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Study of Risk Factors in Global Stock Markets During the COVID-19 Pandemic Under Different Market Conditions

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Abstract

In this paper, we examine the stock markets' response to fluctuations in international risk factors under different market states during the COVID-19 pandemic. Using data from seven countries heavily affected by the sanitary crisis, over the period between January 2020 and December 2021, we estimate an extended risk factor model through the quantile regression approach, with the purpose of identifying distinct sensitivities to risk sources depending on the bullish or bearish state of the market. Our results suggest higher explanatory ability at extreme quantiles, thereby revealing significant disparities in sensitivities, that are found to be dependent on the market conditions, on the country and on the particular risk factor.

JEL classification: C22, C51, F21, G12, G32, H12

Plain language summary

Study of risk factors in global stock markets during the COVID-19 pandemic under different market conditions

Purpose: This study investigates how international risk factors affected stock markets during the COVID19 pandemic. It examines whether these effects varied depending on whether the market was performing well (bullish) or poorly (bearish). Methods: The researchers used data from seven countries hit hard by the pandemic between January 2020 and December 2021. They used "quantile regression" to analyze the data, which allowed them to see how risk factors affected the stock market differently at different levels of market performance. Conclusions: The study found that risk factors had a stronger impact on stock market performance under extreme conditions (e.g., exceptionally good or bad market conditions). These effects varied across countries and risk factors. Implications: Our research highlights the effectiveness of assets such as gold, bitcoin and oil as diversifiers within investment portfolios. In addition, interest rate volatility emerges as a strong explanatory factor, highlighting its importance for international diversification strategies. Limitations: Our study focuses only on the pandemic period, excluding the pre- and post-COVID-19 periods. A broader analysis across different market conditions would enhance our findings. In addition, the deliberate exclusion of countries severely affected by the COVID-19 pandemic may limit the generalisability of our findings. Future research should include a more diverse set of countries to ensure robust conclusions.

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Data Availability Statement included at the end of the article

Keywords
Risk factors, stock market returns, quantile regression, COVID-19

Introduction

During economic crises, identifying the drivers of stock prices becomes particularly important and useful for investors and fund managers trying to control risk through diversification or hedging strategies, as well as for policymakers and regulators in designing policies to maintain the stability of the financial system. The unprecedented nature of the COVID-19 crisis makes the pandemic period a relevant scenario to revisit the interactions among financial assets and the link between asset returns and risk factors, such as the role of safe-haven assets, global economic conditions, media influence, and interest rate volatility. Furthermore, understanding these factors is essential for managing future crises and uncertainties in the global financial landscape.

The outburst and spread of the COVID-19 has caused extraordinary economic damage (Goodell, 2020) with consequences in many aspects of economic and financial reality (Chowdhury et al., 2022; Salem et al., 2023; Wiquar et al., 2022). Since the onset of the coronavirus pandemic, numerous papers have empirically documented the effect of COVID-19 on stock returns and volatility (Ashraf, 2020; Goodell and Huynh, 2020; Huynh et al., 2021a, 2021b; Li et al., 2021; Rahman et al., 2021; Scherf, 2022; Zaremba et al., 2020). Nevertheless, there is a lack of literature on modeling the relationship between stock returns and explanatory variables during a period of global crisis as that experienced as a result of the COVID-19 pandemic.

The objective of this research is to assess the sensitivity of global equity markets to international risk factors in hard-hit countries during the COVID-19 pandemic. In particular, the major stock markets of Germany, Brazil, Spain, the United States, India, the United Kingdom and South Africa are analyzed. These countries are among the most severely affected by the Covid-19 in terms of confirmed cases and deaths, according to the World Health Organization (WHO) (data extracted from the website https://covid19.who.int/). From this ranking, these seven selected countries are in the top most affected of each continent (Salgotra et al. 2020), and have been chosen to provide a representative sample of the world's major developed and emerging economies. Selecting countries solely based on the number of COVID-19 infections and deaths may over-represent the European continent, potentially weakening the power of this study, which aims to focus on countries with very distinct geographical and economic characteristics that can provide a global panorama of the impact of the pandemic on financial markets.

In line with previous financial literature (Cepoi, 2020; Jareño et al., 2021, 2022; Sevillano & Jareño, 2018), the international factors selected for the analysis are: gold, bitcoin and oil prices, the CBOE Volatility Index (VIX), the OFR Financial Stress Index (FSI), the Media Coverage Index (MCI) and the 10-year US bond return volatility.

The time period of the study ranges from January 2020 to December 2021. This span covers the successive waves of the pandemic and concludes prior to the onset of other global events such as the escalation in military tension between NATO and Russia, inflation and energy price rises, among others, whose inclusion could contaminate our findings. The quantile regression method (QRM) is used to estimate the model. This methodology provides a comprehensive understanding of the distribution of the endogenous variable, thereby improving the cross-sectional properties of the model.

Our paper contributes to the literature in several ways. First, we add to the literature on the behavior of stock markets during crashes and crisis, and particularly during the COVID-19 pandemic. Second, we contribute to the literature on the sensitivity of stock returns to economic and financial factors during periods of turmoil. Thus, although several studies have investigated the linkages between equity returns and some particular financial asset or economic variable during the pandemic (Cepoi, 2020; Esparcia et al., 2022; Jareño et al., 2021; Umar et al., 2021), our paper goes further by estimating an extended model using a wide set of risk factors including the FSI and the MCI, whose impact has been scarcely analyzed. Additionally, our research is carried out in countries covering the main economic areas worldwide. Finally, the QR methodology used allows us to assess the explanatory power of risk factors at different quantiles, this is, in different market states, providing evidence as to whether stock returns become increasingly sensitive to fluctuations in risk factors in extreme market conditions, which may have important implications for investors and policymakers. Although Jareño et al. (2023) conduct a similar study analyzing the sensitivity of government bond markets to global risk factors during the pandemic, to the best of our knowledge no study has thus far examined the stock market behavior in this respect.

Our study tests three hypotheses. Hypothesis 1 (H1) states that selected risk factors have a more pronounced effect on stock market returns in extreme market scenarios. Hypotheses 2 (H2) assumes that the response of equity market return to shocks from international risk factors will differ in direction depending on the prevailing bearish

or bullish conditions at the time, which are associated with low and high quantiles, respectively. Finally, Hypotheses 3 (H3) states that the stock market returns of each country will react differently depending on its economic structure and situation. Based on the results obtained, there is evidence supporting all three hypotheses.

The rest of the paper is organized as follows: Section "Literature Review" provides a detailed literature review. Section " Data and Methodology" describes the data and the Quantile Regression methodology applied in this research. Section "Assessing Global Equity Market Response to International Risk Shifts in Pandemic Outbreak" presents the empirical analysis and discusses the results obtained across various quantiles or market conditions. Finally, Section " Concluding Remarks" discusses concluding remarks and lines of future research.

Literature Review

Since its outburst, the COVID-19 pandemic has attracted considerable attention from studies examining its impact on economic activity and on different financial markets (Chowdhury et al., 2022; González et al., 2021; Jareño et al. 2023; Salem et al., 2023; Umar et al., 2021; Wiquar et al., 2022). Focusing on equity markets, numerous studies have empirically investigated the relation between COVID-19 data (confirmed and death cases) and stock returns and volatility. Some of these papers have focused on one country, such as the US market (Goodell and Huynh, 2020) or the Australian market (Huynh et al., 2021a; Rahman et al., 2021), whereas others have compared different international equity markets responses (Ashraf, 2020; Huynh et al, 2021b; Scherf et al., 2022; Ullah, 2023; Zaremba et al., 2020). This recent research suggests that confirmed cases and cases of death had significant negative effects on stock returns and positively affected to stock return volatility in most countries.

But beyond analyzing the direct effects of COVID-19 cases on stock returns, other papers have also examined the impact of the pandemic on the connectedness of stock markets. To this respect, Li et al. (2021) and Liu et al. (2022), among others, examining the volatility connectedness of different international markets, show that the COVID-19 outbreak has significantly impacted the global stock markets, altering considerably financial relationships and, particularly, increasing risk contagion.

From the perspective of portfolio allocation, it is also crucial to analyze the linkages patterns between risk factors and global stock markets. The international factors in which we focus our research can be considered relevant explanatory variables of stock returns in times of turmoil. In particular, they are: the returns of two assets considered as safe havens, such as gold and bitcoin; a factor reflecting the economic situation, such as the price of oil, three factors that are particularly important in times of global crisis, concerning market volatility, financial stress, and media attention (VIX, FMI, and MCI, respectively) and finally, a traditional explanatory factor, interest rate volatility, whose behavior during the pandemic in relation to stock returns has been little studied.

With respect to the first of the factors analyzed in our research, the correlation between gold prices and equity returns stems from gold's recognition as a haven for various assets, particularly equities, during bear markets. In addition, gold is widely acknowledged as an important store of wealth. In their study of different planning horizons, Esparcia et al. (2022) clearly demonstrate the significant diversifying influence of gold amid the COVID-19 pandemic.

As for the bitcoin, building on recent research highlighting bitcoin's status as the modern equivalent of gold, Jareño, González, Tolentino, Sierra, et al. (2020) use the QR methodology to examine how cryptocurrencies serve as diversification, hedging and safe-haven assets. Their results show the increased ability of cryptocurrency returns to explain extreme situations. A positive sensitivity is detected with respect to the US stock market, being especially significant in the high quantiles. In the same vein, González et al. (2021) examine potential interactions between leading cryptocurrencies and gold during the recent pandemic. Interesting results show significant correlations between gold and cryptocurrencies, particularly during periods of economic instability like COVID-19. This result would suggest that, in certain scenarios, cryptocurrencies could play a similar role to gold in investment portfolios.

The financial literature has also reflected the impact of the demand shock caused by the pandemic situation in the energy sector (Jareño et al., 2021; Umar et al., 2021), which has significantly affected oil returns. Given the crucial role of oil as one of the primary production factors on a global scale, it is recommended to investigate its behavior concerning financial markets. Building on prior research, Guesmi et al. (2019) suggest a lower risk investment strategy by diversifying a portfolio with stocks, gold, Bitcoins, and oil.

Another possible international risk factor is market volatility. Whaley (2000) defines the Volatility Index (VIX) created by the Chicago Board Options Exchange as a "fear index for stock market assets." The link between market volatility and stock returns remains controversial, and there is no consensus in the financial literature. Thus, Magner et al. (2021), for example, despite their results indicate a strong predictive performance of the VIX in the timing of equity markets, recognize the need to further test this predictive ability in situations of economic and financial instability. On the other hand, according to Bekaert et al. (2014), the VIX has a strong

predictive ability for financial instability in stock market indicators over a short-term period of 1 to 3 months. However, this study highlights that the volatility index alone is ineffective in predicting stock returns.

Following with the explanatory variables under study, in our model we incorporate financial stress, this is, the systemic risk existing in a financial sector or market (CNMV, 2017). In particular, we use the Office of Financial Research Financial Stress Index (FSI) that includes 33 financial market variables from several advanced economies and emerging regions around the world. With regard to its effects, Bianconi et al. (2013) conclude from their work on the impact of the U.S. financial crisis on BRICS financial markets that there is a negative correlation between stock market performance and financial stress, which increases during periods of economic and financial turmoil.

Another relevant aspect to consider among the drivers of stock returns today is the influence of mass media. Barberis et al. (1998) carried out one of the first studies in this direction and identified the phenomenon of financial markets overreacting to media news, even in cases where the news is not sufficiently significant. In our study we use the Media Coverage Index (MCI) developed by the Spanish company Raven Pack, as several previous studies that have analyzed the influence of the media to study the financial effects of crises. The MCI is composed of other sub-indices that measure the amount of false news, the media coverage based on the percentage of news related to the virus with respect to the total, and the panic or financial contagion index. Cepoi (2020) employs the MCI to examine how media pressure impacts stock returns in the financial markets of the six countries hit hardest by the pandemic. The following conclusions are drawn. First, news coverage of the pandemic is detrimental to market returns in the middle and upper quantiles, but not in the lower one. Similarly, the middle and upper quantiles are negatively affected by the occurrence of financial panic or contagion. In contrast, the existence of fake news hurts the lower and middle quantiles of the return distribution. Umar et al. (2021) also include the MCI in their study of commodity markets during the pandemic outbreak. The variable is shown to be statistically significant with respect to market returns and volatility mainly during the first and third waves of the pandemic.

Finally, another risk factor that can induce international market turmoil is interest rate volatility. Jareño (2008) and González et al. (2016), along with other researchers, have contributed to the financial literature by validating the inverse relationship between stock returns and unexpected interest rate changes. Despite the abundance of previous studies that have delved into the details of this connection (Jareño & Navarro, 2010, and Cano et al., 2016, among others), there is little recent empirical evidence focusing on the explanatory power of interest rate volatility during the period of the coronavirus crisis.

Thus, to contribute to the previous literature, this research estimates a model for equity market indices of selected seven countries to test the explanatory power of the described factors during a period marked by the COVID-19 pandemic through the QR approach, detailed in the following section.

Data and Methodology

Data

In this section, we explain the data selection process that is critical to the empirical underpinning of our study, which aims to assess the impact of the global COVID-19 pandemic on international equity markets. The selection criteria for our dataset were guided by the principles advocated by the World Health Organization (WHO) and considerations of global representativeness, as well as our commitment to drawing sound conclusions.

We selected the following countries for our analysis. Germany, which not only represents the preeminent economic power within the Eurozone, but also exerts significant influence within the European Union and the wider European continent. Brazil, which serves as a prominent example of Latin American financial markets characterized by a pronounced dependence on commodity exports and susceptibility to currency volatility. It also plays a key role in the BRICS consortium. Spain, chosen to represent southern European countries and a member of the Economic and Monetary Union (EMU). The United States, the world's leading economic power and the most influential financial stock market. India, chosen for its classification as a developing Asian nation within the BRICS group. United Kingdom, chosen as a European power outside the European Union with its own currency. South Africa, which represents an emerging African economic power and is also part of the BRICS group.

We have deliberately excluded countries such as France and Italy in the European context, and Mexico in Latin America, because they share economic, social and health characteristics with the countries included in our study. We also acknowledge the limited representativeness of the Asia-Pacific and Oceania regions, which were less affected by the pandemic, particularly in the early stages of our research. Notable regional powers such as China, Japan, South Korea and Australia have therefore been omitted.

Thus, our empirical analysis relies on two categories of variables. On one hand, the endogenous variables include the returns of the main stock markets of the selected countries. Specifically, we track the performance of the DAX-30 (Germany), BOVESPA (Brazil), IBEX-

35 (Spain), S&P500 (United States), BSE SENSEX 30 (India), FTSE-100 (United Kingdom), and JTOPI (South Africa) indices. On the other hand, the exogenous variables are international risk factors and their impact on equity markets is the subject of our research. They include gold yields, bitcoin cryptocurrency values, oil prices, US Volatility Index yields, fluctuations in the Office of Financial Research Financial Stress Index (FSI) and Coronavirus Media Coverage Index (MCI), and changes in the 10-year US bond yield.

The primary sources of our data are reputable financial information repositories, namely the Investing and YahooFinance websites. In addition, we obtained data on the OFR Financial Stress Index from the official website of the Office of Financial Research and information on the Media Coverage Index from Raven Pack, a prominent data analytics company. In concrete, our empirical study includes a dataset of 505 daily observations for each variable. This dataset covers the period from January 2020 to December 2021. Starting on 2 January 2020. This starting point was chosen to capture the impact of COVID-19 before its official declaration as a pandemic by the WHO in March 2020, as noted by González et al. (2021). To account for the successive waves of the COVID-19 outbreak and other global developments, we end our study on 31 December 2021.

The rationale for this specific period is that it covers two full annual cycles and coincides with the easing of disease prevention measures, declining global mortality rates and the emergence of various global instability factors such as geopolitical tensions, inflation and energy price fluctuations. Extending the study period beyond this timeframe could introduce confounding variables unrelated to the COVID-19 pandemic.

Continuing with the treatment of the data on the different stock markets analyzed, it is interesting to note that the information extracted was expressed in terms of prices or quotes and was therefore transformed into logarithmic returns (r_n). For this purpose, the following expression was used:

$$r_n = Ln\left(\frac{P_n}{P_{n-1}}\right) \quad (1)$$

Let P_n be the value of the variable on the current day (n) and P_{n-1} be the value on the previous day ($n-1$) for which data are available. However, it has not been necessary to apply the above expression (1) to three exogenous variables in this paper, namely the FSI and MCI indices and interest rates. With regard to the FSI, the transformation consisting in the application of first differences has been used, as in the financial literature, that is, the variation of the daily frequency variable (n) with respect to the data of the previous day (n–1) is captured. Similarly, the same transformation (first differences) is used for the MCI and interest rates.

Table 1 presents the primary statistical measures used to describe and summarize the stock market returns of the selected countries (Panel A) and the risk factors (Panel B) examined in this study, as well as stationarity tests.

Panel A shows that, with the exception of Spain, almost all markets have positive mean returns, being the upward trend particularly noticeable in the United States, India and South Africa. The highest standard deviation corresponds to the returns of Brazil. In contrast, the UK and Spain have relatively lower standard deviations, indicating lower volatility. All returns are negatively skewed, with the Indian index being the most asymmetric, suggesting a more pronounced left tail. All stock market returns have a high kurtosis, which indicates a heavy tail and the presence of outliers in the distribution. Brazil and Spain have particularly high kurtosis, reflecting the extreme returns observed. On the other hand, the Jarque-Bera statistics and the stationarity tests indicate that all stock market returns are not normally distributed and stationary, respectively. In order to test for the presence of stationarity in the time series, we apply three statistical tests: the Augmented Dickey-Fuller (ADF), the Phillips-Perron (PP) and the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) tests.

Regarding the risk factors, Panel B shows that all except the VIX have a positive mean. The growth has been particularly notable in the case of MCI, a conclusion that seems quite logical due to the nature of this factor. In addition, Bitcoin has the highest average, while interest rates have an average close to zero. The change in MCI has also been the variable with the highest volatility, according to the standard deviation results. Some risk factors, such as Financial Stress and VIX, have positive skewness, indicating a bias toward higher values. Gold has negative skewness, indicating a preference for lower values. Most of the risk factors have high kurtosis, indicating heavy tails and the presence of outliers in their distributions. In particular, Bitcoin and Financial Stress have high kurtosis. The Jarque-Bera test rejects the null hypothesis of normality of all international risk factors. Finally, it is beyond doubt that all variables exhibit stationarity except for gold yields, US 10-year bond yields and changes in the media coverage index. In particular, the null hypothesis for the existence of a unit root is rejected with respect to the ADF and P-P tests, but remains unchallenged with respect to the KPSS test.

As far as the correlation matrix (Table 2) between international risk factors is concerned, Table 2 shows the scarcity of statistically significant links for some variables. In particular, MCI variations, VIX index returns, and

Table 1. Main Descriptive Statistics for the International Stock Market Returns.Panel A: Returns for the Selected Stock Markets.

Variable	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	JB stat.	ADF stat.	PP stat.	KPSS stat.
Germany	0.0004	0.0008	0.1041	−0.1306	0.0160	−1.0261	17.0259	4228.1**	−14.033***	−22.798***	0.0821
Brazil	0.0001	0.0009	0.2004	−0.1599	0.0236	−0.0482	24.0842	9354.1***	−27.038***	−26.577***	0.1070
Spain	−0.0002	0.0005	0.0823	−0.1515	0.0169	−1.5000	19.0368	5600.8***	−13.451***	−24.038***	0.1690
US	0.0008	0.0017	0.0897	−0.1277	0.0165	−1.0489	17.7576	4675.1***	−6.234***	−30.069***	0.0928
India	0.0007	0.0016	0.0675	−0.1410	0.0156	−2.0485	20.6187	6884.9***	−7.449***	−23.680***	0.1740
UK	0.0000	0.0007	0.0867	−0.1151	0.0143	−1.2208	16.0008	3681.8***	−23.265***	−23.252***	0.2210
S. Africa	0.0005	0.0009	0.0906	−0.1045	0.0157	−0.7058	12.9537	2126.6***	−7.736***	−24.832***	0.0695

Panel B: Returns for the selected risk factors.

Variable	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	JB stat.	ADF stat.	PP stat.	KPSS stat.
Gold	0.0007	0.0008	0.0563	−0.0508	0.0119	−0.3349	7.1181	366.3***	−21.714***	−21.934***	0.392*
Bitcoin	0.0036	0.0024	0.1918	−0.4973	0.0495	−2.0132	24.0609	9674.4***	−24.407***	−24.336***	0.105
Crude oil	0.0016	0.0023	0.3196	−0.2822	0.0444	0.0926	21.5062	7207.1***	−20.944***	−20.944***	0.0946
VIX	−0.0003	−0.0105	0.4802	−0.2662	0.0885	1.3643	8.1432	713.3***	−25.891***	−25.973***	0.113
Financial stress	0.0022	−0.0240	3.4540	−1.5800	0.3643	3.5228	32.0213	18,766.6***	−5.205***	−24.049***	0.082
MCI	0.1321	0.1200	13.6100	−7.2400	2.0494	1.1255	10.7769	1379.2***	−6.912***	−27.493***	0.666**
Interest rates	0.0000	0.0000	0.0065	−0.0070	0.0007	−0.3732	44.4674	36,193.8***	−28.4818***	−29.2927***	0.4305*

Note. The following tables present statistics on daily international stock market returns (panel A) and risk factors (panel B) from 3 January 2020 to 30 December 2021: mean, median, minimum (min.) and maximum (max.) values, standard deviation (std. dev.), skewness and kurtosis measures, and the statistic of the Jarque-Bera (JB) test for the normality of the data. The last three columns also report the results of the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests and the Kwiatkowski et al. (KPSS) stationarity test.
As always, *, **, *** indicate statistical significance at the 10%, 5% and 1% level.

Table 2. Matrix of Correlations Between the International Risk Factors Selected in the Research.

Risk Factors	Gold	Bitcoin	Crude oil	VIX	Financial stress	MCI	Interest rates
Gold	1						
Bitcoin	−0.0487	1					
Crude oil	0.0941**	0.0439	1				
VIX	−0.0048	−0.1778**	−0.0639	1			
Financial stress	−0.1451***	0.0008	−0.3676***	0.0494	1		
MCI	−0.0160	0.0447	−0.0588	−0.0010	0.2713***	1	
Interest rates	−0.1014**	0.0211	0.1658***	0.0111	−0.3563***	−0.1679***	1

Note. The ** and *** denote statistical significance at the 5 % and 1 % levels, respectively.

Bitcoin cryptocurrency returns show low levels of correlation with values below 5%, except in some exceptional cases. For example: the relationship between the last two named variables (VIX-Bitcoin) is significant and negative, as established in the literature (Jareño, González, Tolentino, Sierra, et al., 2020), while the variations of the coronavirus-related news index present a more than 25% positive relationship with respect to market stress variations, as in Umar et al. (2021).

In contrast, gold, oil and 10-year US bond yields, as well as changes in the FSI index, together show statistically significant correlations with each other, with values above 10%, although these hardly ever exceed 30%. We highlight the 36% negative link between oil yields and changes in market stress, which, as explained by Jareño et al. (2021, 2023), is a consequence of market shocks that affect crude oil as a fundamental productive factor in the global economic system. Equally noteworthy is the

almost non-existent relationship between gold yields and changes in FSI in the period 2020 to 2021, which confirms the conclusion drawn by the literature (among others, González et al., 2021; Jareño et al., 2023) on the inability of the precious metal to control risk in the pandemic era.

Figure 1 allows us to extract a number of similarities in the path of these variables by showing their variation over time. One apparent implication is the discernible influence of the COVID-19 breakout on financial markets and other international factors studied in March 2020. This is followed by an equally remarkable trend of recovery, which extends mainly until June of the same year (Ramelli & Wagner, 2020), generating extreme market conditions throughout this period.

The sample period also includes new situations of instability in the markets caused by different global events and, in particular, by the consecutive surges in COVID-19 infections. However, despite the episodes of market stress, the evolution of the variables during the second half of 2020 and in 2021 shows a more linear trend, a sign of greater stability.

Methodology

This section introduces and justifies the methodology used in this paper, which focuses on examining the response of stock market returns to shocks from different international risk factors in 2020 and 2021, a period marked by the outburst and spread of the coronavirus crisis.

Unlike the conventional Ordinary Least Squares (OLS) methodology, this study will employ Quantile Regression (QR) estimation. As previously stated, numerous authors have opted for the use of this second methodology since its pioneering explanation and application by Koenker and Bassett (1978). Among them, we highlight the following publications: Chevapatrakul and Paez-Farrel (2014), Ferrando et al. (2017), Sevillano and Jareño (2018), González and Jareño (2019), Jareño, González, & Escolástico (2020), Jareño, Tolentino, & González (2020), Jareño et al. (2023), and Escribano et al. (2023), among others.

Building on previous research by Escribano et al. (2023), González et al. (2021), Jareño, González, & Escolástico (2020), Jareño, González, & Munera (2020), Jareño, González, Tolentino, Sierra, et al. (2020), Jareño, Tolentino, González, Medina, et al. (2020), Jareño et al. (2022, 2023), Sevillano and Jareño (2018), and various others, our model is constructed using the Quantile Regression method. This approach yields more robust results compared to alternative methods such as Ordinary Least Squares (OLS) estimation. Quantile regression is preferred to mean-based regression methods such as OLS for several reasons: (1) robustness to outliers (less sensitive to outliers due to the minimization of absolute deviations), (2) characterizing the entire distribution (provides a comprehensive view of the conditional distribution), (3) handling of heteroscedasticity (suitable for situations with varying variance in the response), (4) distributional assumptions (fewer distributional assumptions compared to OLS), (5) handling skewed distributions (more informative for skewed or asymmetric data), and (6) conditional quantile interpretation (provides estimates directly interpretable as conditional quantiles). In summary, quantile regression is a valuable technique when there is a need to understand and model different parts of the conditional distribution of the response variable. Its robustness to outliers, distributional flexibility, and ability to provide insight into specific quantiles make it a powerful tool in various statistical applications.

Koenker and Bassett (1978) introduced the concept of quantile regressions through the application of minimum absolute deviation. In this framework, given an explanatory variable (y_b) and several explanatory variables (x_b), for each quantile θ, the objective is to minimize the sum of the squares of the absolute values of the errors, taking into account the sign of these errors or residuals. Mathematically, this is expressed as (Jareño et al., 2023):

$$\frac{Min}{\beta}\ 1/n = \sum (y_{bt} - x_{bt}'\beta)^2 \tag{2}$$

To capture the relationship for different quantiles, the optimization problem is formulated as:

$$= \frac{Min}{\beta} 1/n \left\{ \sum_{b\in\{i:yi \geqslant xb\beta} \theta|y_b - -x_{bt}'\beta| + \sum_{b\in\{i:yi \geqslant xb\beta} (1-\theta)|\,|y_b - x_{bt}'\beta\,| \right\} \tag{3}$$

This can be further simplified as:

$$= \frac{Min}{\beta}\ 1/n \sum_{p} \theta(y_{bt} - x_{bt}'\beta) \tag{4}$$

Here, $p(\theta)$ is known as the verification function, with values in the interval (0,1), and it plays a critical role in approximating the vector β.

Assuming y_b - $x_b \cdot U = u_b$, and $E(U_b\,|\,U_b) = 0$ (i.e., the conditional expected value of the error U_b with respect to the observations is zero), the conditional mean of U_b with respect to U_b can be expressed linearly as:

$$E(y_b|x_b) = x_b'\beta \tag{5}$$

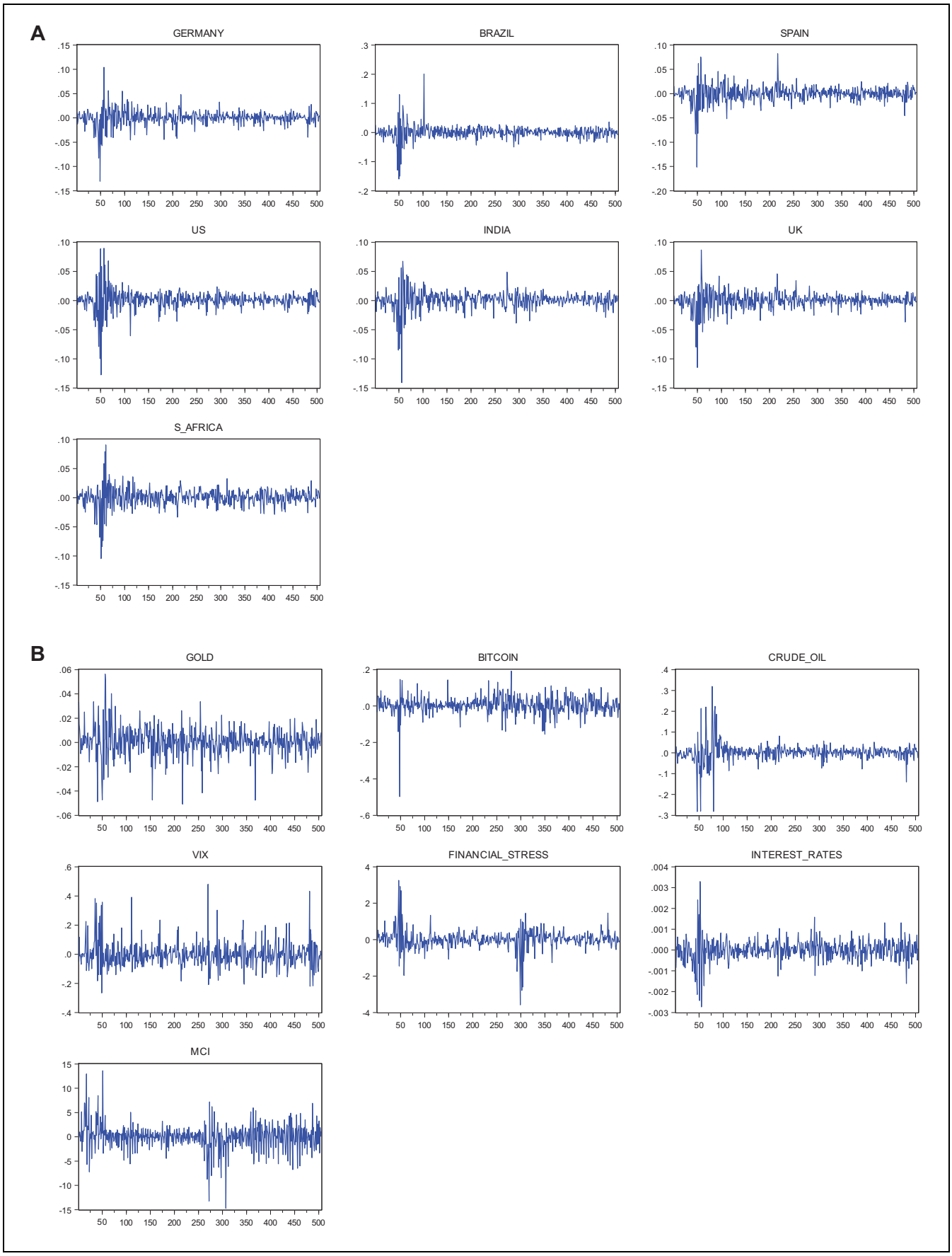


Figure 1. The evolution over time of the variables taken into account in the research: Panel A: International stock market returns and Panel B: International risk factors' variation rates.

The solution to the optimization problem leads to the inverse of the conditional quantiles:

$$F^{-1} = (y_b|x_b) \tag{6}$$

Consequently, we will formulate the following expression, originally proposed by Koenker and Bassett (1978), and applied by Buchinsky (1998), as a particular specification of the QR model (Escribano et al., 2023; Ferrando et al., 2017; Jareño et al., 2016):

$$y_i = x_i^{'}\beta_\theta + u_{\theta i} \tag{7}$$

with y_i being the explained variable or returns of the equity financial markets in the selected countries that are significantly impacted by COVID-19; β_θ, a k x 1 vector of unknown parameters that are fitted over a range of θ values between 0 and 1; x_i, a k x 1 dimensional vector of independent variables; and $u_{\theta i}$ takes into account the unknown error term.

The θ-*th* value of y_i given x_i will be

$$Q_\theta\left(\frac{y_i}{x_i}\right) = x_i^{'}\beta_\theta \tag{8}$$

To estimate the vector β_θ an optimization problem must be solved from the following function, where β is minimized:

$$\sum_{k=0} \theta\left|y_t - x_t^{'}\,\beta\right| + \sum_{t:y_t>x_t^{'}} (1-\theta)y_t - \,x_t^{'}\,\beta \tag{9}$$

Based on the QR model, we incorporate the selected seven international risk factors into an extension of Stone's (1974) two-factor model:

$$\begin{aligned} Q_\theta\left(R_{M,jt}|R_{Gold,t}R_{Bit,t}R_{Oil,t}R_{VIX,t}\Delta FSI_t\Delta I_t\Delta MCI_t\right) = \\ \beta_{0j}^\theta + \beta_{1j}^\theta R_{Gold,t} + \beta_{2j}^\theta R_{Bit,t} + \beta_{3j}^\theta R_{Oil,t} + \beta_{4j}^\theta R_{VIX,t} \\ + \beta_{5j}^\theta \Delta FSI_t + \beta_{6j}^\theta \Delta MCI_t + \beta_{7j}^\theta \Delta I_t + \varepsilon_{jt} \end{aligned} \tag{10}$$

$R_{M,jt}$ is the return of the equity financial markets of each country *j;* $R_{Gold,t}$ is the return on the gold price; $R_{Bit,t}$ represents the returns on the Bitcoin price; $R_{Oil,t}$ reflects the returns on the oil price; $R_{VIX,t}$ captures the yields of the VIX index; ΔFSI_t tracks variations in the OFR Financial Stress Index; ΔMCI_t shows the change in the Media Coverage Index; ΔI_t represents the change in interest rates that are extracted as yields on 10-year US bonds; $\dot{e}_{j,t}$ estimates the random disturbance of the endogenous variable.

Moreover, Q_θ is the θ*th* conditional quantile of the j*th* international stock market return, $0<\theta<1$. Consequently, the parameters β_{0j}^θ, $\beta_{1j}^\theta \ldots \beta_{7j}^\theta$ are subject to estimation for several quantiles, and they explore the reaction of the stock market return at the θ *th* quantile to changes in each international risk factor. In addition, the *theta*-quantiles can be considered as indicating alternative international stock market states. Thus, the coefficients γ_j^θ derived from QR refer to the upper quantiles of θ and provide estimates of the impact of each risk factor close to the upper end of the distribution of stock market returns. This relates to periods characterized by significant increases in stock prices in each international stock market. Conversely, the coefficients related to the lower quantiles of θ measure the responsiveness of the international stock market to fluctuations in each risk factor at the lower tail of the return distribution. This refers to scenarios characterized by significant stock price declines in the various international stock markets studied.

Following the specification of the model to be explored in this paper using a quantile regression approach, the following hypotheses are going to be tested: Consequently, ***H1*** states that stock market returns will show increased sensitivity to variations in specific risk factors during severe market conditions. In other words, the responsiveness of each international stock market's returns will be more pronounced for extreme values of θ. ***H2*** states that stock market returns will respond to shocks in risk factors at the global level in a different way depending on the prevailing bearish or bullish market states. ***H3*** assumes that stock market returns in each country will exhibit different behavior depending on the economic structure and situation of each country.

Assessing Global Equity Market Response to International Risk Shifts in Pandemic Outbreak

This section assesses the impact of COVID-19 on stock market returns in different countries. It examines the sensitivity of these returns to various risk factors, including gold, bitcoin, oil prices, the VIX index, the financial stress index, the media coverage index and interest rates, using quantile regression (Escribano et al., 2023; Ferrando et al., 2017; González & Jareño, 2019; Jareño et al., 2016, 2022; Jareño, González, & Munera, 2020, Sevillano & Jareño, 2018, among others). Specifically, to examine each international stock market's response to fluctuations in the selected international risk factors, we can observe three critical values in the distribution: 0.05 (lower quantile), 0.5 (median), and 0.95 (upper quantile).

Risk Factor Model Estimates for Theta-Quantile 0.05

In this section we present the coefficients obtained for a theta quantile of 0.05, which can be found in Table 3. These coefficients provide valuable insights into the

Table 3. Risk Factor Model Estimates for *Theta*-Quantile 0.05 (the Lowest Tail of the Distribution).

Risk Factors	Germany	Brazil	Spain	US	India	UK	S. Africa
Gold	0.3372***	−0.2182	0.0954	−0.0149	−0.2200***	−0.0486	0.4015***
Bitcoin	−0.0129	0.0775***	−0.0375	0.0136	−0.0771***	0.0012	−0.0114
Crude oil	−0.0287	0.0849***	−0.0527***	0.0082	0.0139	0.0269	0.0449*
VIX	0.0065	−0.02	−0.0269***	0.0132	0.0125	−0.0093	−0.01
Financial stress	−0.0358***	−0.0112***	−0.0229***	−0.0417***	−0.0222***	−0.0060***	−0.0084
MCI	−0.0009**	−0.0005	−0.0004	0.0002	−0.0011**	−0.0002	−0.0028***
Interest rates	−1.5892	−20.019***	5.0550***	2.6467***	−4.6545***	0.3344***	−0.5009
R^2	0.5079	0.103	0.2922	0.5325	0.2203	0.068	0.0862

Note. The *, ** and *** denote statistical significance at the 10 %, 5 % and 1 % levels, respectively.

performance of international stock market returns at the lower tail. The study focuses on analyzing the stock markets of several countries, including Germany, Brazil, Spain, the United States, India, the United Kingdom and South Africa.

In terms of gold returns, the German, Indian and South African markets show statistically significant coefficients at the 1% level. Gold returns show a positive relationship with the DAX and JTOPI indices, while an inverse relationship is observed with the Indian BSE SENSEX 30 index. This result could be consistent with Guesmi et al. (2019), González et al. (2021), and Esparcia et al. (2022), showing the diversification benefits of Gold. In addition, our results contribute to the previous literature as well as to the work of portfolio managers by identifying the particular market (the Indian market) where gold plays a key role in diversifying portfolios at market troughs (low quantiles) during the COVID-19 pandemic. Moreover, these results could be extrapolated to other crisis situations similar to the one studied in this paper. This partial result would support Hypothesis 3 (H3) of this paper, which identifies the differences between the international markets analyzed. The negative relationship between the Indian market returns and Bitcoin is also significant (in accordance with González et al., 2021; Guesmi et al., 2019), with the Brazilian BOVESPA index returns being the only one with a direct relationship with this cryptocurrency at the bottom tail of the distribution, that is, during bearish stock market states. Numerous prior studies, including Jareño et al. (2016), Ferrando et al. (2017), González and Jareño (2019), Jareño, González, & Escolástico (2020), Jareño, González, & Tolentino, et al. (2020), Escribano et al. (2023), and Jareño et al. (2022, 2023), among others, have consistently reported similar findings. However, this research adds value to the existing literature by including in a single study a wide range of risk factors that are scattered in many other papers. Moreover, the group of countries analyzed in this paper, as well as the period examined (COVID-19 pandemic), make it particularly interesting for portfolio managers at an international level, not just in the countries included in the paper.

Oil returns are shown to be statistically significant for Brazilian and South African equity market returns, and their relationship is direct, being inverse for the Spanish case. Significance is 10% in the case of the JTOPI index, and 1% in the rest of the cases. The VIX volatility index returns only show a statistically significant coefficient for IBEX 35 returns, reflecting an indirect relationship at 1% significance. The diversifying role of crude oil in the Spanish market would be in line with recent work such as that of Guesmi et al. (2019), as well as the strong predictive ability of the VIX index during periods of economic turbulence (Bekaert et al., 2014; Magner et al., 2021). In this sense, our work adds value to the previous literature by highlighting that this ability is high during market troughs, which are associated with low quantiles. This finding provides evidence to support Hypothesis 1 (H1) of this research, as we find more pronounced effects in the extreme market scenarios. Again, our results provide valuable information for portfolio managers by identifying specific markets for which the oil price risk factor would provide good diversification options at the worst moments of a crisis period that we are facing.

After conducting a thorough analysis of the Financial Stress Index, we find a statistically significant and negative correlation between these variables and all the markets examined, except for the South African stock market. As a result, our findings suggest that periods of financial stress generally lead to declines in stock market returns, especially for the stock markets analyzed in the lower tail of the return distribution. This result is consistent with the findings of Bianconi et al. (2013). However, our results are valuable in that they allow us to distinguish between periods of economic turbulence and market downturns (low quantiles), which could provide diversification opportunities for portfolio managers. In this case, we find that the South African market could

Table 4. Risk Factor Model Estimates for *Theta*-Quantile 0.5 (Median of the Distribution).

Risk Factors	Germany	Brazil	Spain	US	India	UK	S. Africa
Gold	−0.0036	−0.0044	−0.0231	0.0823**	−0.0786	−0.0486	−0.0083
Bitcoin	−0.0038	0.005	−0.0084	0.003	−0.0093	0.0012	0.0129
Crude oil	−0.0054	0.0264	−0.0166	0.0259***	−0.0272	0.0269	0.0417
VIX	0.0059	−0.0087	−0.0085	−0.0032	0.0145*	−0.0093	−0.0083
Financial stress	−0.0384***	−0.0076	−0.0285***	−0.0348***	−0.0194***	−0.0060***	−0.0053
MCI	−0.0001	0.0005	0.0001	0.0001	−0.0001	−0.0002	−0.0003
Interest rates	−0.6057	−1.5601	2.9325***	0.7132	−2.3229***	0.3344	−0.9622*
R^2	0.3307	0.0108	0.1847	0.3614	0.0786	0.0092	0.0093

Note. The *, ** and *** denote statistical significance at the 10 %, 5 % and 1 % levels, respectively.

mitigate adverse effects in times of crisis, as it does not show negative sensitivity to the financial stress risk factor.

Regarding fluctuations in the MCI index, significant coefficients at 1% are found for the returns of the German, Indian, UK and South African markets, all of which are negative, which is consistent with the findings of Barberis et al. (2013), Cepoi (2020), and Umar et al. (2021), among others. This shows a clearly negative impact of pandemic-related news on equity market returns. Again, our paper contributes to the literature by identifying which countries (among those analyzed) are more sensitive to news in times of crisis and, moreover, in extreme market situations, again supporting Hypothesis 1 (H1) of this study. With regard to changes in US 10-year bond yields, their impact on the stock market indices studied is remarkably particular. It shows significant relationships with all the explained variables, with the exception of Germany and South Africa, being this relationship positive for Spain, the US, and the UK, and negative for Brazil and India. In countries where we find a positive relationship in low quantiles, it would show that equity markets welcome the fact that a rise in interest rates is good news, as this would herald an improvement in the state of the market. Finally, this would lead to an increase in the returns of the Spanish, the US, and the UK equity markets. In principle, this positive interaction would be contrary to what is expected according to previous literature (e.g., Jareño, 2008). However, the specific situation of each country in terms of inflation expectations could justify such results (Cano et al., 2016; Jareño & Navarro, 2010). Therefore, an interesting extension of the paper could be to decompose changes in nominal interest rates into shocks to real interest rates and inflation expectations (González et al., 2016).

To conclude this section, the effectiveness of the estimation at the *theta*-quantile 0.05 differs across international stock markets. Thus, the R^2 coefficient will be above 50% for the analysis of the US and German equity markets, while the explanatory power is only around 10% for the Brazilian, UK and South African markets.

Risk Factor Model Estimates for Theta-Quantile 0.5

The coefficients for the theta-quantile 0.5, representing the median of the distribution, are gathered in Table 4.

For gold returns, we observe a significant and positive coefficient on S&P 500 index returns only at the 5% level. Similarly, when analyzing oil returns, we find a statistically significant and positive impact on US stock market returns, specifically at the median of the distribution (1%). Conversely, in the case of VIX index returns, we observe a statistically significant positive relationship with the Indian BSE SENSEX 30 index only at the 10% level.

As in the lower tail of the distribution, if we analyze the variations in the financial stress index, we observe the statistically significant and negative relationship of these variables with respect to all the markets analyzed, except in this case the Brazilian and South African stock exchanges. As regards fluctuations in interest rates, their impact on the median of the distribution continues to show different signs in the stock markets analyzed. Thus, their relationship is direct and significant at 1% for the IBEX 35 returns, but inverse for the Indian and South African stock market indices, at 1% and 10% significance respectively. This would support the acceptance of Hypothesis 2 (H2) of our study, which states that the response of the international market returns analyzed is different (in terms of sign) depending on the market conditions (high vs. low quantiles). Looking at bitcoin returns and changes in the MCI index, the model estimation for the 0.5 quantile shows no statistically significant relationship with the equity markets under study. This finding contrasts with the results obtained at the ends of the distribution.

Thus, as far as the study of the median of the distribution is concerned, the results are in line with the majority

Table 5. Risk Factor Model Estimates for *Theta*-Quantile 0.95 (the Uppest Tail of the Distribution).

Risk Factors	Germany	Brazil	Spain	US	India	UK	S. Africa
Gold	−0.1595	−0.1024	−0.0283	0.1356**	0.0713	−0.1832***	0.0373
Bitcoin	−0.0125	−0.0742***	−0.0044	−0.0563***	−0.0117	0.0215***	−0.03
Crude oil	−0.0156	−0.0378**	0.0496**	−0.0176	−0.0582***	0.0118	−0.0192**
VIX	−0.0047	0.0011	−0.0248***	0.0148*	−0.0049	−0.0338***	−0.0207***
Financial stress	−0.0317**	0.0029	−0.0221***	−0.0296***	−0.0261***	0.0005	−0.0038
MCI	0.0005	0.0020***	−0.0005	0.0003	0	0	−0.0006
Interest rates	−0.316	−2.7445	6.0310***	2.9298***	−1.5644**	0.9547**	2.1198***
R^2	0.2778	0.0557	0.2011	0.3783	0.1651	0.0551	0.0435

Note. The *, ** and *** denote statistical significance at the 10 %, 5 % and 1 % levels, respectively.

of papers using the quantile regression methodology (González et al., 2019; Jareño et al., 2016; Jareño, González, & Escolástico, 2020; Jareño, Tolentino, González, Medina, et al. 2020). Nevertheless, our paper contributes to the literature by identifying, among the countries analyzed, those that suffer more from the effects of the crisis in "normal" market states (median quantiles).

Finally, the explanatory power of the estimation at the *theta*-quantile 0.5 shows large differences depending on the international stock markets, fluctuating between coefficients of determination close to 35% for the analysis of the US and German stock indices, while the predictive power of the estimate is practically nil for the Indian, the UK and South African markets. Moreover, the achieved levels of the R^2 are lower than when examining the lower tail of the return distribution. These results are in line with previous literature (Escribano et al., 2023; Ferrando et al., 2017; Jareño et al., 2022, 2023; Jareño, González, & Munera, 2020; Sevillano and Jareño, 2018; among others).

Risk Factor Model Estimates for Theta-Quantile 0.9

Table 5 shows the estimated coefficients for the *theta*-quantile 0.95, which represents the upper end of the distribution.

With respect to gold returns, statistically significant coefficients are found for the S&P 500 and FTSE 100 indices. Gold returns are positively correlated to US market returns at 5% level and inversely correlated to UK market returns at 1% level. Bitcoin returns are directly correlated with the FTSE 100 index and have a statistically significant inverse relationship with the returns of the Brazilian and the US markets. Our findings would be in line with previous literature on the role that Gold (Esparcia et al., 2022; Guesmi et al., 2019) and bitcoin (Jareño, González, Tolentino, Sierra, et al., 2020) could play as diversifiers of investment portfolios. Moreover, the results of this paper would be valuable in terms of identifying specific international markets in times of crisis that would help portfolio managers to diversify risk.

The impact of oil returns varies in direction and magnitude across the markets studied, as assessed by the model. The importance of crude oil prices is at a statistically significant level of 5% in the Brazilian, South African and Spanish markets. In the first two markets, the correlation shows an inverse pattern, while in the Spanish scenario it shows a direct relationship. The Indian market also shows an appreciable negative association, with statistical significance at the 1% level. This phenomenon can be explained by the idea that in periods of market excitement and rising oil prices, such events can be interpreted as negative news. As a result, international stock market returns tend to fall. Moreover, these results would be in line with Guesmi et al. (2019), as the price of crude oil would appear as a risk diversifier or even as a possible hedging asset in countries such as India and Brazil, providing concrete evidence for its application in international portfolio management.

Looking at the returns of the volatility index, we first observe a statistically significant coefficient at 10% and with a positive sign for US market returns. However, the changes in VIX reflect a statistically significant and indirect relationship at 1% for the Spanish, the UK and South African markets (Bekaert et al., 2014; Magner et al., 2021). According to these results, an increase in volatility in the North American market is not perceived as bad news in this equity market. However, in countries such as Spain, the UK and South Africa, increased uncertainty in the US market, in a bullish phase of the market, can be interpreted as bad news, which is heralding a turn in the economic cycle. This would therefore imply a decline in the aforementioned international stock market returns.

Next, following the discourse of previous sections, we observe the statistically significant and negative relationship of the variations in the Financial Stress Index with respect to all the markets analyzed (in line with Bianconi et al., 2013) except those of Brazil, the United Kingdom,

and South Africa. Once again, we find results that would be expected, since an increase in the Financial Stress Index would negatively affect international stock market returns, given the uncertainty in the financial system. Again, our results allow us to identify some international equity markets that could act as safe havens in portfolio composition, providing value to market participants.

In the case of changes in the MCI index, only a positive and significant coefficient at 1% is found for the BOVESPA index return. As for variations in 10-year US bond yields, their impact on the stock market indices studied differs. It shows significant relationships with all the variables explained, except for Germany and Brazil, this relationship being positive and significant at 1% for Spain, the US, and South Africa; positive and significant at 5% for the UK; and negative at 5% significance level for India. Therefore, in some cases, an increase in interest rates is good news, as it leads to an increase in the returns of the Spanish, the US, South African, and the UK stock markets. Nevertheless, a rise in interest rates will reduce returns in the Indian stock market (expected result based on previous work, such as Ferrando et al., 2017; Sevillano & Jareño, 2018). Again, the results obtained in this research add value to the previous literature by identifying specific markets where changes in interest rates during a crisis period such as the COVID-19 pandemic, but at high market moments (high quantiles), have positive and statistically significant correlations (Cano et al., 2016; Jareño et al., 2010). This is another result that may be of interest to international portfolio managers whose objective is to manage the impact of the COVID-19 pandemic.

To conclude this section, the degree to which the estimation accounts for the variance of various endogenous variables, specifically at the 0.95 *theta*-quantile, ranges from 38% in the case of the US stock market to almost 5% for the Brazilian, UK and South African stock indices. Thus, our results show that the explanatory power of the model is higher at the extreme quantiles, but mainly at the low quantiles, in line with Escribano et al. (2023) and Jareño et al. (2023), among others. At this point, the different levels of explanatory power of the different markets analyzed (H3), as well as the differences found between some quantiles and others (H1 and H2), would confirm the different hypotheses tested in this paper.

Selected Scenarios for Global Stock Market Returns: Downturn, Normal and Upswing Phases

In this section, we examine the evolution of the correlation between global stock market returns and changes in the selected international risk factors across different quantiles of the distribution (shown in Figure 2). This examination makes it possible to identify differences in the impact of these factors on different international stock markets, depending on whether the return distribution is in a bearish, normal, or bullish state.

First, the increasing trend of the returns of all the equity markets studied in response to changes in the constant is notable. This means that the model tends to explain more within quantiles characterized by lower constant values, that is, in bearish market situations. This conclusion is in line with what was concluded in the previous section, as well as in other previous studies (González and Jareño, 2019; Escribano et al., 2023; Jareño et al., 2023; among others).

With respect to gold returns, we observe, for most of the markets under study, a constant or decreasing trend in the coefficients. This decreasing pattern implies, in the cases of Germany and South Africa, a higher sensitivity to bearish market situations. In addition, there are two stock market indices that diverge from the general behavior expressed. One is the Indian BSE SENSEX, which shows a slightly increasing trend, and the second is the S&P500, which does not follow a specific pattern, but is particularly sensitive to changes in gold prices in stable and rising market situations. In the case of the Bitcoin price, the quantile coefficients for the endogenous variables follow a constant or increasing trend for Germany, Spain, India, and South Africa. Deviating from the overall trend are the remaining global equity markets, with decreasing trends in the Brazilian and the US markets implying greater sensitivity in bear market situations to Bitcoin returns, and indeterminate patterns in the UK market. In the latter equity market, although the implication is similar, a greater impact of the risk factor is observed at the 0.2 quantile and at the upper end of the distribution. In line with the results of Guesmi et al. (2019), González et al. (2021) and Esparcia et al. (2022), we find evidence of gold's diversifying role in certain scenarios (evidence for H1 and H2). The same applies to the findings on the bitcoin risk factor as a risk diversifier (Jareño, González, Tolentino, Sierra, et al., 2020). Moreover, our results contribute to the literature by identifying the specific markets (evidence for H3) in which gold/bitcoin acts as a safe haven asset in times of crisis, depending on the quantiles analyzed (bullish or bearish moments in equity markets).

When looking at oil prices, the evolution of the coefficients does not show a clear pattern, alternating between positive and negative ranges. This suggests that, in most cases, the stock market indices under review show an increased sensitivity to oil price fluctuations in extreme market conditions. In the case of the S&P 500, its sensitivity to this energy source is more pronounced in the intermediate quantiles. Exceptionally, the German DAX 40 shows a stable trend. Our results on oil prices, like the

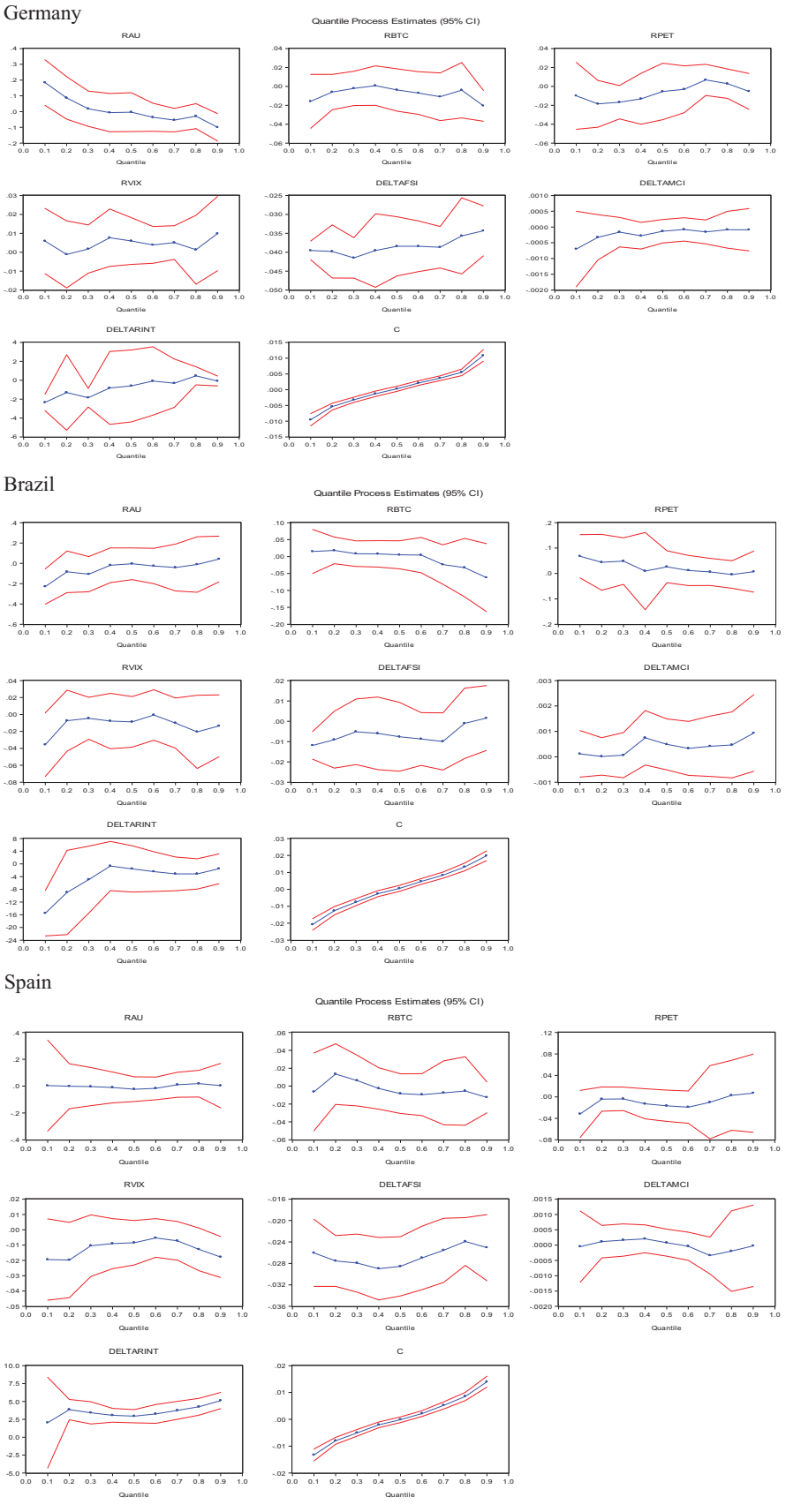
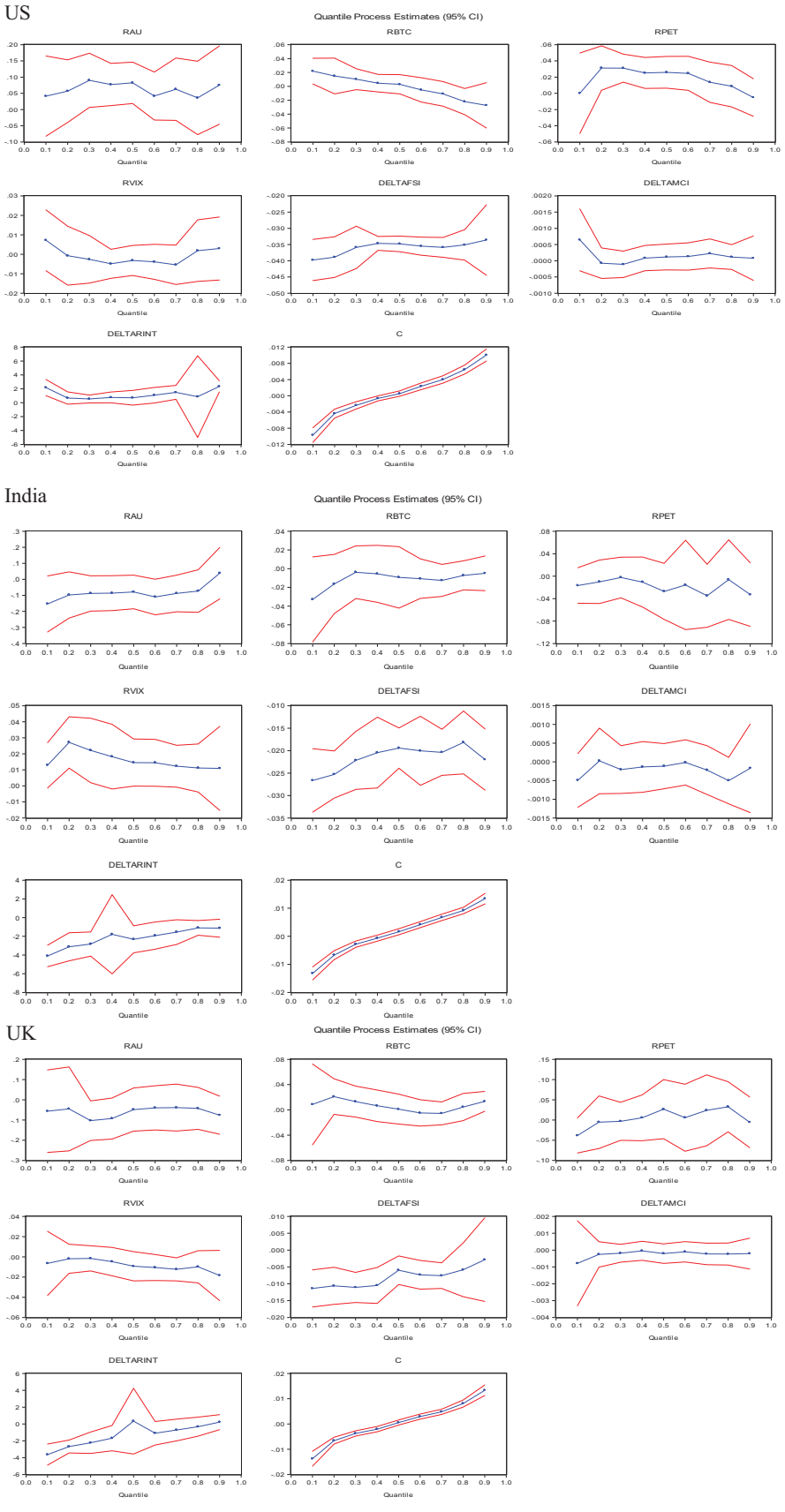


Figure 2. Continued



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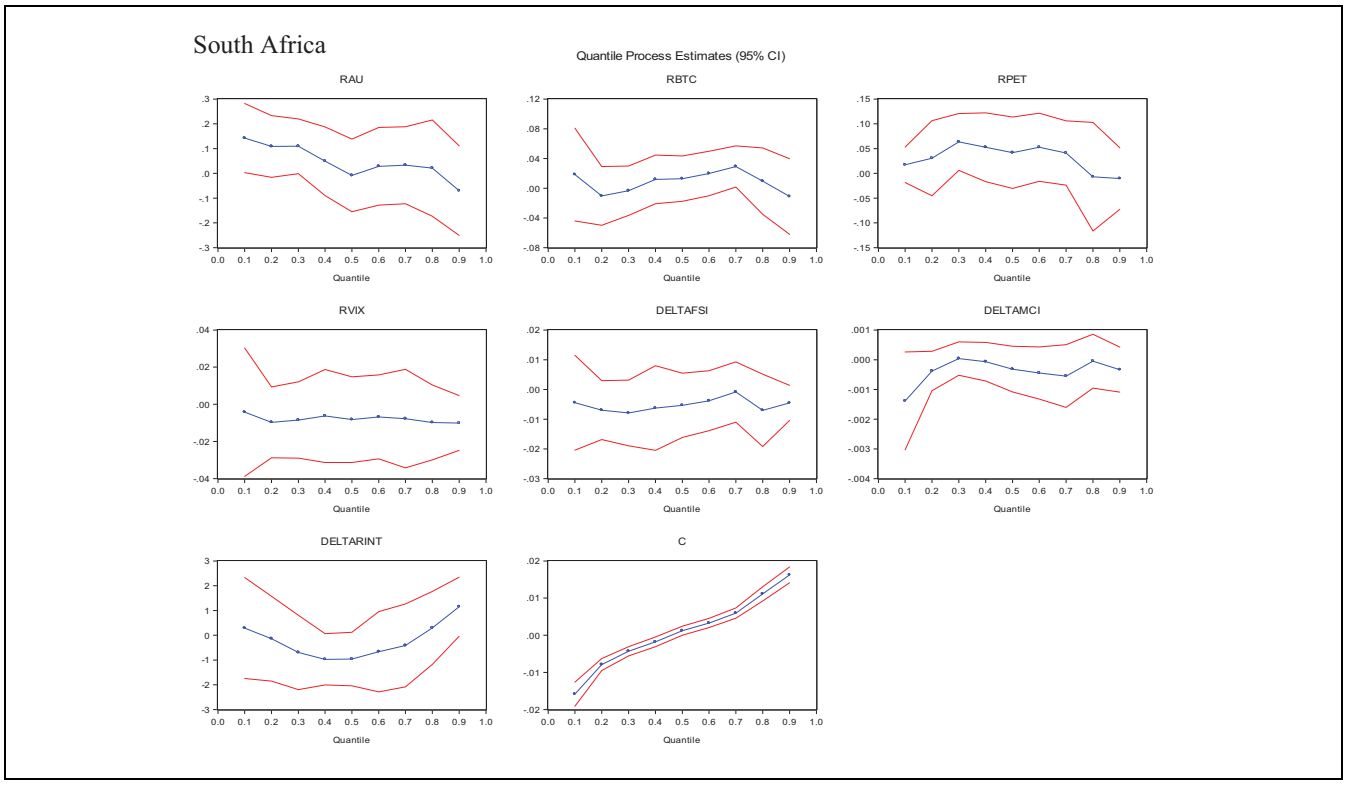

Figure 2. Effect of changes in the factors explaining international stock market returns by quantile over the entire sample.
Note. RAU: Gold returns, RBTC: Bitcoin returns, RPET: Oil returns, RVIX: VIX returns, DELTAFSI: FSI changes, DELTAMCI: MCI changes, DELTARINT: changes in interest rates, C: constant.

work of Guesmi et al. (2019), also suggest that this risk factor could act as a diversifier in investment portfolios in some international stock markets, shedding light on portfolio management in times of crisis such as the COVID-19 pandemic. The evolution of the sensitivity of VIX yields resembles that explained for oil prices. Overall, the various markets analyzed show increased vulnerability to this global risk factor at the extremes of the distribution. This would justify the application of this methodology for the analysis developed in this paper. Conversely, changes in the MCI show distinct behavior, with global equity markets' sensitivity to MCI fluctuations rising. This trend highlights an increased influence during bullish market conditions. Again, these results on the VIX and the MCI index are consistent with those found in the previous literature (Barberis et al., 1998; Bekaert et al., 2014; Cepoi, 2020; Magner et al., 2021; Umar et al., 2021), and contribute to the evidence that international markets generally suffer reversals in the face of increased volatility as well as news about the very crisis in which they are immersed.

Regarding changes in the FSI index, the sensitivity of the equity markets under analysis is mostly stable and negative (Bianconi et al., 2013). Only in the cases of Brazil and the United Kingdom do we find an increasing

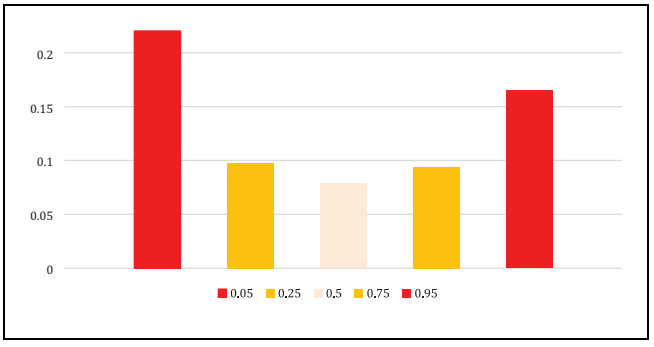

Figure 3. Analysis of the average R^2 coefficient across different quantiles of the return distribution.

trend in the coefficients. Finally, the variation in interest rate yields shows, for most of the indices studied, an increasing trend (greater impact of interest rates in bullish market situations). The sensitivity to this risk factor is only stable in the German market and, also departing from the general rule, the US market is particularly sensitive to changes in interest rates in bearish and bullish market situations. These results contribute to the literature, as we find results consistent with previous studies (Jareño, 2008; González et al., 2016), but only for low quantiles (bearish market moments). However, for high

quantiles, most of the analyzed stock markets show positive coefficients and some of them are statistically significant, providing valuable information for market participants in a crisis context, but in bullish moments of the stock market. This information can be of great interest to international portfolio managers and even to international monetary policy makers.

Thus, consistent with prior research such as Ferrando et al. (2017), Jareño et al. (2017), Sevillano and Jareño (2018), González and Jareño (2019), Jareño, González, & Escolástico (2020), Escribano et al. (2023), and Jareño et al. (2022), among others, the analysis of the coefficients and the exploration of the graphical trends presented highlight significant variations. These variations are due to the unique circumstances of each country, its specific economic landscape and its cultural economic characteristics. These individual factors exert varying degrees of influence during both bullish and bearish market conditions. Consequently, the results support the validity of the original hypotheses (H1, H2, and H3) put forward in this study.

Progression of the Model's Explanatory Power Over Different Theta-Quantile Values

Examining the importance of the variables and the ability of the model to explain variation across quantiles undoubtedly leads to an intermediate conclusion, confirming the appropriateness of the quantile regression approach. In contrast to the results obtained using Ordinary Least Squares (OLS), the use of QR for modeling distribution estimation allows for the analysis of variables to be extended to the extremes of the distribution, where previously OLS was restricted to the median.

Using this approach, we were able to identify a substantial number of statistically significant correlations between the variables located at the extremes of the distribution. In particular, the explanatory power of our model (Figure 3) is significantly enhanced at the 0.05 and 0.95 quantiles. Figure 2 summarizes the results established in the previous section with respect to the coefficients and, at the same time, complements this information with the introduction of the explanatory power of the estimation in the 0.25 and 0.75 quantiles, whose function is to make more evident the convex shape of the graph of the coefficients of determination available along the distribution. Consistent with previous research, as exemplified by the work of Jareño et al. in Jareño, González, & Escolástico (2020), Jareño, González, & Munera, 2020 and Jareño, González, Tolentino, Sierra, et al. (2020), as well as their research in 2022 and 2023, the U-shaped pattern observed in the R^2 coefficient confirms that the model's ability to explain global stock market returns is more pronounced when faced with shifts in risk factors located at the outer edges of the return distribution. These edges are related to bullish and bearish conditions within the international stock market.

Concluding Remarks

This paper has focused on examining the response of several international stock market returns to changes in globally relevant risk factors during the COVID-19 pandemic-dominated timeframe of 2020 to 2021. The time period of our study is longer than the majority of studies focusing on the impact of COVID-19's financial markets. This allows us to use a sample that is not so limited, but still detects the effect of the coronavirus crisis, since other relevant events that occurred during the sample period, such as changes in economic policy and technological disruptions, are largely due to the spread and contention of the COVID-19.

This study employs the Quantile Regression methodology to estimate an extended factor model in seven countries that have been selected among the most heavily affected to represent the main advanced and emerging economic regions around the world. Thus, the endogenous variables of the study consist of the returns of the main stock indices of Germany, Brazil, Spain, the United States, India, the United Kingdom, and South Africa, this is, the DAX-30, BOVESPA, IBEX-35, S&P500, SENSEX 30 BSE, FTSE-100, and JTOPI, respectively. The international factors of the model, chosen basing on previous financial literature, are gold yields, the cryptocurrency bitcoin, oil prices, the VIX index, as well as changes in the OFR FSI and MCI indices, and changes in 10-year US Treasury yields.

The advantage of the QR methodology is to allow for analyzing the behavior of yields in extreme market situations, since, unlike the Ordinary Least Squares (OLS) method, its explanatory power extends to the tails of the distribution. Specifically, as reported by numerous authors (including Sevillano and Jareño, 2018; Jareño, González, Tolentino, Sierra, et al., 2020; and Escribano et al., 2023, among others), this methodology enables us to relate the lowest and highest quantiles to bearish and bullish market states, respectively. Thus, our study explores whether, during the pandemic period, the sensitivity of stock returns to the selected risk factors differs in periods of more acute crisis moments and moments of lower crisis incidence, in terms of the number and sign of significant relationships as well as the region analyzed.

Our findings confirm the three hypotheses tested in the paper. First, results show that the number of significant relationships, and consequently the explanatory

ability of the model, increase in the extreme quantiles, with risk factors explaining equity market returns to a greater extent in the *theta*-quantiles 0.05 and 0.95, and especially in the lower tail of the distribution. Secondly, we find that the sign of significant relationships differs according to the market trend, this is, bearish or bullish. The only exceptions are the FSI index and the interest rate volatility that maintain a constant and significant relationship throughout the distribution for the different stock market indices (with negative and positive sign, respectively). As for the remaining factors, while gold prices and the MCI index are the most important explanatory variables in the lower quantiles, Bitcoin, oil and VIX are the most significant factors in the higher end of the distribution. Finally, results confirm that stock markets respond differently in different countries, depending on their economic structure and situation. In particular, India, Spain, and the United States stand out as the countries with the highest number of statistically significant scenarios, while the South African and German markets have the lowest number of significant relationships with the risk factors. Of particular note are the US and UK markets, which show the highest number of significant relationships in the uptrends, thus departing from the general rule of thumb previously established that maximum statistical significance is found at the lowest quantiles.

Our research findings have important implications for financial market participants in regions with different levels of economic development. In particular, our concrete results regarding the dissimilar behavior of different countries depending on market conditions may be relevant for investors at the international level. Thus, building on the established literature on the diversification potential of assets such as gold, bitcoin, and oil (Esparcia et al., 2022; Guesmi et al., 2019; Jareño, González, Tolentino, Sierra, et al., 2020), our study contributes by identifying specific markets where these assets act as effective diversifiers within investment portfolios. In particular, the price of gold is an outstanding performance, especially in bearish market moments, and bitcoin is another risk factor to consider in both extreme market situations, showing a certain safe-haven role, but only in the face of sharp falls and rises. In addition, our analysis reveals unique market sensitivities to risk factors such as the VIX, FSI, and MCI, providing valuable insights for international portfolio managers seeking to mitigate risk across borders. For example, the Financial Stress Index shows strong explanatory power in some countries, particularly in times of crisis and especially in bear markets. On the other hand, interest rate volatility, which has not been extensively studied in specific crisis situations, emerges as the risk factor with the greatest explanatory power and in a greater number of countries, showing different behavior in each of them, demonstrating the need for portfolio managers to consider it as a key risk factor for international diversification.

The results obtained are therefore highly relevant to international portfolio management, but our research has limitations that need to be addressed in future research. For example, this study only examines the pandemic period, without extending the analysis to the pre- and post-COVID-19 periods. It would therefore be very interesting to be able to compare the interdependencies in the different financial markets analyzed before, during and after the pandemic. In addition, the omission of several countries severely affected by the COVID-19 pandemic may limit the generalisability of our findings. Although this omission was intentional in order to focus on countries with different economic profiles that are representative of different regions of the world, it should be taken into account when interpreting the implications of our research. Future studies should seek to include a more comprehensive range of countries to ensure the robustness and applicability of the conclusions. Moreover, future research could further enrich our understanding by incorporating country-specific data into our analysis. Including variables such as debt levels, inflation rates, digitization indices and the relative importance of domestic sectors would provide a more nuanced perspective on the varying sensitivities of individual countries to global risk factors. This comprehensive approach would not only improve our understanding of international financial dynamics, but also strengthen the validity and applicability of our findings. In addition, examining the impact of unforeseen events, such as other pandemics or geopolitical crises, on market dynamics could provide valuable insights into the resilience and adaptability of investment strategies in volatile environments.

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Ethics Statement

Not applicable.

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Data Availability Statement

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

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