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Master's Degree Program in
Statistics and Information Management

UNDERSTANDING THE RELATIONSHIP BETWEEN IMPACT INVESTMENT FIRMS AND MARKET VOLATILITY

An analysis of European Impact Firms amidst COVID-19 and Ongoing Conflict

Fábio Alexandre Alves de Sousa

Master Thesis

presented as partial requirement for obtaining the Master's Degree in Statistics and Information Management

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Master Thesis presented as partial requirement for obtaining the Master's degree in Statistics and Information Management, with a specialization in Risk Analysis and Management

Supervised by

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STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration. I further declare that I have fully acknowledged the Rules of Conduct and Code of Honor from the NOVA Information Management School.

[Lisbon, July 15, 2024]

DEDICATION

This thesis is dedicated to the many people who supported and encouraged me throughout this journey.

To my girlfriend, whose unconditional support provided me with the strength and motivation I needed during the most stressful times. Your understanding and patience were invaluable.

To my parents, for their support and encouragement, allowing me to pursue my education and follow my dreams. Your sacrifices and belief in me have made this achievement possible.

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ABSTRACT

The past decade has been marked by significant social and racial inequalities, global conflicts, climate challenges, and the ongoing repercussions of the COVID-19 pandemic. Amid these issues, the growth and development of impact investing signal a substantial shift in the investment landscape, suggesting a promising future where investments that drive positive social and environmental change will be crucial in addressing major global problems. Despite the rapid evolution of impact investing, existing research on the financial performance and risk associated with these investments presents a variety of perspectives. This paper employs Dynamic Conditional Correlation GARCH modelling to analyse the time-varying volatility and correlation dynamics between European Impact Firms and European market reference indices, including the STOXX Europe 600 Index and volatility indices such as the EURO STOXX 50 Volatility and DAX-New Volatility Indices. The analysis is conducted across three distinct periods: pre-COVID-19, during COVID-19, and the pandemic-war period, encompassing the pandemic and the ongoing conflict. Our findings suggest potential short-term diversification and risk-hedging benefits for EU impact firms, while long-term volatility contagion highlights the substantial and persistent impact of market volatility on these firms over extended periods.

KEYWORDS

Impact investing; Volatility; COVID-19; Diversification; DCC-GARCH model

Sustainable Development Goals (SDG):

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LIST OF ABBREVIATIONS AND ACRONYMS

IF	Impact Firms
IIFX	Impact Investing Firms Index
STOXX	STOXX Europe 600 EUR Price Index
V2TX	EURO STOXX 50 Volatility (VSTOXX) EUR Price Index
V1XI	DAX-New Volatility Index
DCC	Dynamic Conditional Correlation
GARCH	Generalized Autoregressive Conditional Heteroskedasticity

1. INTRODUCTION

Impact investing has evolved from a niche concept to a widely adopted investment approach. Investors are increasingly aligning their financial goals with positive social and environmental outcomes (Höchstädter & Scheck, 2015). Early pioneers, such as the Global Impact Investing Network (GIIN), were among the early visionaries behind what we now recognize as impact investing. The GIIN defines impact investing as "investments made with the intention to generate measurable positive social and environmental impact alongside financial returns, and specifically use that investment capital along with engagement or investment terms to positively influence targeted impact results." This intentionality differentiates impact investing from purely financially-motivated investments.

The rapid growth of the impact investing market is reflected in the substantial increase in assets under management, which have risen from $95 billion in 2017 to $213 billion by the end of 2022. This surge indicates a promising trajectory, suggesting that impact investments will play a crucial role in addressing some of the world's most pressing challenges in the years to come (Hand et al., 2023).

However, despite the quick expansion of the impact investing landscape, there is still a lack of sufficient literature on the topic (see, Chiappini et al., 2023 and Migliavacca et al., 2022). Questions remain around the definition of impact investing and how it differs from related concepts like socially responsible investing (SRI). Clarifying these boundaries is essential for a better understanding and application of impact investing.

Existing research has contributed to a clearer delineation of impact investing, and to a clear delineation of boundaries to broader concepts like socially responsible investing (Höchstädter & Scheck, 2015). It is commonly perceived as either different from or to go beyond related concepts like socially responsible investing. The reasons are that while impact investors seek to fund projects with positive and measurable societal and environmental goals, and are open to accepting trade-offs between those social and also financial goals (Barber et al., 2021), socially responsible investors often focus on Environmental, Social and Governance (ESG) criteria to improve corporate practices, thereby enhancing financial performance through reputation. Some companies may misrepresent social and environmental impact to portray themselves as "purpose-led brands" (Morduch & Ogden, 2019).

Geczy et al. (2021) delineated the contractual and governance practices inherent in impact investing, emphasizing the delicate balance required between financial objectives and social-benefit goals. In a complementary study, Burton et al. (2021) delved into the characteristics of impact investors, defining them as individuals or entities with a dual mandate of generating social good and financial returns. These investors meticulously select companies that demonstrate a capacity to deliver significant social value, often maintaining higher equity stakes in such enterprises (Chowdhry et al., 2019).

Interestingly, the perception of impact investing has evolved over time. Previously, there was a misconception that there was a trade-off between financial returns and impact, rather than recognizing that both could be pursued together across different types of investments. However, nowadays, impact investing is understood differently. It's seen as an approach that can be applied to various types of investments, not just a distinct asset class. Unlike other responsible investing strategies that focus on managing financial risks or screening for reputational risks, impact investing integrates impact considerations directly into investment decisions, viewing it as a core component of overall performance. This means that impact is seen as a dimension of an investment's overall performance, alongside financial returns (Hand & Gilbert, 2023). Yet, despite its potential, there are behavioural factors that can hinder the effective alignment of financial and social outcomes. Lee et al. (2020) revealed that people often struggle to efficiently achieve both financial and social objectives when allocating their portfolios for impact investing.

To better understand the financial aspects of impact investing, a collaborative effort between practitioners and academics is needed. Most studies are of firms or funds that adopt sustainable practices based on ESG criteria, therefore being engaged in socially responsible investments. Despite existing discussions on these matters, studies conducted by practitioners (e.g. Mudaliar & Bass, 2017) and academics (e.g. Barber et al., 2021) have predominantly relied on privately-owned data, continuing being one of the main limitations in current literature, presenting a mix of evidence and conflicting theoretical frameworks. By bridging the gap between theory and practice, a more comprehensive and nuanced narrative of impact investing can be developed, paving the way for its continued growth and impact (Agrawal & Hockerts, 2021).

As we delve into this paper, our aim is to build upon the analysis conducted by Bernal et al. (2021) , one of the few studies focusing on the financial performance of impact investing in the public equity market and specifically for European impact firms. While Bernal et al. (2021) ’s study was limited to a small sample of 16 European publicly listed firms, Giacomini et al. (2023) recently expanded this analysis to the US market, examining a final sample of 50 US impact firms. Notably, as highlighted by Burton et al. (2021) , there exists a significant gap in the literature regarding impact investing in the public equity market, which has the potential to attract a broader investor base beyond those currently involved in private markets. With this in mind, our study will concentrate on analysing the role of European impact firms within public equity markets, leveraging the emergence of new publicly listed impact firms.

This paper aligns with Chiappini et al. (2023) in its literature review and lays the groundwork for examining impact investing as a strategy for risk hedging, diversification, and exploring their potential as safe-haven assets. The evolving landscape of impact investing presents a unique opportunity to explore the intersection of financial performance, social impact, and market dynamics, offering insights that can shape investment strategies and contribute to the broader discourse on sustainable finance. Previous research suggests that social investments may have low correlation with mainstream market investments, indicating potential for diversification and risk mitigation (Brandstetter & Lehner, 2015). However, the role of impact investing in diversification, hedging, and risk management is not yet fully understood, despite its significant implications for both academia and practitioners.

We use a unique dataset of EU listed companies whose products or services directly address social and environmental challenges outlined in the United Nations Sustainable Development Goals (SDGs), using a process similar to Giacomini et al. (2023) . This approach was endorsed by most of the respondents from GIIN Annual Impact Investor Survey 2020, who invest in companies that already have a positive impact through their products or services. This means selecting companies whose core business activities contribute to positive outcomes in areas such as sustainability, social responsibility, or other environmental or social goals (Hand et al., 2020). The list of companies included in this study, along with a description of their primary business activities, is provided in Appendix A.

From this list of companies, our Impact Investing Firms Index, developed using the STOXX free-float market capitalization weighting methodology, serves as the foundation for our empirical analysis. This index is compared against the STOXX Europe 600 Index, EURO STOXX 50 Volatility, and the DAX-New Volatility Index to examine the relationship of covariance and correlation between impact investments and these market reference indices, employing the DCC Multivariate GARCH model (Engle, 2002; Engle & Sheppard, 2001).

The sample period for this analysis spans from January 2016 to March 2024, encompassing the pre-COVID, during-COVID, and pandemic-war periods. The study's significance is further underscored by its consideration of the post-COVID-19 pandemic and the current context of war. These unprecedented global events have significantly impacted financial markets and the investment landscape. By incorporating these factors into our analysis, we provide a more comprehensive understanding of the financial performance and risk exposure of impact investments in the public equity market.

Our study is structured as follows: the “Literature Review” provides context on the current literature on impact investments, examining their roles as hedging and diversification tools, and their performance during crisis. The “Data and Methodology” chapter details the data collection process, including the screening of impact firms and the construction of an impact investing index, and describes the methodologies used, such as EWMA and DCC GARCH models. The “Empirical Study” offers a preliminary analysis of the collected data. The “Results and Discussion” presents findings on volatility contagion between European impact firms and broader market indices, both in the short and long term. Finally, the “Conclusions and Future Works” summarize the key findings and suggest areas for further research.

2. LITERATURE REVIEW

Impact investing, characterized by its emphasis on social and sustainability outcomes, is a financially sustainable investment practice. Investors in this field actively select firms whose products and services directly contribute to such outcomes (Chowdhry et al., 2019). This proactive selection process stands as a key feature of impact investing.

Achieving impact can take various forms, including the adaptation of existing financial tools like shares and bonds to align with social and sustainable objectives. Alternatively, new financial instruments, such as impact bonds (commonly known as SIBs), can be created for social purposes (Lenzi, 2021).

This field is gaining interest, leading to many questions for practitioners and researchers (Chowdhry et al., 2019; Höchstädter & Scheck, 2015). Among these, two main questions stand out. Firstly, can impact investments be justified through a safe-haven, risk-hedging, and diversification role? Secondly, do they show resilience during crisis periods?

These questions, posed by Chiappini et al. (2023) , remain unanswered as existing literature presents mixed results regarding the risk-return performance of impact investing, and has been predominantly focused on examining the financial performance and risk exposure of firms or funds that embrace sustainable practices.

2.1. CAN IMPACT INVESTMENTS BE JUSTIFIED THROUGH A SAFE-HAVEN, RISK HEDGING AND DIVERSIFICATION ROLE?

In the field of socially responsible investing, studies have shown that investors who care about social responsibility tend to prioritize their values over diversification when making investment decisions. Research by Barreda-Tarrazona et al. (2011) found that these investors are willing to invest more in socially responsible options even if the returns are lower compared to other projects. Similarly, Riedl & Smeets (2017) discovered that only a small portion of investors hold socially responsible investment funds for diversification purposes. This suggests that for many socially responsible investors, aligning their investments with their values is more important than diversifying their portfolios for risk management.

Some economists suggest that constrained investment strategies, particularly impact investing, are likely to yield lower returns, adjusted for risk, compared to unconstrained strategies, assuming perfect and complete capital markets and rational, informed investors (Barber et al., 2021; Brest et al., 2018).

However, others have questioned the soundness of these assumptions, particularly in private markets (Cole et al., 2020). Recently, Jeffers et al. (2023) highlighted that the difference in financial performance between impact funds and non-impact funds diminishes when accounting for market risk exposure, due to a low covariance with the market. This indicates that incorporating impact investing funds into a portfolio can contribute to a more diversified investment strategy with lower market risk exposure compared to similar private market strategies.

Barber et al. (2021) discovered that investors are willing to accept lower financial returns in investments that also have social goals. Their study found that impact funds deliver internal rates of return (IRR) that are 4.7 percentage points lower ex-post and 2.5-3.7 percentage points lower ex-ante compared to traditional venture capital (VC) funds. In contrast, Jeffers et al., 2023 found that while both matched and venture capital funds perform better than impact funds in absolute terms, the risk-adjusted performance among these strategies becomes more comparable when factoring in market risk exposure. Similarly, Cole et al. (2020) also highlighted that the equity portfolio of examined impact investors has performed on par with both public and private equity in the United States, surpassing market performance by 15 percent. These findings collectively suggest that impact investing can leverage market inefficiencies to potentially yield higher risk-adjusted returns compared to unrestricted strategies.

Bernal et al. (2021) attempted to analyse the financial performance of impact investments on the public equity market, but with a limited sample of only 16 European publicly listed firms. Nevertheless, the study found that investors who commit to listed impact firms experience lower returns and increased risk compared to mainstream markets. The diversification potential of impact investments also decreased over time. Therefore, from a financial perspective, listed impact firms are not very attractive to investors. This aligns with the conclusion of Morduch & Ogden (2019) that the willingness to accept a financial trade-off, makes impact investors needed, otherwise, traditional investors would fund impact companies. Additionally, Riedl & Smeets (2017) found that only a small percentage of socially responsible investors hold SRI funds for diversification benefits, indicating that diversification is not their primary concern.

Building on Torre et al. (2017) 's work, who found that non-impact portfolios tend to outperform social impact investment (SII) portfolios in terms of financial returns for the same level of risk, Biasin et al. (2019) further supported the notion that allocating portfolios to companies addressing social and environmental issues can lead to favourable outcomes. They suggested that risk-prone investors can optimize their utility by using a mean-variance allocation strategy with the social impact finance index and the bond index, while very risk-averse investors may benefit from a naïve allocation strategy that includes all indices.

The G8 Social Impact Investment Taskforce's Asset Allocation Working Group also advocates for including impact investments in portfolios to achieve similar financial returns as unconstrained investments while enhancing diversification, although this may come at the cost of liquidity. Participants in social impact investment are often more motivated by creating positive change than by financial gains, operating in high-risk, low-return environments to showcase SII as a viable alternative (Watts & Scales, 2020).

2.2. DO IMPACT INVESTMENTS SHOW RESILIENCE DURING CRISIS PERIODS?

In studies on socially responsible investing, some researchers (Hua Fan & Michalski, 2020; Nakai et al., 2016; J. Nofsinger & Varma, 2014) have found that socially responsible funds often perform better than traditional funds during market crises. This provides some protection against losses for investors in these funds.

Impact investing focuses on businesses that address social needs, which tend to be more important during economic downturns. This means demand for these businesses may actually increase when the economy is struggling. This makes impact investing less dependent on the overall economy. Researchers have explored how a company's sustainability practices relate to its creditworthiness and financial risk (see Brogi et al., 2022). Companies with higher ESG scores are expected to have better creditworthiness, thereby reducing financial risks. Failure to address ESG concerns in credit assessments can lead to a negative investor perception, increasing financial risks such as higher costs and liquidity issues. Same applies for impact investing which can improve a company's reputation and loyalty from stakeholders (Bouslah et al., 2013). This reputation and loyalty may prevent large drops in the company's stock price during difficult times (Godfrey et al., 2009).

Moreover, Boyd et al. (2001) demonstrated that companies with higher quality find it easier to secure financing during periods of high inflation. This is likely due to lenders and investors viewing these firms as more reliable even in challenging economic conditions like high inflation. However, Liu et al. (2021) found that firms with strong corporate social responsibility (CSR) but higher levels of imitative innovation may still face higher financial risks. Engaging in sustainable activities can incur higher costs for a company, thus bringing various risks to the firm.

A study conducted by Kim et al. (2014) highlight the role of CSR in balancing stock returns, reducing extreme negative outcomes. Another conducted by Nofsinger et al. (2019) implies that companies with strong environmental and social performance are less prone to crash risks. Integrating ESG factors in investment decision-making improves the Sharpe ratio and crash risk profile of the momentum strategy, especially when combined with historical returns. This outperformance is particularly evident in times characterised by slow economic growth, elevated inflation rates, and widened credit-spreads (Hua Fan & Michalski, 2020).

The relationship between SRI and ESG strategies in the market remains unclear. Bansal et al. (2022) found that SRI tends to be highly pro-cyclical, meaning it performs well during market upswings. Pástor & Vorsatz (2020) and J. Nofsinger & Varma (2014) found that socially responsible mutual funds tend to perform better during market crises.

Recent research by Giacomini et al. (2023) found comparable financial performance between publicly listed impact firms (IF) and non-impact firms (NIF) in the public market of impact investing. This indicates that constrained investment strategies may yield similar profitability to traditional unconstrained investment approaches. Nevertheless, it tends to behave differently in crisis versus non-crisis periods. While IF portfolios may underperform matched NIF portfolios during non-crisis periods, they outperform NIF portfolios during crises. This suggests that impact investing can provide valuable risk mitigation and resilience during times of financial distress.

During non-crisis periods, SRI funds may slightly underperform conventional funds, but this difference is not considered significant. However, in crisis periods, SRI funds outperform conventional funds, particularly ESG categories within SRI funds, showcasing significant outperformance during these challenging times (J. Nofsinger & Varma, 2014).

3. DATA AND METHODOLOGY

3.1. DATA COLLECTION

3.1.1. SCREENING IMPACT FIRMS

To be eligible for impact investments, the firm's product and mission should target specific social or environmental outcomes, such as contributing to reduce poverty and hunger, improve the quality of education and provide clean water and sanitation. Another common strategy is to invest in companies with positive impact through their operational practices. This involves selecting companies that demonstrate responsible and sustainable business practices in their day-to-day operations, such as reducing their carbon footprint, promoting fair labour practices, or implementing environmentally friendly policies (Hand et al., 2020).

Accessing the right data and metrics for impact investing is a big challenge. Even though efforts have been made to help make data more available, most studies on impact investments still rely on private data. Private impact funds, especially, tend to keep their investment data to themselves. And when they do share, they often leave out any investments that didn't do well, which makes their overall performance look better than it might be (Watts & Scales, 2020).

Hence, to see if impact investments can be justified through a safe-haven, risk-hedging, and diversification role, and if they do show resilience during crisis periods, we meticulously gathered a unique dataset from a selection of EU listed companies. These companies primarily focus on addressing various social and environmental challenges outlined in the United Nations Sustainable Development Goals (SDGs). The SDGs, comprising 17 goals that address a wide array of sustainable development issues, serve as a globally recognized framework for defining impact areas, reflecting a consensus among stakeholders on ambitious development objectives. Impact investors increasingly favoured companies whose offerings align with at least one SDG, using them as a benchmark to establish impact performance goals, as highlighted in GIIN's report (Hand et al., 2020). Consequently, companies are opting to incorporate SDGs into their non-financial disclosures (Pizzi et al., 2022).

Following a similar selection process to Giacomini et al. (2023) , we initiated our study by selecting companies listed in the wikipositive.org database, which featured close to 800 companies globally by the end of April 2024. From this extensive database, we specifically focused on EU-listed companies, narrowing down the selection to just over 200 companies. Subsequently, we got another list of companies by utilizing Refinitiv Screener and applying two filters: ESG negative screening AND alignment with at least one Sustainable Development Goal (SDG). I used web scraping to retrieve a table of company names from the wikipositive.org database, where each name included a hyperlink to additional details about the company. By following each link, I gathered specific information, such as the ISIN code, allowing me to cross-reference both lists ISIN codes to identify which ones meet our study criteria. Finally, by conducting searches on each company's website, we scrutinize their core business descriptions to pinpoint firms explicitly committed to social and environmental sustainability through their products or services. This comprehensive approach enabled us to include companies dedicated to positive social and environmental impact, while also considering ESG criteria and SDG alignment, ensuring a comprehensive and robust analysis of impact investments in our research.

This meticulous screening process yields our final sample comprising 55 EU impact firms (hereafter, IF) spanning the period from beginning 2016 to March 2024. The size of our sample reflects the niche nature of impact investing compared to more traditional ESG and socially responsible investments. As previously mentioned, Bernal et al. (2021) examined the public equity market in Europe, analysing a sample of only 16 listed firms. Our dataset, which includes 55 European impact firms, marks a notable advancement compared to their study.

Appendix A provides a comprehensive list of companies included in this study along with descriptions of their primary business activities. These companies showcase a diverse range of impact focuses. While some prioritize sustainable technology, infrastructure, or construction, others may concentrate on healthcare, education, or environmental conservation. Furthermore, our analysis does not include companies in the banking or government sectors which prevents regulatory influences from biasing our results.

To categorize these 55 impact firms across each impact goal, we have established five impact categories following the recommendations of MSCI ESG Research, which offers a framework encompassing all SDGs. Table 1 illustrates the distribution of the 55 companies across these impact categories. The Empowerment category represents the smallest segment, accounting for 6% of the firms. In contrast, Natural Capital emerges as the most prevalent category, comprising 38.2%, followed by Basic Needs and Climate Change, each representing 21.8%.

Table 1 - Impact investing firms' distribution of impact areas

Impact areas	SDGs	Number	Percent
Basic needs	No poverty, Zero Hunger, Good Health and Well-Being, Clean Water and Sanitation, Sustainable Cities and Communities	12	21,8%
Climate Change	Affordable and Clean Energy, Climate Action	12	21,8%
Empowerment	Quality Education, Gender Equality, Decent Work and Economic Growth, Reduced Inequalities, Industry, Innovation, and Infrastructure	10	18,2%
Nature Capital	Sustainable Consumption and Production, Life on Land, Life Below Water	21	38,2%
Governance	Peace, Justice and Strong Institutions, Partnership	0	0,0%
Total		55	100,0%

3.1.2. CONSTRUCTING OUR IMPACT INVESTING INDEX

In order to construct our Impact Investing Firms Index (hereafter, IIFX), we gathered the daily closing prices for each of the 55 impact firms from January 2016 to March 2024, along with their market capitalization and free-float rate as of March 2024, using Thomson Reuters Datastream. For the index construction, we adopted the methodology employed by STOXX, utilizing the STOXX Europe 600 as our benchmark. This comprehensive index represents the performance of the 600 largest cap companies across 17 European countries, serving as a reliable measure of European equity market performance.

The STOXX Europe 600 employs a free-float market capitalization weighting methodology to ensure that it accurately reflects the portion of the market available to investors for trading. Each constituent's weighting within the index is determined by dividing its free-float rate market capitalization by the sum of all constituents' free-float rate market capitalization. The resulting weight for each constituent is then multiplied by its share price to determine its impact on the overall index performance.

Regular quarterly reviews are conducted, and during the review process, the most recent free-float data available to STOXX is utilized for component selection. This ensures that the index accurately reflects the current state of the market. For our analysis, we utilized the most recent free-float and market capitalization data available at the time of our analysis, March 2024. This approach ensures that the index accurately reflects the market landscape at the end of our analysis period, aligning with industry standards and best practices for index construction.

It is important to note that we have not incorporated adjustments for corporate actions as suggested by STOXX index methodology. Corporate actions such as stock splits, mergers, acquisitions, or spin-offs can impact the composition and weighting of the index, but we have opted for a simplified approach that focuses solely on the free float market capitalization of each company.

3.1.3. BROADER MARKET AND VOLATILITY INDICES

In examining the relationship between European impact investing firms and the European market, it is imperative to establish a comprehensive understanding of the market dynamics. This entails a thorough analysis of key market reference indices that serve as benchmarks for assessing the performance and volatility of European equities.

The STOXX Europe 600 index stands as a prominent benchmark, encompassing a diverse array of large, mid, and small capitalization companies spanning 17 European countries. Its broad coverage, representing approximately 90% of the European stock market capitalization, provides it an important tool for investors seeking insights into the overall performance of European equities.

Moreover, volatility indices such as the EURO STOXX 50 Volatility and the DAX-New Volatility Index offer crucial perspectives on market sentiment and risk perception. The EURO STOXX 50 Volatility Index tracks the implied volatility of options on the EURO STOXX 50 Index, providing valuable insights into investors' expectations regarding future volatility within the Eurozone market. Similarly, the DAX-New Volatility Index monitors the implied volatility of options on the DAX, shedding light on the anticipated volatility of Germany's leading blue-chip stocks. High levels of the EURO STOXX 50 Volatility and DAX-New Volatility Indices often indicate market stress, while low levels suggest market calmness.

Implied volatility reflects market expectations of future price movements, derived from option prices. We relied on these key market reference indices to investigate the potential roles of impact firms as safe-haven, risk-hedging, and diversification in the context of the European market.

3.2. METHODOLOGY

To assess the potential benefits of diversification by including impact assets in a traditional financial portfolio, we analysed the correlation of financial returns between European impact firms and European market benchmark indices. Impact investing has undergone significant changes in recent years, so we wanted to determine if the behaviour of impact assets has changed, particularly during periods of market stress such as the COVID-19 pandemic and its aftermath, as well as the current context of geopolitical tensions in Eastern Europe and the Middle East.

3.2.1. EXPONENTIALLY WEIGHTED MOVING AVERAGE (EWMA)

Before employing the DCC-GARCH (Dynamic Conditional Correlation - Generalized Autoregressive Conditional Heteroskedasticity) model in our analysis, we first utilized the Exponentially Weighted Moving Average (EWMA) method to investigate the dynamic relationships between the Impact Investing Firms Index (IIFX) and the indices STOXX, V2TX, and V1XI. The rationale for using EWMA lies in its ability to provide a preliminary understanding of the time-varying covariances and correlations with less computational complexity compared to DCC-GARCH. EWMA offers a clear and intuitive approach to track changes in the relationships over time, making it an excellent precursor to the more sophisticated DCC-GARCH analysis.

The EWMA method assigns exponentially decreasing weights to older observations, allowing recent data to have a more significant impact on the calculated averages. This weighting scheme is controlled by a smoothing parameter, lambda (λ), set to 0.94.

By using exponentially decreasing weights, the EWMA method places more emphasis on the most recent observations, which is crucial in financial markets where recent events often have a greater impact on current market conditions than older ones. This property makes EWMA particularly useful for modelling financial time series data, as it allows for a more responsive adjustment to changes in market volatility and correlations.

In our analysis, we utilized both a shorter window (lambda = 0.94) and a longer window (half-life = 125 days) for the EWMA calculations. The shorter window provided detailed insights into the short-term fluctuations and immediate impacts of market events on the relationships. We also explored the use of a longer half-life parameter, which effectively adjusts lambda to provide a different perspective on the data. This longer window smooths out short-term fluctuations and highlights longer-term trends, providing a complementary view to the standard lambda setting.

By applying EWMA, we aimed to gain preliminary insights into the dynamic behaviour of the relationships between EU impact firms and the indices before moving to the more complex and computationally intensive DCC-GARCH model. The insights obtained from EWMA analysis served as a foundation for understanding the temporal evolution of covariances and correlations, thereby informing and guiding the subsequent DCC-GARCH analysis.

3.2.2. Dynamic Conditional Correlation (DCC) GARCH

In this study, Dynamic Conditional Correlation GARCH modelling is used to model the time-varying volatility and correlation dynamics between European impact firms and European market reference indices. Understanding how they interact is vital as impact investment grows. After conducting several statistical tests, such as ARCH and ACF tests, we found that the DCC-GARCH model provided the best fit for the data. This finding is further supported by previous studies, including Yousaf et al. (2022); Bernal et al. (2021); Haq et al. (2021); Saeed et al. (2020); and Sadorsky (2014) , which have also demonstrated the effectiveness of the DCC-GARCH model in capturing the dynamic relationships within similar financial datasets.

The Dynamic Conditional Correlation GARCH model (DCC-GARCH; Engle, 2002; Engle & Sheppard, 2001), introduced by Engle (2002) , is a powerful tool for capturing time-varying and dynamic relationships in multivariate settings. By combining the GARCH model to estimate individual assets' conditional variance and the dynamic conditional correlation model to assess time-varying correlations, the DCC-GARCH model offers a comprehensive understanding of volatility and correlation dynamics within financial markets.

When studying the volatility of financial time series, researchers frequently turn to GARCH, a method that uses an autoregressive framework to model a time series' conditional variance, allowing volatility shocks to persist over time. Multivariate GARCH models such as DCC-GARCH have been extensively used to explore contagion effects between markets, providing insights into the intricate interconnections and interdependencies among various assets (see, for example, Nguyen et al., 2022; Zhang et al., 2022; Celık, 2012; Martens & Poon, 2001).

The DCC-GARCH model follows a two-step process:

1. Estimation of the conditional variance ($h_{i,t}$) of each variable, using GARCH(1,1) model, specified in Eqs. (1) and (2).

$$r_{it} = \mu_i + \epsilon_{it} \tag{1}$$

$$h_{i,t} = \omega_i + \alpha_i \varepsilon_{it-1}^2 + \beta_i h_{i,t-1} \tag{2}$$

where, α and β are non-negative parameters, where α signifies short-term volatility sensitivity and β denotes long-term volatility persistence. The sum of alpha and beta coefficients serves as a measure of the persistence of volatility shocks. This sum is expected to be less than 1, indicating that the impact of shocks diminishes over time.

If the sum exceeds 1, it suggests that the shock has an explosive effect, persisting indefinitely and amplifying volatility.

2. Estimation of DCC parameters, to compute the time-varying conditional covariance matrix H_t, which is a function of the conditional correlation matrix R_t and diagonal matrix of time-varying standard deviations D_t.

$$H_t = D_t R_t D_t \tag{3}$$

where R_t is the conditional correlation matrix and D_t represents the diagonal matrix of time-varying standard deviations, specified in Eqs. (4) and (5).

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1} \tag{4}$$

$$D_t = diag\left(h_{1\cdot t}^{1/2} \ldots\ldots h_{n\cdot t}^{1/2}\right) \tag{5}$$

Q_t^{*-1} is calculated as follows: $Q_t^{*-1} = (diag(Q_t))^{-1/2}$.

In this model, the diagonal elements of the conditional covariance matrix are modelled using univariate GARCH processes, while the off-diagonal elements of H_t are represented as nonlinear functions of the diagonal terms and computed as:

$$[H_t]_{ij} = h_{it}^{1/2} h_{jt}^{1/2} \rho_{ij}, i \neq j \tag{6}$$

Therefore, the time-varying conditional correlation is estimated as follows:

$$\rho_{ij\cdot t} = \frac{Q_{ij\cdot t}}{\sqrt{Q_{ii\cdot t} Q_{jj\cdot t}}}, i \neq j \tag{7}$$

This two-step approach allows for the modelling of time-varying correlations in a multivariate setting while preserving the simplicity of univariate GARCH models for individual assets' volatility.

Moreover, we relied on the Maximum Likelihood Estimation (MLE) method to evaluate model fit, ensuring that the parameters were estimated in a way that maximizes the likelihood. As a result, we found that the inclusion of ARMA(1,1) components enhances the log-likelihood of our model, signifying a better fit to the data by capturing linear dependencies in the mean process that a plain GARCH model may overlook. While our return series y_t is approximately uncorrelated but dependent, more than 5 lags fall outside the confidence limits, suggesting the presence of weak serial correlations that an ARMA model could capture. (see, Appendix B).

$$r_{it} = \mu_i + \phi_i r_{it-} \ + \theta_i \varepsilon_{it-1} + \varepsilon_{it} \tag{8}$$

This inclusion of the autoregressive (AR) component allows the mean equation to account for serial correlation in the returns, providing a more accurate representation of the financial data. Additionally, the moving average (MA) component helps to capture the impact of past shocks on current returns. By incorporating both AR and MA components in the ARMA(1,1) model, we can effectively model the dynamics of the returns, allowing for a more comprehensive and nuanced understanding of the underlying processes. This combined approach helps to reduce the residuals' autocorrelation, leading to better performance in subsequent volatility and correlation modelling steps.

Additionally, we tested various distributions for the error terms, including the normal Gaussian and Student's T distributions (see, Appendix C). Among these, the Student's T distribution proved to be the most effective, thus being the one which results we decided to present in the study.

The Student's T distribution was preferred because it accounts for heavy tails and extreme values, which are common in financial data. This distribution enhances the model's ability to capture the risk and volatility associated with financial returns, leading to more robust and realistic modelling. By incorporating these elements, the model with a Student's T distribution offers a more comprehensive understanding of the underlying market dynamics and improves the overall predictive performance of the model.

3.2.3. Copula Dynamic Conditional Correlation GARCH

The Copula-DCC-GARCH methodology is designed to capture the complexities of financial data, particularly the skewed, leptokurtic, and asymmetric dependence patterns exhibited by asset returns. It achieves this by linking univariate marginal distributions to their multivariate distribution through copulas, a concept introduced by Sklar (1959) . This approach allows for a more flexible and accurate representation of the dependencies between asset returns, addressing the limitations of traditional models.

The Copula-DCC-GARCH methodology involves a two-step process. First, univariate return distributions are estimated using GARCH models to capture time-varying volatility. This step ensures that the marginal distributions of each asset are accurately modelled. Then, the conditional dependence structure is modelled using copulas, incorporating dynamic conditional correlations (DCC) to capture time-varying correlations between assets and market indices (Patton, 2012, 2006). This step effectively captures the dynamic interdependencies between assets and market conditions.

The parameters of the Copula-DCC-GARCH model are estimated via maximum likelihood estimation, a standard approach in financial econometrics. This ensures robustness in capturing the evolving market dynamics across different periods of stability and crisis.

4. EMPIRICAL STUDY

The dataset used for the entire sample period has been carefully cleaned to ensure accuracy and consistency. Since the companies in the study are from different parts of Europe with varying holidays and data availability, it was important to address any potential biases. To achieve this, any rows with missing data were excluded. This means that only days where all companies had complete data were included in the analysis, resulting in 1852 daily observations from January 5, 2016, to March 27, 2024. This meticulous process ensures that the analysis is based on a standardized dataset, allowing for fair comparisons and accurate evaluations across all companies. I conducted the analysis using R, utilizing the following packages: “tseries”, “PerformanceAnalytics”, “quantmod”, “rugarch”, “car”, “FinTS”, “rmgarch”, “copula”, and “lmtest”. Specifically, “FinTS” helped justify the use of DCC-GARCH, through ARCH effect tests, “rugarch” was used to fit the univariate GARCH model, and “rmgarch” allowed to fit and evaluate multivariate GARCH models.

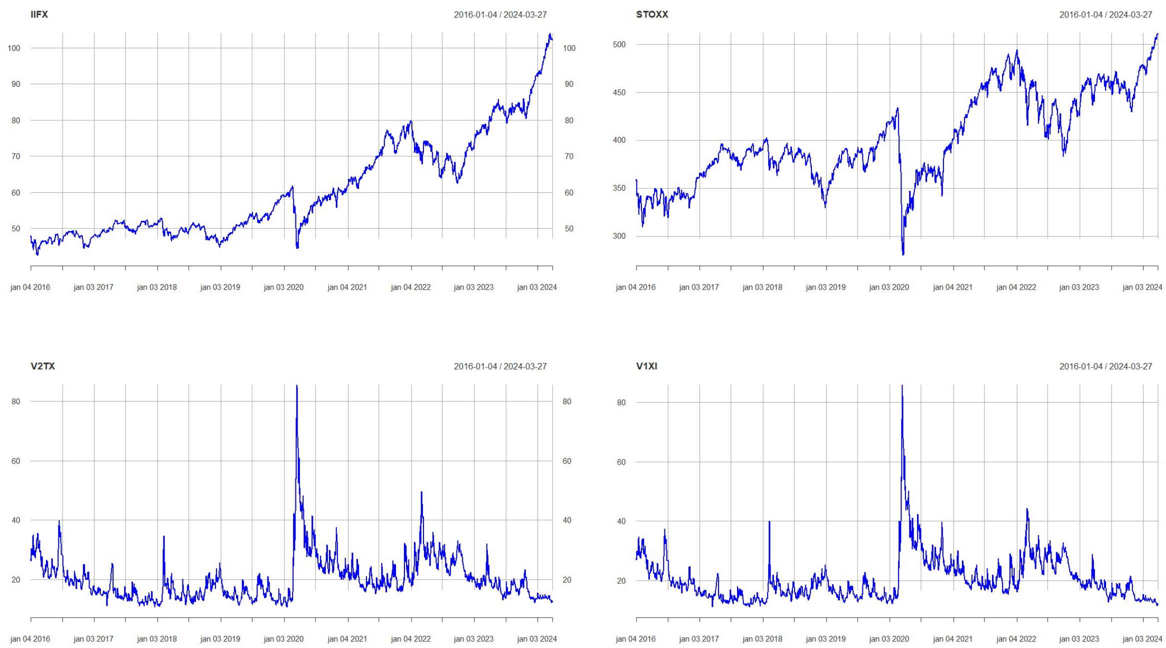

Figure 1 - Prices and values of Impact Investing Firms Index (IIFX) , STOXX Europe 600 Index (STOXX), and the two market volatility indices (V2TX and V1XI) from January 4, 2016, and March 27, 2024.

Figure 1 reveals a similarity in volatility between EU impact firms and STOXX, although the latter exhibits more pronounced fluctuations in prices, particularly during the COVID-19 pandemic period. Both indices show similar non-positive relation with the market volatility indices, which had a significant peak in their values coinciding with the COVID-19 pandemic and reflecting market expectations of future price movements during this time of health crisis.

The peak in early 2022 is attributed to the market's response to the geopolitical tensions triggered by Russia's invasion of Ukraine.

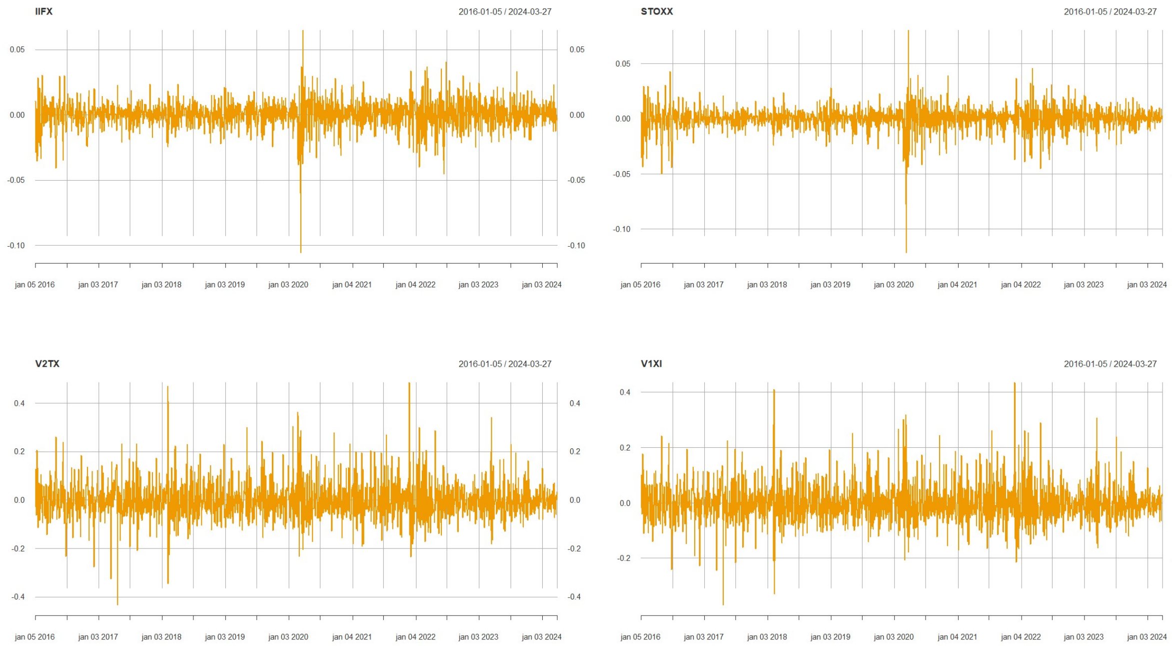

Figure 2 - Log Returns of Impact Investing Firms Index (IIFX) , STOXX Europe 600 Index (STOXX), and the two market volatility indices (V2TX and V1XI) from January 5, 2016, and March 27, 2024.

Figure 2 illustrate a striking similarity in volatility between EU impact firms and STOXX from January 2016 to March 2024, in particular, during the COVID-19 pandemic period. Both volatility indices exhibit significant daily changes during the analysis period, reflecting the high volatility experienced in the European equity market. This volatility was particularly pronounced in early 2018, driven by concerns over rising interest rates and inflation, in early 2020, due to the COVID-19 pandemic, and in early 2022, in response to Russia's invasion of Ukraine. The recent years have been market by uncertainty, which is reflected in these two market volatility indices.

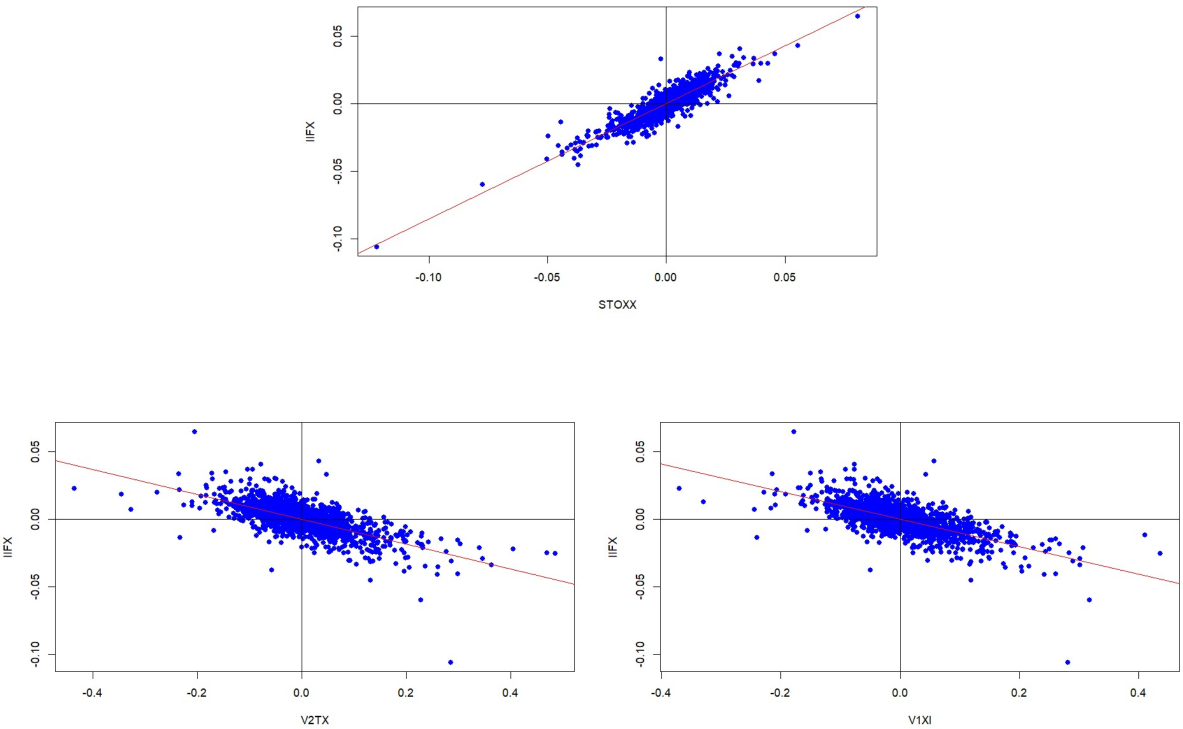

Figure 3 - Scatterplot of returns between Impact Investing Firms Index (IIFX) and STOXX Europe 600 Index (STOXX), and the two market volatility indices (V2TX and V1XI) from January 5, 2016, and March 27, 2024.

Figure 3 illustrates the relationship between returns of EU impact firms and broader market and volatility indices. The scatter plot of IIFX against STOXX reveals a positive correlation, as the data points cluster around an upward-sloping line from left to right. This suggests that when STOXX’s prices are high, IIFX prices tends to be high as well. This suggests that when STOXX's prices are high, IIFX prices tend to be high as well, indicating a strong positive relationship between the two indices. In contrast, the scatter plots of IIFX against V2TX and V1XI show a negative relationship, as the data points cluster around downward-sloping lines from left to right. This implies that when implied volatility (V2TX and V1XI) is high, IIFX prices tend to be low, indicating a negative correlation between the two variables. Furthermore, the scatter plots reveal different distributional characteristics. The data points for IIFX against STOXX are more concentrated, indicating a tighter relationship between the two variables. In contrast, the data points for IIFX against V2TX and V1XI are more scattered, suggesting the presence of outliers. This could be due to the influence of specific events or market conditions that affect the volatility of EU impact firms, leading to deviations from the overall trend.

Table 2 - Summary statistics on indices' daily return series, January 5, 2016, to March 27, 2024.

	IIFX	STOXX	V2TX	V1XI
Descriptive statistics				
Minimum	-0,1058	-0,1219	-0,4347	-0,3700
Maximum	0,0650	0,0807	0,4859	0,4359
1st Quartile	-0,0048	-0,0042	-0,0443	-0,0407
3rd Quartile	0,0062	0,0055	0,0357	0,0312
Mean	0,0004	0,0002	-0,0004	-0,0004
Median	0,0009	0,0008	-0,0069	-0,0065
Variance	0,0001	0,0001	0,0059	0,0049
Stdev	0,0104	0,0109	0,0766	0,0696
Skewness	-0,7772	-1,1371	0,7745	0,7696
Excess Kurtosis	8,4446	13,8968	4,3440	3,9561
J-B Test	5689,3011***	15301,6577***	1641,2933***	1390,5572***
Probability	0.0000	0.0000	0.0000	0.0000
ADF Test	-12,1982***	-12,1530***	-14,0196***	-13,8618***
Probability	0.0000	0.0000	0.0000	0.0000
ARCH Test	406,6429***	444,6648***	119,4972***	154,2555***
Probability	0.0000	0.0000	0.0000	0.0000
Observations	1852	1852	1852	1852

***, **, * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 2 presents the descriptive statistics of the data for the whole sample ranging from January 5, 2016, to March 27, 2024. These statistics reveal interesting insights into the characteristics of the IIFX: Impact Investing Firms Index and its relationship with the STOXX: STOXX Europe 600 Index, V2TX: EURO STOXX 50 Volatility Index and V1XI: DAX-New Volatility Index. Across the board, each index displays distinct features that shed light on their performance and behaviour over the analysed period.

The IIFX demonstrates a relatively stable performance, with a mean return of 0.0004 and a median return of 0.0009. These values suggest a slight negative skewness (-0.7772) and moderate kurtosis (8.4446), indicating a distribution slightly skewed to the left with a sharper peak than a normal distribution. The narrow range of returns (-0.1058 to 0.0650) and low variability around the mean, as indicated by the variance (0.0001) and standard deviation (0.0104), highlight the index's consistency over time.

The STOXX index showcases characteristics of a left-skewed distribution, with a mean return of 0.0002 and a median return of 0.0008. The pronounced negative skewness (-1.1371) and high kurtosis (13.8968) suggest heavier tails and a more peaked distribution compared to the Impact Investing Index. Despite moderate variability around the mean, with a variance of 0.0001 and a standard deviation of 0.0109, the STOXX index exhibits wider fluctuations in returns, as reflected in its range (-0.1219 to 0.0807).

In contrast, both V2TX and V1XI indices display right-skewed distributions, with positive skewness and moderate kurtosis. V2TX demonstrates a mean return of -0.0004 and a median return of -0.0069, with a wider range of returns (-0.4347 to 0.4859) and higher variability around the mean, as indicated by a standard deviation of 0.0766. Similarly, V1XI exhibits comparable characteristics, with a mean return of -0.0004 and a median return of -0.0065, along with a range of returns (-0.3700 to 0.4359) and standard deviation of 0.0696.

The descriptive statistics show that the mean and median values of IIFX are similar to those of STOXX, which could suggest some degree of alignment between the two indices. However, their skewness and kurtosis values indicate different distributional characteristics, which could affect the strength of their covariance and correlation.

Compared to V2TX and V1XI, the IIFX has different distributional characteristics. While the IIFX is skewed to the left, V2TX and V1XI are skewed to the right. The IIFX, being based on price returns, exhibits a left-skewed distribution due to its sensitivity to the price movements of impact investing firms. On the other hand, V2TX and V1XI, focusing on market's expectation of near-term volatility, demonstrate right-skewed distributions as they capture extreme volatility events that tend to be positively skewed. Despite their distinct distributional characteristics, there may exist correlations between the IIFX and V2TX/V1XI, reflecting the impact of market volatility on impact investing performance.

Several statistical tests were conducted to analyse the characteristics of the return series and to see which model would work best. The Augmented Dickey-Fuller (ADF) test was used to check if the return series are stationary. The results show that all series have p-values less than 0.01 (99% confidence level), which means there is strong evidence that the series are stationary.

The Jarque-Bera test was used to check if the return series follow a normal distribution. The results show that all series have p-values less than 0.01 (99% confidence level), which is extremely small. This means there is overwhelming evidence that the series are not normally distributed. Financial return series often exhibit heavy tails and skewness, meaning they have more extreme values and are asymmetric compared to a normal distribution.

The results of the ARCH tests reveal significant ARCH effects, with p-values less than 0.01 (99% confidence level). This suggests the presence of time-varying volatility in the series. Consequently, models that account for time-varying volatility, such as GARCH-type models, are appropriate for these series. These models can better capture the dynamic nature of volatility in the financial time series data we are analysing. Additionally, all excess kurtosis values are greater than 0, meaning the distribution has heavy tails, which is a requirement for the GARCH models.

Thus, the descriptive statistics underscore the unique distributional properties of each index, with implications for their covariance and correlation dynamics. While the IIFX demonstrates relative stability, the STOXX, V2TX, and V1XI indices exhibit varying degrees of volatility and skewness, reflecting distinct market behaviours. These findings provide valuable insights for investors and policymakers seeking to understand the relationship between impact investing firms and broader market trends, particularly in times of market stress and crisis.

Table 3 - Preliminary evidence of unconditional Pearson correlation

Indexes	**Correlation Coefficient**	**t-Stats**	**p-Value**
IIFX-STOXX	0.8927	85.1971	0.0000
IIFX -V2TX	-0.6792	-39.8003	0.0000
IIFX -V1XI	-0.6848	-40.4180	0.0000

We first estimated the unconditional correlation before conducting the DCC-MGARCH estimation, as shown in Table 3. The results indicate a statistically significant relationship between the variables.

The unconditional correlation between EU impact firms and the STOXX index is highly positive and statistically significant, with a correlation coefficient of 0.8927 (p-value < 2.2e-16). This suggests a very strong positive linear relationship, indicating that the returns of EU impact firms and the STOXX index move closely together. Consequently, there is limited diversification benefit, as EU impact firms behave similarly to the broader market represented by the STOXX index.

Conversely, the correlations between EU impact firms and V2TX/V1XI are significantly negative, with correlation coefficients of -0.6792 and -0.6848, respectively (both p-values < 2.2e-16). These strong negative relationships imply that when the broader market experiences volatility or uncertainty, the returns of EU impact firms tend to move in the opposite direction.

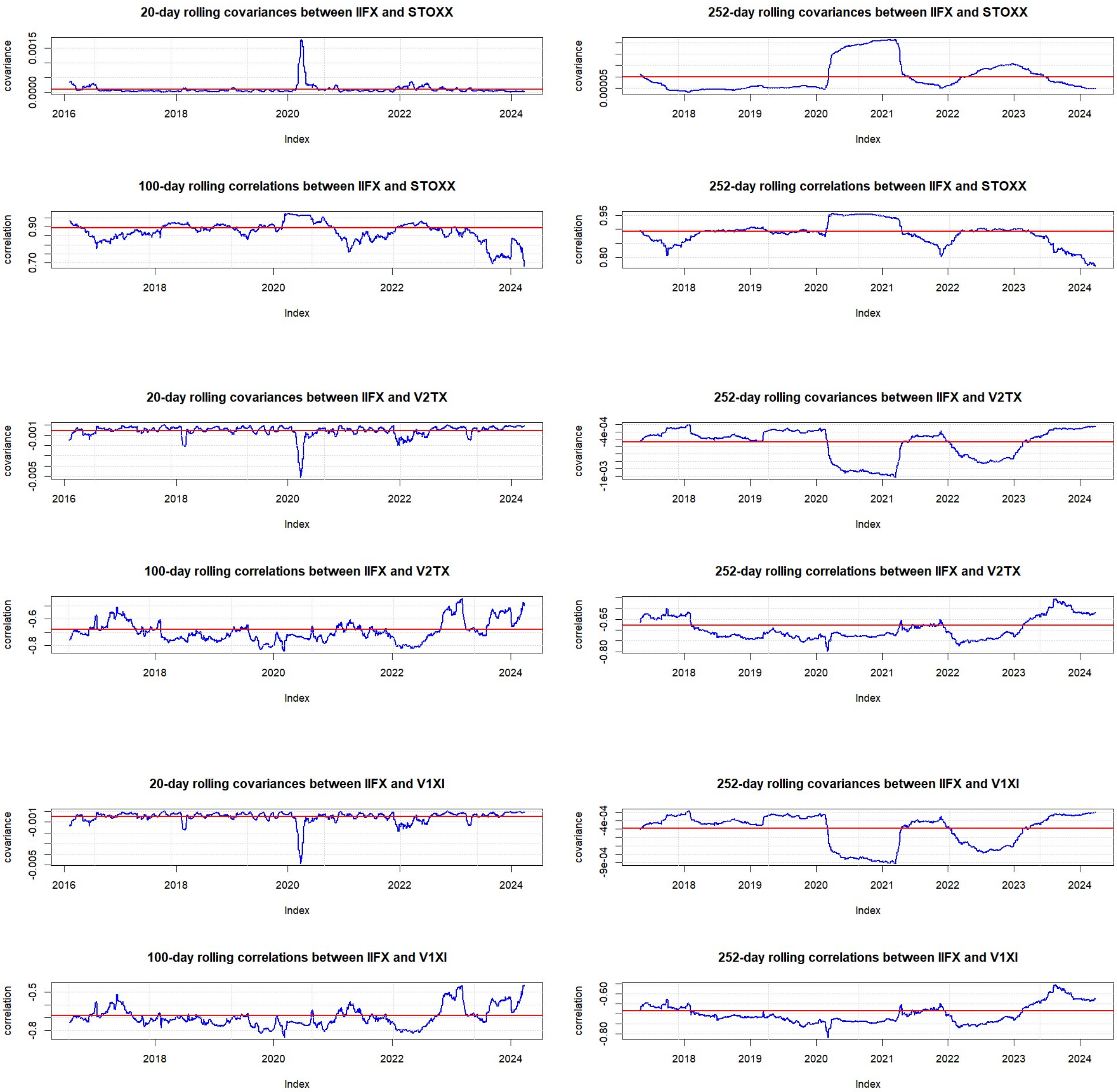

Figure 4 - Rolling covariances and correlations between the Impact Investing Firms Index (IIFX) and STOXX Europe 600 Index (STOXX), and the two market volatility indices (V2TX and V1XI), using different time windows.

For IIFX and STOXX, the 20-day rolling covariances and 100-day rolling correlations show a generally positive relationship, which fluctuates more significantly during periods of market stress, such as the COVID-19 pandemic. The 252-day metrics, however, demonstrate a more prolonged and less volatile correlation, suggesting that despite short-term market disruptions, the relationship between IIFX and STOXX endures over the longer window. This persistence is particularly notable during the pandemic and ongoing war, where the prolonged periods of crisis show strong and persistent impact on correlation.

In contrast, the analysis of IIFX and V2TX highlights a predominantly negative relationship, indicating that as market volatility increases, the Impact Investing Firms Index tends to decline. This inverse relationship is more apparent in the short-term 20-day rolling covariance and 100-day rolling correlation, which exhibit greater sensitivity and volatility during crises. The 252-day rolling metrics smooth out these fluctuations, especially during the prolonged periods of crisis such as the pandemic and the war. The IIFX and V1XI analysis follows a similar pattern to the V2TX analysis, with a negative correlation.

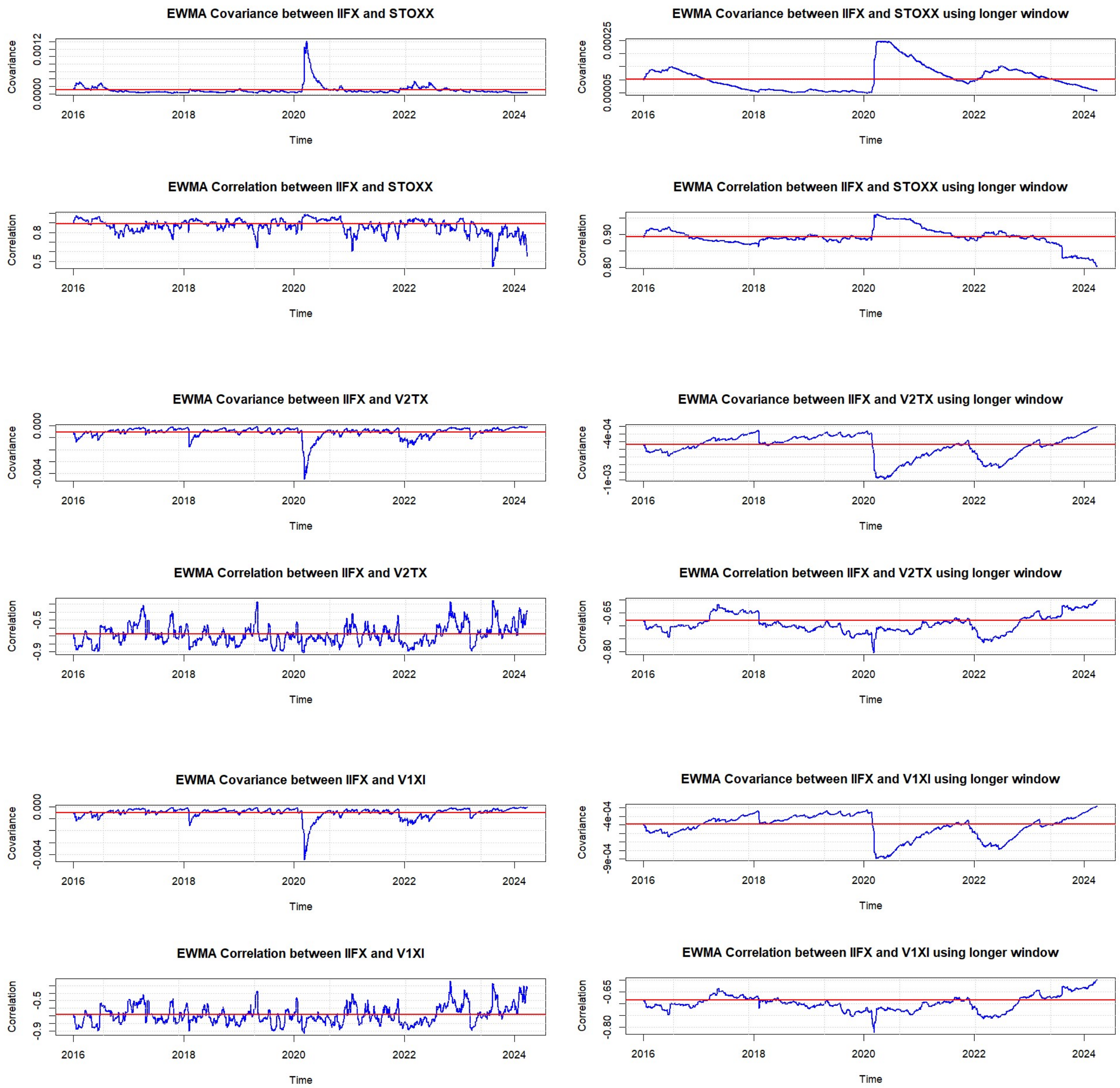

Figure 5 - EWMA covariances and correlations between the Impact Investing Firms Index (IIFX) and STOXX Europe 600 Index (STOXX), and the two market volatility indices (V2TX and V1XI), using different time windows.

For IIFX and STOXX, the short-term window reveals a relatively stable covariance with a significant spike around the onset of the COVID-19 pandemic, indicating a heightened correlation during this period. The longer window, however, smooths out these short-term fluctuations, suggesting prolonged periods of higher covariance during the pandemic. The correlation between IIFX and STOXX shows fluctuations around a strong positive value, revealing a gradual decline since the pandemic, suggesting a weakening but still significant relationship over time.

In contrast, the analysis of IIFX and V2TX highlights a more volatile relationship. The short-term window displays frequent spikes in covariance during market stress periods, such as the COVID-19 pandemic. The correlation in the short-term window fluctuates considerably, reflecting market volatility. However, the longer window demonstrates a consistent upward trend, especially since the pandemic, indicating a weakening but still very significant negative relationship between IIFX and V2TX during volatile and uncertain market conditions. The IIFX and V1XI analysis follows a similar pattern to the V2TX analysis, with a negative correlation.

The results show a more pronounced relationship between EU impact firms and the STOXX index. This indicates that EU impact firms move strongly in tandem with the overall market, suggesting limited diversification benefits within these assets. Conversely, the negative correlations with V2TX and V1XI indices are weaker, implying that EU impact firms are not as strongly affected by these indices. This might suggest some potential diversification benefits against implied market volatility.

5. RESULTS AND DISCUSSION

To determine whether impact investments can serve as a safe-haven, risk-hedging, and diversification strategy, and whether they exhibit resilience during crisis periods, we analysed the financial returns of 55 EU impact firms from January 2016 to March 2024. Using a DCC Multivariate GARCH model, we assessed the correlation of financial returns between these EU impact firms and European market benchmark indices, specifically STOXX: STOXX Europe 600 Index, V2TX: EURO STOXX 50 Volatility Index, and V1XI: DAX-New Volatility Index.

Our dataset consists of 1852 daily observations from January 5, 2016, to March 27, 2024, and is divided into three sub-samples. The first sub-sample covers the pre-COVID-19 period, from January 5, 2016, to January 23, 2020. The second sub-sample, which includes the COVID-19 period, spans from January 24, 2020, marking the beginning of COVID-19 in Europe, to May 5, 2023, marking the end of COVID-19 as a global health emergency by the World Health Organization (WHO). The third sub-sample covers the pandemic-war period, which includes both the COVID-19 period, starting from January 24, 2020, and the ongoing war that began with Russia's invasion of Ukraine on February 24, 2022, and continues to the present. There is an overlap during the COVID-19 and the pandemic-war period sub-samples, both representing periods of uncertainty and crisis in our analysis, while the pre-COVID-19 period represents a more stable period.

Table 4 - Estimation results of DCC-GARCH model

	IIFX -	STOXX	V2TX	V1XI
Interval A: Full sample period (January 5, 2016, to March 27, 2024)				
mu	0,00091***	0,00087***	-0,00234***	-0,00257***
ar1	0,59805**	0,69392***	0,90520***	0,90349***
ma1	-0,65505**	-0,74200***	-0,97919***	-0,97445***
omega	0,00001	0,00000	0,00020	0,00021
alpha1	0,12154***	0,14872***	0,07253	0,09254**
beta1	0,82997***	0,83374***	0,89916***	0,87378***
shape	6,20753***	4,11845***	3,87625***	3,87668***
dcca1		0,05724***	0,04994***	0,04629***
dccb1		0,88929***	0,85095***	0,85290***
mshape		5,25560***	5,05504***	5,07079***
Interval B: Pre-COVID-19 (January 5, 2016, to January 23, 2020)				
mu	0,00072***	0,00069***	-0,00202***	-0,00207***
ar1	-0,98386***	0,89013***	0,89743***	0,88094***
ma1	0,99404***	-0,91941***	-0,98258***	-0,97340***
omega	0,00001***	0,00000	0,00165**	0,00131**
alpha1	0,14919***	0,15629**	0,13187**	0,13571***
beta1	0,73270***	0,79554***	0,58204***	0,58696***
shape	6,23262***	4,45051***	4,13100***	4,47376***
dcca1		0,02638**	0,03193*	0,02366
dccb1		0,89077***	0,86290***	0,77044***
mshape		5,99599***	4,97099	5,27980***
Interval C: During COVID-19 (January 24, 2020, to May 5, 2023)				
mu	0,00115***	0,00116***	-0,00550***	-0,00597***
ar1	0,43800**	0,35614*	0,56564***	0,58181***
ma1	-0,53108***	-0,45583**	-0,70558***	-0,70600***
omega	0,00001**	0,00001	0,00010	0,00009
alpha1	0,10927***	0,17879***	0,05428***	0,06326***
beta1	0,84601***	0,82020***	0,93334***	0,92752***
shape	5,77550***	3,77321***	4,09054***	3,64227***
dcca1		0,07553***	0,05139***	0,05852***
dccb1		0,87301***	0,86181***	0,85152***
mshape		4,79235***	5,21968***	4,70195***
Interval D: Pandemic-War period (January 24, 2020, to March 27, 2024)				
mu	0,00119***	0,00106***	-0,00235	-0,00304***
ar1	0,39749**	0,43635**	0,63472***	0,91642***
ma1	-0,48883***	-0,51604***	-0,75888***	-0,97543***
omega	0,00001	0,00000	0,00004	0,00006
alpha1	0,10810	0,14620**	0,04981***	0,06896***
beta1	0,85384***	0,84787***	0,94483***	0,92499***
shape	6,35171***	3,93751***	4,36091***	3,75488***
dcca1		0,07188***	0,04203**	0,04609***
dccb1		0,88166***	0,87768***	0,87235***
mshape		5,05991***	5,74517***	5,09007***

Coefficient estimates derived from univariate GARCH and Dynamical Conditional Correlations (DCC). Univariate GARCH processes are calculated for each index (with parameters mu, omega, alpha1, beta1), before estimating the DCC parameters dcca1 and dccb1. The indices considered include all three pairs of Impact Investing Firms Index (IIFX) against each of STOXX Europe 600 index (STOXX), EURO STOXX 50 Volatility index (V2TX) and DAX-New Volatility index (V1XI). The use of the multivariate t-distribution allowed the model to account for heavy tails and extreme values in the data, which are common in financial data, leading to more robust and realistic modelling of financial returns. ***, **, * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

SHORT-TERM VOLATILITY CONTAGION BETWEEN EUROPEAN IMPACT FIRMS AND EUROPEAN MARKET'S VOLATILITY (V2TX/V1XI)

Short-term volatility contagion describes the immediate and significant response of volatility in one market—in this case, EU impact firms—to changes in volatility in another market, represented by European market volatility indices V2TX and V1XI. The DCC-GARCH model captures this phenomenon using the alpha 1 coefficients (impact of past shocks on current volatility estimate) and the dcca1 coefficients (short-term dynamics in the correlation between the European Impact Investing Firms Index (IIFX) and the V2TX/V1XI indices).

During the full sample period, the findings using the DCC-GARCH model, as shown in Table 4, suggest a moderate response to recent shocks in both V2TX and V1XI, indicating that 7.253% and 9.254% of the recent shocks persist in the volatility dynamics of these indices. The short-term contagion with EU impact firms, as measured by the dcca1 values of 0.04994 for V2TX and 0.04629 for V1XI, appears to be slight but statistically significant. This means that sudden changes in European market volatility led to a slight sensitivity in the volatility of EU impact firms. The relatively low dcca1 values suggest that while there is some short-term contagion, EU impact firms are not highly reactive to extreme movements in European market volatility, indicating potential diversification benefits.

In the pre-COVID-19 period, the alpha1 coefficients of 0,13187 for V2TX and 0,13571 for V1XI reveal a higher degree of short-term volatility persistence. This means that in stable times, past shocks have a stronger influence on current volatility estimates. The dcca1 values of 0,03193 for V2TX and 0,02366 for V1XI suggest weaker short-term correlations with EU impact firms. This indicates that EU impact firms were not highly sensitive to changes in European market volatility. This weaker sensitivity suggests potential for diversification during stable periods. However, the statistical significance of these values is not strong for all measures, implying that the observed relationship might be due to random chance rather than a robust correlation.

During the COVID-19 period, there is a reduced response to recent shocks, revealed by the alpha1 coefficients of 0,05428 for V2TX and 0,06326 for V1XI, indicating that immediate past shocks had a lesser impact on current volatility. This could reflect the unique market conditions during the pandemic, where volatility was driven more by ongoing uncertainty than by recent shocks. Additionally, the dcca1 values of 0,05139 for V2TX and 0,05852 for V1XI suggest slightly higher short-term contagion compared to the pre-COVID-19 period. This indicates that EU impact firms became somewhat more responsive to recent changes in European market volatility during the pandemic. The increased contagion reflects a more interconnected and responsive market environment, yet the relatively low values still indicate potential diversification benefits as EU impact firms were not excessively sensitive to market volatility.

In the pandemic-war period, which encompasses both the COVID-19 pandemic and the ongoing war, the alpha1 values 0,04981 for V2TX and 0,06896 for V1XI suggest a minor impact of immediate past shocks on current volatility. This continued minor influence reflects the prolonged period of uncertainty where volatility was influenced more by ongoing crises rather than recent shocks. The dcca1 values of 0,04203 for V2TX and 0,04609 for V1XI indicate that the short-term sensitivity of EU impact firms to market volatility remained slight but statistically significant. Despite the extended crisis period, impact firms exhibited relatively stable behaviour in the face of European market volatility, indicating their resilience. The slightly higher dcca1 values compared to pre-COVID-19 suggest a maintained, yet still moderate, sensitivity to market volatility.

Overall, European impact firms show varying degrees of sensitivity to market volatility across different periods. During stable, pre-COVID-19 periods, their volatility was less correlated with broader market volatility, providing potential diversification benefits. However, during times of crisis, such as the COVID-19 pandemic and the ongoing geopolitical conflict, their short-term sensitivity increased, reflecting a more interconnected market environment. Despite the increased short-term sensitivity during crises, the relatively low dcca1 values indicate that European impact firms still offer some diversification benefits.

This analysis supports the strategic inclusion of European impact firms in investment portfolios to mitigate risk and enhance stability in the short-term, especially during stable periods. However, it also highlights the necessity for ongoing research to confirm their diversification and risk-hedging benefits during different market conditions.

Long-term volatility contagion between European impact firms and European market's volatility (V2TX/V1XI)

Long-term volatility contagion describes the enduring and sustained response of volatility in EU impact firms to changes in the European market volatility indices. This can be assessed through the beta1 and dccb1 coefficients. Beta1 captures the persistence of shocks over time, while dccb1 represents the long-term dynamics in the correlation between European impact firms and market volatility indices (V2TX/V1XI).

During the full sample period, the beta1 coefficients of 0,89916 for V2TX and 0,87378 for V1XI suggest a high persistence of volatility in these indices over time. This indicates that volatility shocks have a long-lasting impact, reflecting sustained market uncertainty and investor sentiment. Correspondingly, the dccb1 values of 0,85095 for V2TX and 0,85290 for V1XI imply a strong long-term contagion between EU impact firms and the broader market volatility indices. This suggests that the long-term volatility dynamics of EU impact firms are significantly influenced by the broader European market volatility. This high persistence and strong long-term contagion imply that in the long run, EU impact firms are more likely to follow the trends of expected market volatility.

In the pre-COVID-19 period, the beta1 values of 0,58204 for V2TX and 0,58696 for V1XI are significantly lower than in the full sample period. This indicates that during stable times, the long-term persistence of volatility in these indices was reduced, reflecting a more stable market environment. The dccb1 value of 0,86290 for V2TX and 0.77044 for V1XI suggest a strong long-term correlation with EU impact firms, although slightly weaker than in the full sample period. This indicates that even during stable periods, EU impact firms were influenced by the market's long-term volatility, but to a lesser extent than during crisis periods. The high dccb1 values imply that while EU impact firms might provide some diversification in the short-term, their long-term volatility was very closely aligned with market volatility trends.

During the COVID-19 period, the beta1 coefficients increased significantly to 0,93334 for V2TX and 0,92752 for V1XI, reflecting very high long-term persistence of volatility. This reflects the sustained uncertainty and heightened risk environment during the pandemic. The dccb1 values of 0,86181 for V2TX and 0,85152 for V1XI reveal a strong long-term contagion with EU impact firms, similar to the full sample period. This high long-term correlation indicates that during the pandemic, EU impact firms' volatility was closely tied to the European market's long-term volatility, reducing their diversification benefits in times of prolonged crisis.

In the pandemic-war period, the beta1 values remained high at 0.94483 for V2TX and 0.92499 for V1XI, indicating a persistence of recent shocks similar to that observed during COVID-19. Correspondingly, the dccb1 values of 0.87768 for V2TX and 0.87235 for V1XI indicate a very strong long-term correlation dynamic, comparable to the COVID-19 period. This high long-term correlation during the prolonged period of uncertainty underscores the continued influence of market volatility on EU impact firms. The long-term alignment of their volatility with market trends suggests limited diversification benefits during extended periods of crisis.

Overall, EU impact firms exhibit strong long-term volatility contagion with European market volatility indices across all periods. During stable, pre-COVID-19 periods, their long-term volatility persistence was lower but still significant. During times of crisis, such as the COVID-19 pandemic and the ongoing geopolitical conflict, their long-term volatility closely followed the market volatility trends, reducing their effectiveness as a diversification tool.

In summary, the results of the DCC-GARCH model indicate that while EU impact firms offer some diversification benefits in the short-term, their strong long-term contagion with market volatility suggests limited risk-hedging benefits during extended periods of crisis. Their volatility remains closely aligned with market volatility sentiment/expectancy, highlighting the need for a diversified portfolio strategy that includes other assets to effectively manage long-term risk.

SHORT-TERM VOLATILITY CONTAGION BETWEEN EUROPEAN IMPACT FIRMS AND EUROPEAN MARKET'S BENCHMARK (STOXX)

During the full sample period, the findings suggest a high response to recent shocks, with an alpha1 value of 0,14872, indicating that approximately 14.872% of recent shocks persist in the volatility dynamics of the STOXX Index. This persistence is higher than that observed for V2TX and V1XI, indicating a stronger tendency of STOXX volatility to carry over past shocks. The short-term contagion with EU impact firms, as measured by the dcca1 value of 0.05724, appears to be slight but statistically significant. This implies a modest sensitivity of EU impact firms to sudden changes in the broader European market, highlighting their potential for providing diversification benefits. Although contagion was comparable to V2TX and V1XI, the higher dcca1 value validated the stronger relationship between EU impact firms and STOXX.

In the pre-COVID-19 period, the alpha1 coefficient of 0.15629 reveals a slightly higher degree of short-term volatility persistence compared to the full sample period. The dcca1 value of 0.02638 indicates a statistically significant but modest short-term correlation between EU impact firms and STOXX. This value, similar to the contagion levels with V2TX and V1XI, suggests that EU impact firms were not highly sensitive to changes in the broader European market during this time. Therefore, EU impact firms offered notable diversification benefits, moving independently from the broader market.

During the COVID-19 period, the response to recent shocks increased, as evidenced by the alpha1 coefficient of 0.17879. This high persistence of volatility is greater than the alpha1 values for V2TX and V1XI, indicating that STOXX experienced more enduring volatility during the pandemic. The dcca1 value of 0.07553 suggests that EU impact firms were more responsive to changes in the broader European market compared to V2TX and V1XI. This increased short-term contagion implies that the diversification benefits of impact investments were lower during the pandemic. However, their relative stability still provided some level of resilience, underscoring the interconnected nature of markets during crises.

In the pandemic-war period, the alpha1 value of 0.14620 indicates a slightly reduced persistence of volatility shocks compared to the pre-COVID-19 period. Furthermore, the dcca1 value of 0.07188 reveals that although EU impact firms exhibited higher short-term sensitivity to changes in STOXX volatility compared to V2TX and V1XI, their volatility remained relatively stable. This stability during a prolonged period of uncertainty suggests that EU impact firms maintained potential diversification benefits, exhibiting resilience despite the heightened interconnectedness with the broader market.

In summary, while EU impact firms provide some diversification benefits during stable periods, their increased short-term sensitivity to STOXX volatility during crises suggests limited risk-hedging benefits in the short-term. Investors seeking to use EU impact firms for diversification should consider the heightened correlation with broader European market during times of crisis.

LONG-TERM VOLATILITY CONTAGION BETWEEN EUROPEAN IMPACT FIRMS AND EUROPEAN MARKET'S BENCHMARK (STOXX)

During the full sample period, the beta1 coefficient for STOXX is 0.83374, lower than the estimates for V2TX and V1XI. This indicates that while the persistence of market shocks in STOXX is substantial, it is somewhat less pronounced than in the other two indices. Additionally, the dccb1 value of 0.88929 suggests a strong long-term correlation between EU impact firms and STOXX, implying significant influence by long-term volatility trends in the broader European market and a high level of interconnectedness.

In the pre-COVID-19 period, the beta1 value is 0.79554, indicating slightly lower long-term volatility persistence compared to the full sample period, although higher than the estimates for V2TX and V1XI. This suggests that the persistence of market shocks was more enduring in STOXX compared to the other indices. The dccb1 value of 0.89077 reveals a strong long-term correlation with EU impact firms, similar to the full sample period. This indicates that even during stable periods, EU impact firms were still significantly influenced by the long-term volatility trends in the broader European market.

During the COVID-19 period, the beta1 coefficient increased to 0.82020, which is lower than the values for V2TX and V1XI, but it still reflects a high level of persistence in volatility estimates over the long term. The dccb1 value of 0.87301 indicates a strong long-term correlation with EU impact firms, though slightly lower than the pre-COVID-19 period. This suggests that while EU impact firms were influenced by long-term trends in STOXX volatility during the pandemic, their correlation was slightly reduced and the effects less pronounced.

In the full pandemic-war period, the beta1 coefficient is 0.84787, indicating very high long-term volatility persistence. The dccb1 value of 0.88166, comparable to V2TX and V1XI, reveals a very strong long-term correlation dynamic. This suggests that during periods of prolonged uncertainty, EU impact firms remain highly interconnected with the broader market, reducing their potential for providing diversification benefits.

Overall, the analysis of long-term volatility contagion between EU impact firms and STOXX reveals a pattern similar to that observed with V2TX and V1XI. The beta1 and dccb1 coefficients indicate that EU impact firms are heavily influenced by long-term volatility trends in the broader market. This reduces their potential for providing diversification benefits over the long term, as their performance is closely tied to the broader market's long-term trends.

Table 5 - Estimation results of Copula-DCC-GARCH model

	STOXX	**V2TX**	**V1XI**
Interval A: Full sample period (January 5, 2016, to March 27, 2024)			
dcca1	0,05768***	0,04982***	0,04799***
dccb1	0,88277***	0,84471***	0,84092***
mshape	5,20945***	7,66998***	7,07260***
Interval B: Pre-COVID-19 (January 5, 2016, to January 23, 2020)			
dcca1	0,02796**	0,03164*	0,02405
dccb1	0,88473***	0,85604***	0,77232***
mshape	6,37226***	5,37302***	5,48550***
Interval C: During COVID-19 (January 24, 2020, to May 5, 2023)			
dcca1	0,08002***	0,05316***	0,05911***
dccb1	0,86273***	0,85805***	0,85198***
mshape	5,52369***	12,25248**	8,92788***
Interval D: Pandemic-War period (January 24, 2020, to March 27, 2024)			
dcca1	0,07006***	0,04550***	0,04919***
dccb1	0,88069***	0,86967***	0,86887***
mshape	5,22330***	13,64738**	10,43416**

The results of the Copula-DCC-GARCH and DCC-GARCH models indicate that while both models yield similar dynamic conditional correlations (DCC) between the asset returns, the Copula-DCC-GARCH model demonstrates a better overall fit. This is evident from better values in metrics such as Information Criteria (AIC, BIC, Shibata, and HQC), Log-likelihood, Mean Squared Error (MSE), and Root Mean Squared Error (RMSE).

The estimated parameters (dcca1 and dccb1) for both models show close correspondence across different periods, indicating similar correlation dynamics. However, the shape parameters (mshape) and other fit indices consistently favour the Copula-DCC-GARCH model, suggesting it captures the data characteristics more accurately.

The improvement in model fit for the Copula-DCC-GARCH model is particularly noticeable when examining the statistical significance and the magnitudes of the estimated coefficients. For instance, during the COVID-19 and Pandemic-War periods, the mshape values are markedly higher in the Copula-DCC-GARCH model, indicating a better accommodation of the data's heavy-tailed nature and extreme events. Consequently, it indicates that the Copula-DCC-GARCH model provides more precise and reliable forecasts of volatility and correlations compared to the traditional DCC-GARCH model (see Appendix E).

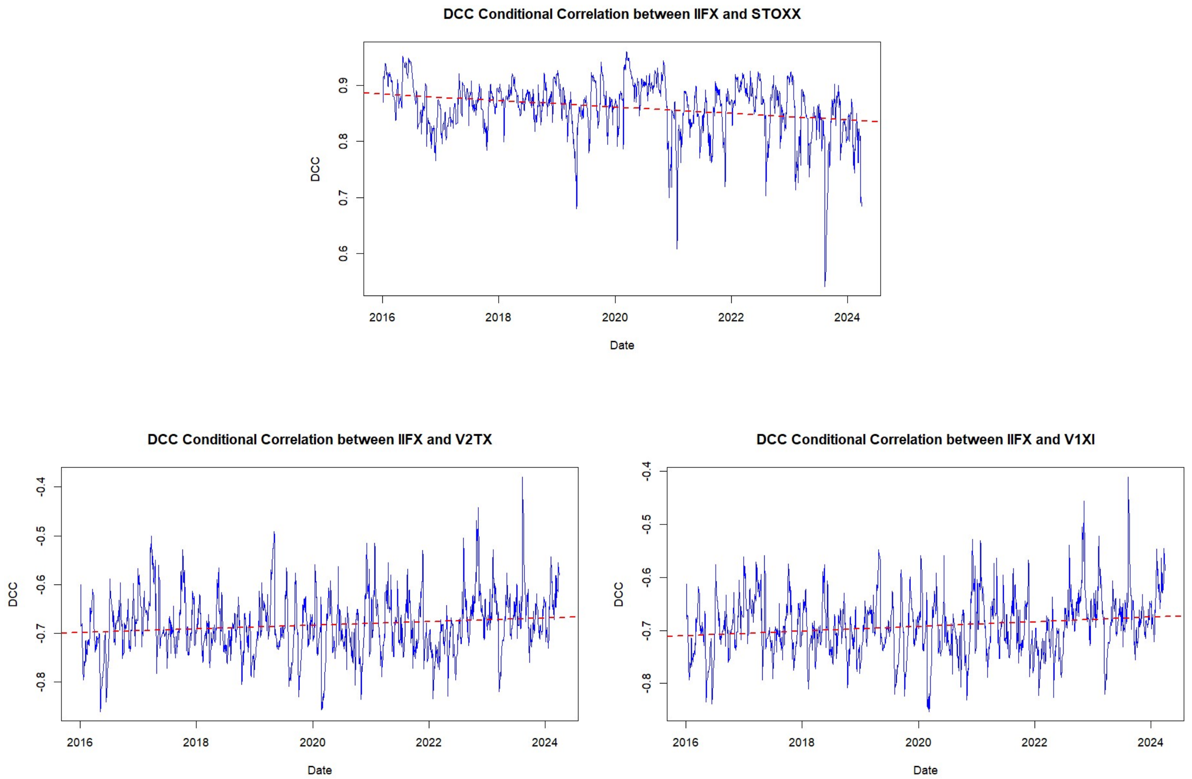

Figure 6 – Dynamic Conditional Correlation (DCC) between the Impact Investing Firms Index (IIFX) and the three broader market (STOXX) and volatility indices (V2TX and V1XI) from January 5, 2016, to March 27, 2024.

The Dynamic Conditional Correlation (DCC) between the Impact Investing Firms Index (IIFX) and the STOXX consistently hovers between 0.8 and 0.9, indicating a very high correlation between EU impact firms and the broader European stock market. This high correlation persists throughout the entire sample period, although with occasional fluctuations. During the COVID-19 period, the DCC values exhibited increased volatility compared to the pre-COVID-19 period, with notable dips during significant market events. However, the overall trend remains relatively stable, reflecting a persistent strong positive correlation despite the pandemic's disruptions (see Appendix D). This stability suggests that EU impact firms' returns closely mirror the overall European market, indicating limited diversification benefits from including these firms in a portfolio if one is already heavily invested in the broader market.

In contrast, the DCC between IIFX and the volatility indices (V2TX and V1XI) is predominantly negative, averaging around -0.7. This negative correlation signifies that as market volatility increases, the returns of EU impact firms tend to move in the opposite direction. The DCC values for V2TX and V1XI show greater volatility compared to STOXX, with significant fluctuations throughout the sample period, ranging approximately between -0.5 and -0.8. In the pre-COVID-19 period, the correlation trend (represented by the red dotted line) seems relatively stable with minor fluctuations, indicating that the relationship between IIFX and market volatility was somewhat consistent during this period. During the crisis period, the DCC values show an upward trend, indicating a reduction in the negative correlation, but an increase in volatility.

The analysis of DCC parameters reveals that EU impact firms are heavily influenced by long-term volatility trends in the broader market, despite the dynamic changes in short-term correlations. The consistently high correlation with STOXX indicates limited diversification benefits when adding EU impact firms to a portfolio already exposed to the broader European market. Conversely, the correlation with V2TX and V1XI although strong is lower compared to STOXX, suggesting that EU impact firms might provide more diversification benefits against European market volatility.

These findings are in line with existing literature indicating a diminishing diversification potential in impact investments over time. For instance, Bernal et al. (2021) observed that investors in listed impact firms experience lower returns and heightened risk compared to mainstream markets, with the diversification potential decreasing over time. This reflects a similar trend observed in the DCC-GARCH results, where the long-term correlation between EU impact firms and broader market indices remained strong, suggesting reduced effectiveness in providing diversification benefits.

Research by Riedl & Smeets, 2017 and Barreda-Tarrazona et al. (2011) have shown that socially responsible investors prioritize their values over diversification, corroborating the assumption that impact investors tend to accept lower financial returns for social goals, as indicated by Barber et al. (2021) and Morduch & Ogden (2019) . The DCC-GARCH model results, which show strong long-term correlations with broader market trends and limited diversification benefits during crises, reflect this willingness to accept financial trade-offs for social impact.

While impact investments may offer short-term diversification benefits, they are not entirely insulated from broader market movements. These investors are often less fixated on maximizing financial returns and more invested in the social outcomes. The strong long-term correlation with broader market indices echoes the findings of Jeffers et al. (2023) , who found that while impact funds might offer risk-adjusted returns comparable to non-impact funds, their performance is still closely tied to market trends when accounting for market risk exposure.

During crises, such as the COVID-19 pandemic, the increased short-term sensitivity of EU impact firms to market volatility diverges from the observations made by Hua Fan & Michalski (2020) and J. Nofsinger & Varma (2014) for socially responsible funds, and Giacomini et al. (2023) for US impact firms. These studies observed that these assets tend to perform better during crises, suggesting resilience. However, the slight increase in sensitivity during crises indicates that while EU impact firms might offer some resilience, they are not completely immune to broader market shocks. Consequently, they appear to exhibit some diversification benefits, although more prominently during stable periods, such as the pre-COVID-19 era.

6. CONCLUSIONS AND FUTURE WORKS

Impact investing has surged in recent years, emerging as a dual-purpose strategy aimed at achieving both financial returns and measurable social or environmental benefits (Höchstädter & Scheck, 2015). Despite this growth, the industry and research fields remain in their beginning stages, leaving many aspects of impact investments' financial performance and diversification potential, particularly within mainstream markets, ambiguous (see, for instance, Chiappini et al., 2023; Migliavacca et al., 2022 and Agrawal & Hockerts, 2021).

This study aimed to contribute to the literature by exploring the dynamics of impact investing within European impact firms, focusing specifically on their volatility contagion and diversification potential relative to broader market indices. To achieve this, we constructed an Impact Investing Firms Index comprising European publicly listed impact firms and evaluated their correlation dynamics and diversification potential against key benchmarks: the STOXX Europe 600 index (STOXX) as a broader European market benchmark, and the EURO STOXX 50 Volatility index (V2TX) and DAX-New Volatility index (V1XI) as European market volatility benchmarks.

Our analysis revealed several key insights into the relationship between EU impact firms and European market indices. During stable market periods, these firms demonstrated lower but still significant short-term volatility contagion with broader European market indices such as STOXX, V2TX, and V1XI. However, amid crises such as the COVID-19 pandemic and geopolitical tensions, we observed an increase in short-term volatility contagion, indicating heightened sensitivity to market fluctuations during turbulent times, although still exhibiting relatively moderate short-term volatility contagion.

Over extended periods, EU impact firms showed significant long-term volatility contagion with European market indices. This suggests that while impact investments may offer some short-term diversification benefits, they tend to align closely with broader market trends over the long-term, thereby reducing their effectiveness as independent diversification tools (Jeffers et al., 2023). This finding align with existing literature, indicating a diminishing diversification potential in impact investments over time (Bernal et al., 2021).

In summary, our study contributes to a nuanced understanding of impact investing by highlighting the evolving nature of its diversification potential. These findings underscore the importance of further research to validate our conclusions across a broader range of impact firms and to explore the underlying drivers of long-term contagion with the broader market. Future research should also delve deeper into sector- and region-specific analyses within impact investing, examining how regulatory changes, policy shifts, or economic policy uncertainties influence the volatility and correlation dynamics of impact firms. Additionally, the uncertain economic and societal conditions of recent years underscore the need for deeper insights into how impact firms perform and adapt over time. As the field continues to grow, understanding the drivers of financial performance, resilience during crises, and the effectiveness of impact measurement frameworks will be crucial for stakeholders seeking to optimize both financial returns and social or environmental impact.

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APPENDIX A

Table A1 List and summary characteristics of impact firms

Company name	Impact Investing areas	Business activity (brief description)
Abb Ltd	Natural Capital	Provides sustainable and resource-efficient electrification, motion and robotics, and automation technologies and solutions for optimizing, electrifying, and decarbonizing operations, in order to enhance energy efficiency, and attain a low-carbon society and net-zero future. It provides digitally connected and enabled industrial equipment and systems to customers in utilities, industry, transport, and infrastructure sectors.
ACS Actividades de Construccion y Servicios SA	Natural Capital	Is a reference in the construction business: developing highways, railways, maritime and airports projects, also residential buildings, social infrastructure, and facilities projects; transport concessions industry: developing "greenfield" infrastructures; and infrastructures and environmental services: such as street cleaning, waste collection and transportation, waste recycling, and others.
Alstom SA	Natural Capital	Offers proven alternatives to diesel on non-electrified networks by being the first player with hydrogen-powered fleets in commercial service, and by developing and promoting innovative and sustainable (hydrogen and battery-electric) mobility and infrastructure solutions that help reduce energy consumption.
Anheuser-Busch Inbev SA	Natural Capital	Produces, distributes, and markets beer, alcoholic beverages, and soft drinks made from simple ingredients, grown locally, and brewed with the aim to preserve natural resources. They partner with local farmers and invest in research and development of sustainable brewing methods. Also, have a business-to-business e-commerce platform to empower small and medium-sized retail partners and help grow their businesses.
Athens Water Supply and Sewerage Company SA	Basic Needs	Responsible for managing the water supply and sewerage systems in the region of Attica, Greece, providing clean and safe drinking water to residents, businesses, and other customers within its service area, and collecting and treating wastewater to protect public health and the environment.
BAE Systems PLC	Empowerment	Is a defense, aerospace, and security company that develops, engineers, manufactures, and supports products and systems to deliver military capability, protect national security and people, and keep critical information and infrastructure secure. It also drives the development of sustainable electric solutions in the defence and commercial sector.
Barratt Developments P L C	Natural Capital	Is a commercial property developer and residential construction contractor whose primary business involves the construction, sale, and development of residential properties, incorporating energy-efficient features, sustainable building materials, and environmentally friendly practices into its projects to minimize environmental impact and meet sustainability goals.
Beiersdorf AG	Basic Needs	Develops and markets personal care products and self-adhesive product solutions, such as face care, body care, sun protection, and wound care, considering the decarbonisation of their operations and transport by embracing renewable energy. It commits to sourcing raw materials from various origins, including palm oil, shea butter and paper-based materials, and promotes wastewater recycling across their production. Markets its products under NIVEA, Eucerin, and other brands.
Boiron SA	Basic Needs	Engages in the provision of homeopathic medicines providing safe and quality medicines and drugs that are used as alternative or

		complementary treatments for various health conditions. Commits to sourcing raw materials from various origins, including plants, minerals/chemicals, and animals (e.g. venom). Gives preference to short channels and all cultivated plants are GM-free.
BT Group PLC	Empowerment	Is a telecommunications and network provider which provides fixed and mobile telecommunications and related secure digital products, solutions and services powered by renewable electricity in their journey to net zero emissions and a circular world. Has empowered people and has accelerated digital transformation through their responsible, inclusive, and sustainable technology.
Centrica PLC	Climate Change	Operates as an integrated energy company that carries out electricity generation through combined cycle gas turbine (CCGT) power stations, and nuclear power plants, and it delivers integrated energy solutions, helping organizations balance the demands of profitability and sustainability by providing tailored zero carbon and renewable energy supply options.
Coloplast A/S	Basic Needs	Develops, manufactures, and markets medical devices and services that make life easier for people with very personal and private medical conditions, like ostomy care, urology, continence, and wound care. It uses raw materials such as renewables and promotes product and packaging recyclability.
Corticeira Amorim SGPS SA	Natural Capital	Leading specialist in cork processing, having a portfolio of cork products like cork flooring, insulation, and other cork-based solutions with high added value. Focuses on sustainable cork production and innovative applications by offering eco-friendly solutions across various sectors such as architecture and design, construction and infrastructure, mobility, energy, aerospace, and others.
Danone SA	Basic Needs	Is a manufacturer and producer of essential dairy and plant-based products, early life nutrition, medical nutrition and waters that prioritize people's health and well-being. It distributes its products through retail chains, traditional market outlets and specialized distribution channels, including hospitals, clinics, and pharmacies.
Dassault Systemes SE	Empowerment	Operates as a software company, which provides a 3Dexperience platform to create innovative new products and services using virtual experiences, and in this way model the social and environmental impacts of every innovation and evaluate how it improves the lives of other people and their communities.
Deutsche Telekom AG	Empowerment	Is a leading global telecommunications company that provides mobile fixed-line, internet, and IT services to consumers and businesses and offers smart products and services from renewable energy sources that help reduce energy consumption and conserve resources. Also, empowers projects and initiatives with a positive contribution to social and environmental challenges in the digital world.
EDP Renovaveis SA	Climate Change	Is a renewable energy company that concentrates on the production of energy from renewable resources, and its activities comprise the development, operation, and maintenance of such electric power stations as hydroelectric, wind, solar, tidal, biomass and waste plants, among others, reducing carbon emissions.
EnBW Energie Baden Wuerttemberg AG	Climate Change	Transmits, distributes, and trades electric energy and natural gas, and provides energy-related services. It generates electricity from conventional fuels such as nuclear power, as well as renewable sources such as wind, solar, and hydroelectric to reduce its carbon footprint and increase its share of clean energy production.
Endesa SA	Climate Change	Generates, distributes, transmits, and sells eletricity through the participation in hydro, thermal, nuclear, combined cycle, and renewable and cogeneration plants. Operates also in the natural gas sector and

		provides other value-added services to wind farms, mini hydraulic, biomass, and waste treatment plants.
Enel SpA	Climate Change	Generates, transports, and distributes electricity and sells electric energy and natural gas, green certificates, and CO2 emission rights, with a strong emphasis on renewable energy sources like wind, solar, geothermal and hydropower, providing the solutions to power electric vehicles and smart cities as it participates in renewables markets.
Fagerhult Group AB	Climate Change	Designs, manufactures, and sells a wide range of lighting fixtures and systems that caters to different lighting requirements and energy efficiency goals, minimizing energy consumption and environmental impact, for various professional applications, including offices, schools, hospitals, retail spaces, and industrial facilities, providing therefore sustainable solutions for urban areas.
Fortum Oyj	Climate Change	Provides electricity, gas, heating, and cooling services. The generation of electricity comprises nuclear, hydro, wind, and thermal power generation, as well as power portfolio optimisation, trading, industrial intelligence, and global nuclear services. It's responsible for sustainable solutions for urban areas.
Fresenius SE & Co KGaA	Basic Needs	Develops and manufactures a wide variety of health care products, which includes dialysis and non-dialysis products. Provides dialysis care and related services to persons suffering from end-stage renal disease (ESRD), as well as other healthcare services for hospitals and medical care of patients at home.
Geberit AG	Natural Capital	Provides sanitary products and systems including faucets and flushing systems, and waste fittings and traps, ceramics and pipes and fittings for the residential, commercial, new construction and renovation markets considering ecological and social aspects. Contributes to sustainable construction of buildings by providing water efficiency solutions and saving materials.
Gerresheimer AG	Natural Capital	Develops and manufactures specialty and innovative products for drug delivery, such as insulin pens, inhalers, and prefillable syringes, and it produces drug packaging of glass for medicines and cosmetics, such as pharmaceuticals jars, ampoules, and others for the pharmaceutical, biotech, and healthcare industries.
Grifols SA	Basic Needs	Develops, manufactures, and distributes a broad range of biological medicines based on plasma derived proteins that enable patients with rare and chronic diseases to lead healthier lives. It helps ensure the safety of the world's blood supply, provides biological materials, including plasma, for life-science research and further manufacturing, and has a comprehensive portfolio of tools, information and services that enable hospitals to efficiently deliver medical care.
Indra Sistemas SA	Empowerment	Provides consulting and technology solutions such as systems integration and outsourcing services, installs railway management and ticketing systems, installs road traffic toll and signalling systems, constructs satellite communications systems, manufactures radar air defence systems, and installs insurance management systems for aerospace, defence & security, and mobility sectors.
Kingspan Group PLC	Natural Capital	Is a global leader in high-performance insulation and building envelope solutions enabling low-energy and low-carbon buildings. It also specializes in the manufacture and distribution of sustainable building materials, including insulation boards, insulated panels, renewable energy systems, and water management solutions.
Legrand SA	Natural Capital	Is an electrical and digital building infrastructure company for residential, commercial, and industrial buildings that offers a wide range of products and solutions for electrical installations, data networks, building

		automation, and control systems that are simple, innovative, and sustainable.
Naturgy Energy Group SA	Climate Change	Is an integrated gas and electric utility company that carries out the exploration, development, liquefaction, regasification, transportation, storage, distribution, and commercialization of natural gas. Also, the generation, distribution, and commercialization of electricity through combined cycle, thermal, nuclear, hydro, co-generation and wind farm plants, and other special regime technologies.
NOS SGPS SA	Empowerment	Engages in the telecommunications, media and entertainment businesses offering state-of-the-art solutions for fixed and mobile telephony, television, Internet, voice, and data for all market sectors. Operates in the area of pay television, next-generation broadband services, and film distribution, and has been investing in energy-efficient technologies, transitioning to renewable energy sources, and implementing initiatives to reduce waste generation and promote recycling.
Novartis AG	Basic Needs	Develops, manufactures, and markets pharmaceutical and consumer healthcare products such as branded and generic prescription drugs, active pharmaceutical ingredients (APIs), biosimilars and ophthalmic products. It uses innovative science and digital technologies to develop transformative treatments and patent-protected prescription medicines in areas of great medical need.
Novo Nordisk A/S	Basic Needs	Develops, produces, and markets pharmaceutical products focused on diabetes care and offers insulin delivery systems and other diabetes products. It also works in the therapy areas of haemophilia care, growth hormone therapy and hormone replacement therapy.
Novozymes A/S	Natural Capital	Is a biotechnology company engaged in the production and sale of industrial enzymes, microorganisms, and biopharmaceutical ingredients for use in agriculture, bioenergy, food & beverages, household care, leather, pharmaceuticals, forest products, textile, and wastewater treatment.
Pearson PLC	Empowerment	Operates in the education, assessment, and certifications markets, and provides digital content, learning experiences, assessments, qualifications, and data in the learning market. It publishes across the curriculum and provides a range of education services, including teacher development, educational software, and system-wide solutions. Also owns and operates schools and colleges.
Proximus NV	Empowerment	Engaged in the telecommunication, information, communication, and technology (ICT) industries. It transforms a range of technologies, such as Internet of Things (IoT), Big Data, Cloud and Security, into new digital ecosystems and innovative solutions, and provides reliable and secure communications shaping a fair, trustworthy, and inclusive digital world and accelerating the transition to a green society.
Rockwool A/S	Natural Capital	Is a manufacturer and supplier of stone wool-based insulation products such as floor insulation, ceiling insulation, internal wall insulation external wall insulation, HVAC insulation, passive fire protection, acoustic insulation, and other mineral wool products, for use in applications, including friction and water management while lowering emissions, improving infrastructure, or enabling modern horticulture using fewer resources.
Schneider Electric SE	Climate Change	Provides energy-related solutions that combine energy management, automation, and software. Some of its products include automation and control products, low voltage products and systems, solar and energy storage, medium voltage distribution and grid automation, and critical power, cooling, and racks. It also offers energy and sustainability services, field and automation, cloud, consulting, and training services.

Severn Trent PLC	Basic Needs	Provides clean water and wastewater services, and it's also involved in areas related to climate change, protecting water supplies, improvement of biodiversity, and developing renewable energy solutions, generating renewable power, through wind turbines, solar panels, and anaerobic digestion of specially grown crops.
SGL Carbon SE	Natural Capital	Is a manufacturer of products and solutions based on carbon fibres and specialty graphite serving several industries, such as steel, aluminium, automotive, aerospace, chemical, wind energy, and environmental protection among others. It contributes to the developments of sustainable mobility, new energies, and cross-industry digitalization.
Siemens AG	Natural Capital	Operates in the electrification, automation, and digitalization fields, as it designs, develops, and manufactures products, and installs complex systems and projects, focusing on power generation and distribution, and intelligent infrastructure for buildings and distributed energy systems. It also provides smart mobility solutions for rail and road transport, medical technology, and digital healthcare services.
SKF AB	Natural Capital	Is a supplier of products, solutions and services for bearings, seals, mechatronics, and lubrication systems that offers services such as technical support, condition monitoring, maintenance services, asset efficiency optimization, engineering consultancy, including material analysis and testing, and training. It provides clean technology solutions for the industrial transformation, and has been developing products to become lighter, more efficient, longer lasting, repairable, and, ultimately, recyclable.
Smith & Nephew PLC	Basic Needs	Engages in the development, manufacture, marketing, and sale of medical devices and services focused on the repair, regeneration, and replacement of soft and hard tissue, and for use in orthopaedic reconstruction and trauma, sports medicine, ENT, and advanced wound management. Some of its products include knee and hip implants to replace diseased, damaged, or worn joints; robotics-assisted technologies; and trauma-related products to stabilize fractures and deformity correction procedures.
Smiths Group PLC	Natural Capital	It provides critical solutions for the energy and process, medical devices and consumables, devices for the detection and identification of security threats and contraband, solutions for high-speed connectivity, and components to heat and move fluids and gases.
SSAB AB	Natural Capital	Is engaged in the development, manufacture and marketing of high strength fossil-free steel products and solutions in order to create an offering comprised of solutions ranging from lightness and durability to strength, efficiency, sustainability, and safety, for customers in the heavy transport, construction and infrastructure, industrial applications, construction machinery, energy, and material handling markets.
Stora Enso Oyj	Natural Capital	Is a provider of renewable solutions in packaging, biomaterials, wooden construction, and paper industries that develops and produces solutions based on wood and biomass for a range of industries and applications such as building, retail, food and beverages, manufacturing, publishing, pharmaceutical, and others.
Swisscom AG	Empowerment	Is a provider of telecommunication products and services such as mobile, fixed and Internet protocol (IP) based voice and data communications, and is characterized by its sustainability practices by becoming climate neutral and promoting circular economy. It offers digital access services, mobile network, and broadband services over existing subscriber lines.
Telefonica SA	Empowerment	Operates as a telecommunications company that offers fixed and mobile telephone, broadband, and subscription television services, as well as provides cybersecurity, IOT, big data, and cloud solutions. Promotes

		decarbonisation and circularity, economic and social progress through digitalization.
Tomra Systems ASA	Natural Capital	Provides technology-led solutions that enable the circular economy with advanced collection and sorting systems that optimize resource recovery and minimize waste in the food, recycling, and mining industries.
Ucb SA	Basic Needs	Is a biopharmaceutical company that is engaged in the discovery and development of novel medicines and solutions for the treatment of various severe diseases striving to develop products for the treatment of neurology and immunology related conditions.
Umicore SA	Natural Capital	Develops technologies and produces materials for solar cells used in satellites, rechargeable batteries, LED applications, catalysts, etc. It recycles and extracts precious metals from laptops and mobile phones, among other things. It also reduces harmful emissions, power the vehicles and technologies of the future, and gives new life to used metals.
Veolia Environnement SA	Climate Change	It designs and provides water, waste, and energy management solutions: Water solutions cover potable water plants and supply systems, wastewater systems and treatment plants, among others; Waste solutions include waste collection services on behalf of local authorities, management of specialist sorting centres and platforms, among others; Energy solutions offer power generation and related services, such as consulting and plant design.
Verbund AG	Climate Change	Provides integrated electric generations, transmission, and distribution services. Trades power and energy derivatives over the counter and at the major power exchanges across Europe. It generates electricity via its large network of hydroelectric power plants, which accounts for approximately 90% of the power generated, supplemented by wind, solar and thermal power plants, powered by fossil fuels.
Vestas Wind Systems A/S	Climate Change	Is a renewable energy company, active within the wind power industry, that designs, manufactures, installs, and provides services to onshore and offshore power converters, wind turbines, blades, and towers. It offers services including data-driven consultancy, fleet optimization, blade maintenance and inspection, power generator repairs, and gearbox exchange.
Vossloh AG	Natural Capital	Is a provider of rail infrastructure services and transport technology for rail infrastructure and technology markets that it offers a unique product range for rail infrastructure, such as rail fastening systems, concrete sleepers, switch systems and crossings as well as services related to the value maintenance of the rails, thereby being an important contributor to the mobility of people and the transport of commodities.

APPENDIX B

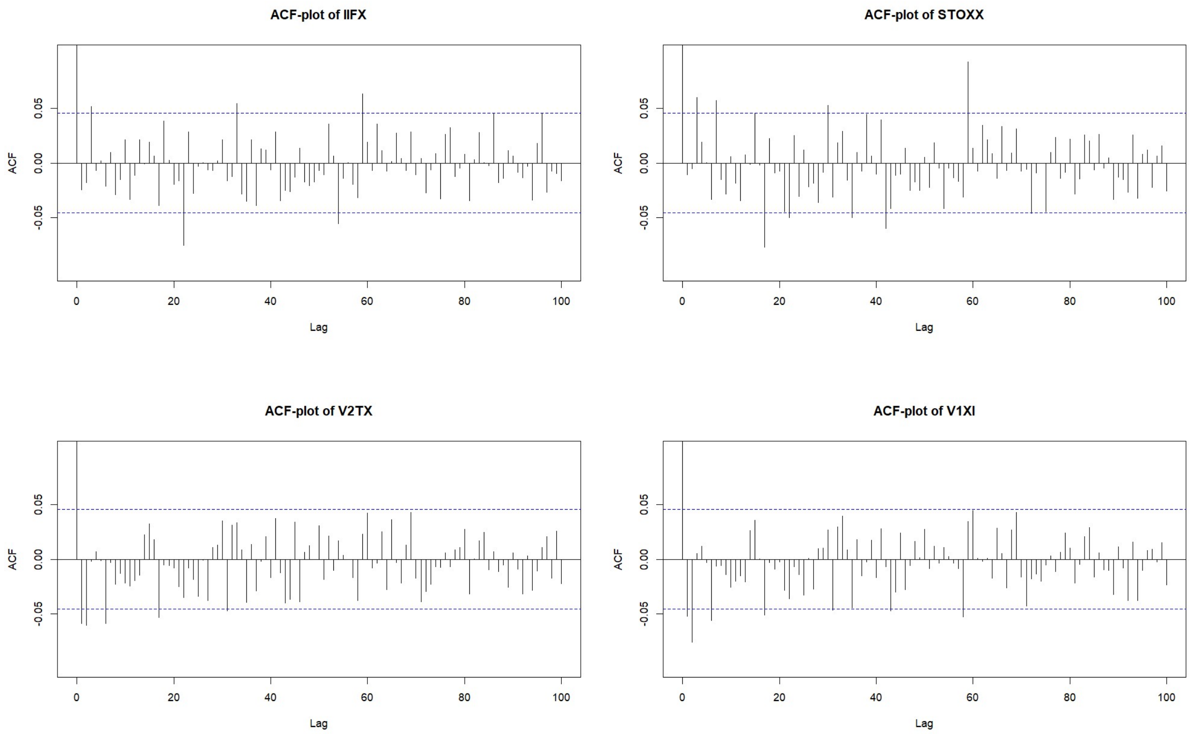

Figure B1 - Autocorrelation function (ACF) of the four return series (y_t): Impact Investing Firms Index (IIFX), STOXX Europe 600 EUR Price Index (STOXX), EURO STOXX 50 Volatility (VSTOXX) EUR Price Index (V2TX), and DAX-New Volatility Index (V1XI)

If the data is serially uncorrelated, we would expect 5% of the lags in the ACF plot to fall outside the limits (represented by the blue dotted lines). With 100 lags, only 5 lags are expected to fall outside by chance. We can observe that more than 5 lags fall outside the limits for all the series. However, the lags that fall outside do not exhibit a clear pattern; it appears to be random which lags fall outside, and most of these lags are only slightly beyond the limits. Therefore, we can conclude that the data is approximately uncorrelated.

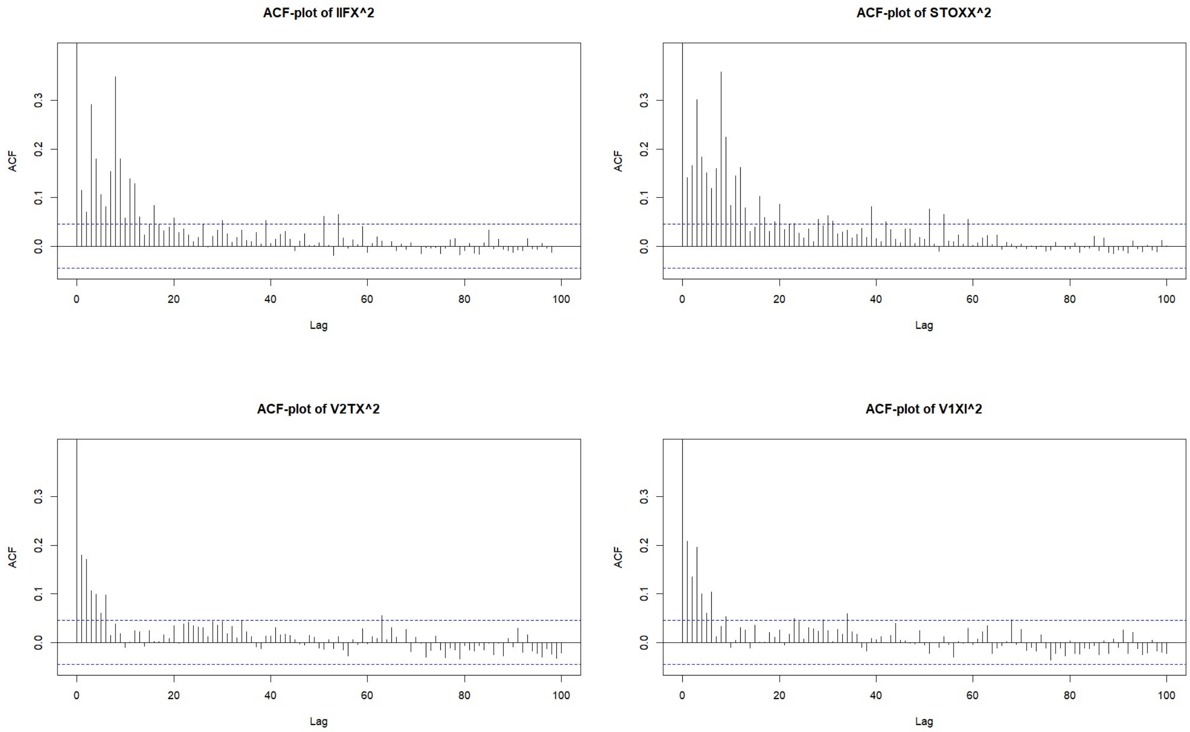

Figure B2 - Autocorrelation function (ACF) of the four return series as power of 2 (y_t^2): Impact Investing Firms Index (IIFX), STOXX Europe 600 EUR Price Index (STOXX), EURO STOXX 50 Volatility (VSTOXX) EUR Price Index (V2TX), and DAX-New Volatility Index (V1XI)

The lags that fall outside the limits in the ACF of y_t^2 do display a more distinct pattern. The first few lags show the highest values, and then the ACF decreases gradually. Therefore, given the large number of lags falling outside the limits and the clearer pattern observed, we can infer that y_t^2 is not uncorrelated. If y_t is serially independent, y_t^2 should be uncorrelated. However, since y_t^2 it is not, it implies that y_t is dependent. This suggests that a GARCH (Generalized Autoregressive Conditional Heteroskedasticity) model would be a suitable choice for modeling y_t, because it captures the dependence in a_t, even though y_t itself is approximately uncorrelated.

APPENDIX C

Table C1 - Maximum likelihood estimation for univariate GARCH model

Variable	Interval	Distribution	ARMA(1,1)	ARMA(1,0)	ARMA(0,0)
IIFX	Full Period	Student's T	6071,442	6070,104	6066,999
		Normal	6034,602	6033,256	6031,903
	Pre-COVID-19	Student's T	2972,630	2971,129	2970,679
		Normal	2952,975	2952,043	2951,869
	During COVID-19	Student's T	2378,472	2377,269	2374,510
		Normal	2362,260	2361,525	2360,332
	Pandemic-War Period	Student's T	3107,665	3106,355	3103,061
		Normal	3089,643	3088,819	3087,083
STOXX	Full Period	Student's T	6168,519	6166,056	6164,182
		Normal	6074,726	6074,636	6074,536
	Pre-COVID-19	Student's T	3002,293	3000,364	3000,277
		Normal	2965,380	2965,464	2965,299
	During COVID-19	Student's T	2402,229	2401,167	2397,801
		Normal	2356,959	2356,837	2355,784
	Pandemic-War Period	Student's T	3170,915	3169,513	3166,897
		Normal	3115,072	3114,943	3114,341
V2TX	Full Period	Student's T	2359,535	2329,823	2326,175
		Normal	2228,378	2202,487	2200,755
	Pre-COVID-19	Student's T	1099,945	1081,979	1081,875
		Normal	1046,926	1025,923	1025,429
	During COVID-19	Student's T	921,627	914,678	909,484
		Normal	864,861	862,534	860,194
	Pandemic-War Period	Student's T	1266,205	1257,036	1252,252
		Normal	1194,865	1191,735	1189,479
V1XI	Full Period	Student's T	2528,891	2503,013	2499,379
		Normal	2410,092	2388,980	2387,329
	Pre-COVID-19	Student's T	1175,002	1158,486	1157,684
		Normal	1137,995	1120,590	1119,552
	During COVID-19	Student's T	999,800	993,638	989,379
		Normal	939,340	937,794	935,993
	Pandemic-War Period	Student's T	1364,585	1354,125	1350,707
		Normal	1285,361	1283,370	1281,917

APPENDIX D

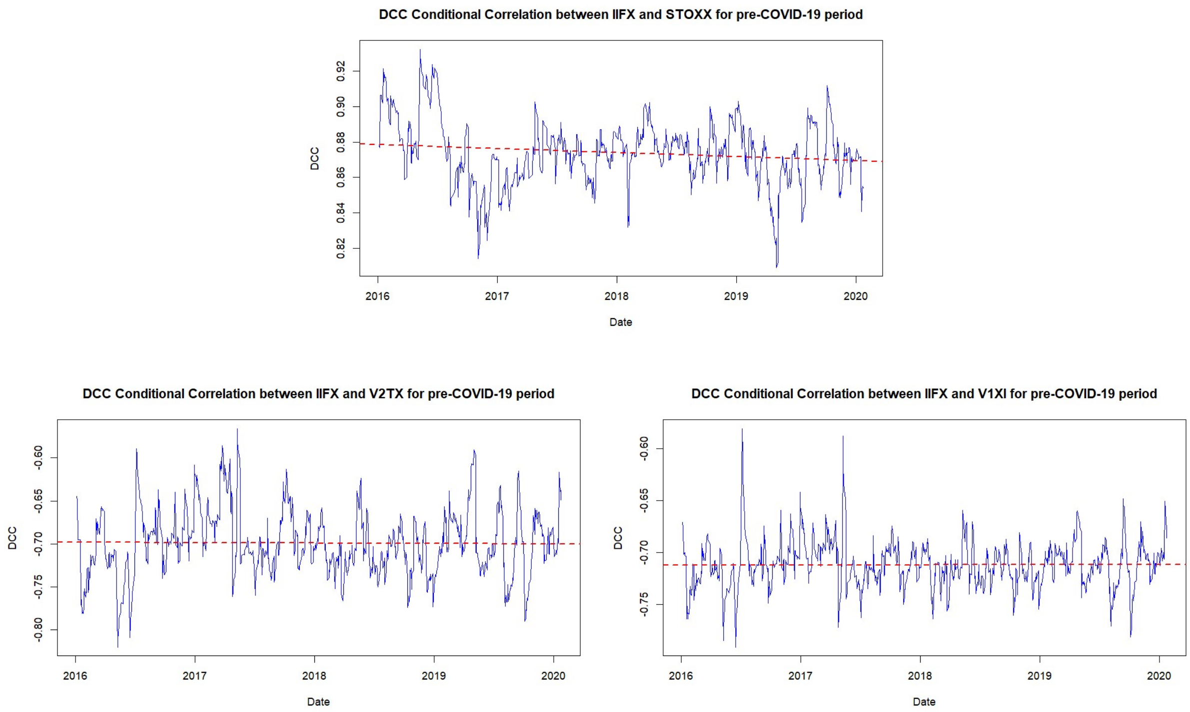

Figure D1 - Dynamic Conditional Correlation (DCC) between the Impact Investing Firms Index (IIFX) and the three broader market (STOXX) and volatility indices (V2TX and V1XI) from January 5, 2016, to January 23, 2020 (Pre-COVID-19 period).

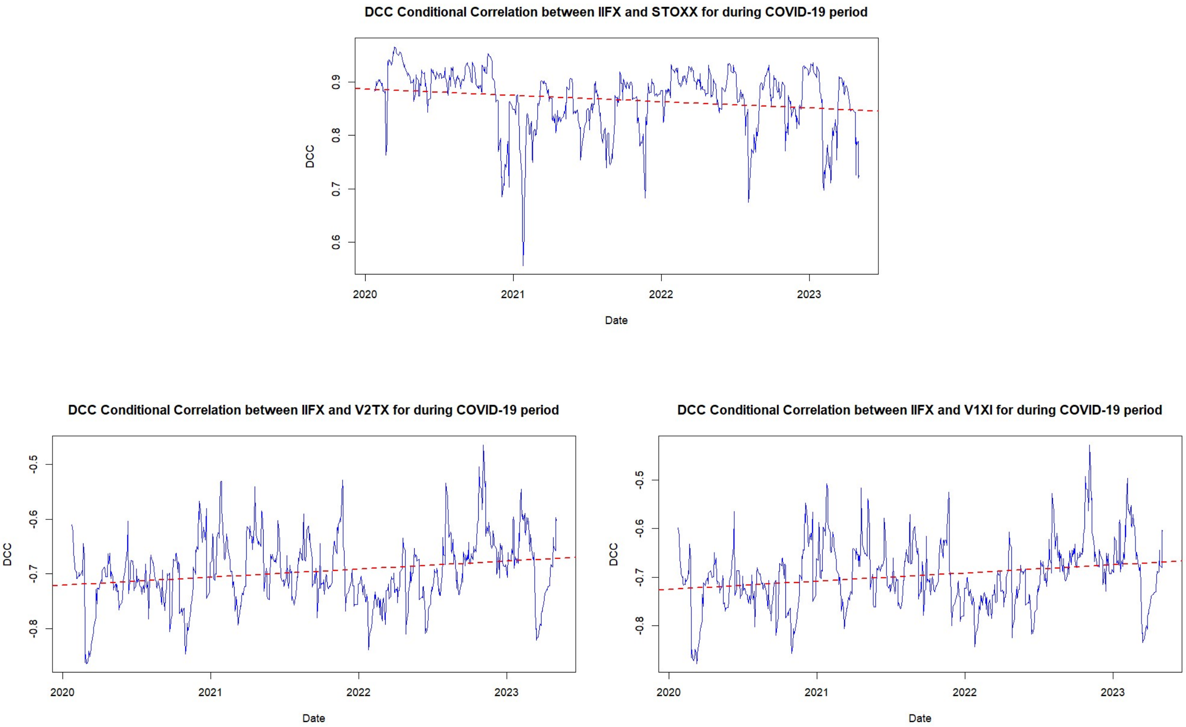

Figure D2 - Dynamic Conditional Correlation (DCC) between the Impact Investing Firms Index (IIFX) and the three broader market (STOXX) and volatility indices (V2TX and V1XI) from January 24, 2020, to May 05, 2023 (During COVID-19 period).

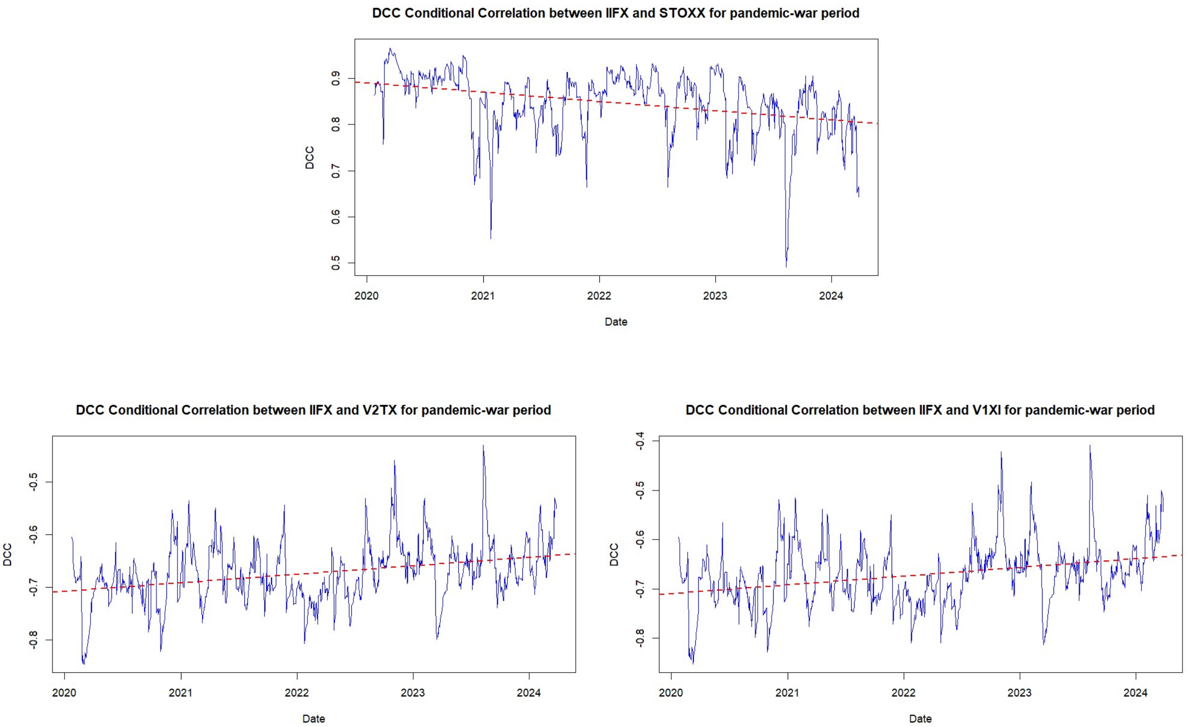

Figure D3 - Dynamic Conditional Correlation (DCC) between the Impact Investing Firms Index (IIFX) and the three broader market (STOXX) and volatility indices (V2TX and V1XI) from January 24, 2020, to March 27, 2024 (Pandemic-War period).

APPENDIX E

Table E1 - Information Criteria, Log-likelihood, MSE and RMSE of multivariate GARCH models with mvt-distribution for **IIFX-STOXX** series

Model	Interval	AIC	BIC	Shibata	HQC	Log-Lik	MSE	RMSE
DCC-GARCH	Full Period	-14,623	-14,569	-14,623	-14,603	13558,769	0,000	0,011
	Pre-COVID-19	-15,168	-15,070	-15,169	-15,131	6601,086	0,000	0,009
	During COVID-19	-13,872	-13,763	-13,873	-13,830	5358,613	0,000	0,013
	Pandemic-War Period	-14,105	-14,016	-14,106	-14,071	6957,725	0,000	0,012
ADCC-GARCH	Full Period	-14,622	-14,566	-14,623	-14,602	13559,342	0,000	0,011
	Pre-COVID-19	-15,166	-15,062	-15,167	-15,126	6601,086	0,000	0,009
	During COVID-19	-13,869	-13,755	-13,870	-13,825	5358,666	0,000	0,013
	Pandemic-War Period	-14,106	-14,012	-14,107	-14,070	6959,181	0,000	0,012
Copula-DCC-GARCH	Full Period	-14,639	-14,588	-14,639	-14,620	13572,435	0,000	0,011
	Pre-COVID-19	-15,179	-15,086	-15,180	-15,143	6604,758	0,000	0,009
	During COVID-19	-13,909	-13,806	-13,909	-13,869	5371,775	0,000	0,013
	Pandemic-War Period	-14,130	-14,046	-14,131	-14,098	6969,148	0,000	0,012

Table E2 - Information Criteria, Log-likelihood, MSE and RMSE of multivariate GARCH models with mvt-distribution for **IIFX-V2TX** series

Model	Interval	AIC	BIC	Shibata	HQC	Log-Lik	MSE	RMSE
DCC-GARCH	Full Period	-9,729	-9,675	-9,729	-9,709	9027,033	0,003	0,055
	Pre-COVID-19	-10,043	-9,944	-10,044	-10,005	4376,766	0,003	0,054
	During COVID-19	-9,199	-9,091	-9,200	-9,158	3559,759	0,004	0,059
	Pandemic-War Period	-9,462	-9,372	-9,462	-9,428	4673,116	0,003	0,055
ADCC-GARCH	Full Period	-9,728	-9,671	-9,728	-9,707	9027,033	0,003	0,055
	Pre-COVID-19	-10,041	-9,937	-10,042	-10,001	4376,766	0,003	0,054
	During COVID-19	-9,197	-9,082	-9,198	-9,153	3559,824	0,004	0,059
	Pandemic-War Period	-9,460	-9,365	-9,461	-9,424	4673,187	0,003	0,055
Copula-DCC-GARCH	Full Period	-9,750	-9,699	-9,750	-9,731	9045,444	0,003	0,055
	Pre-COVID-19	-10,057	-9,964	-10,058	-10,021	4381,797	0,003	0,054
	During COVID-19	-9,222	-9,119	-9,223	-9,183	3567,452	0,004	0,059
	Pandemic-War Period	-9,482	-9,398	-9,483	-9,450	4682,141	0,003	0,055

Table E3 - Information Criteria, Log-likelihood, MSE and RMSE of multivariate GARCH models with mvt-distribution for **IIFX-V1IX** series

Model	Interval	AIC	BIC	Shibata	HQC	Log-Lik	MSE	RMSE
DCC-GARCH	Full Period	-9,927	-9,873	-9,927	-9,907	9210,045	0,002	0,050
	Pre-COVID-19	-10,248	-10,149	-10,248	-10,210	4465,457	0,002	0,049
	During COVID-19	-9,408	-9,299	-9,409	-9,366	3639,993	0,003	0,054
	Pandemic-War Period	-9,655	-9,566	-9,656	-9,621	4768,384	0,003	0,051
ADCC-GARCH	Full Period	-9,926	-9,869	-9,926	-9,905	9210,045	0,002	0,050
	Pre-COVID-19	-10,245	-10,141	-10,246	-10,205	4465,457	0,002	0,049
	During COVID-19	-9,405	-9,291	-9,407	-9,361	3640,049	0,003	0,054
	Pandemic-War Period	-9,654	-9,559	-9,655	-9,618	4768,636	0,003	0,051
Copula-DCC-GARCH	Full Period	-9,947	-9,896	-9,947	-9,928	9227,438	0,002	0,050
	Pre-COVID-19	-10,256	-10,162	-10,257	-10,220	4468,012	0,002	0,049
	During COVID-19	-9,438	-9,336	-9,439	-9,399	3650,761	0,003	0,054
	Pandemic-War Period	-9,687	-9,603	-9,688	-9,655	4783,094	0,003	0,051

This is to certify that

Project No.: FIN2024-6-149921

Project Title: Understanding the relationship between impact investment firms and market volatility

Principal Researcher: Fábio Sousa

according to the regulations of the Ethics Committee of NOVA IMS and MagIC Research Center this project was considered to meet the requirements of the NOVA IMS Internal Review Board, being considered APPROVED on 6/14/2024.

It is the Principal Researcher's responsibility to ensure that all researchers and stakeholders associated with this project are aware of the conditions of approval and which documents have been approved.

The Principal Researcher is required to notify the Ethics Committee, via amendment or progress report, of

- Any significant change to the project and the reason for that change;

- Any unforeseen events or unexpected developments that merit notification;

- The inability of the Principal Researcher to continue in that role or any other change in research personnel involved in the project.

Lisbon, 6/14/2024

NOVA IMS Ethics Committee

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NOVA IMS

Information Management School

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Instituto Superior de Estatística e Gestão de Informação

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