCI WORLD UCITS ETF	0,01201661	0,007374737	0,0133465	0,01091262
ISHARES CORE MSCI WORLD UCITS ETF USD (ACC)	0,01147568	0,007206381	0,0138200	0,01083402
ISHARES MSCI WORLD UCITS ETF (DIST)	0,01199842	0,00733011	0,013421	0,01091651
LYXOR CORE MSCI WORLD (DR) UCITS ETF - ACC	0,01206563	0,007406025	0,0133293	0,01093365
LYXOR MSCI WORLD UCITS ETF - DIST	0,01224497	0,0074451	0,0133563	0,01101546
LYXOR MSCI WORLD (LUX) UCITS ETF	0,01190165	0,00741071	0,0136482	0,01098685
SPDR MSCI WORLD UCITS ETF	0,01205491	0,00735218	0,01342	0,01094236
UBS ETF (IE) MSCI WORLD UCITS ETF (USD) A-ACC	0,01186786	0,0073595	0,0133558	0,01086105
UBS ETF (IE) MSCI WORLD UCITS ETF (USD) A-DIS	0,0118431	0,00728169	0,0135974	0,0109074
UBS ETF (LU) MSCI WORLD UCITS ETF (USD) A-DIS	0,01175412	0,007253624	0,0136515	0,01088641
XTRACKERS MSCI WORLD SWAP UCITS ETF 1C	0,01194909	0,00729041	0,0135396	0,01092637
XTRACKERS MSCI WORLD UCITS ETF 1C	0,01170409	0,00723414	0,0138028	0,01091368
XTRACKERS MSCI WORLD UCITS ETF 1D	0,01204338	0,00739125	0,0136046	0,01101308

On Table 4.9 for the period of 01/01/2020 to 31/12/2020, the TE1 method has a minimum tracking error of 0,01147568 (iShares Core MSCI World UCITS ETF USD (Acc)) and a maximum of 0,01224497 (Lyxor MSCI World UCITS ETF – Dist).

The TE2 method has a minimum tracking error of 0,007206381 (iShares Core MSCI World UCITS ETF USD (Acc)) and a maximum of 0,0074451 (Lyxor MSCI World UCITS ETF – Dist).

The TE3 method has a minimum tracking error of 0,013111 (HSBC MSCI World UCITS ETF USD) and a maximum of 0,0138200 (iShares Core MSCI World UCITS ETF USD (Acc)).

We then calculated the average of the results from the three methods used. The minimum average tracking error is 0,01083402 (iShares Core MSCI World UCITS ETF USD (Acc)) and the maximum average tracking error is 0,01101546 (Lyxor MSCI World UCITS ETF – Dist)

6. Conclusion

Throughout this dissertation we analyzed the performance of the 17 ETFs that have the MSCI World Index as the underlying benchmark index. We went through three important performance indicators in the literature: pricing efficiency, replication strategy and tracking error.

Fama (1970) tested empirically the statement that, in an efficient market, prices fully reflect all available information, and introduced the idea that it is impossible to constantly beat the market. To do this, three different tests were used, those being weak form tests, semi-strong form tests and strong form tests. Weak form tests focused on historical prices, semi-strong form tests considered whether prices adjust to the information that is publicly available (such as annual reports and stock splits) and strong form tests review if price formation is affected by monopolistic access to information.

According to Fama (1970), there is extensive evidence in support of the efficient markets model and sparse contradictory evidence. The author also considers that one of the most pressing fields for the future is to develop and test models of the market equilibrium under uncertainty.

In our research uncertainty is certainly a big factor in the pandemic period. Our results show that market efficiency is still true in an uncertain environment as arbitrage opportunities are diminished and corrected at a faster pace than in the pre-pandemic period.

Our results for the pricing efficiency indicator show clear differences in the price deviations between the two periods analyzed. The average price deviation for the pre-pandemic period is 2,243388235 and for the pandemic period is 0,562858824. This means that during the pandemic there we less deviations between the market price and NAV values of the ETF.

When we go on to analyze the persistence of the price deviations, the results are the expected ones after the previous conclusion. During the pre-pandemic period ETFs tend to have longer price deviation persistence, even though during this period there was 8 ETFs that eliminated the price deviation within the next day, there are 7 ETFs that take at least 6 days to eliminate the existing price deviations. This can be considered a long period for the persistence of arbitrage opportunities.

During the pandemic period ETFs tend to have shorter time persistence of price deviations. Our results show that 9 of the ETFs do not have persistence of price deviation as it disappears within the next day. The remaining 8 ETFs have a price persistence of one day. This shows a significant improve in the possibility of arbitrage.

The results for the replication strategy are technically similar as in both periods they indicate the ETFs do not perform a full replication strategy.

In both the pre-pandemic and the pandemic periods, alpha values are not statistically significant, meaning there is no return generated by the ETF regardless of the return generated by the underlying benchmark index. This means that the ETF have a passive investment strategy in both periods, regardless of the effects of the pandemic on the financial market.

The estimated beta coefficients are, on the other hand, statistically significant in both periods analyzed. The results obtained for beta coefficients before the pandemic period are however higher than those obtained for the pandemic period. This means that even though in both periods the ETF do not perform a full replication strategy, they were closer to full replication before the pandemic hit. A fair conclusion to this is that in the pandemic, where beta coefficients are further from one and therefore present a more pronounced selective replication strategy, the fund manager selected the securities to optimize its returns.

On our last indicator, tracking error, all ETFs have higher tracking errors during the pandemic when compared to the pre-pandemic period. Overall, ETFs had a higher difficulty to mimic the MSCI World Index. This can be attributed to higher uncertainty in the financial markets during the pandemic, as new developments in the pandemic were taking place. While the pre-pandemic period has the highest tracking error average at 0,00540885 (Lyxor MSCI World (LUX) UCITS ETF), the pandemic period has 0,01101546 (Lyxor MSCI World UCITS ETF – Dist) as the highest average tracking error.

It is save to say that the pandemic brough some uncertainty to the financial market, however not all consequences were negative. While tracking error was higher than in the pre-pandemic period, pricing efficiency was better during the pandemic as price deviations were generally smaller and their persistence was shorter in working days. The replication strategy stayed the same, although coefficients became smaller.

Further investigation could be done on the performance of these ETFs, such as using Jensen's alpha and Treynor ratio, to determine any abnormal returns that may have occurred between these periods.

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