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Rethinking Financial Contagion: Information Transmission Mechanism During the COVID-19 Pandemic

Larisa Yarovaya*

Centre for Digital Finance, Southampton Business School, University of Southampton, United Kingdom

Email: l.yarovaya@soton.ac.uk

Janusz Brzeszczynski

Newcastle Business School (NBS), Northumbria University, Newcastle upon Tyne, United Kingdom;

Email: janusz.brzeszczynski@northumbria.ac.uk

John W. Goodell

College of Business Administration, University of Akron, USA

Email: johngoo@uakron.edu

Brian Lucey

Trinity Business School, Trinity College Dublin, Dublin 2, Ireland; University of Economics, Ho Chi Minh City, Vietnam; Jiangxi University of Economics and Finance, Nanchang, China.

Email: blucey@tcd.ie

Chi Keung Marco Lau

University of Huddersfield, Huddersfield, United Kingdom

Email: chi.lau@hud.ac.uk

*Corresponding author. Pre-print submitted to SSRN.

Abstract

Rapidly growing numbers of empirical papers assessing the financial effects of COVID-19 pandemic triggered an urgent need for a study summarising the existing knowledge of contagion phenomenon. This paper provides a review of conceptual approaches to studying financial contagion at four levels of information transmission: (i) Catalysts of contagion; (ii) Media Attention; (iii) Spillover effect across financial markets; (iv) Macroeconomic fundamentals. We discuss the unique characteristics of COVID-19 crisis and demonstrate how this shock differs from previous crises and to what extent the COVID-19 pandemic can be considered a ‘black swan’ event. We also summarise the main concepts, definitions and methodologies that are frequently, but inconsistently, used in contagion literature to unveil the existing problems and ambiguities in this popular area of research. Finally, we review the empirical results from the studies published during the first 2 years of the COVID-19 pandemic and identify the main strands and themes of the contagion and interconnectedness research. This paper will help researchers to conduct coherent and methodologically rigorous research on the impact of COVID-19 on financial markets during the pandemic and its aftermath.

Keywords: Contagion, COVID-19, Return and volatility transmission, Literature review, spillovers effect, Coronavirus, Black Swan event

Highlights

- This paper introduces a conceptual framework of COVID-19 contagion and other “black swan” events;
- We discuss the unique characteristics of the COVID-19 crisis in comparison to previous crisis episodes;
- Contagion literature in accordance with four levels of information transmission is reviewed.
- We argue that public attention and media are channels of contagion that should no longer be ignored;
- We also review the results from academic papers on contagion published during the first 2 years of the COVID-19 pandemic;
- Literature gaps are identified and directions for future research are discussed.

1. Introduction.

In 2020 the global economy faced unprecedented shock caused by the rapid spread of the deadly COVID-19 and associated high scale disruption to businesses and to the lives of hundreds of millions of people. The COVID-19 pandemic has been compared with the Great Depression in the 1930s in the US and the financial effects have been likened to the Global Financial Crisis of 2007-2009. The community of finance and economics scholars rapidly responded to the urgent need for research on the impact of pandemics (e.g. Goodell, 2020 Corbet et al., 2020a; Sharif et al., 2020; Szczygielski et al., 2021a and 2021b). COVID-19 can be considered a "black swan" event: a situation that has never previously occurred and which caused existing risk management models to fail to adequately evaluate the risk (Yarovaya et al., 2021). While it is difficult to predict the scale of the economic consequences of the COVID-19 crisis, we believe that previous literature already contains some answers and approaches that can be used to analyse the financial effects of the current pandemic. This paper provides, therefore, the review of key studies that analysed the transmission of the crisis shocks across borders, with particular emphasis on the channels through which it takes place. Although the available knowledge is very vast, we believe that there are several unique features of the COVID-19 spread that can help in rethinking the contagion phenomenon and developing new ways of assessing this complex and unprecedented event.

Financial market interconnectedness has been the subject of many theoretical and empirical studies and it is one of the most popular areas of research in finance. The interactions between financial markets are typically discussed in the contexts of the geography of market integration (e.g. Erb et al., 1996; Kearney and Lucey, 2004; Carrieri et al., 2007; Hardouvelis et al., 2006; Kearney and Poti, 2006; Bekaert and Mehl, 2019), globalisation (e.g., Dodge et al. 2020; Carrieri et al., 2013), international portfolio diversification (e.g. Markowitz, 1952, Adler and Dumas, 1983, Aggarwal et al., 2012), contagion phenomenon (e.g. Forbes and Rigobon, 2002; Yarovaya et al., 2016a, 2017) and the predictive power of information transmitted from various financial markets (e.g. Engle et al., 1990; Ibrahim and Brzeszczyński, 2009, 2014 and Brzeszczyński and Ibrahim, 2019), to name but a few. The determinants of financial spillovers also receive a great deal of interest from finance scholars who aim to understand which factors can explain the intensity and dynamics of spillovers across various asset classes and geographical locations. The contagion effect and increased interconnectedness between financial markets following the crisis shocks has been analysed in relation to the various crisis episodes and recessions, such as the October Crash in 1987 (e.g., Roll, 1988, 1989; Eun and Shim, 1989; Von Furstenberg and Jeon, 1989; King and Wadhani, 1990), the Mexican Currency Crisis in 1994-1995

(e.g., Calvo and Reinhart, 1996; Caramazza et al., 2004; Haile and Pozo, 2008), the Asian Crisis in 1997 (e.g., Sheng and Tu, 2000; Masih and Masih, 2001; Climent and Meneu, 2003; Khalid and Kawai, 2003; Caporale et al., 2006; Engle et al., 2012), the Russian Default in 1998 (e.g., Chen et al., 2002; Yang et al., 2006), as well as other crises. One of the largest literature strands contains analyses of contagion during the Global Financial Crisis in 2007-2009 (e.g., Zhang et al., 2013; Bekiros, 2014; Luchtenberg and Vu, 2015) and the European Debt Crisis in 2010-2011 (e.g., Petmezas and Santamaria, 2014; Albulescu et al., 2015) or both those crisis episodes. Finally, there are papers that analysed the impact of global epidemics and natural disasters. For example, Saker et al. (2004) report that stronger economic linkages between countries affect the spread of the infectious diseases. Studies by Haacker (2004); Hoffman and Silverberg (2018), Bloom et al. (2018), to name but a few, considered previous pandemics, such as Ebola, SARS, Zika and HIV. Pastor-Satorras et al. (2015) provide a comprehensive review of the multidisciplinary approaches used in the epidemic modelling, highlighting the importance of network analysis and research of the online community including social media (Twitter, Facebook) in order to establish a better understanding of the information cascade affecting the spread of the contagion diseases. Regarding the recent COVID-19 crisis, several studies addressed the economic, social, and financial effects of pandemic (e.g. Corbet et al., 2020a,b; Goodell, 2020; Conlon and McGee, 2020; Sharif et al., 2020; Yarovaya et al., 2022; Szczygielski et al., 2021a and 2021b).

The field of research reviewed in this paper is very broad, and even though it is very challenging to aggregate all useful findings reported in the literature and consider every single study published to date, we believe that our work will help to enhance the understanding of information transmission mechanisms and the channels through which they take place¹. Andersen and Bolleslev (1997) divided existing literature into three categories. The first group of studies analyse the interrelation between returns in geographically separated financial markets that trade sequentially, while the second group of studies is concerned with the lead-lag relations between two or more markets that trade simultaneously. A third group of studies investigates the role of information flow and other microstructure variables as determinants of intraday return volatility. Another classification is provided in Gagnon and Karolyi's (2006) notable literature review. First, they divided early papers on international portfolio diversification into the following three categories: i) studies motivated by the mean-variance relationship introduced by Markowitz (1952), which investigate the potential benefits of international diversification; ii) studies analysing the structural patterns in international financial market co-movements; iii) studies focusing on the lead-lag relationships between

¹ Comprehensive literature survey papers are available in each of specific literature strands, with a large number of papers cited, for example see Eichengreen et al. (1996) for comprehensive literature review of early papers on contagion, Gagnon and Karolyi (2006) for equities, Vigne et al. (2017) for precious metals, Corbet et al. (2018) for cryptocurrencies, Lucey et al. (2018) for financial integration, to name but a few.

international markets. Gagnon and Karolyi (2006) further split the third category, i.e. studies on lead-lag relationships across markets, according to data sample and data frequency employed in the analyses. In this paper, we structure the review based on each level of information transmission presented in the conceptual framework: (i) catalysts of contagion and “black swan” event; (ii) media attention; (iii) spillovers effect in financial markets; iv) contagion through macroeconomic fundamentals. This paper aims to support the academic community in developing an original and methodologically rigorous research framework for analysing the financial effects of the COVID-19 pandemic. We present a novel conceptual approach, explaining the information transmission mechanism and channels of financial contagion that is useful for COVID-19 research, but also for a broader range of “black swan” events that may occur in the future.

Based on our literature survey, it was clear, as per December 2021, scholars and analysts were still assessing several seminal questions regarding the impact of COVID-19 on financial systems. These questions include: 1) How have investors updated expectations for future long-term economic growth? 2) How have investors revised their ongoing risk perceptions of financial markets? 3) Will the global financial system have more or less predilection for contagion post the immediate COVID-19 global crisis?

Several studies consider whether COVID-19 will alter investor expectations over the long-term (Sharif, Aloui, and Yarovaya (2020)) or investigate how COVID-19 updated investor expectations. For instance, Gormsen and Koijen (2020) analyse how COVID-19 affected investors’ expectations regarding economic growth in the US, Japan and the EU using the data from aggregate stock and dividend futures markets. They find that COVID-19 has elicited a sharp decline in investor expectations for global growth. However, they also show evidence that these downward expectations may be revised into the short or medium-term future. In another example, Corbet, et al. (2020a), investigate the extraordinary drop in WTI oil prices to negative values in April 2020, finding that, contra expectations, green-energy firms concomitantly gained in value. Corbet et al. (2020a) attribute this result to investors updating expectations to consider that green-energy and non-fossil-fuel energy sources will be more likely to meet future demands as expectations for global energy usage fall.

Papers investigating COVID-19’s impact on risk perceptions include Bai et al. (2020) who identify that COVID-19, and pandemics in general, permanently upwardly impact risk perceptions. As the COVID-19 experience shows us, global macroeconomic conditions will especially impact industries dependent on global interconnections, such as transportation, tourism and service sectors (Choi (2020); Goodell and Huynh (2020); Gunay and Kurtulmuş (2021); Izzeldin et al. (2021); Ramelli and Wagner (2020); Szczygielski et al. (2021a); Thorbecke (2020). Future studies may examine whether

COVID-19 has altered risk perceptions for particular industries. Szczygielski et al. (2021a) highlight that fossil-fuel related firms were particularly impacted, while Akhtaruzzaman et al. (2020) draw distinctions, with regard to impacts, between oil suppliers and oil users. Akhtaruzzaman et al. (2021) find that the financial industry experienced more severe and rapid contagion than, in general, non financial firms. Future studies may investigate whether effects of COVID-19 on the financial firms and energy firms are due to updated expectations of future economic growth or, alternatively, updated risk perceptions for these industries.

Will the global financial system become more or less susceptible to financial contagion post COVID-19? Contagion channels were found to be more reactive across the global financial system during COVID-19 (Guo et al., 2021). But should we expect permanent increases in the response sensitivity of these channels moving forward? One the one hand, the world is now aware of how sudden and unexpected events, in a globalized market, can rapidly impact the financial system of the entire planet, and not be necessarily reasonable contained in one region of the globe (Yarovaya et al., 2021). The severity of COVID-19-induced market downturns (Ashraf, 2020); Heyden and Heyden, 2021); Zhang et al. (2020), along with their rapidity (Ali et al., 2020) has been well documented. That the downturn(s) would have been less if social distancing measures were not implemented or expected to be implemented either globally or locally in response to future pandemic outbreaks (Baker et al. (2020) is perhaps a rather moot question. Globally, with exceptions limited to Sweden, Brazil and the USA during the Trump administration, governments and societies around the world were largely committed to imposed, economically impacting, social distancing measures. Indeed, O'Donnell et al. (2021) suggest, contrary to Baker et al. (2020), that aggressive early pandemic containment measures suppressed downward falls in local markets. It is reasonable to assume that financial markets will anticipate similar global-wide actions as similar pandemics or other globally shared events threaten. Threfore, it is reasonable to expect that in the future financial contagion will be more sensitive to triggers, as the channels of global transmission have so evidently been highlighted during the COVID-19 pandemic.

Although some researchers suggest that the experience of COVID-19 may have a mitigating or insulating effect on market reactions to future pandemics (e.g., Bissoondoyal-Bheenick et al., 2020); Ru et al., (2021); Szczygielski et al. (2021a), others find that heightened interaction sensitivities were manifested during COVID-19 were not long lasting (see, e.g., Lin and Su, 2021). While Google searches and social media platforms have provided means to measure population, and more specifically, investor COVID-29 fears (e.g., Lyócsa et al., 2020); Smales, 2021; Szczygielski et al. (2021b), does the

COVID-19 experience teach us that social media platforms now have a greatly heightened role in catalyzing and promoting financial contagion? Cepoi (2020) suggests that this may be the case.

The COVID-19 pandemic has also elicited debate regarding the role of governments in controlling market contagion. De Kizys et al. (2021) suggest that government implementation of pandemic controls has a role in inhibiting market herding. Others find that during COVID-19, governments' effectiveness to steer economies was significantly curtailed (Wei and Han, 2021) or suggest a heightened role for government fiscal stimulus (Seven and Yilmaz, 2021).

The COVID-19 crisis, because of its magnitude, and arguably also considerably more impacting effect on the global financial system, i.e. even greater than the GFC (Gunay, 2021), may allow for closer identification of safe havens, allowing investors greater opportunity in the future for portfolio rebalancing in the face of future contagion catalysts—even those of less severity. Nevertheless, even with the benefit of COVID-19 as an investigation platform for safe havens, we are still far from consensus regarding which investment vehicles are safe havens. For instance, Conlon et al. (2020); Conlon and McGee (2020); Goodell and Goutte (2021a); Goodell and Goutte (2021b) all evidence that Bitcoin is not a safe haven against COVID-19 or as a diversifier for equity, while Corbet et al. (2020b); and Le et al. (2021a) cautiously evidence contrastingly that Bitcoin is a safe haven, while Iqbal et al. (2021) presents mixed results. Others identify pairings of assets that become particularly correlated during COVID-19. For instance, Sakurai and Kurosaki (2020) find that correlations between US market and oil markets greatly increased, while, somewhat differently, and intuitively surprisingly Salisu et al. (2020) evidence commodities as a safe haven for COVID-19 fear. Moreover, some other studies (e.g., Sherif, 2020) examine whether CSR or faith-based portfolios have safe haven properties.

This paper is motivated by the need to aggregate the empirical evidence on the contagion effect of the COVID-19 crisis and summarise the results of studies published during the first 24 months of the global pandemic. During this period, it became clear that the COVID-19 crisis will have strong long-term negative effects on the economy and wellbeing of people around the world. Therefore, by identifying the main strands of COVID-19 literature we aim to help academic community to further research the aftermath of COVID-19 crisis and help economies and businesses to recover from this pandemic. This paper discusses the main patterns of spillover effect between various asset classes identified in the most recent literature and explains how the COVID-19 changed the information transmission in the interconnected system of financial assets.

We begin our analysis with clarification of the key concepts and definitions currently used in the markets' interconnectedness literature, highlighting the ambiguities and lack of consistency of the

terminology in these studies. In the next step, we present the conceptual model that can be used to assess the financial effects of COVID-19 at different levels of information transmission, indicating the specific features of COVID-19 that must be considered. We further explain the framework and each of the major contagion channels providing review of the notable papers. Finally, we identify the research questions that have not been fully explored yet and require urgent attention from finance scholars and policy makers to develop effective mitigation strategies to the COVID-19 crisis. The issue of information transmission between global financial markets is often related to many disciplines, and not exclusively analysed by economics and finance scholars, therefore our review can be used as guidance for a broad range of academics, for example in management and international business fields. Furthermore, this paper can help policy makers and practitioners to enhance their knowledge of the existing approaches to contagion analysis and offers the conceptual framework that can be used by various businesses around the world.

Our paper is also motivated by a problem related to the process of new knowledge creation in the broader finance discipline. The number of papers providing similar results is growing, while the contribution of each of them naturally tends to be marginal. Lagoarde-Segot (2015) challenged finance scholars with questions about how and why financial research is conducted, highlighting the problem of paradigm unity. Although the nature of the research questions explored in this topic area often goes beyond positivist philosophical assumptions, the existing studies demonstrate no, or only weak, attempts to address these epistemological issues prior to implementing the quantitative data exercises. Consequently, there is an increasingly expanding number of research papers with very limited scientific novelty. Thus, this study also aims to highlight the phenomena that require further conceptualisation in the literature. This is particularly important considering that we are currently at the beginning of the new strand of COVID-19 research and as an academic community we need to ensure that those papers, which will be accepted and published in this area, will provide truly novel evidence rather than replicate existing previous studies but using new COVID-19 data.

Moreover, our study is motivated by another problem in the field: the lack of practical significance in published findings. Although return and volatility transmission studies have various practical implications that are also policy relevant, many papers fail to provide any specific interpretations of the empirical results that can be useful for practitioners, policy makers and the general public. Placing a greater emphasis on the real-world impact of research is critically important. The commonly used statement "the results are useful for practitioners and policy makers" is, in reality, in many papers often an overstretch, so more detailed policy recommendations and practical

implications should become a new standard in high-quality academic papers, especially addressing such urgent issues as COVID-19.

Our study contributes to the existing knowledge in a few different ways. First, this paper provides the conceptual framework explaining the necessity of assessment of the COVID-19 contagion phenomenon at four different levels of information transmission: (i) analysis of the main catalysts of contagion; (ii) transmission of information *via* international media and social media; (iii) assessing the spillovers effect in financial markets; (iv) contagion through macroeconomic fundamentals. Second, our review identifies and explains the gaps in the existing literature and research questions that require urgent attention. Third, we highlight the existing problems and ambiguities in contagion research providing useful insights for maintaining the academic integrity of COVID-19 research, which is beneficial for the community of finance scholars conducting research in this area and for those who are going to review papers or handle manuscripts as journal editors. Finally, our paper contributes to the COVID-19 literature by providing the literature survey of contagion literature available to date. It was evident that productivity of finance researchers during COVID-19 pandemic period has fallen more for women and faculty with young children. In addition, there are concerns about feedback, isolation and health that have large negative research effects (Barber et al., 2021). Therefore, the framework of assessing COVID-19 financial contagion and review of the literature presented in this study can help academic scholars to identify articles relevant for their research. Our paper offers ideas regarding research gaps that need to be addressed, hence it should help scholars to select future research agendas.

The paper is organised as follows. Section 2 discusses the main concepts, definitions and drivers of contagion literature as well as the main approaches used to analyse contagion. Section 3 describes the unique characteristics of the COVID-19 crisis. Section 4 introduces the conceptual framework that can be applied in the analyses of COVID-19 contagion. In order to aid the exposition, this review has been organized around specific themes representing different channels of information spillovers. Section 5 discusses the impact and practical implications of various studies and provides an overview of future research directions. Section 6 concludes the paper.

2. Theory development

2.1. Defining contagion

The use of the term “contagion” in analysis of spillovers of the crisis shocks across borders has never been as appropriate as in the case of the COVID-19 pandemic, because it captures the spread of the infectious disease itself, as well as the transmission of social, financial and economic impacts across borders. The term “contagion” is consistently used within this literature, however its definition varies between studies.

Allen and Gale (2000, p. 2) describe contagion as a situation when a small shock that initially affects only a few institutions or a particular region of the economy spreads to the rest of the economy and then infects the larger economic systems, and in extreme cases the crisis passes from region to region and becomes a contagion. They further emphasise that there are different channels of contagion that can be analysed to comprehensively understand this phenomenon. Calvo and Mendoza (2000) claim that informational frictions *per se* cannot produce contagion, but they can cause contagion only if they are combined with particular institutional or regulatory features of financial markets. Kyle and Xiong (2001, p. 1402) describe contagion as a rapid spread from one market to another of declining prices, declining liquidity, increased volatility and increased correlation associated with the financial intermediaries’ own effect on the market in which they trade.

Forbes and Rigobon (2002) criticized the mainstream approach to measuring financial contagion as a comparison of the correlation between stock markets during the stable period to that during the crisis. According to the common understanding of contagion, the significant increase in cross-market correlation during the period of turmoil constitutes contagion. Therefore, if markets were already highly correlated before the crisis then a contagion does not necessarily take place. Thus, contagion implies changes in fundamental linkages between markets, where correlation coefficient is not able to capture them, since the correlation coefficient is conditional on market movements over the observation period and unadjusted estimates may be biased upward. Alternatively, Bekaert et al. (2005), who used an asset pricing approach to model the shock and correlation structure around crisis periods, defined contagion as the correlation among residuals of a two-factor asset pricing model. They claim that an increase in correlation between returns during the crisis can be the consequence of their exposure to a common factor.

The concept of contagion has been defined as “the significant increase in cross-market linkages after a shock” (Forbes and Rigobon, 2002, p. 2224). Forbes and Rigobon (2001) use the

alternative term “shift-contagion”, or “pure contagion”, which means that contagion arises from a shift in cross-market linkages and gives a straightforward framework for assessing contagion effect. However, Morales and Andreosso-O'Callaghan (2014) argue that the impact of the Global Financial Crisis on cross-markets interdependencies across various regions could be defined as “spillover effect”, rather than contagion, clarifying the difference between these two terms. This view on contagion is supported in an early paper by Eichengreen et al. (1996) who claim that contagion exists if the probability of a crisis in one country increases conditionally on the occurrence of a crisis elsewhere (after allowing for the standard set of macroeconomic fundamentals). Furthermore, a similar definition of contagion has been used by Edwards (1998) and Eichengreen and Rose (1999). An alternative viewpoint was provided in studies by Wolf (1999), Masson (1999, 2004) and Pretorius (2002) who claimed that the term contagion can be used to describe only those transmissions of crises that cannot be identified with observed changes in macroeconomic fundamentals. For example, financial contagion according to Masson (1999, 2004) involves changes in investors' expectations and, consequently, market behaviours that are not related to changes in a country's macroeconomic fundamentals.

Jokipii and Lucey (2006, p. 9) provide another explanation of contagion phenomenon associating the term contagion with “a structural break producing an intensification of relationships during a period of turmoil”. In the debate about differences in the terms “contagion” and “interdependence”, they considered contagion as a dynamic process, i.e. changes in the degree of co-movements during a period of turbulence, while interdependence is assumed to be “a divergent phenomenon whereby stability persists, and no change in the relationships between markets is evident” (Jokipii and Lucey, 2006, p.8). They proposed two ways as to how the contagion phenomenon can be explained: the fundamental causes and investor behaviour theories. The fundamental reasons why contagion may occur include: i) a common shock, which can result in large capital outflows from the emerging markets affecting the degree of co-movements, for example a major economic shift in industrial countries, a change in commodity prices or a reduction in global growth (p. 9); ii) changes in trade linkages during the crisis due to the reduction in demand affecting the trade balance and other fundamentals; iii) strong intra-regional financial linkages causing the spread of crisis shock from one country to another within the same region through trade credit reductions, direct foreign investment and other capital flows (Jokipii and Lucey, 2006, p.9).

Alternatively, the contagion can be explained using investors behaviour theories. For example, a crisis occurring in the domestic market may cause a liquidity problem for a large group of investors and cause them to sell the foreign assets from their portfolios causing, in turn, a fall in the prices of

securities in the foreign markets. Similarly, the investor behaviour can be understood through risk aversion bias. Evaluation of the risk of the portfolio against the same benchmark may force investors to sell their holdings in emerging markets simultaneously during the crisis, which can destabilise the market of the other country without any fundamental reasons. Finally, Jokipii and Lucey (2006) claim that information asymmetries and imperfect information may affect an investor's behaviour due to a belief that a crisis can simply spread to neighbouring markets, forcing numerous investors to leave the market without proper evaluation of the macroeconomic fundamentals of that market.

A similar explanation of contagion presented in the study by Haile and Pozo (2008, p.574) contained a review of various definitions of contagion and a variety of economic models explaining how a crisis that occurred in one country can spread to other countries. They also provided two major categories of models explaining contagion. The first category is named "fundamentals-based contagion", which includes models that assume that crises spread through changes in macroeconomic fundamentals caused by shocks from the country where a crisis originally occurred. The second category includes models explaining contagion through changes in the behaviour of investors. In this case, crises spread from one country to another following the information flows transmitted across borders through various channels affecting the behaviour of financial agents rather than the macroeconomic fundamentals of the specific country.

Both fundamental and behavioural explanations are very useful in understanding the contagion phenomenon. They support the approach of Forbes and Rigobon (2002), who critiqued studies that employed cross-market correlation coefficients to test contagion, due to the fact that a conditional correlation coefficient can increase after a crisis episode. This effect is mainly due to the increase in market volatility rather than any unconditional correlation across markets. Thus, the increase in cross-market correlation coefficient is a biased measure and it is not possible to prove either contagion or spillover effect across markets by relying on it. The terms "stock market interconnectedness", "stock market interdependencies", "stock market interlinkages" or more generic term "connectedness" can be used as synonyms to describe the linkages across stock markets that can be measured by conditional correlation coefficients. However, "contagion" and "spillover effect" are more specific terms and they cannot be used interchangeably. Particularly, analysis of contagion requires the application of more sophisticated techniques and approaches exceeding the analysis of cross-market correlation. In the COVID-19 literature, the term "connectedness" tends to be employed more frequently (e.g., Lin and Su, 2021; So et al., 2021; Hasan et al., 2021; Katsiampa et al., 2021), while the methodological approaches used in these papers could either assess "interconnectedness", i.e. correlation patterns, or "spillover effect", i.e. causal patterns, between

financial markets, where both would effectively employ very narrow definition of “shift-contagion”, as it is explained by Forbes and Rigobon (2002).

2.2. The main drivers of contagion literature and the approaches employed.

The background literature regarding the drivers of contagion is vast, however while analysing the papers published since Markowitz (1952) and Tobin (1958) seminal studies, it can be observed that the development of the literature in this field has been dominated by several main forces. Firstly, the globalisation of the world economy became the main driver and historically the most important underlying force (e.g., Calvo and Mendoza, 2000). The second reason is the integration of financial markets at the institutional level, such as the creation of stock trading platforms for global trading, mergers of stock exchanges as institutions, to name but a few (Kearney and Lucey, 2004; Gai and Kapadia, 2010). The third driver is the emergence of new asset classes and markets, such as financial derivatives, commodities, exchange-traded funds (ETFs) and, more recently, cryptocurrencies (Corbet et al., 2018). The fourth force is an increase in the speed and ease of gathering information about global events that changes the risk perceptions of investors around the globe *via* a variety of media channels. While early papers analysed the impact of traditional mass media (e.g. magazines, newspapers, reports) and television, later with the emergence of the Internet and the increased amount of electronic media sources this field has significantly expanded. More recently, social media have become one of the key sources of information and the main channel of its transmission across borders. Thus, media sentiment extracted from social media and online search engines became a popular variable to include in analysis of market interactions. The fifth driver is the “black swan” event itself that causes sever disruptions of financial services, such as innovation, new technology or crisis shocks, originating a new stream of academic literature addressing the issues of connectedness around these key episodes. Notable examples are the Global Financial Crisis of 2007-2009, Dot.com bubble effect, blockchain technology and, more recently, COVID-19 pandemic. We also call it the *“catalyst”* of contagion and it can, technically, be any main driver of contagion, which can have its own unique features and variables that characterise a specific contagion event.

The drivers of contagion literature also influenced the approaches used by the researchers to understand the financial contagion as a phenomenon. For example, Allen and Gale (2000) specifically focused on just one channel of financial contagion, which promotes the banking crisis, and omitting other propagation mechanisms, such as international currency markets and transmission of signals and expectations in financial markets. Alternatively, Galvo and Mendoza (2000) considered different channel of financial contagion, i.e. arguing that globalisation weakens incentives for gathering costly

information and promotes herding among investors, which consequently exacerbates contagion. They considered contagion from the perspective of global portfolio diversification claiming that contagion is driven by fixed information costs and short-selling constraints. Kyle and Xiong (2001) presented a continuous-time model in which risk aversion is based on a wealth effect of financial intermediaries. They used two risky assets and three types of traders, i.e. noise traders, long-term value-based investors and short-term convergence traders, to demonstrate that wealth effect leads to contagion, and explain the mechanism behind it. Kodres and Pritsker (2002) focused on contagion through cross-market rebalancing and argued that investors transmit idiosyncratic shocks from one market to others by adjusting their portfolio's exposures to shared macroeconomic risks. They propose that changes in information asymmetries during the turbulent periods may help to explain the time-series patterns of contagion. Eichengreen et al. (1996) discussed various channels of contagion in foreign exchange markets and highlighted the role of trading linkages between countries and speculative attacks on the international competitiveness of the countries. In their seminal paper, Forbes and Rigobon (2002) discuss three different mechanisms of international shock propagation: (i) aggregate shocks which affect the economic fundamentals of more than one country; (ii) country-specific shocks which affect the economic fundamentals of other countries; (iii) shocks which are not explained by fundamentals and are categorized as pure contagion. Using similar critique of correlation coefficient as main measure of contagion as Boyer et al. (1999), they report absence of contagion and argue for strong interdependence between markets during the 1987 crash, East Asian and Mexican crises. Gai and Kapadia (2010) introduced contagion model in arbitrary financial networks, claiming that while the interconnectivity may reduce the probability of contagion, it can increase its intensity when the problems occur. Nier et al. (2007) further demonstrated that in banking systems the effect of the degree of connectivity is non-monotonic and a small growth in connectivity increases the contagion effect, however after a certain threshold value the connectivity improves the ability of the banking system to absorb shocks.

Bekaert et al. (2011) examined six different categories of international information transmission channels: (i) international banking sector links at the country level; (ii) country-specific policy responses to the crisis; (iii) trade and financial linkages; (iv) information asymmetries and informational flows; (v) domestic macroeconomic fundamentals and (vi) "investor contagion" caused by herding behaviour. They proposed an international three-factor model including the US factor, a global financial factor and domestic factor. Two hypotheses have been tested: first, the 'globalization hypothesis', i.e. countries that are highly integrated globally, through trade and financial linkages, are more susceptible to the crisis shock and, second, "wake-up call" hypothesis, which proposes that a crisis initially restricted to one market segment or one country provides new information that may

prompt investors to reassess the vulnerability of other market segments or countries, which triggers the spread of the crisis across markets and borders (Bekaert et al., 2011, pp. 2-3). Bekaert et al. (2011) analysed information transmission across 55 equity markets during the GFC and provided empirical support for the wake-up call hypothesis as well as some limited evidence in support of the globalisation hypothesis.

Ross (1989) showed that in absence of arbitrage, the volatility in asset returns depends on the rate of information flow, which means that information transmitted from one market can generate an excess of volatility in another market.

Engle et al. (1990) incorporated the ARCH approach to the analysis of transmission of information contained in the first and second moments of stock market returns and the impact of those returns in other markets. They used the astronomical analogy of a meteor shower to describe the process of information transmission across global markets. The analogy of heat waves phenomenon has been further used by Engle et al. (1990) to postulate that financial market volatility depends only on its own past shocks. The phenomenon of the meteor shower is widely discussed in astrophysics and astronomy literature and comes in the form of a parallel stream of meteoroids entering the Earth's atmosphere at high speed. It is called a "shower", because from the viewpoint of the observer on Earth, it can appear that it has been generated from one point in the sky. The heat waves phenomenon describes an abnormal increase in temperature in one particular country relative to the standard temperature levels, which lasts from a few days up to several weeks. Using the above two analogies, Engle et al. (1990) introduced the meteor shower hypothesis which assumes positive volatility spillover effects across markets and, alternatively, the heat wave hypothesis, which assumes that volatility exhibits only country-specific autocorrelation. In other words, the meteor shower hypothesis postulates that a volatile day in one market is likely to be followed by a volatile day in another related market, while the heat wave hypothesis proposes that a volatile day in one market is likely to be followed by a further volatile day in the same market. The heat wave hypothesis assumes that volatility is susceptible to past shocks in the same market and that it is independent from volatility in another market. These effects are equivalent to the notions of inter-regional and region-specific information transmission effects (more detailed discussions and the results illustrating those phenomena are presented in the studies e.g. by Melvin and Melvin, 2003, Ibrahim and Brzeszczyński, 2009 and 2014, Brzeszczyński and Ibrahim 2019; Yarovaya et al. 2016a,b, among others).

Bae et al. (2003) introduced the approach for measuring financial contagion using the coincidence of extreme return shocks across countries within a region and across regions. They adopted multinomial logistic analysis that been extensively used in epidemiology research on

contagion diseases, for example by Hosmer and Lemeshow (1989), to analyse the transmission of information across regions and within regions. Their paper reports strong evidence of inter-regional contagion. Diebold and Yilmaz (2009; 2012) proposed a quantitative measure of interdependence between returns and volatilities and argued that these two variables should be analysed separately from each other. Return and volatility spillover indices analysis by Diebold and Yilmaz (2012) became one of the mainstream approaches for measuring spillover effect between markets. For example, Yarovaya et al. (2016a) investigated intra- and inter-regional returns and volatility spillovers across 10 developed and 11 emerging markets in Asia, the Americas, Europe and Africa and provided the evidence that markets are more susceptible to domestic and region-specific volatility shocks than to inter-regional contagion. This approach has been employed widely in contagion literature and, in particular in the papers cited above, it utilises a narrow definition of financial contagion and omits the transmission of information *via* macroeconomic fundamentals. The increase in spillovers indices during the crisis episode indicates the presence of contagion.

3. What is unique about the COVID-19 crisis?

COVID-19 is obviously enormous in its implications. The US, for instance, is undertaking a \$2.2 trillion bailout (*versus* a \$750 billion package during the GFC)². However, as recently noted by Goodell (2020), unlike global nuclear conflict, or perhaps the larger consequences of climate change, COVID-19 is both massive and immediate and yet survivable and manageable. Nevertheless, to date, the pandemic has been lasting for over 24 months and socio-economic consequences are widespread. The first COVID-19 vaccine was approved in December 2020, i.e. 12 months from the first appearance of the virus, however the vaccine supply and demand disparities made recovery from crisis much slower than it was expected. Apart from drastic rate of loss of lives due to the virus and pressures on healthcare system, the COVID-19 had devastating impacts on the economy and financial well-being of nations. Understanding the impact of COVID-19 on financial markets therefore will be particularly important moving forward for investors, businesses, and policy makers. It is very likely that the next time when there is a sudden appearance of a contagious respiratory illness, there will concomitantly be a substantial global financial market reaction. Certainly COVID-19 will shape future investigations of tail risk and financial markets (see, e.g., Kwon, 2019).

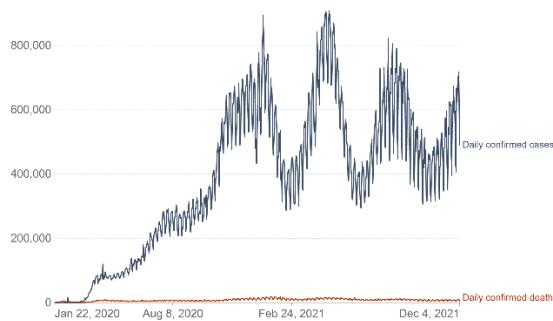
² For further information about the policy response please see International Monetary Fund COVID-19 Policy Tracker: <https://www.imf.org/en/Topics/imf-and-covid19/Policy-Responses-to-COVID-19>

The COVID-19 pandemic has several unique characteristics that distinguish it from previous crises and which open a new avenue for research of financial interconnectedness and contagion.

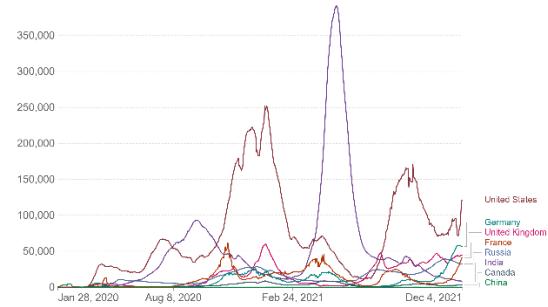
First, it is possible to timestamp the crisis and identify its main catalyst. With COVID-19 the main driver of contagion is clear: the spread of a deadly contagious disease across borders. The first spike of the coronavirus has been detected in China, in Wuhan City in Hubei Province, on 31st December 2019, whereas on the 3rd of January 2020 the Chinese authorities reported 44 confirmed cases of unknown pneumonia. On the 5th of January 2020 the World Health Organisation published its first report of the outbreak of an unknown virus, and the genetic sequence of COVID-19 was first published on the 12th of January 2020. Figure 1 below presents key COVID-19 data from January 2020 to December 2021, such as number of confirmed cases globally, daily confirmed new cases and share of fully and partially vaccinated against COVID-19 people across countries. These variables have been used frequently in the COVID-19 contagion literature to identify different waves of the COVID-19 pandemic and establish observation periods, as well as determinants of the spillover effect between financial markets.

Figure 1. Key statistics of COVID-19 pandemic

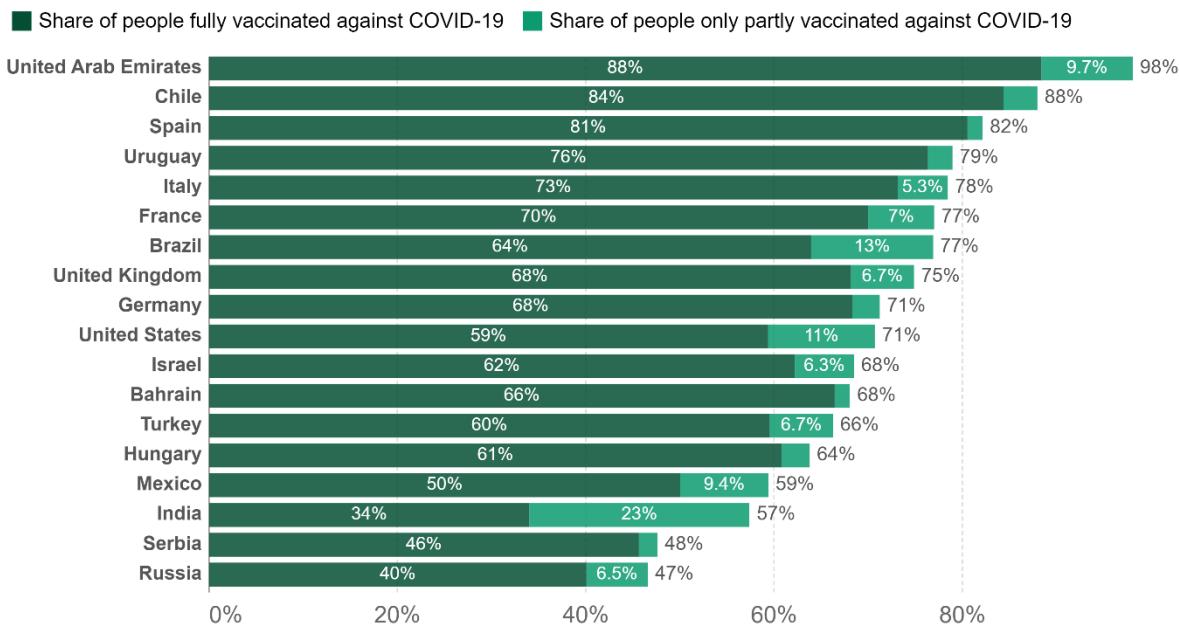
(a) Daily confirmed COVID-19 cases and deaths, World



(b) Daily confirmed new COVID-19 cases, selected countries.



(c) Vaccination rate, December 2021



Source: All data retrieved from OurWorldInData.org/coronavirus, accessed on 5 December 2021.

In analysis of financial contagion caused by COVID-19 virus spread, there is one clear catalyst of contagion that can be precisely timestamped. This feature distinguishes the COVID-19 crisis from the majority of other well-researched economic and financial crises in the past, e.g. the Global Financial Crisis of 2007-2009 (GFC). Many papers that analysed contagion during the GFC emphasize that it is hard to identify the precise beginning and the end of it, while the timelines and crisis periods

vary substantially across those studies. In case of COVID-19 pandemic, we can use a clear timeline of virus spread across regions and countries and also keep a record of any relevant government responses to the pandemic. This accuracy in timing, which is quite unique and unprecedented, provides researchers with numerous opportunities to detect contagion in a much more accurate way that was not possible for previous crisis shocks. While it is still challenging for early COVID-19 papers to detect/predict the precise end of the pandemic and related economic downturn, the impact of vaccination on spread of virus and decline in new confirmed cases across countries can indicate the “beginning of the end” of the pandemic (e.g. Rouatbi et al., 2021; Kizys et al., 2021). Consequentially, the ease of restrictions, i.e. travel bans, social distancing, lockdowns, can manifest the beginning of recovery stage when the economy should start going back to normal. David et al. (2021) examined the impact of various pandemics (i.e. the COVID-19, EBOLA, MERS and SARS) on several stock exchange indices (i.e. Dow Jones, S&P 500, EuroStoxx, DAX, CAC, Nikkei, HSI, Kospi, S&P ASX etc.) and concluded that they experienced speedy recovering after the outbreak of those pandemics, however with the exception of COVID-19.

Second, in case of COVID-19 we have one unique and distinctive cause of the crisis and the catalyst of the contagion. In the analysis of the East Asian crisis, Forbes and Rigobon (2002) highlighted that one of the main challenges to detect contagion is the lack of clear catalyst driving this turmoil. In comparison to previous crises, for example the GFC, there were many structural problems in the economy, such as the increasing, and proportionately shorter maturity, borrowing by banks to buttress a credit boom and the overall leverage position of companies and households. However, in 2020 we could not observe other typical early warning signals of financial crisis. Therefore, this contagion shock has one single cause, i.e. COVID-19, which encourages the use of different approaches to contagion research in comparison with the GFC studies. Particularly, in analysis of contagion, there are several unique variables that can be included representing the speed of the contagion across borders, for example number of confirmed cases, number of deaths as well as variables that determine the resilience to COVID-19 contagion, such as readiness of health care system to respond to the pandemic, population density and overall population demographics and morbidity. However, considering the financial effects of the COVID-19 pandemic, we cannot ignore the other major shock that occurred during the same period, for example the oil price crash. According to the recent paper by Sharif et al. (2020), oil price volatility shock affected the US stock markets more severely than the COVID-19 pandemic itself.

Third, the speed of the transmission of the crisis and recovery are also unique. As highlighted by Harvey (2020), we can expect not only quicker escalation of the crisis, but also quicker recovery from the COVID-19 pandemic, since a temporary shock to the economic fundamentals can be followed

by a rapid jump back to normal. Indeed, the dramatic increase in the unemployment rate caused by the COVID-19 crisis was mainly due to the lockdowns and social distancing and when all SMEs will re-open after the lockdown, we should expect to observe a drop in unemployment in a relatively short period of time.

Finally, during the past crises episodes, the social media played a much less important role in forming public opinions, providing pressure on government and shaping investors' expectations. Therefore, in comparison with previous approaches to financial contagion, transmission of the information *via* media channels will be more significant for facilitating the response to the current COVID-19 crisis.

Therefore, in the recent financial contagion literature the scholars actively use COVID-19 statistics not only as determinants of the spillover effect, but also to rationalise the selection of observation periods. Very popular approach in contagion literature is to analyse the interconnectedness or spillover effect in two different periods: pre-COVID and during COVID. However, the selected "end" of the COVID period will often correspond with the time when data have been collected. Another approach is to ensure equal number of observations in pre-COVID and during COVID periods. For example, Katsiampa et al. (2021) analyse the high-frequency connectedness between Bitcoin and thirty digital assets and split their sample period into two sub-periods of equal size: from 1st January 2019 to 31st December 2019 (pre-COVID period) and from 1st January 2020 to 31st December 2020 (COVID-19 period). Their findings show significant differences in the patterns of interconnectedness between digital assets. Specifically, Katsiampa et al. (2021) report that Ethereum became much more influential cryptocurrency during the COVID-19 pandemic, while before COVID the role of cryptocurrency market leader has been played by Bitcoin. Alternatively, Yousaf and Yarovaya (2021) specify a longer COVID-19 period from January 2020 to July 2021, hence they further adjust the length of pre-COVID period and utilise data from May 2018. Their results show that the dynamic return and volatility connectedness between new NFTs and DeFi assets with conventional cryptocurrencies become higher during the COVID-19 pandemic. Different approach has been used by Mirza et al. (2022) who divided COVID-19 period into 6 different sub-periods based on the COVID-19 spread statistics: stages 1-5 comprising observations from the year 2020 (January 1 - March 19; March 20 - May 11; May 12 - June 14; June 15 - September 1; September 2 - December 31) and stage 6 covering the period from January 2021 to May 31 2021. Their results indicate that Islamic equity funds are more resilient to COVID-19 shock since they outperformed non-Islamic peers during the peak months of the pandemic.

While COVID-19 is unique in terms of how it has manifested as a global health and economic crisis, it should not have been unexpected. Neither should we assume that similar events in the future are so unlikely that we should not be concerned. It is noteworthy that there have been many recent cases of infectious disease breakouts that could well have turned into pandemics, although they did not. Thomas (2018), for instance, describes a recent lethal outbreak of the highly contagious respiratory disease Nipah in the Kerala area of India. In this case, a larger global health issue was averted by a remarkably fast response from public health workers. This has not been the only outbreak of Nipah. Further, as listed by Bloom, Cadarette and Sevilla (2018), other recent contagious disease outbreaks include Middle East Respiratory Syndrome corona virus (MERS), Zika, Severe Acute Respiratory Syndrome (SARS), Rift Valley fever and others. According to the Global Preparedness Monitoring Board (2019), during 2011–2018 the World Health Organization tracked 1,483 epidemic events in 172 countries.

Research on contagion is undoubtedly vast and many useful approaches have been proposed to analyse the information transmission mechanisms during the previous crises. However, the public health emergency situations leading directly to financial and/or economic crises, such as global or regional pandemics etc. (which include most notably: Ebola virus in 2014, SARS virus in 2003 and the earlier occurrence of the Spanish flu in 1918), have been largely under-researched in previous finance literature. The existing studies have focused predominantly on the impact of pandemic related news on stock price reactions. For example, Funck and Gutierrez (2018) investigated the effects of Ebola news coverage on the performance of stocks covered by the media. Ichev and Marinč (2018) further analysed the relationship between the geographic proximity of information related to the Ebola outbreak and the US stock returns concluding that the Ebola crisis had stronger influence on stocks of firms with operations that were geographically closer to West Africa from where the Ebola virus originated. In an earlier study, McTier et al. (2013) assessed the US stock market responses to flu outbreaks and concluded that higher cases of flu were linked to changes in trading activity as well as affected stock returns and their volatility.

New research, which started to emerge after the COVID-19 pandemic began at the end of 2019, includes such studies as Ramelli and Wagner (2020), who explored a link between the differences in the responses of the financial market in the US to the COVID-19 outbreak and to the Asian financial crisis in 1997 and an increase of globalisation in the world economy, or Gormsen and Kojien (2020), who investigated the response of the stock market to different news within the sequence of events following the initial outbreak of COVID-19 in China and its subsequent spread around the world. Moreover, Alfaro et al. (2020) examined the relation between stock market price variability and the revisions of predicted infections from the epidemic model. They found that the

volatility of US stock returns was decreasing as the trajectory of the pandemic's development was becoming clearer.

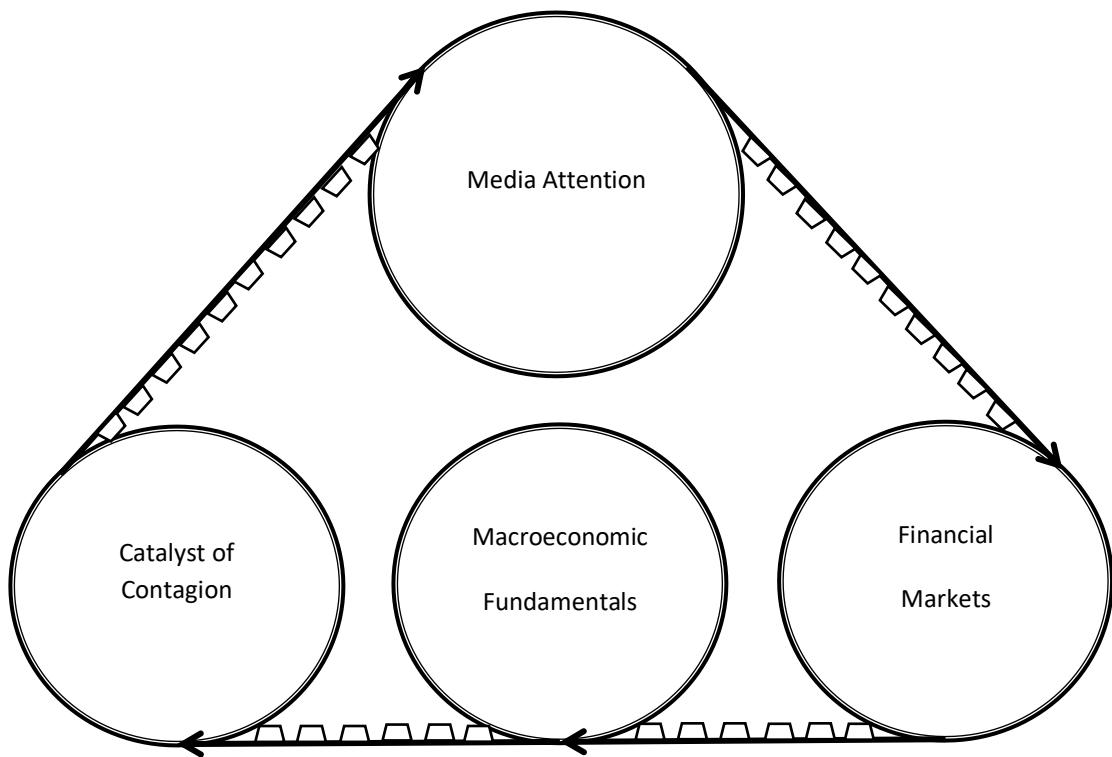
4. Conceptual Framework for analysis of COVID-19 contagion.

While there are numerous channels of financial contagion explored in the literature, the unique characteristics of the COVID-19 pandemic demonstrated that existing contagion frameworks might be too narrow to fully understand the information transmission mechanism during this crisis. The main criticism of past frameworks, however, is the period when these approaches have been introduced. The majority of popular conceptual models of financial contagion were developed before the wide adoption of internet, while other theoretical models have been introduced before the global increase in the use of social media as a networking and information channel. Thus, the speed of the COVID-19 crisis spread can be determined not only by the increased economic and financial ties between countries, but also by the speed and ease of transmission of information about the pandemic through various media channels.

We suggest that contagion can be assessed by analysing four main channels of information transmission driving the spread of the crisis across region and countries: (i) analysis of the main catalysts of contagion; (ii) transmission of information *via* international media and social media; (iii) assessing the spillovers effect in financial markets; (iv) contagion through macroeconomic fundamentals.

Figure 2 presents the information transmission mechanism and how information can flow from one level to another.

Figure 2. Information transmission mechanism during the COVID-19 pandemic



The interconnectedness between markets and regions is present in crisis or tranquil periods of investigation and there are multiple channels through which information transmits across borders. However, contagion phenomenon manifests itself when the specific crisis originating in one country spills over to other countries and regions causing the diverse economic, financial and social impacts, whereas the increased connectedness between financial markets is only one level of those processes, and all fours levels have to be assessed to gain a more comprehensive understanding of the contagion.

4.1 Catalyst of contagion

The first level is analysis of the main catalyst of contagion, i.e. the variable related to the specific event that played a catalysing role in starting the contagion. The “black swan” metaphor can be used in finance to describe the unprecedented shocks that occur rarely and cause major effects on financial markets and economy, changing the expectations and risk perceptions, and causing the failure of standard tools and techniques to predict the dynamics of the crisis. For example, COVID-19

can be considered a black swan event (Yarovaya et al., 2021), because the spread of the pandemic resulted in extreme measures of social distancing and government restrictions on a scale that has not occurred in the recent history.

The black swan metaphor has been widely used in finance literature beginning with Taleb (2007) who claims that the event can be considered as a black swan if it simultaneously has the three following attributes: (i) it is an outlier, i.e. it lies outside the realm of regular expectations, because nothing in the past can convincingly point to its possibility; (ii) it carries an extreme impact; (iii) in spite of its outlier status, human nature makes us concoct explanations for its occurrence *ex post*, making it explainable and predictable. This metaphor has been employed previously with regards to the Global Financial Crisis in 2007-2019 (Hilal et al., 2011; Singh et al., 2013; Bekiros et al., 2017), which was the strongest global economic shock after the Great Depression. However, it is not only global crises that have been considered black swans and this metaphor has been used in studies of technological innovations (Krupa and Jones, 2013), increase in the US LIBOR spread (Taylor and Williams, 2009; Olson et al., 2012), China's stock market crash of 2015 (Lin and Tsai, 2019) or federal policy change (Wang et al., 2019). More recently, Yarovaya et al. (2022) analysed whether COVID-19 can be considered a black swan effect by examining the response and recovery of 15 equity indices, four bond benchmark indices, nine precious metals and three popular cryptocurrencies: Bitcoin, Ethereum and Litecoin using quantile autoregression model and quantile unit root test by Koenker and Xiao (2006). The results evidence a heterogenous reaction of financial markets to the COVID-19 shock, which implies that the impact of the pandemic varies across different asset classes. Therefore, response to the COVID-19 pandemic from traditional financial markets can be compared to previous crisis shocks and pandemics/epidemics, or natural disasters, while for new financial asset classes, such as cryptocurrencies, this crisis will be the first in the history of these instruments and truly unprecedented, making the use of the black swan metaphor even more appropriate. The probability of black swan events and their predictability have been discussed in the previous literature, for example, in Alekserov and Egorova (2012) and Flage and Aven (2015), among others.

Ashraf (2020) analysed the stock markets' response to the COVID-19 pandemic and found that stock market returns declined as the number of confirmed cases increased. The reactions were stronger when the growth in number of confirmed cases is considered compared with the growth in the number of deaths. Markets responses were also most pronounced during the early days of confirmed cases and later between 40 and 60 days after the initial confirmed cases were reported. Overall, Ashraf (2020) results show that stock markets reactions were quick, but they also subsequently varied over time depending on the stage of outbreak. Ali et al. (2020) reported that

COVID-19 has quickly evolved from a provincial health scare to a global meltdown and investigated the reaction of financial markets globally in terms of their decline and the respective changes in volatility as the COVID-19 epicentre moved from China to Europe and then to the US. Their findings suggest that as the original source location in China has stabilized, the global markets have gone into a freefall, particularly in the later phase of the spread, and even the relatively safer commodities have suffered as the pandemic moved into the US.

Zhang et al. (2020) mapped the general patterns of country-specific risks and systemic risks in the global financial markets following rapid spread of the COVID-19 pandemic. They reported that both COVID-19 infections and deaths contributed to a rise in systematic risk and that the individual stock market reactions depend on the severity of the outbreak. Zaremba et al. (2020) explored the stringency of policy responses to the COVID-19 pandemic in 67 countries around the world in order to answer the question whether the governments interventions, which aimed at curbing the spread of the COVID-19 virus, had an impact on the stock market volatility. They report that non-pharmaceutical interventions significantly increased equity market volatility and that this effect was independent from the role of the coronavirus pandemic itself. Moreover, the two types of actions that were usually applied chronologically particularly early, i.e. information campaigns and public event cancellations, were the major contributors to the growth of volatility.

Alexakis et al. (2021) estimated the effect of COVID-19 lockdown measures on 45 stock market indices. They found evidence that the intensity of lockdown measures negatively affected the stock returns and further suggested that future research agendas could include the investigations of social trust, costs of capital and political stability. O'Donnell et al. (2021) examined the linkage between COVID-19 and the prices of six international stock indices from China, Italy, Spain, the United Kingdom, the United States and the world index. They concluded that changes in stock prices can be explained by the growth rate in COVID-19 cases. However, they also evidenced that the Chinese SSE 180 index and the MSCI World index prices were not significantly affected by COVID-19 pandemic. Matos et al. (2020) reported the results showing short-term co-movements between S&P 500 index returns and the COVID-19 cases in the US, as well as deaths in France, Italy, US and across the whole world, during the COVID-19 pandemic, while the S&P 500 returns had longer term coherence with deaths in the UK.

Ramelli and Wagner (2020) measured how stock prices reacted to COVID-19 virus pandemic and found that initially the internationally oriented firms, especially those which were more exposed to trade with China, substantially underperformed. As the virus spread to Europe and to the US, the corporate debt and cash holdings emerged as important value drivers, which were relevant even after the Fed intervention. They also report that the consumer services and energy sectors were the most

severely impacted in the US economy during the initial phase of COVID-19 outbreak. Gunay and Kurtulmus (2021) examined the effect of COVID-19 social distancing on the US service sector and they found evidence that entertainment and airline industries were mostly affected by the COVID-19 pandemic. Fahlenbrach et al. (2021) investigated the value of financial flexibility when revenues stopped during the COVID-19 pandemic. Their findings suggest that firms with high financial flexibility suffered from stock price drop that is 26% lower than in case of firms with low financial flexibility. This effect persisted even when the stock prices bounced back. Li et al. (2021) argue that corporate culture is an intangible asset capable to counteract such uncertainty as in case of the COVID-19 pandemic. Using 40,927 COVID-19-related paragraphs in 3,581 earnings calls over the period from January 22, 2000 to April 30, 2020, they found that the firm-level measures of exposure and responses related to COVID-19 for 2,894 US firms indicated that companies with strong corporate culture outperformed others during this initial COVID-19 crisis period. Qiu et al. (2021) report that corporate social responsibility (CSR) activities can have positive effect on stock returns of hospitality firms during the COVID-19 pandemic.

Ding et al. (2021) investigated the linkage between corporate characteristics and the reaction of stock returns to COVID-19 cases using data from more than 6,700 firms across 61 economies. The adverse effect of COVID-19 was weaker in case of stock returns among firms with larger profits before the year 2020. Firms with less exposure to COVID-19 through global supply chain and customer locations were less affected. In addition, stock returns of firms controlled by families, large corporations and government did perform better during the COVID-19 pandemic. Corbet et al. (2021) focused on companies, which shared their corporate identity with aspects of the rapidly evolving COVID-19 virus and found the existence of sharp, dynamic and new correlations between firms related to the term ‘corona’ outside of the pre-existing interrelationships. Rizvi et al. (2020) analysed the impact of COVID-19 crisis on performance of 5342 listed non-financial firms across 10 EU member states and showed a significant loss in valuations across all sectors due to a possible decline in sales and increase in cost of equity. Their results evidence that pandemic is the main driver behind the shareholder value destruction.

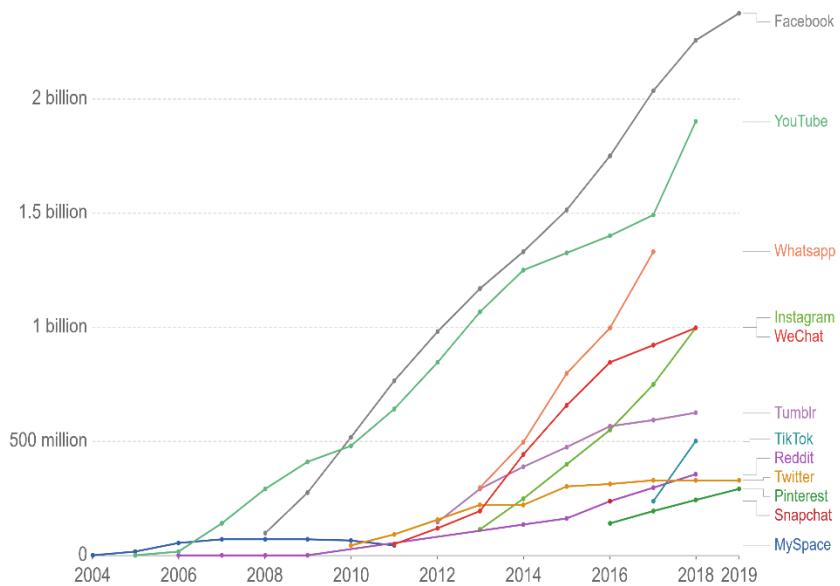
4.2. Media Attention

The second level is contagion *via* various media channels. The black swan event attracts attention from the public and the media, resulting in higher social media engagement, as well as in the official mass media, such as television, newspapers, magazines and online information portals.

Thus, information regarding the catalyst of contagion is quickly transmitted and widely cascaded. This channel of contagion plays a key role in forming actual expectations and public opinions, and, more importantly, it exerts pressure on governments and institutions to respond to the crisis shock. Interestingly, the term “contagion” has also been used in the context of emotional contagion in psychology, referring to how both positive and negative emotions can be contagious in humans (e.g. Hatfield et al., 1993; Rozin and Royzman, 2001), however the term emotional contagion is not yet widely used in the financial contagion literature. The bridge between psychological biases and emotion in the finance world is positioned within the behavioural finance literature in studies of information cascades and herding behaviour. In particular, regarding COVID-19, herding behaviour in cryptocurrency markets was analysed by Yarovaya et al. (2021) and their results suggest that herding is conditioned to upward and downward market movements, but not necessarily amplified by the COVID-19 pandemic.

The speed of global response to the COVID-19 pandemic is one example of the importance of the media as a main channel of information transmission across borders. The way that the governments reacted to tackle the crisis, and how quickly issued relevant directives across the globe, accelerated the financial contagion. Usage of social media started to rise in the early 2000s, and from 2004 there has been a substantial global increase in social media users (see Figure 3). However, the majority of the existing conceptual frameworks used to analyse financial contagion do not consider how the social media platforms affect the speed of information transmission, and, in particular, how they cause changes in investors’ sentiment. We argue that this channel of contagion should no longer be ignored, but should be considered in conjunction with other channels of information transmission.

Figure 3. Number of people using social media platforms from 2004 to 2019



Source: Statista and TNW (2019), accessed on 5th May 2020 from OurWorldinData.org³

Baig and Goldfajn (1998) studied the impact of daily news in one country's stock market (the exogenous event) on other countries markets during the East Asian crises (Forbes and Rigobon, 2002). They found the significant impact of country's news on neighbouring economies. Apergis et al. (2016) demonstrated that the news variable generated significant spillover effects across the underlying CDS markets of Greece, Italy, Ireland, Portugal, and Spain (GIIPS) during the European sovereign crisis. Textual analysis has been used to extract the sentiment from the news stories, similar to studies by Hanley and Hoberg, (2010), Loughran and McDonald (2011), Long et al. (2021), among others. Aloui et al. (2016) analysed the co-movement between investor sentiment (Baker and Wurgler, 2007) and the Islamic and conventional equity returns in the US. Risteski and Davcev (2014) extended the conventional EGARCH model by adding Search Volume Index (EGARCH-SVI) as measured by Google Trends data. Corbet et al. (2020c) provided several theoretical explanations on why media affects Bitcoin returns and they constructed a sentiment index based on news stories that follow the announcements of four macroeconomic indicators: GDP, unemployment, Consumer Price Index (CPI) and durable goods. In another notable paper, Corbet et al. (2020d) demonstrates that digital assets

³ See: <https://www.statista.com/> and TNW: <https://thenextweb.com/tech/2019/06/11/most-popular-social-media-networks-year-animated/>

do not, in fact, react in an identical manner and so they should not be viewed as one category or one market. Therefore, even in relation to COVID-19, the impact of the media and news announcements on cryptocurrency markets could potentially be different if it is taken into account which of the three categories this asset belongs to: currencies, protocols or decentralised applications (dApps).

Ru et al. (2020) presented evidence showing delayed attention and inaction in response to COVID-19 outbreak in countries, which did not experience SARS in 2003. Early interest in COVID-19 pandemic, as measured by Google searches, is associated with deeper stock market drops in countries affected previously by the SARS virus. Ru et al. (2020) also suggest that the imprint of similar viruses' experience is a fundamental factor underlying timely responses to COVID-19 across countries around the world. Szczygielski et al. (2021a) examined the timing and quantified the impact of COVID-19 related uncertainty on returns and volatility for international regional stock market aggregates. The uncertainty was measured by searches for information for COVID-19 terms captured by Google search trends. Asian markets were found to be more resilient than others, while Latin American markets were most severely impacted in terms of returns and volatility. For most regions, there is evidence of an increasing impact of COVID-19 related uncertainty, which dissipated as the crisis evolved. Szczygielski et al. (2021b) investigated further the impact of COVID-19 related uncertainty on international energy stocks and they proposed a novel measure, which captures the overall impact of uncertainty. The OIU measure combines the magnitude and intensity of the impact of uncertainty.

Szczygielski et al. (2021b) found that the impact of COVID-19 depends on the net energy and net oil exporter / importer country status. Moreover, their results show that COVID-19 related uncertainty had stronger influence on energy sector returns the further west a country is located from the COVID-19 origin (in Wuhan, China). This finding suggests that geographical proximity matters. The results reported by Szczygielski et al. (2021b) may also mean that the closer a region is positioned to the epicentre of the COVID-19 pandemic in China (according to the geographical sequence of locations from east to west) the more investors may have known about the virus or possibly had better information about the likely future development of the pandemic.⁴ Salisu et al. (2020) studied the impact of the new COVID-19 related fear index of Salisu and Akanni (2020) on the commodity and stock markets. They found evidence that COVID-19 related fear increases the commodity returns and

⁴ The Overall Impact of Uncertainty (OIU) measure introduced by Szczygielski et al. (2021b), which combines the magnitude and intensity of the impact of uncertainty and which is designed relying on the estimates from GARCH models, is used as a novel tool in investigations of these effects. OIU captures the directional strength of the effect of uncertainty, which is adjusted by the intensity with which information enters a market. Szczygielski et al. (2021b) argue that the idea of the OIU measure is similar to the concept of a natural phenomenon, such as the impact of a rainstorms, which can produce different amounts of water (an analogy for the magnitude component in OIU) and there may also be a varying force of the rain and wind (the "volatility" of the storm). The impact of a rainstorm on the environment is, therefore, a function of such two factors.

in comparison with stocks, the commodities offered better safe-haven properties. Moreover, the use of COVID-19 fear index as the predictor improved both the in-sample and out-of-sample forecasts performance of the investigated models.

Using 726.9 million news articles from the Lexis Nexis database, Lucey et al. (2021) introduced a new Cryptocurrency Uncertainty Index that reflects policy (UCRY Policy) and price (UCRY Price) uncertainty around major cryptocurrencies. They show that both indices experienced distinctive movements during the COVID-19 outbreak, which confirms that COVID-19 pandemic increased uncertainty for digital assets. Similarly, COVID-19 amplified uncertainty and media attention to new digital assets, as shown by Central Bank Digital Currency Uncertainty and Attention indices (Wang et al., 2021). Umar and Gubareva (2020) examined the impact of the COVID-19 panic, measured by the Coronavirus Panic Index, on the volatility of fiat currency and cryptocurrency markets by using wavelet analyses. The coronavirus index was measured by the level of news referring to panic and the pandemic. Their findings indicate that there is high coherence between the Coronavirus Panic Index and the EUR, GBP and RMB currencies. The implication which follows this observation is that the function of cross-currency hedges may fail during periods of COVID-19 panic. Furthermore, Umar and Gubareva (2020) also found evidence about high coherence between the Coronavirus Panic Index and eleven major cryptocurrencies. Bouri et al. (2021) presented results about dramatic change in the structure and time-varying patterns of return connectedness across various assets (gold, crude oil, world equities, currencies and bonds) around the COVID-19 outbreak. Using the newspaper-based index of uncertainty in financial markets due to infectious diseases in order to capture the recent impact of COVID-19 pandemic, they also found that connectedness is positively related to it. Bouri et al. (2021) further argue that the reported results reduce the benefits of diversification. These examples show how closely is media literature linked to the spillover effect and interconnectedness literature, because any news based index or investment sentiment can be used as a determinant of spillover effect between financial markers.

4.3 Spillover effect across financial markets

The third level of analysis is spillover effect across financial markets. The financial markets participants are typically the first to react to all the negative news and stories appearing in the media. Therefore, the financial markets spillovers is the next channel of contagion that should be analysed. Individual and institutional investors are continuously monitoring news and the media is powerful tool in shaping investors expectations and changing market sentiments. While the members of the general public do not always have sufficient knowledge and skills to interpret the news rapidly and correctly, stock market investors appear to be more efficient in this process, therefore it is highly expected that

they will observe the immediate collapse of financial markets following the widespread of rumours and news about the crisis shock. The literature on this topic is very large, since the majority of contagion papers utilise narrow definition of contagion, i.e. the increase in spillover effect between financial markets after crisis shock occurred in one of the markets. For example, inter-regional spillover effect has been analysed between the US, Europe and Hong Kong by Jung and Maderitch (2014) and Maderitsch (2015), among the stock markets of Tokyo, London and New York by Hamao et al (1990), between Germany, the US and the UK by Choudhry and Jayasekera (2014) and relying on other combinations of markets, such as between the US, German and Japanese stock markets (Golosnoy et al., 2015; Karanasos et al., 2014), between the US, the EU and the BRIC markets (Bekiros, 2014; Kenourgios et al., 2011; Syriopoulos et al., 2015; Dimitriou et al., 2013), to name but a few. Moreover, other studies analysed spillovers across large selection of markets (e.g. Morales and Andreosso-O'Callaghan, 2014; Bekaert et al., 2011).

Furthermore, several seminal papers investigated financial spillovers across different asset classes (e.g. Dees et al., 2007; Ehrmann et al., 2011; Ito and Hashimoto, 2005; McKibbin and Martin, 1998; Dungey and Martin, 2005; Narayan et al., 2010). Dees et al. (2007) find evidence that the bond and equity markets are highly synchronous using a GVAR model for 26 countries. Ehrmann et al. (2011) examine the relationship between short-term interest rates, government bonds, equity markets and exchange rates in the US for the period 1989-2004 and confirm that the US is the main driver of global financial markets. Ito and Hashimoto (2005) examine contagion between the equity and currency markets using high-frequency data among six Asian countries and they conclude that bilateral trade linkage is an important factor for such a financial spillover. McKibbin and Martin (1998) argue for the volatility transmission from the equity markets to currency markets during Asian financial crisis. Dungey and Martin (2005) examines the linkage between equity and currency markets during the East Asian financial crisis of 1997–98. Their results provide evidence of cross-market linkage, in particular that the currency market contributes 11% of the volatility in the equity markets, and in returns the equity market transmits 36% of volatility to the currency markets. It is also well documented in the commodity literature that oil is an important source of production cost and, therefore, the oil market is positively related to the silver and gold market. Narayan et al. (2010) finds co-movement between oil price and gold price, in particular showing that an increase in oil price leads to a rise in the gold price. Corbet et al. (2018) analysed the interconnectedness between cryptocurrencies and other assets, i.e. the MSC GSCI Total Returns Index, the US\$ Broad Exchange Rate, the SP500 Index and the COMEX closing gold price, VIX and the Markit ITTR110 index, and showed that the cryptocurrencies constitute a new investment asset class, because they are interconnected with each other and exhibit similar patterns of connectedness with other asset classes.

In the literature focused on the international information transmission processes, an important methodological development concerns time-varying parameters models, which helps us to understand some other aspects of the nature of the stock market interconnectedness, such as the variation in the intensity of spillovers over time. For example, Ibrahim and Brzeszczyński (2009) proposed Foreign Information Transmission (FIT) model as a conditional time-varying parameters methodology, which allows to capture the information transmission effects across international stock markets in direct and indirect channels. The time-varying parameters specification of the FIT model also helps to better understand the changes in the intensity of the returns spillovers and it captures the effects of e.g. intermediate markets trading, that are active in particular geographical sequences, which is not possible to quantify using the more traditional methodologies. Ibrahim and Brzeszczyński (2014) and Brzeszczyński and Ibrahim (2019) further applied the FIT model for the design of investment strategies and they measured the economic benefits of the ‘meteor shower’ type of the inter-regional information transmission effects executed in the major international stock trading centres in such countries as the US, the UK, Japan and Australia.

By employing the Diebold–Yilmaz (2009) spillover index methodology, Gunay (2021) compared the shockwave effects of the COVID-19 pandemic and that of the global financial crisis (GFC) on currency markets. Gunay (2021) concluded that the shockwave of the COVID-19 pandemic in the total volatility spillover was almost eight times greater than in case of the GFC crisis. Regarding the impact of COVID-19 on the debt market, Haddad et al. (2021) documented extreme disruption in debt markets during the COVID-19 crisis. They found evidence that there was a severe price crash, for example the investment-grade corporate bonds traded at a discount to credit default swaps and the exchange-traded funds traded at a discount to the net asset value. Corbet, Larkin and Lucey (2020) investigated the volatility relationship between the main Chinese stock markets and Bitcoin. They found that it evolved significantly during the COVID-19 pandemic period characterised by enormous financial stress. Corbet, Larkin and Lucey (2020) also argue that the dynamic correlations during such periods of stress present further evidence to cautiously support the validity of the development of the Bitcoin as a new financial product within mainstream portfolio design through the possible diversification benefits.

Cabellero and Simsek (2021) proposed a model which captures the scenario related to the COVID-19 shock. Their simulations imply that the decline of asset prices and wealth reduces the market’s risk tolerance and triggers further price declines. Therefore, the large-scale asset purchases are deemed to be effective, because they transfer unwanted risk to the government’s balance sheet in face of the interest rates constraint. Akhtaruzzaman et al. (2021) analysed how contagion occurred

through financial and non-financial companies between G7 countries and China during the COVID–19 pandemic. Both financial and non-financial firms experienced significant increase in conditional correlations between their stock returns, however the magnitude of this effect was considerably larger in case of the first group during the COVID-19 outbreak, which means that the financial companies were more prominent in transmitting contagion than the non-financial firms.

Okorie and Lin (2021) investigated fractal contagion effect of the COVID-19 pandemic on the stock markets. Using the data from the top 32 coronavirus affected economies, they confirmed its existence, but also found that it fizzles out over time (in the middle-term and long-term) for both the stock markets returns and volatility. Bissoondoyal-Bheenick et al. (2021) analysed the impact of COVID-19 on stock return and volatility connectedness in a sample of the G20 countries and explored whether the connectedness measures behave differently for countries with SARS 2003 experience. They found that both stock return and volatility connectedness increased across the phases of the COVID-19 pandemic, which was more pronounced as the severity of the pandemic was increasing. However, the degree of connectedness was significantly lower in countries with SARS 2003 death experience. So et al. (2021) examined the impact of the COVID-19 pandemic on the connectedness of the Hong Kong financial market using the dynamic financial networks based on correlations and partial correlations of stock returns. In comparison with other crises, where the network density and clustering can be explained by co-movement with market indices as in normal periods, both network density and clustering were found to be higher in the partial correlation networks during the COVID-19 outbreak.

Belaid et al. (2021) investigated the impact of the COVID-19 crisis on the interdependencies between emerging and advanced economies. Using the Diebold and Yilmaz spillover index and Toda–Yamamoto and Dolado and Lütkepohl causality approach, they found evidence of increased transmission of the stress and uncertainty between financial markets during the pandemic period. In particular, Belaid et al. (2021) argue that the European market was the primary driver of the major source of contagion and transmission of stress and uncertainty to other financial markets. Yousfi et al. (2021) examined the consequences of the COVID-19 pandemic on the volatility spillovers between the Chinese (CSI 300) and US (S&P 500) stock market indices before and during the COVID-19 crisis period and found that they were stronger during the COVID-19 pandemic. Karkowska and Urjasz (2021) analysed the direction and scale of connectedness of markets from Central and Eastern Europe (CEE) and major global and European sovereign bond markets in the period from 2008 to 2020 covering also the COVID-19 pandemic. They found that the CEE countries are more interlinked with each other than with the global markets.

Corbet et al. (2020a) analysed the existence of volatility spillovers and co-movements among energy-focused corporations during the outbreak of the COVID-19 pandemic (including April 2020 events when West Texas Intermediate (WTI) oil future prices became negative). They found positive and economically meaningful spillovers from falling oil prices to both renewable energy and coal markets. However, this result was only detected for the narrow portion of the investigated sample surrounding the WTI event. Lin and Su (2021) investigated the variation of the inter-connectedness before and after the COVID-19 outbreak for the major energy commodities, including energy commodities used in industrial applications of the United States, such as West Texas Intermediate (WTI) crude oil, New York Harbor Conventional Gasoline Regular (NYHCGR), Heating oil #2, Ultra-Low-Sulfur#2 Diesel Fuel, Kerosene-Type Jet Fuel, Propane and natural gas. Using the TVP-VAR based connectedness index method, they found evidence that the total connectedness in energy markets following the outbreak of COVID-19 has strengthened, but it reverted to its normal level after two months. Moreover, Lin and Su (2021) also report that three pairwise connectedness relations have changed in direction before and after the outbreak of COVID-19.

Bouri et al. (2021) extended the mean-based VAR framework of connectedness to the quantile VAR connectedness framework, which allows to examine the connectedness measures at the upper, middle and lower quantiles of the conditional distribution. They investigated cryptocurrencies data and found that the behaviour of return connectedness for major cryptocurrencies in lower and upper quantiles is asymmetric. Adekoya and Oliyide (2021) investigated the impact of COVID-19 pandemic on the connectedness across commodity and financial markets using the TVP-VAR models. The reported results evidence the existence of significant volatility spillovers across the markets with gold and USD being net receivers of shocks. The causality-in-quantiles test further suggests that the connectedness across the markets was primarily caused by the COVID-19 pandemic.

Hassan et al. (2021) report a time-varying connectedness between Bitcoin and Altcoins peaks during the COVID-19 pandemic. Le et al. (2021b) examined the spillover effect between financial technology (Fintech) stocks and other financial assets, such as gold, Bitcoin, a global equity index, crude oil and the US Dollar, during the COVID-19 crisis. Their findings demonstrate the linkages between intensity of spillover effect across markets and the number of new confirmed COVID-19 cases. Jalan et al. (2021) report strong spillover effect from gold to gold-backed cryptocurrencies during the COVID-19 period and show that gold-backed stablecoin has similar risk profile to Bitcoin, hence they cannot be considered as a safe haven assets. Yarovaya et al. (2021b) report that although the Islamic bonds (Sukuk) demonstrated safe haven properties during the COVID-19 pandemic, oil and gold are still strong determinants of the conventional-Islamic markets spillovers.

4.4 Contagion via macroeconomic fundamentals

Fourthly, the crisis shock will be reflected in macroeconomic fundamentals, however it will take longer to observe the changes in the economic variables in comparison to asset prices. Thus, while international economic linkages are determinants of intensity of contagion and macroeconomic variables have been traditionally used in the contagion literature, the changes in those fundamentals should be analysed in conjunction with three other main channels of contagion. Closely related to contagion through macroeconomic fundamentals is the literature on international market integration (Hardouvelis et al., 2006; Kearney and Poti, 2006). Contagion phenomenon has been explained by the increased economic and financial ties between countries. While some factors, such as growth in international trade, increasing business cycle synchronization, low and convergent inflation and interest rates, can facilitate the integration process, others, such as various regulatory barriers, can slow it down and constrain it (Aggarwal et al., 2010). Integration is a dynamic process and it is related to increasing financial liberalization, globalization and economic development and absence of arbitrage opportunities among markets situated in different countries and geographical regions. According to the definition provided by Lagoarde-Segot and Lucey (2006), the financial markets are integrated when market participants face a single set of rules while they deal with financial instruments, have equal access to these assets and they are treated equally when they are active in the financial market.

A notable paper by Kearney and Lucey (2004) provides a useful conceptualisation of integration. They propose a tripartite classification of measures both direct (which rely on some international parity conditions, such as the law of one price or interest rate conditions) and indirect. The first one, a direct measure, is as to whether similar assets yield similar returns internationally. It is in this area that much of the contagion literature lies (e.g. Lewis (1999), Ayuso and Blanco (1999), Coelho et al. (2007), to name but a few). However, it might be challenging to identify assets that are sufficiently homogenous in terms of their risk profiles to make an adequate comparison of the equalisation of financial markets. The second approach invokes the concept of international capital market completeness and the third approach looks at domestic/international funding of investments (e.g. Portes and Rey, 2000; Bekaert et al., 2003; Goetzmann et al., 2005). According to Coelho et al. (2007, p. 456) the direct approach, despite the complexity in finding reliable data and a method to prove the existence of integration, remains favourable among academics. The detailed review of the integration literature was provided by Lucey et al. (2018).

Among the decreased diversification benefits, Aggarwal et al. (2010, p. 643) suggest that increased financial market integration may have the following implications: i) the more complete the world's capital markets are, the more robust the economies of individual states will be; ii) household savings rates will consequently change over time. While the former will have a generally positive impact on the economic growth of a country, variability of household savings has a more uncertain impact. First, the increased attractiveness of domestic stock investment may lead to the restructuring of household expenditure, replacing the consumption on domestic stock market investment. Second, lessening regulatory barriers will encourage a search for more profitable investments in foreign markets, ultimately resulting in a higher mobilization of savings (Oshikoya and Ogbu, 2003; Lagoarde-Segot and Lucey, 2006).

Flood and Rose (2005a,b) suggests that markets are integrated if, at one point in time, the expected discount rates in different markets are equal. This methodology has been employed by Claus and Lucey (2012) in their analysis of stock market integration across 10 emerging and developed markets in the Asia Pacific region over the period from April to May 2006. The findings for Asian markets, i.e. Japan, Hong Kong, Singapore, South Korea, Taiwan and Malaysia, show higher degrees of integration in the developed markets of Japan and Hong Kong and lower in those of Singapore and the emerging markets of Taiwan and Malaysia. The results also show that emerging markets from the Asian region have a relatively lower degree of financial integration than those of developed markets. Many papers have analysed co-integration between financial markets (e.g., Alagidede and Panagiotidis, 2009; Cajueiro et al., 2009; Singh et al., 2010) and with the increased role of developing countries in the global economy it becomes essential to include emerging markets in any analysis of information transmission mechanisms (e.g., Syriopoulos et al., 2015, Diebold and Yilmaz, 2009, 2012; Singh et al., 2010; Yilmaz, 2010; Kumar, 2013; Cho et al., 2014).

The model presented in Figure 3 demonstrates that this process is continuous and new information can unendingly transmit through this mechanism, adjusting and changing the respective variables. The information flow does not end at the macroeconomic fundamentals level and the new catalyst of contagion may occur in addition to existing ones causing new cycles of contagion, new stories, and market reaction. For example, while the COVID-19 situation keeps escalating, and more deaths and confirmed cases are reported daily, keeping contagion mechanisms running, new shocks like oil prices dropping due to the decrease in demand for crude oil can become an additional catalyst, further aggravating the spillover effect at the financial markets. In a similar manner, there could be driving forces that can help the economy to resist the transmission of the contagion shock. Defined as the ability of the macroeconomy to rebound from shocks to trend paths (Briguglio et al, 2009) the

key drivers of resilience have been found by Jolles et al. (2018) to lie in the areas that make the markets function effectively: capital, goods, and labour.

Wei and Han (2021) examined the impact of the transmission mechanism of monetary policy to financial markets during the COVID-19 pandemic and report evidence that the effectiveness of the monetary channel transmission has weakened. This finding means that the use of unconventional monetary policies should be more effective during the COVID-19 crisis. Brada, Gajewski and Kutan (2021) investigated resiliency to the economic shocks in 199 regions of Central and Eastern Europe (CEE). Using the experience of the recovery from the 2008 financial crisis, they simulated the effects of the COVID-19 pandemic on the ability of those markets to counteract a shock to employment caused by the COVID-19 pandemic. Brada et al. (2021) found that employment in no more than 31 of the 199 regions should fully recover in 2-years period after the onset of the recovery from the COVID-19 crisis.

Hong et al. (2021) proposed an epidemic model which incorporates the aggregate transmission shocks and links firm valuations with infections. It generated predictions, which were consistent with the real-world data.

Thorbecke (2020) analysed stock returns of 125 sectors in the US and investigated the impact of COVID-19 by disaggregating them into components driven by sector-specific factors and by macroeconomic factors. Idiosyncratic factors harmed industries such as airlines, aerospace, real estate, tourism, oil, brewers, retail apparel and funerals. On the other hand, macroeconomic factors played a major role in case of such industries as production equipment, machinery and electronic and electrical equipment.

5. Recommendations for future COVID-19 research

From the perspective of our review, it is important to emphasize that the existing literature includes effectively almost no previous research which deals directly with such important issues as how the earlier pandemics affected stock markets interconnectedness and information transmission mechanisms or how they changed the spillovers/contagion effects on the global scale. Future pandemics of the magnitude of COVID-19 will likely not be dismissed by financial markets as extremely improbable. Therefore, it is important to consider how catalysts and mechanisms related to contagion might be either exacerbated or dampened during COVID-19 or similar other pandemics. This issue also concerns how pandemics such as COVID-19 might change the conditions for future financial

contagion. The circumstances of COVID-19, alongside previous research, suggest reconsideration of several catalysts and mechanisms of financial crises and subsequent contagion. These circumstances include a global impact rather than a local impact, a dramatic and temporary decline in global domestic demand, a marked downturn in enthusiasm for leverage by both firms and households—even as greater borrowing may be a temporary exigency, an increased risk perception of equity markets, and an increase in the stress on banking solvency in developing countries.

Unprecedented events, like the COVID-19 pandemic, challenge academics to reassess the available approaches to the investigation of financial contagion and also to ensure that this research informs policy makers and practitioners, and society as a whole, how to cope with the crisis. COVID-19 attracted attention not only due to the threats to health and social life of individuals, but also because of the uncertain and diverse impacts on the economy and businesses. The analysis of financial effects of COVID-19 pandemic can be used by policy makers in planning the recovery strategies from this crisis, while for investors the results of such papers should provide additional information for the creation of trading strategies able to outperform the market. Information transmission mechanisms provide the opportunity to forecast the behaviour of return and volatility of the markets which are susceptible to foreign shocks. The analysis of the dynamic, intensity and direction of return and volatility spillovers can be extended to the analysis of the transmission of positive and negative shocks across markets and, moreover, to the assessment of the predictive power of foreign information.

COVID-19 represents a macroeconomic shock that has not been particularly localized (except rather momentarily in China). Instead, it has extended over the world largely because of social distancing requirements. While some countries, perhaps Nigeria or India for example, may ultimately experience less health impacts from COVID-19, implementations of social distancing along with global interlinkages of supply chains and trade suggest that all nations will be severely economically impacted by COVID-19. By extension, in future, it is reasonable to expect that fears of pandemics, due to a discovery of new cases or a new disease etc., will almost certainly lead to quick and severe global financial impacts. Future research should consider whether to regard these events as either extremely fast contagion or, alternatively, as simultaneities. In some ways COVID-19 will leave the world less globalized with countries having greater aspirations to be able to close borders rapidly, but in other ways COVID-19 will engender the world to become more keenly aware of the need to coordinate activity with regard to preventions of global natural disasters (Ghesquiere and Mahul, 2010). Preparations against pandemics will be seen as a global public good (e.g., Kölle, 2015; Yamey et al., 2018).

While differences across regions can always be found if we look closely enough, the unprecedented global nature of COVID-19 presents a new view of how financial crises might or might not spread. During truly global crises, many previously identified financial transmission mechanisms between emerging and developed countries are likely less relevant than they would have been under more localized crises. The transference of liquidity for instance through dividends or stock sales, is less likely if all countries are being impacted as opposed to some impacted and others not. A number of studies consider the comparative advantage of possessing liquidity in times of financial crisis (e.g., Allen and Gale, 1994; Brown, 2000; Pulvino, 1998; Shleifer and Vishny, 1992). Shleifer and Vishny (1992) suggest that, during financial downturns, liquidity is a cost of leverage. While these studies focus mainly on firms with differences in liquidity levels within the same stressed environment, firm-level liquidity can be transferred (exported and imported) across regions when a financial crisis manifests itself in one region of the world while other regions are comparatively less affected. Liquidity shock in one region of the globe causes selling pressure on stocks in another area (e.g. Antón and Polk, 2014; Jotikasthira, Lundblad, and Ramadorai, 2012). With COVID-19, it is difficult to see how one region of the globe will have greater liquidity pressure than another with economies of all regions being severely impacted. In contrast to the COVID-19 crisis, the GFC of 2007–2009 is not seen as having as much global uniformity (Goodell et al., 2020b).

Examining further the issue of leverage during COVID-19, Elnahas, Kim, and Kim (2018) find that firms located in more disaster-prone areas adapt to be less levered. They attribute this finding to firms in disaster zones being concerned with operating disruption, increased costs of capital and tightened financial flexibility (Kraus and Litzenberger, 1973). While companies are often seen as persistent in their capital structure policy, they also adjust such policies to macroeconomic shocks (Huang, Gao, and Chen, 2018). A lessening of leverage by firms across the globe, as a response to COVID-19, could potentially have impact on the likelihood and degree of future financial contagion. Levels of leverage, specifically those of financial institutions, have also been closely associated with contagion (Van Wincoop, 2013). How will COVID-19 shape the future leverage practices of banks and ultimately shape the nature of future banking crises? Lagoarde-Segot and Leoni (2013) modelled the increasing likelihood of the collapses of the banking industries of developing countries as the likelihood of a large pandemic increases. Much of the group lending of microfinance institutions will be pressured during epidemics because all members of groups will be pressured by the aggregate shock (Binswanger and Rosenzweig, 1986; Skoufias, 2003). It remains to be seen how COVID-19 will change the practices of financial institutions and ultimately how this will change the nature of how financial crises are formed and transmitted.

Regarding sharp decline in global domestic demand, future research will need to consider how it impacts the potentiality for financial and economic crises. Research shows that household credit booms take a prominent role in driving financial crises and recessions (Mian et al., 2007 ; Mian and Sufi, 2015). How will a reduced domestic demand impact household credit booms? Certainly, there may be considerable need for additional borrowing during economic crises. But will households be so shaken by COVID-19 as to permanently adjust personal savings rates? If so, how will this impact the potential for future financial contagion?

On the equity side of firm financing, COVID-19 clearly suggests a previous underpricing of equity risk. Will there be a very long-term shifting in the costs of equity? Lee and McKibbin (2004) find a 200-basis points increase in the country risk premium for China and Hong Kong following SARS. While the impact of country-risk premiums on costs of equity will vary with firm exposures to various markets, certainly an increase of two percentage points in a country risk premium (likely much higher for COVID-19) would lead to a significant increase in the cost of equity capital. COVID-19 may bring to the global collective consciousness a new assessment of global risks. The findings of increased country risk from Lee and McKibbin (2004) for China and Hong Kong are based on China and Hong Kong being particular risk areas for SARS. With a genuine pandemic like COVID-19, however, the exposure is global rather than localised in selected countries. Furthermore, it has been shown that banking crises also lead to increased equity market risk (Grout and Zalewska, 2016). There is a possibility of a significant increase in equity premia (Aggarwal and Goodell, 2011) across all countries with concomitant impact on investment. Overall, it is for future research to consider how COVID-19 will change attitudes towards equity risk and how this change in risk perception will in turn shape equity market bubbles, crises and contagion.

The question of which data is appropriate to use in the analyses of international information transmission and global market linkages is still a matter of debate. While there is some consensus in the literature employing daily data, a more mixed evidence is available for intraday spillovers and in papers applying high-frequency data. The major challenge is that it is hard to compare the findings and check the validity of the results reported in various papers. Thus, we recommend ensuring that data used in COVID-19 studies are available for academic community, and that it can be reused in replication studies, so that the results can be verified. For example, data can be deposited in the Mendeley database, made available from a personal website, or published as a separate data article in the Data-in-Brief format.

Finally, based on our review of the studies discussed in this paper, and with reference to the identified gaps in the existing literature, we suggest the following future research agenda, which is

relevant particularly from the point of view of the current COVID-19 crisis and the new data generated since its start in December 2019:

1. High frequency data (i.e. higher than daily) have not been used very extensively yet in the existing contagion literature, so given the nature of return and volatility transmission relationships, which occur in the geographical sequences of markets trading in the intra-daily time intervals, we believe that this is the area where a number of different types of contributions can still be made. In particular, the current COVID-19 crisis creates new opportunities to investigate the information transmission processes in response to the news about the COVID-19 pandemics and to contribute to our understanding of the spillovers/contagion mechanisms in the ultra-short term using e.g. minute-by-minute data from the global financial market.
2. Use of futures contracts data, as a relatively new type of data in the international information transmission research, has not been fully explored yet in previous studies. This is also the area which should involve more intensive work (and exploit futures as directly investable instruments as opposed to e.g. the underlying stock indices). Inclusion of trading volume in better understanding of return and volatility transmission relationships is another under-research field.
3. There are various methodological issues that need to be re-visited following the development of new methods, e.g. some early studies failed to address heteroscedasticity, so a revision using ARCH models is possible to do now.
4. New methodological tools, such as the novel Cryptocurrency Uncertainty Index of Lucey et al. (2021) or the Overall Impact of Uncertainty (OIU) measure of Szczygielski et al. (2021b), should be more extensively used as well.
5. The opportunity to include more emerging markets in the new studies should be explored more intensively. Given that the COVID-19 outbreak originated in China, and that it subsequently spread around the world affecting equally the developed markets and the emerging markets, this specific situation also creates new possibilities to contribute to the emerging markets literature.
6. More studies are needed that make use of the empirical findings from the in-sample periods, such as forecasting experiments conducted in the out-of-sample periods and their further applications, such as, for example, simulation of investment strategies relying on the in-sample results about return and volatility transmission processes.
7. Analysis of return and volatility transmission effects across different asset classes is also a research direction worth further investigation. There are relatively few studies available yet examining

this issue, and, as emphasized earlier, the magnitude of the black swan effect on patterns of contagion is likely to differ among different categories of assets.

8. Another important area is stability of the return and volatility transmission relationships over time. This is a key issue also from the point of view of forecasting and construction of investment strategies (mentioned above).

9. Behavioural finance aspects should be included more broadly into the research on return and volatility transmission (i.e. integration of this research stream with such other behavioural finance topics as e.g. herding effects on financial markets and the role of institutional investors etc.). The emotional contagion and changes in investment sentiments play an important role in financial contagion process, therefore the analysis of media, news and the impact of announcements on dynamic linkages between financial markets should be deeper explored in contagion literature.

10. Last but not least, given that there is a clear gap in the previous literature in the areas related to the effects of previous pandemics on the nature and intensity of stock markets interconnectedness etc., it is particularly important to conduct more analyses that will lead to understanding how such health emergency situations as pandemics have been changing the spillovers/contagion mechanisms, which link international stock markets (as well as the relationships between stock market and other segments of the broader financial market) on the global scale.

6. Conclusions

There are many reasons to believe that COVID-19 pandemic will be a “game-changer” regarding how individuals, firms, financial institutions and governments behave in ways that we can now only partially foresee. As a result, research on financial contagion in the near future will be particularly vital and relevant. In this paper, we consider several unique characteristics of the COVID-19 crisis and we demonstrate in which manner the impacts of the pandemic may be different from previous crises and to what extent the COVID-19 can be considered a ‘black swan’ event.

This paper introduces a new conceptual framework that can be used to assess the financial contagion of the COVID-19 pandemic, or any other future global unexpected and unpredictable events, at four levels of information transmission: (i) Catalysts of contagion, which is particularly important in the current context COVID-19 pandemic; (ii) Media attention; (iii) Spillover effect in financial markets; (iv) Macroeconomic fundamentals, contributing to several strands of academic literature on financial integration (e.g., Portes and Rey, 2000; Bekaert et al., 2003; Kearney and Lucey, 2004; Coelho et al., 2007; Aggarwal et al., 2010; Cajueiro et al., 2009; Singh et al., 2010), contagion

effect (e.g., Zhang et al., 2013; Bekiros, 2014; Karanasos et al., 2014; Luchtenberg and Vu, 2015; Petmezas and Santamaria, 2014; Albulescu et al., 2015) and intra- and inter- regional return and volatility spillovers (e.g., Engle et al., 1990; Hamao et al., 1990; Melvin and Melvin, 2003; Ibrahim and Brzeszczyński, 2009, 2012; Yarovaya et al. 2016a,b; Brzeszczyński and Ibrahim, 2019), to name but a few. Furthermore, our paper contributes to the literature on the financial effect of the COVID-19 pandemic (e.g. Corbet et al., 2020a; Goodell, 2020a; Sharif et al., 2020; Yarovaya et al., 2021), providing better understanding of the nature of this crisis and its unique characteristics.

We propose specific directions and recommendations for future research, which may be useful for the academic community to conduct original and impactful new work on financial contagion focused on the analyses during and after the COVID-19 crisis. They can also be helpful for journal editors and editorial board members when assessing the novelty and contribution of COVID-19 papers, especially those that address issues of contagion and financial market interconnectedness during the pandemic. For policy makers, this study provides comprehensive overview of the available academic knowledge and frameworks in this area, as well as some explanations of information transmission mechanisms across borders, which can help to develop effective mitigation and resilience strategies leading to a quicker recovery from the COVID-19 crisis.

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