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Interdependence between the Moroccan and international stock markets before and during the Covid-19 crisis

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Abstract: This paper examines the degree of interdependence between Moroccan and international stock markets (USA, Germany, and China). To test time-varying correlations, we used the dynamic conditional correlation model (DCC-GARCH). In addition, we used daily returns from stock market indices from January 2019 to January 2021, before and after the emergence of Covid-19. The study results indicate that the conditional correlations between Morocco and the selected markets are time-varying, with the existence of strong and weak correlations phases. We also noted that the Covid-19 crisis had an impact on the increased interdependence of the Moroccan stock market, with the US and German stock markets.

Keywords: stock returns; DCC-GARCH model; COVID-19; interdependence; behavioral finance theory; volatility; financial crisis.

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1 Introduction

The year 2020 was marked by an unprecedented crisis, in both its nature and by the magnitude of its consequences (Phan and Narayan, 2020; Song et al., 2021; Johansson et al., 2021). The Covid-19 pandemic has hit a large part of the world and damaged the global economy. Albitar et al. (2020) sees Covid-19 as being the biggest challenging obstacle since the financial crisis of 2007, this is why they recommend that the government agencies and stock markets mobilise to overcome it. In light of this, the drop in stock prices caused by the Covid-19 pandemic was worse among companies with international supply networks and local consumers who were more exposed to the pandemic, as argued by Ding et al. (2020). The current context of the health crisis has profoundly affected financial markets, with both operational repercussions, linked to generalised confinement and financial repercussions marked by the significant declines recorded by the markets (Goodell, 2020; Zhang et al., 2020). During this crisis, the financial markets experienced volatility and significant declines in the prices of financial assets, forcing governments, and financial market regulators to take appropriate actions to these circumstances (Corbet et al., 2020; Pak et al., 2020).

At the international financial level, during the first days of March 2020, Standard and Poor's 500 index (SP500) fell about 6%. During the same period, there was a notable decline in the Dow Jones: more than 2000 points. The Nasdaq Composite Index dropped about 5.4%. After stocks fell by more than 7%, the New York Stock Exchange (NYSE) stopped trading for 20 min. After the market opened, part of their losses was compensated. On a national financial level, Morocco's economy was expected to suffer in 2020 as a result of the Covid-19 crisis. According to a baseline scenario, Morocco's gross domestic product (GDP) could fall by 1.5% in 2020, resulting in the country's first recession in more than twenty years. The High Commissioner for Plan (HCP) plans to cut down its 2020 growth forecast by a third. According to HCP, this year's GDP growth is expected to be 3.5%. In addition, IMF (International Monetary Fund) predicted, in its April 2020 report (World Economic Outlook, April 2020), a drop in the growth of the Moroccan economy of 3.7% during 2020. Indeed, the worsening of the deficit is due to an increase in Covid-19-related to the socio-economic expenditure, as well as a decrease in tax revenues. The pandemic also slowed down the consolidation of the government budget, leading to an increase in gross financial requirements and loans. The overall budget deficit was expected to deteriorate by over 6% of GDP in 2020. As a result, government debt reached a peak of 73% of GDP in 2020. Morocco's financial market also recorded losses. Indeed, on February 9, 2020, the main index at Casablanca's stock exchange suffered from the steepest single-day plunge in its history amid a similar trend on international stock exchanges due to Covid-19 fears. Investors rushed to sell shares causing a 5.82% drop in MASI, Casablanca's main index, lost 11.2% of its value during the period January 1, 2020 to March 10, 2020. In response to the impact of the health crisis posed by the Covid-19 virus, and the operational constraints generated by confinement in Morocco, the AMMC (Moroccan Capital Market Authority) adopted a comprehensive intervention plan to ensure the proper functioning of the capital

market, and the maintenance of the activities of infrastructure and market participants. A number of measures have been taken to reduce the price volatility of commodities listed on the Casablanca Stock Exchange. As of March 17, 2020, the most liquid shares have a maximum authorised price variation of 4% (instead of 10%) and 2% for other equity securities (instead of 6%).

In general, stock markets are known to be interdependent (Gunay, 2020; Youssef et al., 2021). These financial interdependencies provide a way of transmitting crises quickly as financial markets react immediately to “news”. The degree of market interdependence may be greater in “crisis” phases, than in so-called “normal” ones. An and Xu (2021) indicate that during the crisis, corporate scandals, the stock markets of US, and Italy seem to be more interdependent. Therefore, in the context of analysis of multiple stock markets (multivariate analysis), it seems reasonable to assume alternating periods of strong and weak bonds in the context of an analysis of several stock markets (a multivariate analysis). Additionally, the recent health crisis has also shown how interconnected the global economy is, and how sanitary events can have global impacts as a result of financial and economic interdependence. Covid-19 which started in China has escalated into an economic crisis with disastrous effects even for countries with limited financial development. It was the most severe economic crisis since the 2007 Great Depression, and the first to simultaneously affect so many markets.

This paper aims to make the following contributions to the existing literature. First, to verify whether the hypothesis of variation in correlations is relevant. For that, conditional correlation is used as a measure of the interdependence or degree of connection between two or more variables. DCC-GARCH also permits the analysis of the dynamics of linear conditional correlation coefficients following the financial crisis. Secondly, we try to quantify the degree of the interdependence between the Moroccan financial market, and the major foreign financial markets, most affected by the pandemic of Covid-19, by examining the dynamic conditional correlation (DCC) between MASI (Moroccan market) and other indices, which include: DAX (German market), Dow Jones (US market), and SSEC (Chinese market). Third, we test whether the propagation gap of Covid-19 over different selected financial markets, as pointed out by several researchers, affects the fact that “the interdependence between markets increased during the crisis periods”.

The rest of the paper is sorted out as follows: Section 2 highlights a literature review. Section 3 describes the data. Section 4 presents the methodology. Section 5 discusses results and interpretation. The last section concludes.

2 Literature review

Events such as Covid-19 outbreak, can contribute to negative changes in investor expectations that have a direct impact on stock market prices. Previous research suggests strong cross-market correlations during financial crises. Chiang et al. (2007) studied the stock market returns of 9 Asian countries from 1996 to 2003 and observed that there was a significant correlation between Asian markets during the economic recession. However, Kuper (2007) studied the markets for foreign exchange, and the money markets in Indonesia, and Thailand during the Asian crisis. He found a weak degree of interdependence during the crisis. During the Sovereign Debt Crisis, Tamakoshi and Hamori (2013), using the DCC-GARCH model, found significant increases in the intercorrelations between several combinations of financial institution stock returns. Furthermore, Naoui et al. (2010) used

DCC-GARCH to evaluate the dynamic conditional correlations between US market and other markets (developed and emerging markets). The results appear to point to an increment in interdependencies during the crisis period. DCC-GARCH Analysis in Dajčman and Festić (2012) confirmed that the financial crises had a significant impact on the increased interdependence of European stock markets and the Slovenian stock market. This study also shows high volatility of dynamic conditional correlation coefficients during the global financial crisis (2007).

According to the behavioural finance theory, the psychological factor can be considered as an important element in explaining market instability, especially when an unanticipated event occurs. The Covid-19 crisis was unexpected, and it caused serious damage to the global economy, which may be due to contagion effects. Several studies soon emerged to analyse some of the economic consequences of Covid-19. For example, Ashraf (2020) studied the response of 64 stock markets to the Covid-19 crisis from January 2020 to April 2020. He suggests that financial markets are negatively correlated to the increase in cases Covid-19. Therefore, the response was very strong in the first few months after the cases confirmation. Sansa (2020) studied the impact of Covid-19 in US and Chinese financial markets, represented respectively, by the Dow Jones and the Shanghai Composite (SSEC) from March 1, 2020, to March 25, 2020. By using the regression model, the paper (Sansa, 2020)) argues that there was a significant and positive correlation between Covid-19 confirmed cases and the two markets during the study period. The response of the global financial market during epidemic and pandemic periods (January 1, 2020, to March 20, 2020), was studied by Rizvi and Ali (2020). The sample of the study includes China, US, Germany, and other countries that have been most affected by Covid-19. The results show that the US and German financial markets experienced significant volatility increasing from epidemic to pandemic period, while the Chinese financial market experienced a relatively smaller decline in returns during the pandemic and epidemic periods.

In the context of developing countries, the response of some Arab countries, including Morocco, to the spread of the Covid-19 pandemic from January 29, 2020 to June 1, 2020 was investigated by Almarayeh (2020). According to this study, stock markets did not respond to the daily increase in the number of confirmed Covid-19 cases, while the financial market was negatively correlated with the growth in the number of deaths. Based on a particular DCC-GARCH model, Yousaf and Ali (2020) study the frequency of information transmission between major cryptocurrencies (Ethereum, Bitcoin, Litecoin) during pre-Covid-19 and post-Covid-19. They revealed that the return spillovers differ between the two periods for the major cryptocurrencies. Indeed, there is more DCC between all digital currency pairs in the Covid-19 period than in the pre-Covid-19. In addition to the literature, our paper uses the DCC-GARCH model to analyse the interdependence of the Moroccan stock market, with the major financial stock markets during the pre- Covid-19 and Covid-19 periods.

In this paper, interdependence is described as a general correlation, in the broadest sense, between financial markets. Indeed, Rosecrance et al. (1977) argued that correlation could interpret the interdependence between different countries. Correlation analysis was then applied to examine the change in interdependence overtime over several periods. Our results not only show whether Covid-19 has significantly impacted stock market returns and volatility, but seek to understand the nature, and level of interdependence between the Moroccan stock market, and some developed markets, especially in financial crisis. Because understanding the interaction between different markets is important and can help

both investors and policy-makers predict which market is causing the swings seen in other markets and what can be done to stabilise the second market.

According to the Behavioural Finance Theory, and the Efficient Market Hypothesis (Yildirim, 2017)), prices are balanced according to both negative and positive news reports. We have no doubt that the Covid-19 pandemic has affected many parts with negative experiences. As such, it can cause negative changes in investor expectations, which will have a direct, and harmful effect on stock market prices across the world. Thus, according to this theory, the Covid-19 crisis has increased the interdependence between stock markets. In fact, this finding was supported by several studies examining interdependence during different types of crises (Chiang et al., 2007; Naoui et al., 2010; Dajčman and Festić, 2012; Tamakoshi and Hamori, 2013; Yousaf and Ali, 2020; An and Xu, 2021). However, from Kuper (2007) we know that there are notable exceptions where interdependence was not significantly affected, despite the economic crisis. Therefore, we propose the following hypothesis based on previous documentation: on the one hand, the emergence, and the spread of the Covid-19 will have a substantial impact on the interdependence between Moroccan and international selected stock markets. On the other hand, it is important to consider that there is a gap in the spread of Covid-19, that could impact assumptions about the interdependence between different financial markets during such type of crisis. In particular between China, as it is the focal point of Covid-19, and other countries.

3 Data

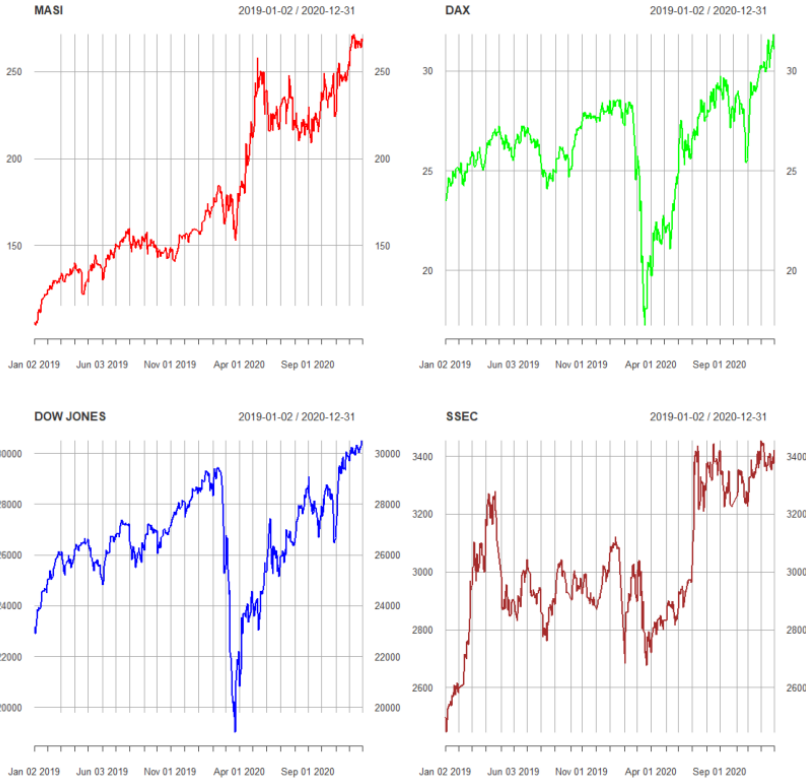
A dynamic conditional correlation (DCC) model was chosen to study the interdependence between Morocco, one of the most developed countries in Africa, and international stock markets before and during the Covid-19 crisis. Because it tracks the correlation evolutions between two or more assets and can be regarded as an original specification of multivariate models' conditional correlations (Naoui et al., 2010)). Moreover, four markets are selected: Morocco, Germany, US, and China, as these are among the countries most affected by Covid-19, in addition to this, maybe considered the most representative of the financial markets of the four main continents: Africa, Europe, America, and Asia. Furthermore, the following stock market indices are chosen: MASI, DAX, DOW JONES, and SSEC, to represent these selected markets. These indices are considered the most representative economic indexes of these countries' stock markets in the international press.

The data is daily log returns of each of these indices over three periods. Indeed, considering the evolution of the markets (Figure 2) and the volatility of stock returns (Figure 1), Each period is independently investigated to ensure the absence of autocorrelation (Table 4) and to confirm stationarity (Table 5) of log returns within each period: period I represents the pre-Covid-19 phase, periods II and III represent the post-Covid-19, period I: January 1, 2019, to December 1, 2019 period II: January 1, 2020 to June 1, 2020, Period III: June 1, 2020, to January 1, 2021.

According to the Figures 1 and 2, we conclude that the Covid-19 outbreak has had a reasonably strong impact on various financial markets. Indeed, at a certain stage, there is a sudden fall in all indices. But, after a few days, all indices started to increase. Indeed, on March 1, 2020, we saw a rapid downturn in US, Moroccan, and German stock markets, but a few days later, all indices started to rise. Figure 1 also shows that from December 17, 2019 to March 2, 2020, MASI appears to be reacting in the same way to the propagation of Covid-19, as DAX and DOW JONES. Two significant periods of decline can be identified

in the Chinese market. the first occurred in mid-January 2020. This is because a period of market growth is followed by a sharp increase in the number of confirmed cases in China. The SSEC declined sharply in March 2020 as signs of profound economic implications increased along with concerns of a recurrence of the second-wave disease outbreak rate of reproduction.

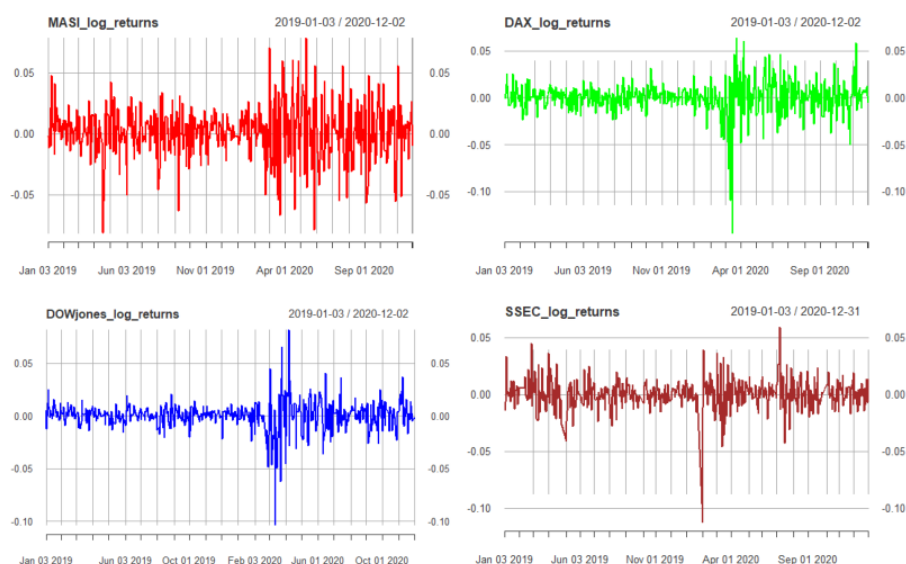
Figure 1 Evolution of indices during January 1, 2019, to January 1, 2021 (see online version for colours)



4 Methodology

4.1 Descriptive statistics

Concerning the descriptive statistics, Table 1, the standard deviation (Std. Dev) shows that the daily log-returns are much more unstable during the Covid-19 periods (II and III) compared to the period I. The stock markets then experienced significant volatility during the Covid- 19 crisis. Also, we note that for each series: the kurtosis coefficient is greater than 3 and the asymmetry coefficient is different from zero. Because the mean differs from the median, these results indicate that the series under study is not normally distributed Agouram and Lakhnati (2015a, 2015b, 2016).

Figure 2 Daily log returns evolution (see online version for colours)

During all periods, it can be seen that only the means of MASI returns are positive (whereas, all other markets exhibit negative returns). This can be explained by the AMMC's measures to reduce the fluctuations of the prices of instruments listed on the Casablanca Stock Exchange.

Table 1 Descriptive statistics

	Returns	SD	Skewness	Kurtosis	Max	Median	Mean	Min
Period I	MASI	0.0167	-0.8282	6.2557	0.0481	0.0027	0.0015	-0.0811
	DAX	0.0098	-0.0994	3.1908	0.0312	0.0015	0.0008	-0.0238
	DOW JONES	0.0069	-0.1282	4.0070	0.0250	0.0012	0.0008	-0.0202
	SSEC	0.0117	0.1973	4.6767	0.0450	0.0006	0.0007	-0.0405
Period II	MASI	0.0257	-0.0312	3.8138	0.0782	0.0039	0.0040	-0.0670
	DAX	0.0266	-1.8287	11.2910	0.0632	0.0005	-0.0014	-0.1439
	DOW JONES	0.0220	-0.5754	8.2582	0.0816	0.0010	-0.0011	-0.1035
	SSEC	0.0163	-2.7257	20.6093	0.0391	0.0007	-0.0001	-0.1118
Period II	MASI	0.0222	-0.2022	3.3460	0.0562	0.0018	0.0007	-0.0569
	DAX	0.0171	-0.1149	3.9887	0.0580	0.0030	0.0015	-0.0502
	DOW JONES	0.0122	0.0388	4.0711	0.0409	0.0012	0.0022	-0.0362
	SSEC	0.0121	0.4237	6.6485	0.0588	0.0005	0.0012	-0.0432

4.1.1 Simple correlation before and during Covid-19

We conclude our descriptive analysis by also examining the basic correlations between the Moroccan market, and other markets through three different periods.

Table 2 presents the simple correlations, calculated before and after Covid-19 (divided into two periods: period II and period III). We note that the values of the simple correlations

are positive, suggesting that the Moroccan stock market is evolving in the same direction as the other markets. During the pre-Covid-19 period (January 1, 2019 to December 1, 2019), the correlation coefficient between the returns in the German, and Chinese financial markets, and the Moroccan market returns are relatively weak, and insignificant for those in Chinese financial markets. This can be interpreted as a measure of the limited interdependence between the Moroccan, German, and Chinese financial markets before the outbreak of Covid-19. During the same period, the US market was an exception, which showed a moderate interdependence with the Moroccan financial market. Indeed, the correlation coefficient between the US financial market and the Moroccan financial market is relatively moderate and significant. However, with the onset of Covid-19 (period II: December 1, 2019 to June 1, 2020), the correlation between the German and Moroccan financial market increased considerably. The correlation between the US and Moroccan markets is relatively moderate and significant. On the other hand, the correlation coefficient between the Chinese market and Moroccan market remains very weak and insignificant. Concerning period III, it can be noticed that the correlation coefficients between the Moroccan market and all other markets have become very low. This can be explained by the weak positive interdependence between the Moroccan market and the global financial markets (German, US, and Chinese) six months after the beginning of Covid-19. These findings indicate a significant change in the interdependence between the Moroccan, German, and US stock markets, while there is no significant interdependence between the Moroccan and Chinese stock markets. Therefore, to optimise our evaluation, we need to apply the DCC GARCH model to visualise the change in correlation over time. As a result, we formulate the following hypothesis: the onset of the Covid-19 pandemic will have a significant effect on the interdependence between the Moroccan, US, and German financial markets. However, this does not significantly affect the interdependence of Moroccan and Chinese financial markets.

Table 2 Simple correlation with MASI (see online version for colours)

	Returns	Correlation	P-value
Period I	DAX	0.2663	6.60E-05
	DOW JONES	0.4700	1.97E-13
	SSEC	0.0197	1.58E-01
Period II	DAX	0.3686	4.02E-05
	DOW JONES	0.4571	1.96E-07
	SSEC	0.0059	9.49E-01
Period III	DAX	0.3340	4.02E-05
	DOW JONES	0.2879	4.45E-04
	SSEC	0.0134	1.18E-01

4.1.2 Statistical tests

Normality test

For all periods, the observed time series fails to meet the assumption of normal distribution based on the results of the Jarque-Bera test presented in Table 3.

Table 3 Normality test of series

Returns	Period I		Period II		Period III	
	<i>X-squared</i>	<i>p-value</i>	<i>X-squared</i>	<i>p-value</i>	<i>X-squared</i>	<i>p-value</i>
MASI	62.905	2.187E-14	3.2754	0.1944	1.7109	0.4251
DAX	3988.1	<2.2e-16	403.74	<2.2e-16	6.2243	0.0445
DOW JONES	2843.1	<2.2e-16	142.45	<2.2e-16	6.9672	0.0307
SSEC	2965.6	<2.2e-16	1670.7	<2.2e-16	84.761	<2.2e-16

Autocorrelation test

To validate the absence of autocorrelation of returns, we test this hypothesis through the Box-Ljung test. The test results are shown in the Table 4.

Table 4 Autocorrelation test of series using Box-Ljung test

Returns	Period I		Period II		Period III	
	<i>X-squared</i>	<i>p-value</i>	<i>X-squared</i>	<i>p-value</i>	<i>X-squared</i>	<i>p-value</i>
MASI	0.26723	0.6052	0.0084735	0.9267	0.63229	0.4265
DAX	1.478	0.2241	0.00095142	0.9754	0.57071	0.45
DOW JONES	0.76969	0.3803	0.35476	0.5514	0.17147	0.6788
SSEC	0.77864	0.3776	0.72313	0.3951	0.028195	0.8667

According to Table 4, we can confirm the absence of autocorrelation in all indices during the three periods.

Remark 1: As shown in Table 4, for period I, the DAX index has the highest value of $X_squared=1.478$ (the only coefficient greater than 1) and the lowest $p_value = 0.2241$. This means that DAX is the most stable of the chosen indices, as shown in Figure 2. For Box_ljung test, the autocorrelation test that we have done, $X_squared$ represents the critical value that allows us to compare it with the standard value, at a specific degree of freedom, to confirm the absence of autocorrelation. Therefore, although $X_squared$ is greater than 1, it does not matter in our case, as we already have a p_value that is greater than 0.05, which is sufficient to confirm the absence of autocorrelation of $DAX_log_returns$ during the first period.

Stationarity test

For GARCH-DCC the temporal stability of the stochastic properties of financial series is a key condition for the validity of the estimates obtained based on them. Therefore, it is necessary to study the normality of a series of index returns. To test the stationarity of indices returns we applied the augmented Dickey-Fuller test and KPSS test (Table 5).

From the results presented in the Table 5, ($P_value(Dickey-Fuller) < 0.05$ and $P_value(KPSS) > 0.05$), we conclude that time series of indices returns are stationary.

Student's *t*-distribution

We have shown that the majority of returns do not adjust to the normal distribution. Then rare events often occur. These results show that Student's distribution could have been better.

To check whether the indices returns adjust correctly to Student's distribution, we perform the Kolmogorov-Smirnov test in Table 6.

Table 5 Stationarity test of series

	<i>Returns</i>	<i>Augmented Dickey-Fuller Test</i>		<i>KPSS Test</i>	
		<i>Dickey-Fuller</i>	<i>p-value</i>	<i>KPSS Level</i>	<i>p-value</i>
Period I	MASI	-6.1840	0.010	0.3391	0.100
	DAX	-5.6349	0.010	0.1180	0.100
	DOW JONES	-5.5882	0.010	0.1908	0.100
	ESSC	-5.4185	0.010	0.2825	0.100
Period II	MASI	-5.8094	0.010	0.2215	0.100
	DAX	-3.7153	0.026	0.1233	0.100
	DOW JONES	-3.7791	0.022	0.1273	0.100
	ESSC	-5.3385	0.010	0.0606	0.100
Period III	MASI	-7.2028	0.010	0.1461	0.100
	DAX	-5.8039	0.010	0.0619	0.100
	DOW JONES	-5.6387	0.010	0.0290	0.100
	ESSC	-5.1084	0.010	0.1599	0.100

Table 6 Kolmogorov-Smirnov test

<i>Returns</i>	<i>Period I</i>		<i>Period II</i>		<i>Period III</i>	
	<i>D</i>	<i>p-value</i>	<i>D</i>	<i>p-value</i>	<i>D</i>	<i>p-value</i>
MASI	0.97198	<2.2e-16	0.91949	<2.2e-16	0.90134	<2.2e-16
DAX	0.98257	<2.2e-16	0.92318	<2.2e-16	0.97084	<2.2e-16
DOW JONES	0.98801	<2.2e-16	0.89813	<2.2e-16	0.94366	<2.2e-16
SSEC	0.98064	<2.2e-16	0.8959	<2.2e-16	0.90671	<2.2e-16

To refine our examination, it is important to show how the correlation coefficients changed over time, during the selected periods. To achieve this goal, we used the DCC-GARCH methodology (Engle and Sheppard, 2001; Engle, 2001, 2002; Tse and Tsui, 2002).

4.2 Dynamic conditional correlation model

The DCC, is divided into two steps. This simplifies the estimation of the time-varying correlation matrix. The first step was to evaluate the univariate volatility parameters using GARCH models for each series.

In the second step, standardised residues from the first step are used as inputs to approximate a time-varying correlation matrix. DCC allows asymmetries, which assumes that the weights are divergent for negative and positive changes in the series, which is a great benefit of this model.

Kearney and Poti (2003) and Engle (2002) provide additional guidelines for implementing the model. The model proposed by Engle (2002) can be written as follows:

$$\mu_t/J_{t-1} \sim \mathcal{N}(0, A_t) \quad A_t = B_t C_t B_t \quad (1)$$

where

- μ_t represent the $m \times 1$ vector of demeaned variable values conditional on information available at $t - 1$ (denoted as J_{t-1}); μ_t is presumed to be conditionally multivariate normal.
- A_t represent the conditional covariance matrix.
- C_t represent the $m \times m$ dynamic correlation matrix.
- B_t is a $m \times m$ diagonal matrix of conditional (i.e., time varying).

Let ϵ_t be the standardised residuals that are obtained from the univariate GARCH models, according to Engle (2002), the DCC estimator's likelihood can be expressed as:

$$L = -0.5 \sum_{t=1}^T (m \log(2\pi) + 2 \log(|B_t|) + \log(|C_t|) + \epsilon_t' C_t^{-1} \epsilon_t) \quad (2)$$

The likelihood (L) is a function of B_t and C_t . As a result, the estimation can be done in two steps.

In the first step, B_t is optimised (minimised). This is accomplished by substituting C_t with a $m \times m$ identity matrix, giving the first-stage likelihood. This means that the log-likelihood is reduced to the sum of the log-likelihoods of univariate GARCH equations.

The second step optimises (maximises) the correlation component, C_t , conditional on the estimated B_t from the first step. The second step provides the DCC parameters, β , and α :

$$C_t = (1 - \beta - \alpha) \bar{C} + \beta C_{t-1} + \alpha \epsilon_{t-1} \epsilon_{t-1}' \quad (3)$$

Remark 2: When, $\alpha = 0$ and $\beta = 0$, the constant conditional correlation model is sufficient (because R_t is simply $\bar{R}$: unconditional covariance).

5 Results and interpretation

It is important to note that the correlation between markets changes over time. Hence, we would like to highlight the interest in studying levels of DCCs between the MFM, and other financial markets during the Covid-19 crisis. Especially, regarding international portfolio if its diversification models take into account the interdependence of markets during the sanitary crisis. In Table 7, we estimated the parameters of DCC between MASI returns and DAX, DOW JONES and SSEC returns (we noticed that DDC-Alpha for period III is not significant). Additionally, the following graph shows the evolution of the conditional correlation over the three periods.

Table 7 DCC parameters

	DCC-Alpha		DCC-Bêta	
	Parameter	Pr(t)	Parameter	Pr(t)
Period I	0.0401	0.0436	0.8268	0.0000
Period II	0.0272	0.0004	0.7215	0.0000
Period III	0.0282	0.2808	0.7963	0.0000

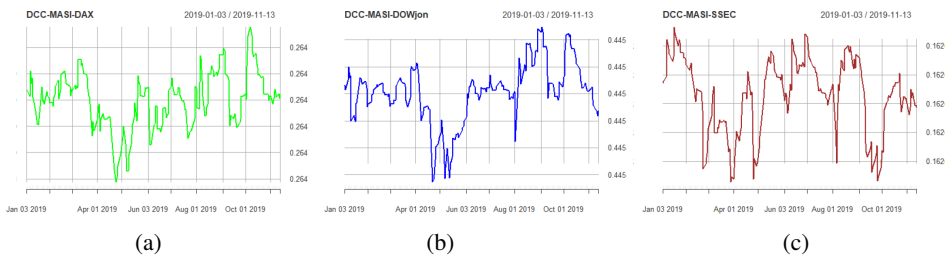
The analysis of the graphical evolution of the dynamic correlations between the different couples of returns (MASI-DOW JONES, MASI-DAX, MASI-SSEC) leads to the following remarks:

- Whatever a couple of returns are considered, periods of strong and weak correlations appear. High volatility of conditional correlations between indices can be observed. This is the materialisation of the phenomenon of time-varying correlation.
- The correlation coefficients calculated for the MASI-DOW JONES and MASI-DAX couples are close and have the same profiles and trends. For example, the same peaks or troughs are observed in the correlations.

Period I

During period I, the two graphs (Figure 3(a) and (c)) depicting the variations in the DCCs of the two markets, German and Chinese, with the Moroccan market, appear to show a weak and stable interdependence. This conclusion is supported by the fact that the German and Chinese markets had low dynamic correlation coefficients during the same period. Indeed, the conditional correlation coefficients of the two countries, Germany and China, with Morocco do not exceed respectively: 27% and 17% (relatively stable), during this period. The exception is that the dynamic conditional correlations between the US and Moroccan markets is around 45%, with some up and downtrends noted.

Figure 3 DCC for period I: (a) DCC between MASI Returns & DAX Returns; (b) DCC between MASI Returns & DOW JONES Returns and (c) DCC between MASI Returns & SSEC Returns (see online version for colours)

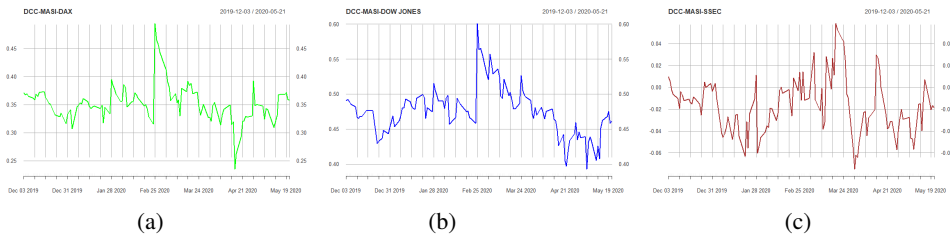


Period II

Compared to the graphs of period I, we are particularly interested in examining how Covid-19 affects the interdependence between the MFM and the other financial markets in our sample. Overall in period II, as shown in Figure 4, the conditional correlation coefficients of the series: MASI-DAX are positive and relatively stable at the interval [30%, 40%] throughout a period, but at the end of February, when Covid-19 touched Morocco, the correlation increased to over 50%. Also, the interdependence between the MFM and the US financial market began to increase sharply at the end of February and reached a peak between February 25, and March 10, when Covid-19 outbreak began in Morocco. Indeed, the DCC between MASI returns, and DOW JONES returns is substantial, and has risen to over 60% at the end of February. This means that the impact of Covid-19 in Morocco will have a huge impact on MFM's interconnection with the US financial market. However,

for the Chinese financial market, the DCC coefficients between the MASI returns and the SSEC returns are very low, not exceeding $[-6\%, 6\%]$. This indicates that the early months of the Covid-19 crisis were characterised by a weak interdependence, between the Moroccan and Chinese financial markets. This is also justified by the results of Rizvi and Ali (2020) which indicates that the Chinese financial market experienced a relatively small decline in returns during the pandemic, and in the epidemic periods of Covid-19.

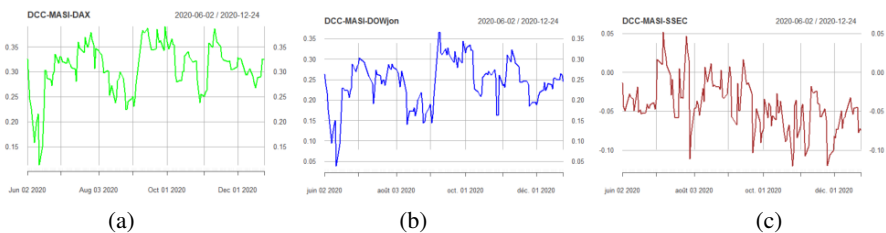
Figure 4 DCC for period II: : (a) DCC between MASI Returns & DAX Returns; (b) DCC between MASI Returns & DOW JONES Returns and (c) DCC between MASI Returns & SSEC Returns (see online version for colours)



Period III

Moving on to period III (Table 5), DCC analysis reveals a subdued level of interdependence between the Moroccan market and the other markets in our dataset. Concerning period III, the DCC witness a weak interdependence between the Moroccan market and all other markets in our sample. indeed, DCC coefficients of the couples MASI-DAX returns, and MASI-DOW JONES returns are relatively stable in the interval $[30\%, 35\%]$ during period III. Moreover, the DCC coefficients of the couple MASI-SSEC returns are considerably low and do not exceed 10%.

Figure 5 DCC for period III: : (a) DCC between MASI Returns & DAX Returns; (b) DCC between MASI Returns & DOW JONES Returns and (c) DCC between MASI Returns & SSEC Returns (see online version for colours)



Remark 3: The results of our study can be summarised in Table 8.

During the first months of the Covid-19 crisis (period II), the level of DCC for the three markets with the Moroccan market, enable us to categorise these markets into three groups, as shown in Table 8.

Table 8 Estimated interdependence between the Moroccan and international financial markets

<i>Financial markets</i>	<i>Period I</i>	<i>Period II</i>	<i>Period III</i>
German financial market	[26%,27%]	[25%,45%]	[15%,35%]
American financial market	[24%,45%]	[40%,60%]	[5%,35%]
Chinese financial market	[16%,17%]	[-6%,4%]	[-10%,5%]

The first group with high interdependence with MFM includes US financial markets (DOW JONES) and has a very strong DCC with MFM in period II. Indeed, when Moroccan health authorities announced the first cases of Covid-19, the country's DCC level reached 60%. This means that DOW JONES has had a strong impact on the indices of the Moroccan stock market. The second group, which is moderately interdependent with MFM, contains the German financial market, with average conditional correlations of around 45. The third group, which presents a low interdependence with MFM, includes the Chinese financial market, with weak and unstable conditional correlations with the Moroccan market.

Consequently, our results for the couples: MASI-DOW JONES and MASI-DAX confirm that the interdependence between stock markets increases during the crises, as argued by the theory of financial behaviour. Therefore, most of our results are in line with the discovery of the mentioned literature (Chiang et al., 2007; Naoui et al., 2010; Dajčman and Festić, 2012; Tamakoshi and Hamori, 2013; Yousaf and Ali, 2020; An and Xu, 2021). However, we notice that the interdependence between the MASI and the SSEC has not been strongly affected by the Covid-19 crisis, (exception in this case as in Kuper (2007), which can be explained by: the differences in the level of risk aversion among investors of the two markets, because they are in a completely different environment (particularly the Chinese financial markets experienced relatively low returns during the pandemic and pandemic, whereas the US and German financial markets, on the other hand, are subject to significant volatility, that has increased from the epidemic to the pandemic period as pointed in Rizvi and Ali (2020), or by the gap in the spread of the Covid-19 over countries. These results are invaluable to investors interested in diversifying their portfolios to minimise market risk.

For period III, it can be noticed that DCC coefficients between the Moroccan market and all other markets have become very low, which can be explained by the public policies undertaken to limit the impact of the external shocks on Morocco, and to provide a response to the economic impact caused by Covid-19 such as the creation of a Solidarity Fund, aid measures to households, companies, and the massive injection of liquidities by Bank Al-Maghrib (Ali and Bassou, 2020).

6 Conclusion

The purpose of this paper was to study the interdependence between Morocco and other stock markets. Within the realisation of the objective, we used the DCC-GARCH model. We have considered four time series represented by MASI, DAX, DOW JONES, and SSEC stock indices for the period from January 1, 2019, to January 1, 2021.

Our empirical results support the hypothesis of variation of correlations in time and reject the normal distribution law, which confirms the existence of rare events. We note the existence of phases of strong and weak correlations. We also, confirm that the Covid-19 crisis has increased the interdependence of the Moroccan stock markets with the US and German ones. The observation of a variable correlation over time calls into question

many models in which this is assumed to be constant. The Markowitz portfolio, the capital asset pricing (CAPM), and the Value at Risk models are examples. Also, the integration of dynamic market interdependence in previous models, could make it possible to better take the risk of contagion.

This paper has focused on four financial market indices that are representative of various major global markets. Whereas financial markets are known to be dynamic and depend on a large number of complicated elements that we cannot easily overcome. We also conclude that investor psychology plays a central role in influencing stock prices and overall financial market policy. This suggests that traditional risk measures for portfolio investment, are not robust in practice unless they take into account the psychological impact of the investor and the consumer. The emergence of a new type of risk measurement is therefore necessary, this is precisely the focus of our forthcoming work on portfolio optimisation.

We can also notice that the efforts of individual governments, immediately after the peak of the crisis, to recover their economies have greatly affected the interdependence between the different financial markets.

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