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Article

Has COVID-19 changed the correlation between cryptocurrencies and stock markets?

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Abstract. The COVID-19 pandemic has challenged the notion that cryptocurrencies are uncorrelated with traditional asset markets. This study uses VAR-OLS techniques to investigate the time-varying correlation between Bitcoin and three major European stock market indices from January 4, 2016, to February 26, 2021. Our results show that cryptocurrencies and stock markets are dependent during crisis periods, but not during non-crisis periods. This confirms the time-varying correlation between cryptocurrencies and stock markets, which depends on the extent and persistence of responses to own and cross shocks. To improve the robustness of our results, we also test the impact of government measures on Bitcoin and stock market indices, and find that they are both affected by these measures. Our study adds to the literature by examining the impacts of pandemics on the correlations between Bitcoin returns and the stock market, oil, and gold index returns, which have so far been unaddressed.

Keywords: COVID-19; financial markets; Bitcoin; stock indices
JEL classification:I1; D53; G15; G12; C22

1. Introduction

The concept of safe haven value for investment is driven by investor loss aversion (Tversky & Kahneman, 1991), where investors are more concerned about avoiding losses than the associated potential gains (Hwang & Satchell, 2010). This loss aversion encourages investors to seek safe haven assets, i.e. assets that are not correlated or correlated negatively with traditional assets in times of market turbulence (Baur & Lucey, 2010). Various safe haven assets have been established at short to medium horizons, including gold (Bredin et al., 2015), currency (Ranaldo & Söderlind, 2010), long-term treasury bills (Flavin et al., 2014) and, more recently, cryptocurrencies. The role of alternative investments in improving the returns of traditional equity bond portfolios has long been the subject of academic research. Given the shortage of "traditional" alternative investment classes, the role of the increasingly important cryptocurrency markets becomes relevant. Cryptocurrency is a digital or

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virtual currency that is exchanged between peers without the need for a third party.

Since the introduction of Bitcoin in 2008, academic research has highlighted the low correlation between Bitcoin and traditional financial markets (Baur et al., 2018; Corbet et al., 2018). This correlation, however, became stronger after the introduction of futures contracts on Bitcoin in December 2017 (Matkovskyy & Jalan, 2019; Sami & Abdallah, 2021). This discovery led to a more in-depth investigation into the hedging and diversification properties of Bitcoin compared to traditional financial assets (Urquhart & Zhang, 2019; Guesmi et al., 2018; Bouri et al., 2017; Cretarola et al., 2021). Other authors suggest that the assets become more correlated during economic downturns. Thus, many studies have explored the response of cryptocurrency markets to the COVID-19 pandemic as well as changes in interactions between cryptocurrencies and other traditional asset classes (Lahmiri & Bekiros, 2020; Conlon & McGee, 2020; Mnif et al., 2020; Ali et al., 2020; Goodell & Goutte, 2021; Ji et al., 2020). Indeed, the COVID-19 global health crisis has the potential to slow down the global economy and increase the level of volatility in financial markets. Baker et al. (2020) have explained the stronger impact of the COVID-19 pandemic on equity markets than previous outbreaks of infectious diseases. This crisis is an opportunity to study much more about the evolution of the crypto-currency market as well as the interdependencies between the crypto-currency market and the traditional asset classes.

The objective of this article is to examine the correlation between crypto-currencies and stock markets. We study the impact of the introduction of Bitcoin into investors' portfolios on their efficiency in the context of the COVID-19 pandemic.

The remainder of this document is organized as follows. Section 2 presents the literature review. Section 3 describes the methodology. Section 4 examines the empirical results. Section 5 is devoted to discussion and the final section presents the main conclusions.

2. Literature review

The usefulness of alternative investments is confirmed in the literature which documents that a planned asset allocation between various super form asset classes systematically involves both a strategic commodity portfolio and a full equity portfolio (Conover et al., 2010; Ciner et al., 2013; Li & Lucey, 2017; Gao & Nardari, 2018) recent studies suggest that there now appears to be a shortage of alternative assets that can be used to reduce the risk of declining equity investments (Bouri et al., 2019; Shahzad et al., 2019).

Regarding portfolio diversification with cryptocurrencies, Chen and Vivek (2014) show that Bitcoin can play an important role in improving the efficiency of the portfolio. Based on an analysis of traditional assets and alternative investments, Bouri et al. (2017) show that investing in bitcoin offers significant diversification benefits. Bouri et al. (2019) document that hedging stocks with cryptocurrencies is beneficial. Inci and Lagasse (2019) explain the role of crypto-currencies in improving investment portfolios. They found that private and listed companies recorded huge profits in these assets. They confirmed that ownership of crypto-currencies varies between companies, ranging from investment objectives to supporting future plans to accept digital currencies as a means of payment for goods and services. Kajtazi and Moro (2019) demonstrate that the addition of Bitcoin,

despite its speculative characteristics, results in an improvement in the performance of asset portfolios in the US, China and Europe. Chan et al. (2019) suggested strong Bitcoin hedging properties against five international stock indexes, including the S&P 500. Urquhart and Zhang (2019) investigate the hedging, diversification and value-safe-haven properties of Bitcoin against global currency fluctuations. Their results support the assumption that alternative investments, in this case cryptocurrencies, add value by improving the performance of traditional financial assets. Platanakis et al. (2019) suggest that investors should include Bitcoin in their portfolios as it generates significantly higher risk-adjusted returns. In line with this thinking, Frankovic et al. (2021) analysed the relationship between the share prices of Australian companies holding crypto-currencies and their prices. They found that these companies adopt positions that are sensitive to fluctuations in crypto-currency prices. Similarly, Xu et al. (2022) examined the strategic reasons for crypto-currency integration by corporate treasury departments and explored the risk-return outcomes of these decisions and strategies. As a result, they confirmed in their study that the emergence of jumps in crypto-currencies increases the probability of jumps in the returns of said US companies.

Empirical studies have also emerged to explore the response of cryptocurrency markets to the COVID-19 pandemic as well as changes in interactions between cryptocurrencies and other traditional assets. In the US context, Sharif et al. (2020) examined the reaction of crypto-currencies during the period of the health crisis. They found that the correlation between price volatility shocks on economic policy uncertainty and the oil market is also related to the spread of the COVID-19 pandemic in the US. They confirmed that the health crisis is a geopolitical threat. These results are confirmed by the study by Umar and Gubareva (2020). Al-Awadhi et al. (2020) found evidence of a significant negative impact of COVID-19 on the equity returns of all companies included in the Hang Seng Index and the Shanghai Composite Index. These results are confirmed with studies by Sharif et al. (2020) and Zhang et al. (2020). Lahmiri and Bekiros (2020) suggest that the cryptocurrency market has been relatively more volatile than international equity markets during the COVID-19 pandemic. The empirical results show the variable relationship over time between the cryptocurrency market and the US stock market or the price of the gold market. Recent data has shown that there has been a positive relationship that has varied over time between these two markets since COVID-19. Mishra et al. (2022) demonstrated a reduction in market linkage during a recession as compared to expansion. Hung (2019) suggested that portfolio managers need to adjust their asset allocations in times of turbulence or crisis when asset volatility shifts from one market to another. In this sense, Kim et al. (2020) examined the relationship of major financial assets, Bitcoin, Gold and S&P 500 with GARCH models. They show the relationship of Bitcoin with Gold and S&P 500. They also analyzed the relationships between the conditional correlation varying over time with the volatility of Bitcoin and the volatility of the S&P 500 by a marginal regression of the Gaussian copula (GCMR). The empirical results show that the S&P 500 and gold prices are statistically significant for Bitcoin in terms of log-back and volatility.

3. Methods

We examine the nexus between cryptocurrencies and stock markets before and after the COVID-19 pandemic. Our study retrieved global daily-frequency data from 4 January 2016 to 26 February 2021. We divide our sample to before COVID-19 and COVID-19 period around December 31, 2019 which corresponds to the date the first cases were discovered by Chinese authorities. Our choice is justified since investors are more sensitive to negative information. Data on cryptocurrencies and stock markets were collected respectively from Coinbase, retrieved from Federal Reserve Economic database, and the data of oil and gold price are extracted from dtastream. The data of governmental measures are extracted from Oxford Data base. These governmental measures are used herein as a proxy for reducing actions of global pandemic uncertainty. Moreover, we calculate the continuous compounded daily returns for all the series as $100 \times \ln\left(\frac{Pt}{Pt-1}\right)$, where Pt represents the daily closing price of each asset.

Descriptive statistics results clearly show that during the COVID-19 outbreak, all indices return downturn dramatically. The mean returns of all stock market indices are very small, among which DAX30 is positive, while CAC40 and FTSEMIB turn out to be negative with a significant increase in volatility. As expected, the Bitcoin has high mean returns and standard deviations (Std. Dev.) This result suggests its potential hedge role to investors (Kajtazi & Moro, 2019; Kim et al., 2020). Besides, we can easily notice the free fall in oil price return and the remarkable increase in volatility. Finally, according to the results, gold's return slightly decreased in crisis period amid a slight decrease in volatility. Thus, we confirm the previous findings of Bouri et al. (2020), who suggests the hedging role of gold, especially in mitigated periods.

For government measures, we can easily notice that all countries are seriously implementing controlling the disease with a high index (at least 79%) and that the most applied measures are *School closure*, *Workplace closures*, *Cancel public events*, *Testing policy* and *Contract tracing*. On the other hand, Stay at home, and Restrictions on internal movement are comparatively less applied. This result could be explained by the difficulty of forcing people to stay at home and outlaw movements since it is socially difficult to accept and harmful for economic activities. The first confinement is marked by a drop in wages. France has a drop in wages of the poorest among the lowest in Europe. Its decline is lower than in Germany. This impact is particularly present in local businesses that suffer from this effect: confinement causes a considerable decrease in the number of people who use the shops (restaurants, small markets, bakeries, tourism, etc.).

Table 1. Descriptive statistics for Bitcoin and Stock indices before and during COVID-19

	Before COVID-19					**During COVID-19**				
Variable	Obs	Mean	Std. Dev.	Min	Max	Obs	Mean	Std. Dev.	Min	Max
lnbitcoin	1028	0.0027301	0.0462737	-0.247405	0.221747	297	0.0062591	0.0520257	-0.497278	0.193671
dax30	1028	1.000292	0.0097051	0.931767	1.03506	297	0.0001463	0.0195434	-0.130549	0.104143
lncac40	1028	0.0002763	0.0095263	-0.083844	0.040604	297	-0.0001585	0.0193948	-0.130983	0.080561
lnftsemib	1028	0.0001299	0.0128752	-0.133314	0.049111	297	-0.000109	0.0212854	-0.185411	0.085495
Lngold	1028	0.0005163	0.02189	-0.082336	0.136944	297	0.0004485	0.0121427	-0.058928	0.042968
Lnwti	1028	1.000376	0.007489	0.968084	1.04022	297	0.0000159	0.064684	-0.601676	0.319634

Source: Authors calculations

Table 2. Variables measurement and descriptive statistics for governmental responses

		Germany				France				Italy			
Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**	**Mean**	**Std. Dev.**	**Min**	**Max**	**Mean**	**Std. Dev.**	**Min**	**Max**
lnschoolcl~g	294	.811	.404	0	2	.791	.412	0	2	.817	.386	0	1
lnworkplace	294	.828	.381	0	1.5	.846	.374	0	2	.898	.327	0	2
lncancelev~s	294	.874	.342	0	2	.874	.350	0	2	.891	.312	0	1
lnstayhome	294	.495	.520	0	2	.573	.501	0	2	.686	.473	0	2
lnmouvements	294	.760	.450	0	2	.597	.504	0	2	.566	.509	0	2
lntestingp~s	294	.950	.259	0	3	.956	.226	0	2	.935	.260	0	2
lncontactt~g	294	.962	.203	0	2	.954	.223	0	2	.932	.252	0	1
Δcumcases	294	.0861	.322	0	4	.099	.410	0	5	.086	.259	0	2.575

Source: Authors calculations

According to INSEE, "73% of companies report a decrease in their sales of more than 10%. and 35%, a decrease of more than 50% during the trigger period." To get more detailed results, we present below the time series of each variable in Figure 1.

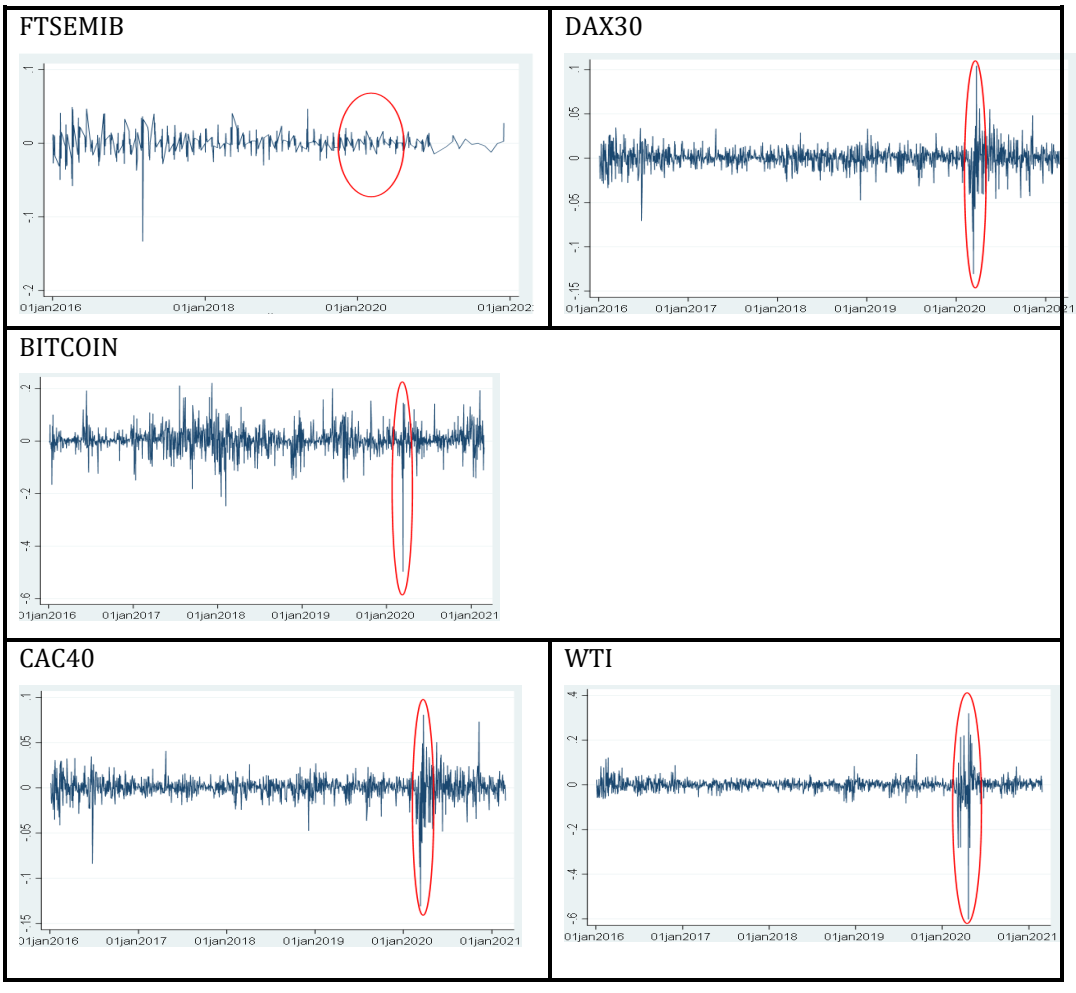


Figure 1. CAC40, DAX30, WTi and Bitcoin return over the whole period. *Source:* Own elaboration.

The trends of CAC 40, DAX30 and FTSE MIB stock market indices and prices of Bitcoin, Oil and Gold are similarly affected by COVID-19 in the first quarter of 2020 with clearly persistent high volatility for stock indices, gold and Bitcoin, while oil return almost rejoin it trend as before COVID-19 period. Concretely, during the outbreak of COVID-19 from 1rst January 2020 to 17 September 2020, the prices of cryptocurrencies and the stock indices of the world fell sharply first and then rose moderately. All series show a downward trend.

4. Results

4.1 Pearson matrix

Table 3 presents the Pearson's correlations between Bitcoin return, stock market, oil and gold indices returns.

Table 3. Pearson matrix

	Before COVID-19						During COVID-19					
	lnbitc~n	**dax30**	**lncac40**	**lnftse~b**	**gold**	**lnwti**	**lnbitc~n**	**dax30**	**lncac40**	**lnftse~b**	**gold**	**lnwti**
lnbitcoin	1						1					
dax30	0.004	1					0.390*	1				
	0.903						0.000					
lncac40	-0.003	0.917*	1				0.384*	0.957*	1			
	0.931	0					0	0				
lnftsemib	-0.008	0.792*	0.829*	1			0.491*	0.908*	0.914*	1		
	0.795	0	0				0	0	0			
gold	0.049	-0.268*	-0.272*	-0.240*	1		0.262*	0.163*	0.108	0.117*	1	
	0.118	0	0	0			0	0.005	0.062	0.043		
lnwti	-0.011	0.254*	0.302*	0.311*	-0.034	1	0.161*	0.285*	0.292*	0.283*	0.074	1
	0.730	0	0	0	0.264		0.005	0	0	0	0.202	

Note: * p-value <0.05. *Source:* Authors calculations.

Before COVID-19, it can be easily observed that in addition to the weak and positive correlations between the stock market returns of the three countries and Bitcoin, there is a positive correlation between Bitcoin and gold, proving their similarity. Therefore, we employ the VAR approach to study the heterogeneous relationships between these variables. Next, we check the robustness of our results and test whether bitcoin and stock market indices are similarly affected by government actions using a GLS regression.

4.1 VAR model

We intend to figure out the existence of a potential link between cryptocurrencies and stock returns before and during COVID-19 period through VAR model. The lagged Bitcoin returns, stock returns, and oil and gold are used as exogenous factors to detect the mean spillover effect within the studied indices. The stationary tests of ADF and PP with the null hypothesis of having a unit root confirm that all indices are stationary at first level as indicated in Table 4. The lags orders are selected according to FPE, AIC, HQIC and SBIC criteria allowed in Tables 5, 6. and 7.

Table 4. Stationary tests

	Before COVID-19				During COVID-19			
	Stationary level I(0)		Stationary at first difference I(1)		Stationary level I(0)		Stationary at first difference I(1)	
	ADF test	PP test	ADF test	PP test	ADF test	PP test	ADF test	PP test
	Case 1: Model without trend		Case 1: Model without trend		Case 1:Model without trend		Case 1: Model without trend	
FTSE MIB	-1.934	-1.934	-13.942 ***	-29.949***	-2.08	-2.08	-13.941***	-29.949***
DAX30	-1.720	-1.720	-14.777***	-27.550***	-2.08	-2.09	-14.765***	-27.536***
CAC40	-1.518	-1.518	-14.625***	-25.483***	-1.67	-1.67	-25.489***	-25.489***
Bitcoin	2.990	2.990	-15.949***	-29.233***	2.20	2.20	-29.429***	-29.429***
gold	-1.698	-1.698	-30.922***	-30.922***	-1.86	-1.86	-30.957***	-30.957***
wti	-2.851	-2.851	-29.718***	-29.718***	-2.84	-2.84	-29.712***	-29.712***

Note: *** statistical significance at 1%. *Source:* Authors calculations

Table 5. Selection-order criteria before and after COVID-19 for Italy

Selection-order criteria before COVID								
lag	**LL**	**LR**	**df**	**p**	**FPE**	**AIC**	**HQIC**	**SBIC**
0	2049.12				8.2e-15*	-21.0837*	-21.0564*	-21.0163*
1	2063.69	29.157	16	0.023	8.3e-15	-21.069	-20.9326	-20.7321
2	2080.01	32.637	16	0.008	8.3e-15	-21.0723	-20.8267	-20.4659
3	2091.51	22.995	16	0.114	8.7e-15	-21.0259	-20.6712	-20.15
4	2109.72	36.422*	16	0.003	8.5e-15	-21.0487	-20.5849	-19.9032
Selection-order criteria during COVID-19								
lag	**LL**	**LR**	**df**	**p**	**FPE**	**AIC**	**HQIC**	**SBIC**
0	535.012				4.8e-14	-19.3095	-19.2531	-19.1635*
1	563.308	56.592	16	0.000	3.1e-14	-19.7566	-19.4744*	-19.0267
2	574.879	23.143	16	0.110	3.7e-14	-19.5956	-19.0875	-18.2817
3	602.427	55.095	16	0.000	2.5e-14	-20.0155	-19.2816	-18.1177
4	619.753	34.652*	16	0.004	2.5e-14*	-20.0637*	-19.104	-17.5819

Source: Authors calculations

Table 6. Selection-order criteria before and after COVID-19 for France

Selection-order criteria before COVID								
lag	**LL**	**LR**	**df**	**p**	**FPE**	**AIC**	**HQIC**	**SBIC**
0	2113.24				4.2e-15*	-21.7447*	-21.7175*	-21.6774*
1	2123.72	20.954	16	0.180	4.5e-15	-21.6878	-21.5514	-21.3509
2	2138.02	28.605	16	0.027	4.6e-15	-21.6703	-21.4248	-21.0639
3	2147.04	18.045	16	0.321	4.9e-15	-21.5984	-21.2437	-20.7225
4	2163.06	32.037*	16	0.010	4.9e-15	-21.5986	-21.1347	-20.4531
Selection-order criteria during COVID-19								
lag	**LL**	**LR**	**df**	**p**	**FPE**	**AIC**	**HQIC**	**SBIC**
0	529.101				6.0e-14	-19.0946	-19.0381	-18.9486*
1	554.908	51.615	16	0.000	4.2e-14	-19.4512	-19.1689*	-18.7213
2	570.998	32.18	16	0.009	4.2e-14	-19.4545	-18.9464	-18.1406
3	596.131	50.266	16	0.000	3.1e-14*	-19.7866	-19.0527	-17.8887
4	612.474	32.686*	16	0.008	3.2e-14	-19.799*	-18.8393	-17.3173

Source: Authors calculations

Table 7. Selection-order criteria before and after COVID-19 for Germany

Selection-order criteria before COVID-19

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	2120.86				3.9e-15*	-21.8233*	-21.796*	-21.7559*
1	2131.18	20.634	16	0.193	4.1e-15	-21.7647	-21.6283	-21.4278
2	2145.85	29.346	16	0.022	4.2e-15	-21.751	-21.5055	-21.1446
3	2154.89	18.073	16	0.320	4.5e-15	-21.6792	-21.3245	-20.8033
4	2170.5	31.24*	16	0.013	4.5e-15	-21.6753	-21.2115	-20.5299

Selection-order criteria during COVID-19

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	535.6				4.7e-14	-19.3309	-19.2744	-19.1849*
1	560.191	49.183	16	0.000	3.5e-14	-19.6433	-19.361*	-18.9134
2	574.783	29.184	16	0.023	3.7e-14	-19.5921	-19.084	-18.2782
3	598.892	48.218	16	0.000	2.8e-14*	-19.887*	-19.1531	-17.9891
4	612.624	27.465*	16	0.037	3.2e-14	-19.8045	-18.8448	-17.3227

Source: Authors calculations

Then, the Granger causality and VAR results quality are validated in tables 10, 11 and 12 for Italy, France and Germany, respectively before and after the COVID-19 pandemic crisis. It is confirmed that all the eigenvalues lie inside the unit circle. Consequently, VAR satisfies stability condition for France, Italy and Germany before and during COVID-19. After running the VAR, we support our findings by implementing the impulse function in figure 2.

Table 8. Granger causality for Italy

Italy		Before Covid	After Covid
Equation	Excluded	Prob> chi2	Prob> chi2
dLnΔFTSEMIB	dlnΔBitcoin	0.864	0.018**
dLnΔFTSEMIB	dlnΔgold	0.265	0.587
dLnΔFTSEMIB	dllnΔwti	0.402	0.009**
dLnΔFTSEMIB	ALL	0.596	0.003**
dlnΔBitcoin	dLnΔFTSEMIB	0.944	0.000***
dlnΔBitcoin	dlnΔgold	0.24	0.095*
dlnΔBitcoin	dllnΔwti	0.093*	0.007**
dlnΔBitcoin	ALL	0.192	0.000***
dlnΔgold	dLnΔFTSEMIB	0.72	0.002**
dlnΔgold	dlnΔBitcoin	0.81	0.033**
dlnΔgold	dllnΔwti	0.048**	0.013**
dlnΔgold	ALL	0.193	0.005**
dllnΔwti	dLnΔFTSEMIB	0.055*	0.080*

Source: Authors calculations

Table 9. Granger causality for France

France		**Before Covid**	**After Covid**
Equation	Excluded	Prob> chi2	Prob> chi2
dLnΔCAC40	dlnΔBitcoin	0.657	0.033
dLnΔCAC40	dlnΔgold	0.378	0.287
dLnΔCAC40	dllnΔwti	0.285	0.018
dLnΔCAC40	ALL	0.57	0.005
dlnΔBitcoin	dLnΔCAC40	0.36	0
dlnΔBitcoin	dlnΔgold	0.175	0.083
dlnΔBitcoin	dllnΔwti	0.061	0.006
dlnΔBitcoin	ALL	0.134	0
dlnΔgold	dLnΔCAC40	0.961	0.013
dlnΔgold	dlnΔBitcoin	0.818	0.09
dlnΔgold	dllnΔwti	0.039	0.014
dlnΔgold	ALL	0.204	0.021
dllnΔwti	dLnΔCAC40	0.302	0.002
dllnΔwti	dlnΔBitcoin	0.747	0.248
dllnΔwti	dlnΔgold	0.02	0.244
dllnΔwti	ALL	0.042	0.013

Source: Authors calculations

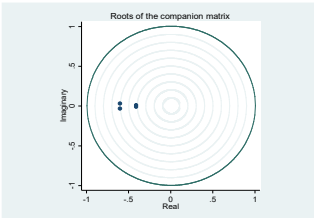
Table 10. Granger causality for Germany

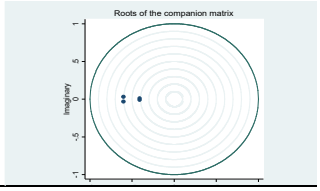
Germany		**Before Covid**	**After Covid**
Equation	Excluded	Prob> chi2	
dLnΔDAX30	dlnΔBitcoin	0.824	0.078*
dLnΔDAX30	dlnΔgold	0.054*	0.484
dLnΔDAX30	dllnΔwti	0.098*	0.012**
dLnΔDAX30	ALL	0.102	0.012**
dlnΔBitcoin	dLnΔDAX30	0.984	0.000***
dlnΔBitcoin	dlnΔgold	0.251	0.149
dlnΔBitcoin	dllnΔwti	0.093	0.010***
dlnΔBitcoin	ALL	0.192	0.000***
dlnΔgold	dLnΔDAX30	0.648	0.001**
dlnΔgold	dlnΔBitcoin	0.796	0.043**
dlnΔgold	dllnΔwti	0.045	0.008**
dlnΔgold	ALL	0.187	0.003**
dllnΔwti	dLnΔDAX30	0.462	0.014**
dllnΔwti	dlnΔBitcoin	0.737	0.329
dllnΔwti	dlnΔgold	0.017	0.34
dllnΔwti	ALL	0.054	0.066*

Notes: *p< 0.1, ** p < 0.05, *** p < 0.01
Source: Authors calculations

Table 11. Stability test for Italy

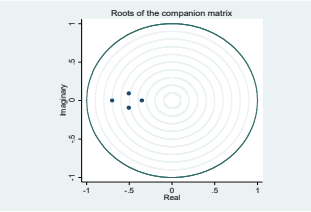
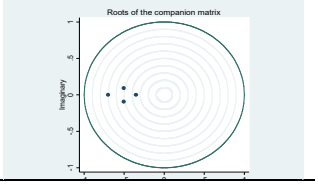
	Eigenvalue	**Modulus**
Before COVID	.603695 + .03151711i	.604517
	.603695 - .03151711i	.604517
	.4107565 + .01133293i	.410913
	.4107565 - .01133293i	.410913
	All the eigenvalues lie inside the unit circle. VAR satisfies stability	
After COVID	.8291133	.829113
	.4813131 + .07542815i	.487188
	.4813131 - .07542815i	.487188
	.4038571	.403857
	All the eigenvalues lie inside the unit circle. VAR satisfies stability	





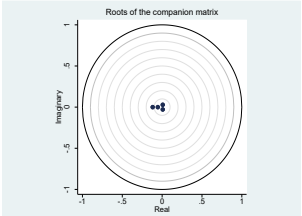
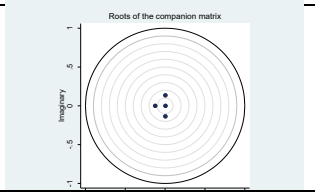
Source: Authors calculations

Table 12. Stability test for France

	Eigenvalue	Modulus	
Before COVID	.5998576	.599858	
	.5304404	.53044	
	.4077736 + .01516735i	.408056	
	.4077736 - .01516735i	.408056	
	All the eigenvalues lie inside the unit circle. VAR satisfies stability		
After COVID	.7005232	.700523	
	.5066378 + .09266491i	.515042	
	.5066378 - .09266491i	.515042	
	.3528257	.352826	
	All the eigenvalues lie inside the unit circle. VAR satisfies stability		

Source: Authors calculations

Table 13. Stability test for Germany

	Eigenvalue	Modulus	
Before COVI D	-.118457	0	
	-.0539891	0	
	.0078151	.028414	
	.0078151	-.028414	
	All the eigenvalues lie inside the unit circle. VAR satisfies stability		
After COVID	.0033594	.1356476	
	.0033594	-.1356476	
	-.1243459	0	
	.0044669	0	
	All the eigenvalues lie inside the unit circle.VAR satisfies stability condition.		

Source: Authors calculations

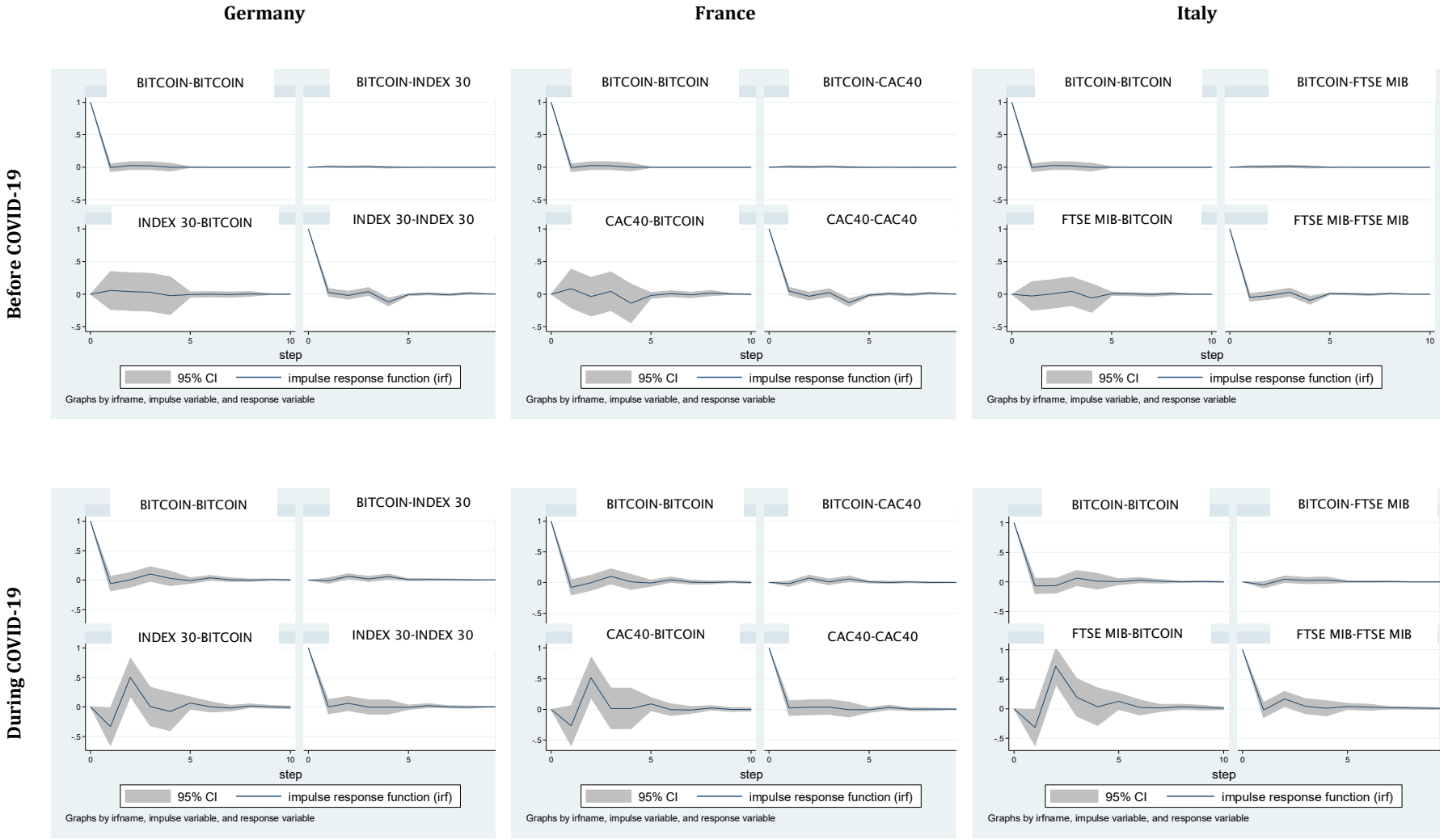


Figure 2. Impulse response functions. *Source: the authors.*

4.2 Impulse response function results

Figure 2 provides the responses of the variables to their own and cross-shocks during the two periods. The impulse–response graph places one impulse in each row and one response variable in each column. The horizontal axis is time. The vertical axis is in units of the variables measured in percentage points.

4.3 LS and GLS regressions

In order to confirm our findings, we test if, in the case of COVID-19, both stock indexes and Bitcoin are affected by governmental actions to control the pandemic through an OLS regression. If so, we confirm the existence of coherency between Bitcoin and stock indices during mitigated periods. We test for and residual autocorrelation. Since results confirm the existence of such problems (see Table 14), we turn to estimate GLS regression for the following models (Table 15):
Bitcoin = f (governmental measures), FTSE MIB = f (governmental measures of Italy)
CAC= f(governmental measures of France), DAX30= f(governmental measures of Germany)

Table 14. Estimation of OLS regression

	Italy		**France**		**Germany**	
	lnΔBitcoin	**lnΔFTSEMIB**	**lnΔBitcoin**	**lnΔBitcoin**	**lnΔBitcoin**	**lnΔCAC40**
	Coeff	**Coeff**	**Coeff**	**Coeff**	**Coeff**	**Coeff**
lnschoolclosing	.0445947***	.0258763***	.0278783**	.006253	-.011966	.0059655
lnworkplace	-.0177996	-.003466	-.0208287	.0080479	.0615218***	.0231909**
lncancelevents	-.0199816	-.0279787***	-.0012075	-.0109665	-.039791**	-.0244232***
lnstayhome	-.0125133	.0004167	.0065614	.0015334	.0102935	.0004281
lnmouvements	.0166239*	.0013323	-.0083567	-.0013301	-.0037976	-.0006247
lntestingpolicies	.038037	.0123604	.0022607	-.0132201	.0111725	.0020282
lncontacttracing	-.0514426	-.0066714	-.0091534	.0096287	-.038255*	-.0037589
Δcumcases	.0044208	-.0023159	-.0043617	-.0034895	.0022145	.0032284
_cons	.0151017	.0006138	.0114601	.0014226	.0239506	-.0008544
R-sq	0.0516	0.1022	0.0319	0.0415	0.0579	0.1036
Hetheroscedasticity test	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Durbin'	0.0107	0.0134	0.0212	0.8027	0.0067	0.4364

Notes: *p< 0.1, ** p < 0.05, *** p < 0.01. *Source:* Authors calculations

Table 15. Estimation of GLS regression

	Italy		**France**		**Germany**	
	lnΔBitcoin	**lnΔFTSEMIB**	**lnΔBitcoin**	**lnΔCAC40**	**lnΔBitcoin**	**lnΔDax30**
lnschoolclosing	.0445947***	.0258763***	**.0278783****	.006253	-.011966	.0059655
Lnworkplace	-.0177996	-.003466	-.0208287	.0080479	**.0615218*****	**.0231909****
Lncancelevents	-.0199816	-.0279787**	-.0012075	-.0109665	**-.039791****	**-.0244232*****
Lnstayhome	-.0125133	.0004167	.0065614	.0015334	.0102935	.0004281
Lnmouvements	.0166239***	.0013323	-.0083567	-.0013301	-.0037976	-.0006247
lntestingpolicies	.038037	.0123604	.0022607	-.0132201	**.0111725****	.0020282
lncontacttracing	-.0514426	-.0066714	-.0091534	.0096287	-.038255	-.0037589
Δcumcases	.0044208	-.0023159	-.0043617	-.0034895	.0022145	.0032284
_cons	.0151017	.0006138	.0114601	.0014226	.0239506*	-.0008544

Notes: *p<0.1, ** p < 0.05, *** p < 0.01. *Source: Authors calculations*

5. Discussion

5.1 Theoretical implications

The results of Pearson matrix illustrate a negative correlation between gold and returns of stocks and oil, confirming the hedging role of gold acknowledged by Yousaf et al. (2021) and Salisu et al. (2021). The outcomes of Soomro et al. (2022) show the results of developed further intention and trust of investors towards cryptocurrency adoption.

During COVID-19, all correlations are positive and particularly, the correlations between Bitcoin and the indices are stronger than those between gold and indices. This result seems to imply that a cryptocurrency is more likely to be a diversifier or a weak hedge for stock markets rather than a strong hedge during crisis period. However, some studies show that there are heterogeneous relationships between cryptocurrencies and stock market indices (Bouri et al., 2017; Feng et al., 2018; Shahzad et al., 2019) and the BDS[1] test indicates that all series have nonlinear structures.
According to results shown in Table 8, before COVID-19, we notice the absence of causality between Bitcoin and the stock index in Italy, while there is a unidirectional causality from oil to Bitcoin and from FTSE MIB to oil and bidirectional causality between oil and gold. But things changed after the first discovered cases of COVID-19. We interestingly find bidirectional causality between Bitcoin and the stock index, oil and stock index and Bitcoin and gold.

Table 8 shows that before COVID-19, in France, almost like Italy, there was a unidirectional causality from oil to Bitcoin and a bidirectional causality between oil and gold. After the announcement of the first COVID-19 cases, we found that causality relations significantly changed. In fact, we prove the existence of directional causality between Bitcoin and CAC40, oil and CAC40 and Bitcoin and gold (Table 8).

For the case of Germany, we notice the absence of causality between DAX30 and Bitcoin before COVID-19, suggesting their independence, while gold and oil caused Bitcoin variation, in line with Aysan (2021). After the outbreak of the pandemic, the results confirm the existence of bidirectional causality between DAX30 and Bitcoin. Furthermore, interestingly, gold is affected by the stock index, Bitcoin and oil (see Table 8). Our results join Huang et al. (2021). Finally, we note bidirectional causality between the stock index and oil, confirming previous studies of Mariana et al. (2021).

To conclude, we clearly notice the significant pattern change of correlations between studied assets and the strengthening of directional causalities during crisis periods, according to Mishra et al. (2022). Besides, we confirm the previous results of Corbet et. al (2018) supporting the common consensus regarding weak correlations between cryptocurrencies and stock market and re-examine it during a crisis period. Thus, we join the line of thoughts of Jiang et al. (2021); Bouri et al. (2017) and Kristoufek (2015). At last, investors and decision-makers would reconsider their investment strategies in mitigated periods since cryptocurrencies cannot be used as a strong hedge against the risks of stock indices.

According to the results, school closing and movement restrictions measures to control the

[1] The Broock, Dechert and Scheinkman (BDS) test (Broock et al. 1996) to test the linearity of all the returns series.

spread of COVID-19 enter a significant and positive impact on the FTSE MIB, reflecting its reducing effect on uncertainty and consequently rebuilding investor's confidence in the Italian stock market. Bachman (2020) and Sarkis et al. (2020) prove that while trying to save lives, some governmental measures controlling COVID-19 spread are economically efficient, whereas others lack financial efficiency. Thus, we prove the previous results of Corbet et al. (2018), who prove turning to the impact on the cryptocurrency market. We find that the "stay at home" measure and the growth of the number of confirmed cases have a negative impact on Bitcoin. In the case of France, international travel restricting measures, testing policy and the growth number of confirmed cases have a negative impact on the stock return CAC40. These measures should generate negative impacts (see Tables 7 and 8).

Figure 2 details that responses of Bitcoin to the effect of a one-standard-deviation impulse of stock return (DAX30, CAC40 and FTSE MIB) are more pronounced during COVID-19. Specifically, it declines slightly after one day and then peaks at one percentage point increase before declining. It should be noted that the Bitcoin response is not persistent. Conversely, stock return response to choc due to Bitcoin is barely significant. Besides, responses to own chocks show that an impulse to Bitcoin and each stock return causes a decline by about one percentage point over the following day. They respond strongly to their own shock. Our findings imply that the investors in Bitcoin and stock markets during the COVID-19 pandemic would face an abnormal initial impact on shock after the pandemic compared to stable periods.

5.2 Policy implications

The OECD (2020) announced that the health crisis linked to COVID-19 has severely affected the tourism sector in France. The losses are 20 billion euros in 2020, and it has lost between 70% and 80% of its turnover. Finally, COVID-19 cases are a negative sign for investors worldwide, and France was among the worst-affected countries. As for CAC40, Bitcoin is also negatively affected by international travel restricting measures. This is quite understandable since most Bitcoin transactions are for international travelers. For Germany, we find that workplace closing has a positive and significant effect on Bitcoin and DAX30 while the cancel events measure has a negative and significant effect. Besides, testing policy measures has a positive and significant effect on Bitcoin. In doing so, both Bitcoin and stock indices are influenced by governmental measures. The results are useful for portfolio diversification and risk management. Cardona-Montoyaet al. (2022) point out that the pandemic has taught us to improve biosecurity measures and that financial strength, remote working and income diversification are key factors in dealing with negative shocks. Valerio Roncagliolo and Villamonte Blas (2022) argued that the stock market index could serve as a precautionary measure against possible crises in the financial market and thus inform measures to reduce the financial stress impact of on economies.

Thus, policymakers would have to reduce uncertainties in financial markets by reducing policy inconsistencies and enhancing monetary and fiscal policy coordination that would guarantee the effective implementation of policy decisions that would reduce the impact of the pandemic on the global economy.

5.3 Future research agenda

The results are useful for portfolio diversification and risk management. Future studies may consider a larger sample covering Europe and North America. In addition, the overall level of stock market indices used could mask the potential heterogeneity of the gold hedging ability across stock market indices. Therefore, future studies could expand our analysis by considering the level of stock market indices by sector of activities. Another possible direction is to adopt the artificial neural network approach to study the relationship between cryptocurrencies and stock market indices.

6. Conclusions

Previous studies have provided strong evidence of the hedging and safe-haven properties of commodities relative to equity indices in times of stress. The unprecedented outbreak of COVID-19 has had a negative impact on human health and caused economic gridlock and uncertainty in financial markets around the world. Due to the recent evidence of a stronger impact of the COVID-19 pandemic on stock markets than previous epidemics and the lack of related empirical studies on the link between gold, crypto-currencies and stock markets, we analyse this missing insight for France, Italy and Germany before and during the COVID-19 epidemic. Specifically, we use the VAR model to understand the relationship between crypto-currencies and stock market returns before and during the COVID-19 period. The main results are summarised below:

In the Italian and French contexts and for the period from 4 January 2016 to 31 December 2019, we show the non-existence of causality between Bitcoin and the stock market index. Instead, we note unidirectional causality from oil to Bitcoin and from FTSE MIB to oil and bidirectional causality between oil and gold. In the German context, we find no causality between the DAX30 and bitcoin prior to COVID-19, suggesting their independence, while gold and oil cause Bitcoin volatility index. In contrast, for the period from 31 December 2019 to 26 February 2021, we find that things change in France and Italy as we find bidirectional causality between bitcoin and the stock market index, oil and the stock market index and bitcoin and gold. In Germany, the empirical results confirm the existence of bidirectional causality between the DAX30 and bitcoin. It is also interesting to note that gold is affected by the stock market index, bitcoin and oil.

Finally, we find bidirectional causality between the stock market index and oil, which confirms previous studies by Mariana et al. (2021). Second, we support our findings by implementing the impulse function to study both own and cross shocks for Bitcoin and each stock market before and during the global COVID-19 pandemic. The results show that Bitcoin's responses to the effect of an increase in stock market performance at one standard deviation (DAX30, CAC40 and FTSE MIB) are more pronounced during the COVID-19 pandemic. Third, we test, during the pandemic, which stock market indices and bitcoin are affected by government actions to control the pandemic via an OLS regression. We find that Bitcoin's response to the effect of an increase in stock market performance (DAX30, CAC40 and FTSE MIB) is more pronounced during the COVID-19 period.

Specifically, it declines slightly after one day before peaking at a one percentage point increase, before declining. Consequently, bitcoin's reaction is not persistent. On the other hand, the reaction of stock market returns to the bitcoin shock is not very significant. Investors are now better informed about the role of gold in hedging the risk of certain Asian stock markets, not only in normal times, but also during the catastrophic event of the COVID-19 epidemic. Therefore, the results have important policy implications for investors and authorities. The analysis highlights the importance of clarifying the link between crypto-currencies and stock markets in the short and long term in order to establish policies aimed at stabilising stock markets. In addition, they are useful for portfolio diversification and market risk management.

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