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# How do stock price indices absorb the COVID-19 pandemic shocks?

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ABSTRACT

To assess the resiliency of stock price indices during the COVID-19 crisis, this study provides a distinctive perspective; that is, we evaluate the ability of stock price indices to absorb COVID-19 shocks. We construct the measures of absorptive intensity and duration to identify a stock price's absorptive capacity. We then employ the Granger causality test and a topology network approach to investigate the interactions of absorptivity among stock price indices. Our results show that stock price absorptivity varies over time and across countries and industries. The US and the Brazil stock indices have relatively high absorptive intensity while short duration. The health care industry shows distinctive trend in absorptive intensity from the other industries. The intensity of the non-cyclical industries such as utilities and consumer staples is high, while the cyclical industries such as banking, real estate, and energy have lower absorptive intensity. Moreover, the utilities, consumer staples, and financials industries are the main resiliency transmitters.

## 1. Introduction

Due to its strong infectiousness, the COVID-19 poses a great threat to human health and thus becomes a huge shock to economic activities. The COVID-19 pandemic has affected nearly all economic and financial activities and brought unprecedented uncertainty as to the length and breadth of economic shutdowns, how the economy will recover, and how the stock market will perform in the future. Thus, scholars have conducted extensive and in-depth research on the financial impacts of COVID-19 (e.g., Topcu and Gulai, 2020; Takyi and Bentum-Ennin, 2020; Sun et al., 2021). However, it seems more reasonable that we should focus on how the financial system absorbs the uncertainty shocks brought by the pandemic, which is conducive to assessing the resilience of the financial system, thereby facilitating more accurate forecasts and policies. Our aim in this paper is dual: first, to measure the capacity of stock price indices to absorb COVID-19 shocks; and second, to examine the interaction of absorptivity across countries and industries.

The literature on the impact of the COVID-19 pandemic on stock market performance has grown rapidly since the third quarter of 2020. Many studies provide empirical evidence that the COVID-19 pandemic has significantly affected stock returns (Topcu and Gulai, 2020; Takyi and Bentum-Ennin, 2020; Sun et al., 2021; Xu, 2021; Li et al., 2021), co-movement of the stock returns (Rehman et al.,

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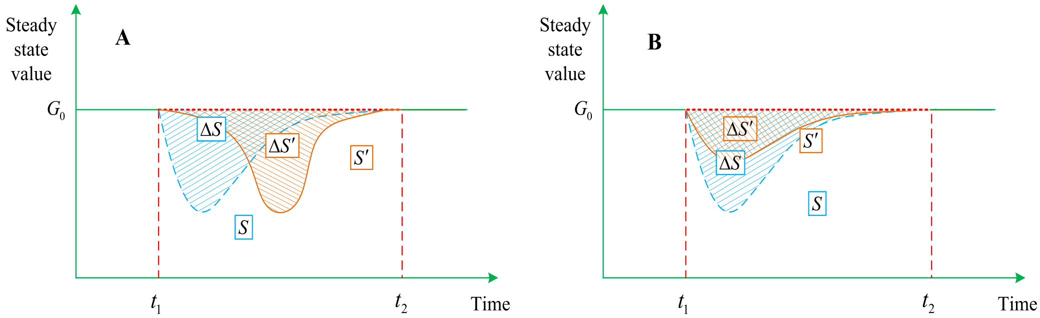


**Fig. 1.** Trajectories of stock prices before and after shocks.

2021), volume (Chiah and Zhong, 2020), liquidity (Just and Echaust, 2020; Baig et al., 2021; Tissaoui et al., 2021), volatility (Baek et al., 2020; Sergi et al., 2021; Izzeldin et al., 2021; Tissaoui et al., 2021), herding behavior (Ferreruela and Mallor, 2021) and term structure of earnings expectations (Landier and Thesmar, 2020). Three recent papers that investigate the impact of COVID-19 on industry stock prices are closely related to our work. In their survey paper, Baek et al. (2020) conclude that the total and idiosyncratic risks caused by COVID-19 shocks vary across all industries. Using data from the business sectors of G7 countries, Izzeldin et al. (2021) document how the impacts of COVID-19 on volatility differ across sectors—the health care and consumer services sectors are the most severely affected, while the technology sector is the least severely affected. Using a time–frequency approach, Matos et al. (2021) provide evidence of sectoral contagion during the outbreak of COVID-19. Overall, the existing literature agrees that the impacts of COVID-19 on stock markets are significant and vary across industries.

A number of other papers are also related to our study. Some papers draw much attention to evaluating the resiliency of stock prices during the COVID-19 crisis by using an event study approach. For example, Ramelli and Wagner (2020) investigate the impact of firm characteristics and financial policies on the reaction of stock price to COVID-19 shock and find evidence of heterogeneous impacts of COVID-19 on stock returns across industries. Using a DiD approach, Albuquerque et al. (2020) evaluate the resiliency of environmental and social (ES) stock price and find that stocks with higher ES ratings show significantly higher returns and lower return volatility during the COVID-19. Fahlenbrach et al. (2020) examine the value of financial flexibility in the unique situation of a sudden and unexpected revenue shortfall brought by COVID-19 and find that firms with high financial flexibility experience a lower stock drop bought by revenue shortfall. Heyden and Heyden (2021) study short-term market reactions during the beginning of the COVID-19 pandemic and document how stocks react significantly and negatively to the announcement of the first death in any given country. Rahman et al. (2021) examine how the Australian stock market responded to the COVID-19 pandemic and identify a negative reaction to the pandemic announcement. Yong and Laing (2021) analyze the U.S. stock market's reaction to the WHO's announcement and find that international exposure through foreign sales, foreign assets, imports, and exports was significantly and negatively associated in the short run with standardized cumulative abnormal returns. Moreover, some papers focus on the other determinants of the stock resiliency to COVID-19 shocks. Those determinants include culture (Fernandez-Perez et al., 2021), economic resilience (Uddin et al., 2018), sentiments (Sun et al., 2021), and trust (Engelhardt et al., 2021).

This study contributes to the literature in at least three important ways. First, we construct two measures that assess the capacity of stock price indices to absorb COVID-19 shocks. The two measures are absorptive intensity and duration. There are several studies on the impact of the COVID-19 pandemic on stock markets; yet, to the best of our knowledge, ours is the first to measure the resilience of stock prices from a time-varying perspective. Second, we employ the Granger causality approach and a network topology approach to investigate the interrelations among the resiliency of stock price indices. Third, we provide new empirical observations that foster a better understanding of the roles of each stock price index in resisting COVID-19 shocks.

We focus on the heterogeneity in stock price resiliency of the COVID-19 shocks. For that reason, we conduct a cross-country analysis by collecting 8 composite stock price indices and 83 industry indices. We provide evidence that stock price absorptivity varies over time and across countries and industries. The US and the Brazil stock indices have relatively high absorptive intensity while short durations. The health care industry shows a distinctive trend in absorptive intensity from the other industries. The intensity of the non-cyclical industries such as utilities and consumer staples is high, while the cyclical industries such as banking, real estate, and energy have lower absorptive intensity. According to the results of the topology network, the utilities, consumer staples, and financials industries are the main resiliency transmitters, while the IT and telecommunications industries are the major resiliency receivers.

The remainder of this paper is structured as follows. Section 2 outlines the research design. Section 3 describes the data. Section 4 provides the empirical results, and Section 5 concludes the study.

## 2. Research design

### 2.1. Defining absorptive intensity and duration

Absorptivity to shocks can be traced back to concepts related to shock resiliency in physics. Shock resilience refers to the capacity of an object to absorb deformation and fracture work under shock loads, reflecting the internal defects of the object and its resistance to

**Table 1**
Resiliency spillover matrix.

| | $Y_1$ | $Y_2$ | ⋯ | $Y_N$ | $FROM$ |
|---|---|---|---|---|---|
| $Y_1$ | $d_{11}^T$ | $d_{12}^T$ | ⋯ | $d_{1N}^T$ | $\sum_{i=1}^N d_{1i}^H, i \neq 1$ |
| $Y_2$ | $d_{21}^T$ | $d_{22}^T$ | ⋯ | $d_{2N}^T$ | $\sum_{i=1}^N d_{2i}^H, i \neq 2$ |
| ⋯ | ⋯ | ⋯ | ⋯ | ⋯ | ⋯ |
| $Y_N$ | $d_{N1}^T$ | $d_{N2}^T$ | ⋯ | $d_{NN}^T$ | $\sum_{i=1}^N d_{Ni}^H, i \neq N$ |
| $TO$ | $\sum_{j=1}^N d_{j1}^T, j \neq 1$ | $\sum_{j=1}^N d_{j2}^T, j \neq 2$ | ⋯ | $\sum_{j=1}^N d_{jN}^T, j \neq N$ | $S^T$ |

external shock loads. In economics, resiliency mirrors the internal resistance of the economic system to external shocks.

According to Liu et al. (2021), absorptive capacity can be measured from two dimensions: the magnitude and “speed” of shock absorption. The magnitude of shock absorption is defined as the absorptive intensity, and the “speed” is defined as the absorptive duration. Fig. 1 illustrates the two possible reactions of the stock price index to external shocks. As shown in Panel A of Fig. 1, although the absorptive intensity is identical, there is a significant distinction in the duration (or average time) of shock absorption. In Panel B of Fig. 1, when the absorptive duration is the same, there are significant differences in the intensity of shock absorption.

### 2.2. Measuring absorptive intensity and duration

Financial variables will deviate from the original trajectory when receiving external shocks. Because the shocks are temporary, their impacts on financial variables are short-term. In the long term, financial variables are determined by fundamentals. As shown in Panel A of Fig. 1, the shaded zone indicates the loss caused by shocks. Based on the methods of Liu et al. (2021), we construct the following measure of absorptive intensity:.

$$Resiliency^I = \frac{S - \Delta S}{S} \tag{1}$$

where $Resiliency^I$ represents the absorptive intensity and $\Delta S$ is the area of the shaded zone and represents the loss. This measure quantifies the magnitude of a financial variable’s absorptive capacity, reflecting the intensity at which it can absorb shocks.

Calculating the absorptive intensity of stock prices must account for the response to COVID-19 shocks. Fortunately, the impulse response function provides an appropriate model. Therefore, this paper uses a time-varying impulse response function to measure the absorptive capacity indicators. Assuming that at time$t$, the impulse response of financial variable $i$ to shock $j$ is$\Phi_{t,i\leftarrow j}^n$, then formula (1) can be rewritten as:.

$$Resiliency_{t,i\leftarrow j}^I = \frac{N\overline{h} - \sum_{n=1}^N \left|\Phi_{t,i\leftarrow j}^n\right|}{N\overline{h}} \tag{2}$$

where $N$ is the number of impulse response periods and $\overline{h}$ is the selectable reference value of the impulse response. This indicator quantifies the intensity with which financial variables restore their original trajectories following external shocks.

The absorptive duration can be understood as the average duration of financial variables absorbing shocks. The longer the duration, the longer it takes for the variables to recover their original level. Absorptive duration can also reflect the variables’ trajectory after a shock; as Panel A in Fig. 1 displays, the greater the absorptive duration, the more delayed the “center of gravity” of the trajectory. Inspired by the duration of bonds, this paper constructs the following measure of absorptive duration:.

$$Resiliency_{t,i\leftarrow j}^D = \sum_{n=1}^N n\Phi_{t,i\leftarrow j}^n \Big/ \left(\sum_{n=1}^N \left|\Phi_{t,i\leftarrow j}^n\right|\right) \tag{3}$$

This measure takes the impulse response proportion of a single period as the weight and calculates the impact of external shocks on financial variables from the “speed” dimension.

To estimate the time-varying impulse response, this paper adopts the TVP-VAR model with random fluctuations proposed by Nakajima (2011). The model is expressed as:.

$$y_t = X_t\beta_t + A_t^{-1}\Sigma_t\varepsilon_t \tag{4}$$

where $y_t$ is a $k$-order variable matrix, and the coefficient$\beta_t$, parameter matrix$A_t$, and random fluctuation covariance matrix $\Sigma_t$ are time-varying. According to Primiceri (2005), let $\alpha_t = (\alpha_{21}, \alpha_{31}, \alpha_{41}, ..., \alpha_{k,k-1})'$ be a vector of elements arranged in the lower triangular matrix$A_t$, and let$h_t = (h_{1t}, ..., h_{kt})'$, where$h_{jt} = log\sigma_{jt}^2$. The time-varying parameters in the model follow the random walk process:.

**Table 2**
Sample variables.

| | US | UK | FR | GER | ITA | IND | ARG | BRA |
|---|---|---|---|---|---|---|---|---|
| Composite index | S&P 500 | FTSE 100 | CAC 40 | DAX 30 | FTMIB | SENSEX | MERVAL | IBOVESPA |
| Industry index | Health Care | Aerospace and Defense | Utilities | Automobile | Chemicals | Health Care | Communication Service | Real Estate |
| | Utilities | Banks | Technology | Banks | Health Care | Infrastructure | Consumer Discretionary | Utilities |
| | Basic Materials | Chemicals | Oil and Gas | Chemicals | Industrials | Commodities | Consumer Staples | Industrials |
| | Industrials | Construction Building | Industrials | Financial Services | Real Estate | Auto | Energy | Financials |
| | Consumer Staples | Electricity | Health Care | Industrials | Oil and Gas | Consumption | Financials | Electric Power |
| | Information Technology | Financial Services | Financials | Insurance | Insurance | IT | Industrials | Consumption |
| | Energy | Utilities | Consumer Service | Health Care | Food and Beverage | Energy | Basic Materials | Basic Materials |
| | Telecommunications | Industrials | Consumer Goods | Software | Financial Services | Telecom | Real Estate | |
| | Financials | Metals and Mining | Basic Materials | Technology | Construction and Materials | Financial Services | Utilities | |
| | Consumer Discretionary | Telecommunications | | Telecommunications | Banks | | | |
| | Real Estate | Oil and Gas | | Transport and Logistics | Utilities | | | |
| | | Real Estate | | Utilities | IT | | | |
| | | Health Care | | | Travel and Leisure | | | |
| Interest rate | 3-month | 3-month | 3-month rate | 3-month rate | 3-month rate | 3-month rate | 3-month rate | 3-month rate |
| Panic index | VIX | VIX | VIX | VIX | VIX | VIX | VIX | VIX |
| Sample periods | 2020/2/18–2021/11/26 | 2020/2/18–2021/11/26 | 2020/2/18–2021/11/26 | 2020/2/18–2021/11/26 | 2020/2/18–2021/11/26 | 2020/3/2–2021/11/26 | 2020/3/4–2021/11/26 | 2020/2/26–2021/11/26 |
| Obs. | 450 | 446 | 450 | 445 | 448 | 426 | 418 | 433 |

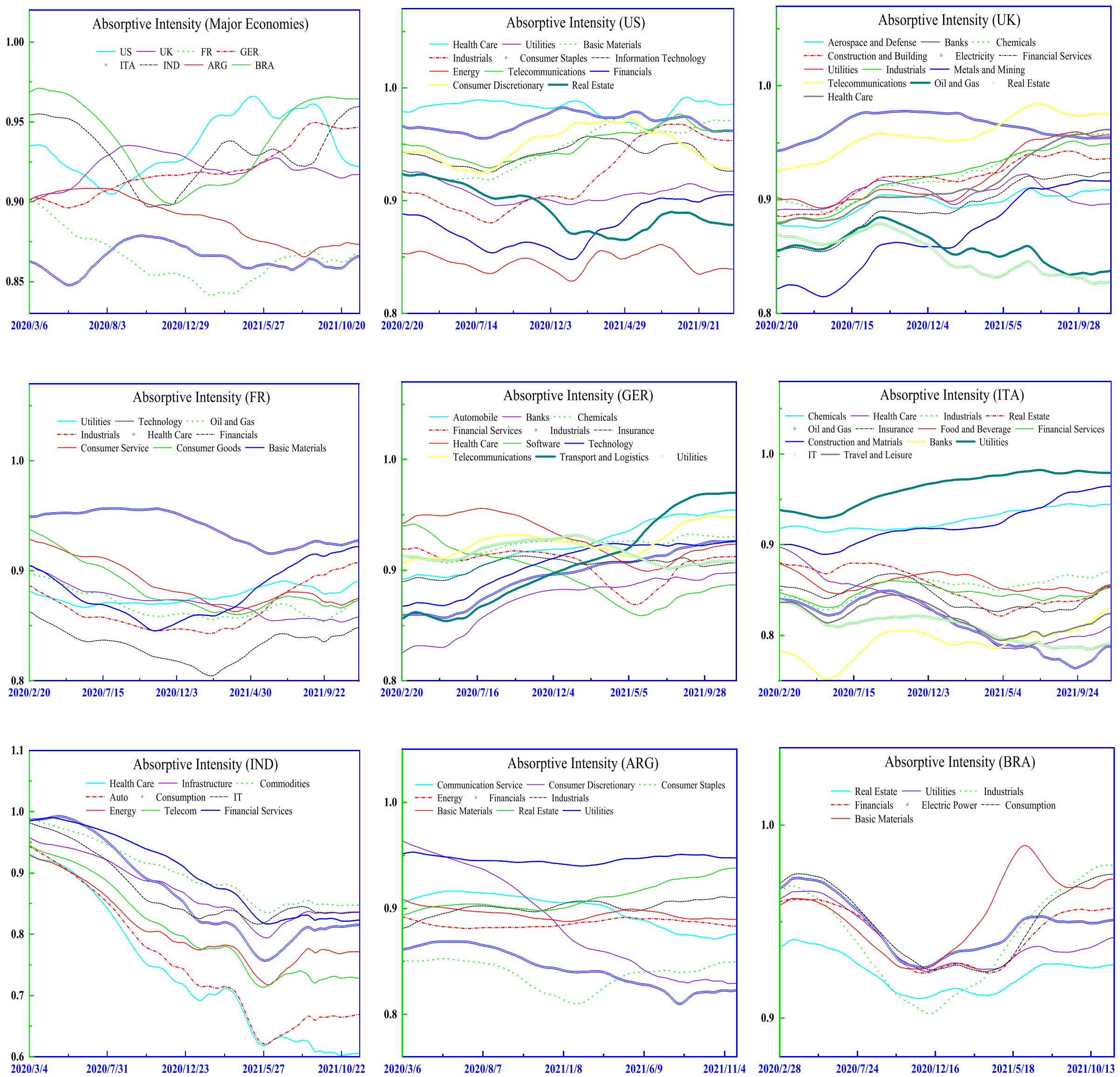


**Fig. 2.** Absorptive intensity of stock price indices to COVID-19 shocks.

$$
\begin{matrix} \beta_{t+1} = \beta_t + \mu_{\beta t} \\ \alpha_{t+1} = \alpha_t + \mu_{\alpha t} \\ h_{t+1} = h_t + \mu_{ht} \end{matrix}, \quad \begin{pmatrix} \varepsilon_t \\ \mu_{\beta t} \\ \mu_{\alpha t} \\ \mu_{ht} \end{pmatrix} \sim N\left(0, \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \Sigma_\beta & 0 & 0 \\ 0 & 0 & \Sigma_\alpha & 0 \\ 0 & 0 & 0 & \Sigma_h \end{pmatrix}\right) \tag{5}
$$

Then, we perform Bayesian estimation of time-varying parameters using the MCMC method and calculate the time-varying impulse response, through which we can measure absorptive capacity indicators.

### 2.3. Estimating the interaction of stock price resiliency

Due to the comovement of stock prices after a shock (López-Espinosa et al., 2015; Li and Zhao, 2016), the stock price index of a certain industry or country will spill over into other industries or countries. The shock absorptive capacity of stock prices is a single manifestation of stock price fluctuations, compelling us to investigate the spillover effect of shock absorption. Hence, we apply the typical network topology method proposed by Diebold and Yilmaz (2014). We construct the following spillover matrix based on the forecast-error-variance decompositions.

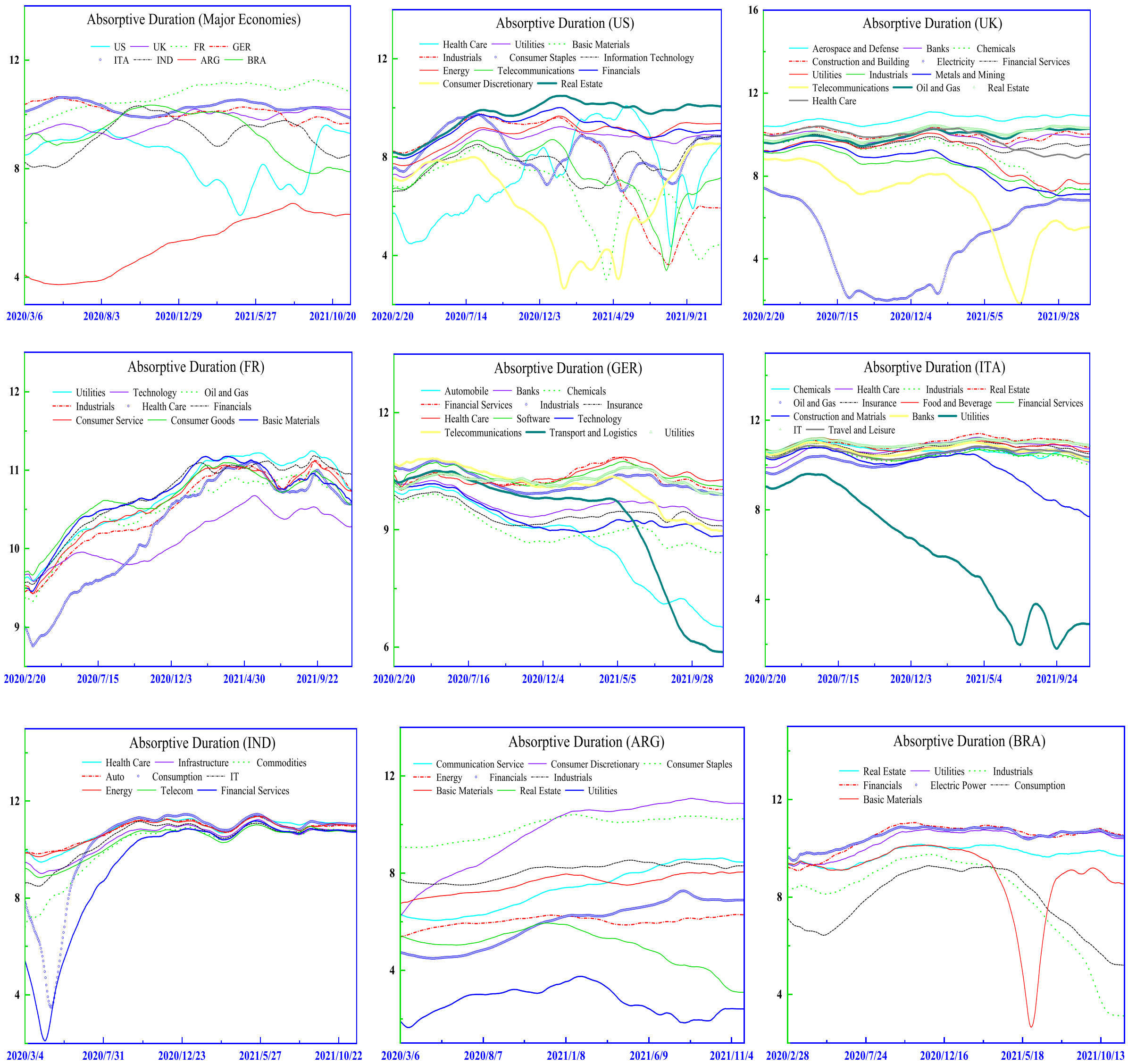


**Fig. 3.** bsorptive duration of stock price indices to COVID-19 shocks.

In Table 1, $d_{ji}^T$ represents the proportion of changes in $Y_j$ caused by the shock of an endogenous variable $Y_i$ in a certain period$T$, capturing the contagion effect among different industries, which is expressed as:.

$$d_{ji}^T = \frac{\sum_{t=0}^{T-1} e_{jit}^2}{\sum_{t=0}^{T-1} trace(E_t E_t')} \tag{6}$$

where $\sum_{t=0}^{T-1} e_{jit}^2$ describes the prediction error variance of variable $Y_j$ caused by the impact of an endogenous variable $Y_i$ in a certain period$t$, $E_t E'$ is the covariance matrix of prediction error, and $\sum_{t=0}^{T-1} trace(E_t E_t')$ represents the variance of total forecast error.

The elements of column *FROM* in Table 1 represent the absorptivity spillover of $Y_j$ from other variables, namely:.

$$S^T_{FROM,j\leftarrow\cdot} = \sum_{i=1}^{N} d_{ji}^T, \quad i \neq j \tag{7}$$

The elements of line *TO* in Table 1 represent the absorptivity spillover of $Y_i$ on other variables, namely:.

$$S^T_{TO,\cdot\leftarrow i} = \sum_{j=1}^{N} d_{ji}^H, \quad i \neq j \tag{8}$$

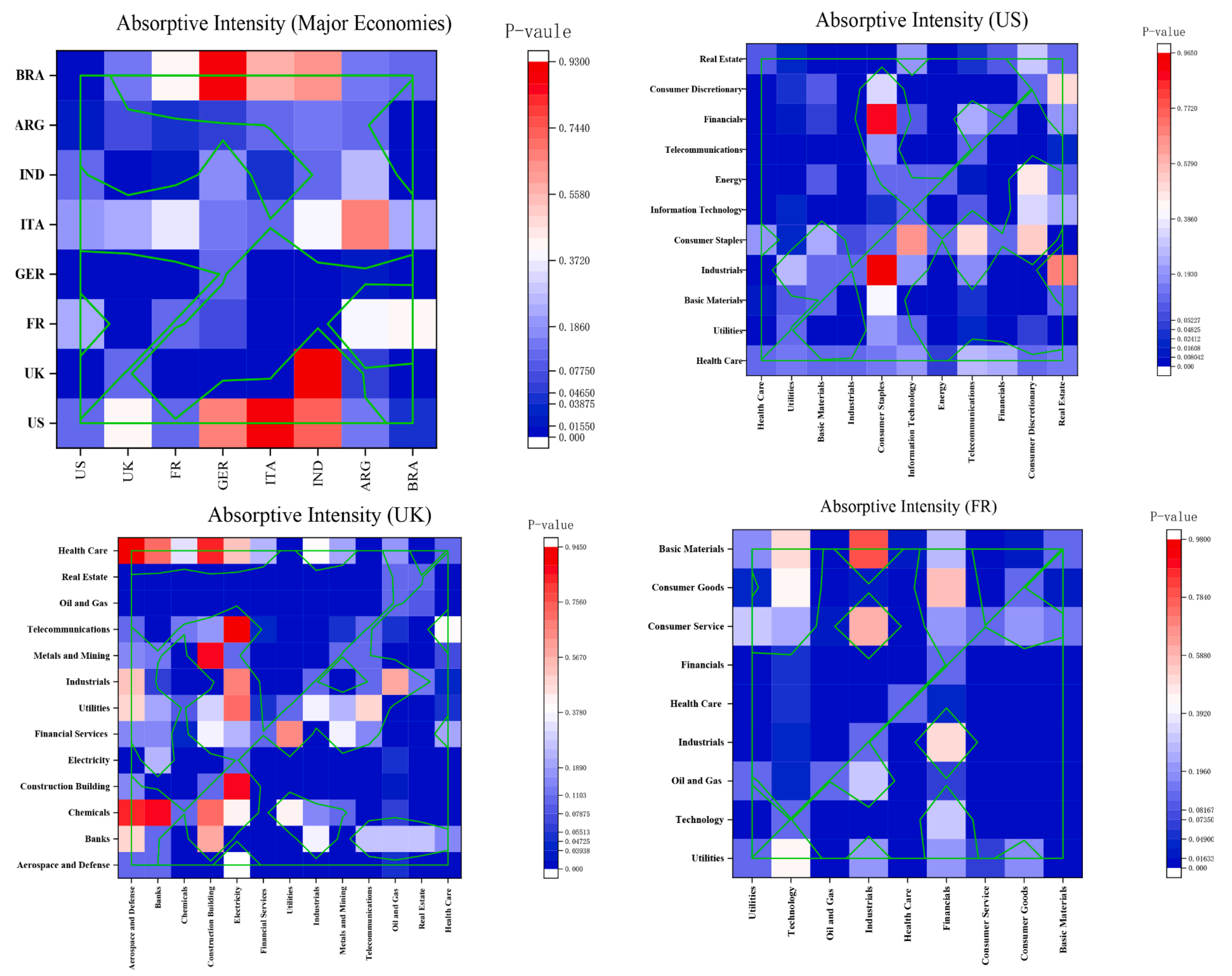


**Fig. 4. Causality in absorptive intensity among stock price indices.** *Note*: The variables on the lateral axis are the causal variables, and the variables on the vertical axis are the effect variables.

The element $S^T$ in the lower right corner of Table 1 measures the total spillover effect among $N$ variables, which is calculated as:.

$$S^T = \frac{\sum_{j,i=1}^{N} d_{ji}^T}{N}, \quad i \neq j \tag{9}$$

To analyze the role of certain variable in the spillover network, we need to further calculate the net spillover effect based on the *TO* index and the *FROM* index; the net spillover effect of variable $n$ is calculated as follows:.

$$NS_n^T = S^T_{TO,\cdot\leftarrow n} - S^T_{FROM,n\leftarrow\cdot} = \sum_{j=1}^{N} d_{jn}^T - \sum_{i=1}^{N} d_{ni}^T, \quad i \neq n, j \neq n \tag{10}$$

## 3. Data

This paper evaluates the stock price resiliency to COVID-19 shocks for the 8 stock markets in mainly affected countries including the US, the UK, France, Germany, Italy, India, Argentina, and Brazil. For each country, we select the stock price composite index and industry indices to measure stock price resiliency. The data used to measure the absorptive capacity of stock price indices include four types of variables: COVID-19 infections (*cases*), the short-run Treasury interest rate (*rate*), CBOE VIX, and composite and industry stock price indices. We use the cumulative infection number in these countries as the proxy for the COVID-19 pandemic. The 3-month

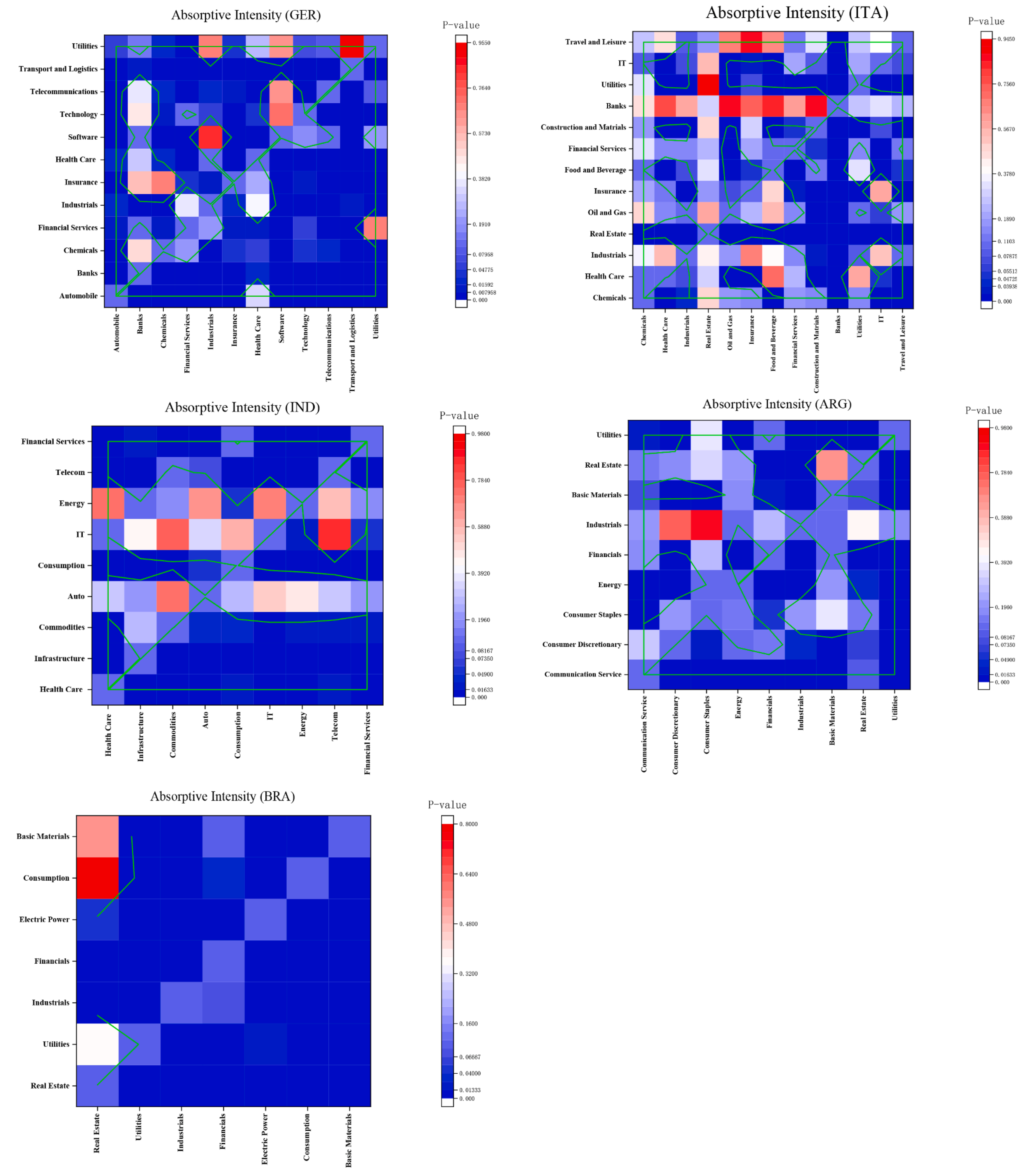


**Fig. 4.** (*continued*).

treasury rate functions as the proxy for the short-run interest rate.[1] All the data are of daily frequency. All variables except for the short-run interest rate are transformed into their differences of natural logarithms. The data were obtained from the CSMAR database and Investing website. Our sample periods for the 8 countries are different, depending on the availability of daily COVID-19 data. The sample information is described in Table 2.

[1] The 3-month treasury rate is highly negatively correlated with the Oxford government response index.

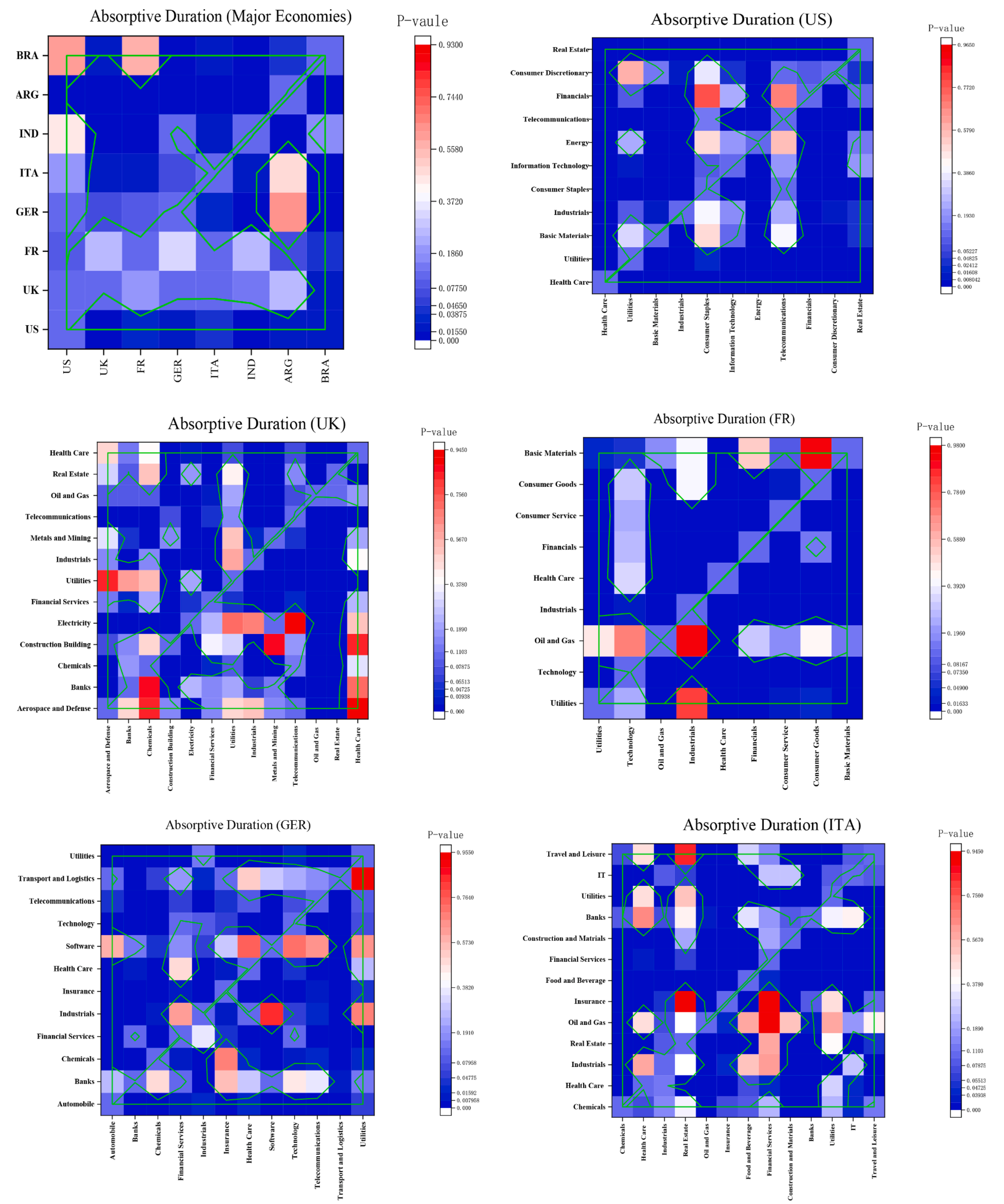


**Fig. 5. Causality in absorptive duration among stock price indices.** *Note*: The variables on the lateral axis are the causal variables, and the variables on the vertical axis are the effect variables.

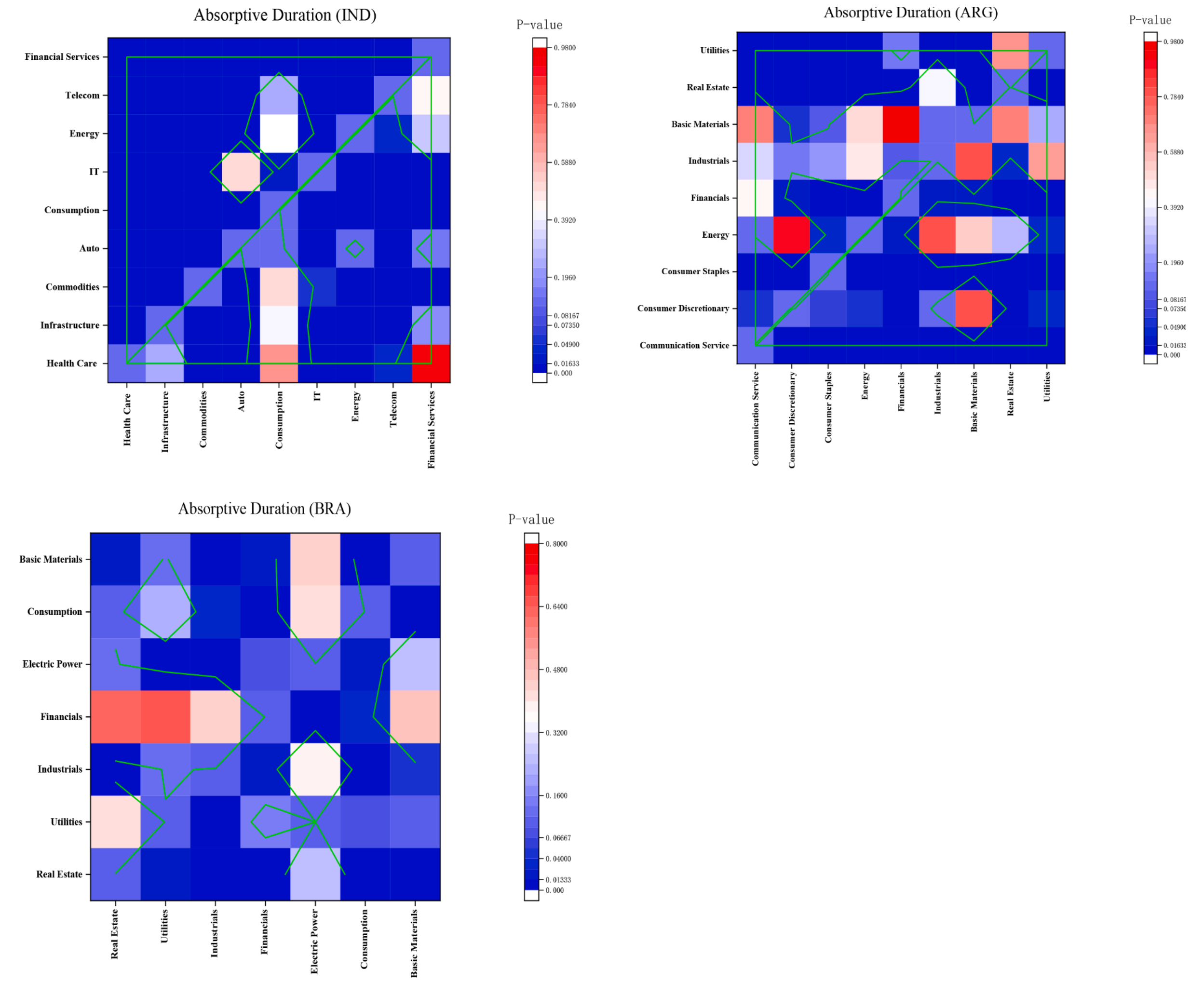


**Fig. 5.** (*continued*).

## 4. Empirical results

### 4.1. Results of shock absorptive capacity

To estimate the TVP-VAR model used to measure the absorptivity of stock prices, we first perform unit root tests. From the ADF tests, we fail to reject the null hypothesis of a unit root for all of the series at the 5% significance level. To compare the impulse responses of COVID-19 shocks, we set the TVP-VAR shocks to 1 and select the maximum absolute value of all the impulse responses as the value of$\bar{h}$. According to equations (2) and (3), we further calculate the shock absorptive intensity and duration, which are plotted in Fig. 2.

As Fig. 2 demonstrates, the absorptive intensity of stock price indices for the 8 countries and 83 industries vary over time. In general, the lines of stock price absorptive intensity for the 8 countries present four types of trajectories. The first type, as shown by the US, India, France, and Brazil, starts in decline and ends with a rise, presenting a U-shaped trend with a valley in the end of 2020. The second type, represented by the UK and Italy, presents an inverted U-shaped trend with a peak in September 2020. Moreover, the Germany stock price index exhibits a slow rise during the sample period. On the contrary, Argentina has a decreasing absorptive intensity. Of the averages of absorptive intensity for each country index, the largest value appears in the US and the Brazil stock markets, implying that the US and the Brazil stock price indices own striking resiliency to COVID-19 shocks. India has a relatively large average. However, France and Italy have the two smallest average values, implying that their stock price indices are more seriously affected by COVID-19. One possible explanation for why emerging markets such as India and Brazil have higher absorptive intensity is that their investors focus more on their national situation and are less affected by external shocks.

From the results of the US industry intensity, we can observe that the intensity of all the industry indices, except for the health care industry, shows a similar trend with that of the S&P500 index. According to the average values of the absorptive intensity, the health

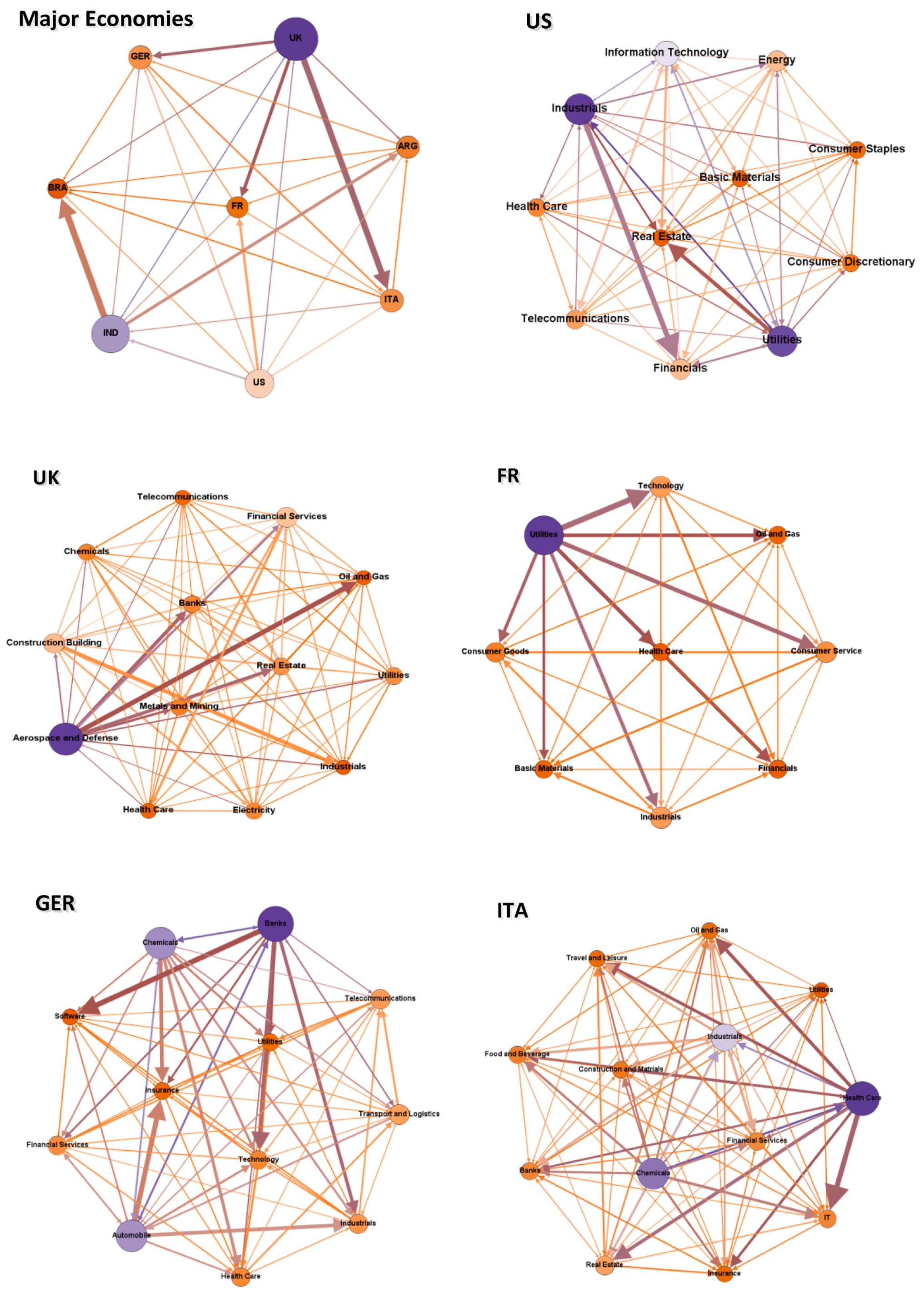


**Fig. 6.** Spillover networks of stock price absorptive intensity.

care and consumer staples industries have a high absorptive intensity, which is in line with our expectations. The energy, real estate, and financials industries have relatively low absorptive intensity. Similarly, the health care industry in the France stock market has relatively high absorptive intensity and its trend is significantly different from other industries, while the financials has the weakest absorptive intensity. From the UK stock market, the absorptive intensity of all industries maintains a consistent trend with that of the FTSE100 index. According to the values, the energy and real estate industries present a weak shock absorptive ability. In the Germany stock market, the health care industry has the highest absorptive intensity, while the banks industry has the lowest. From the results of

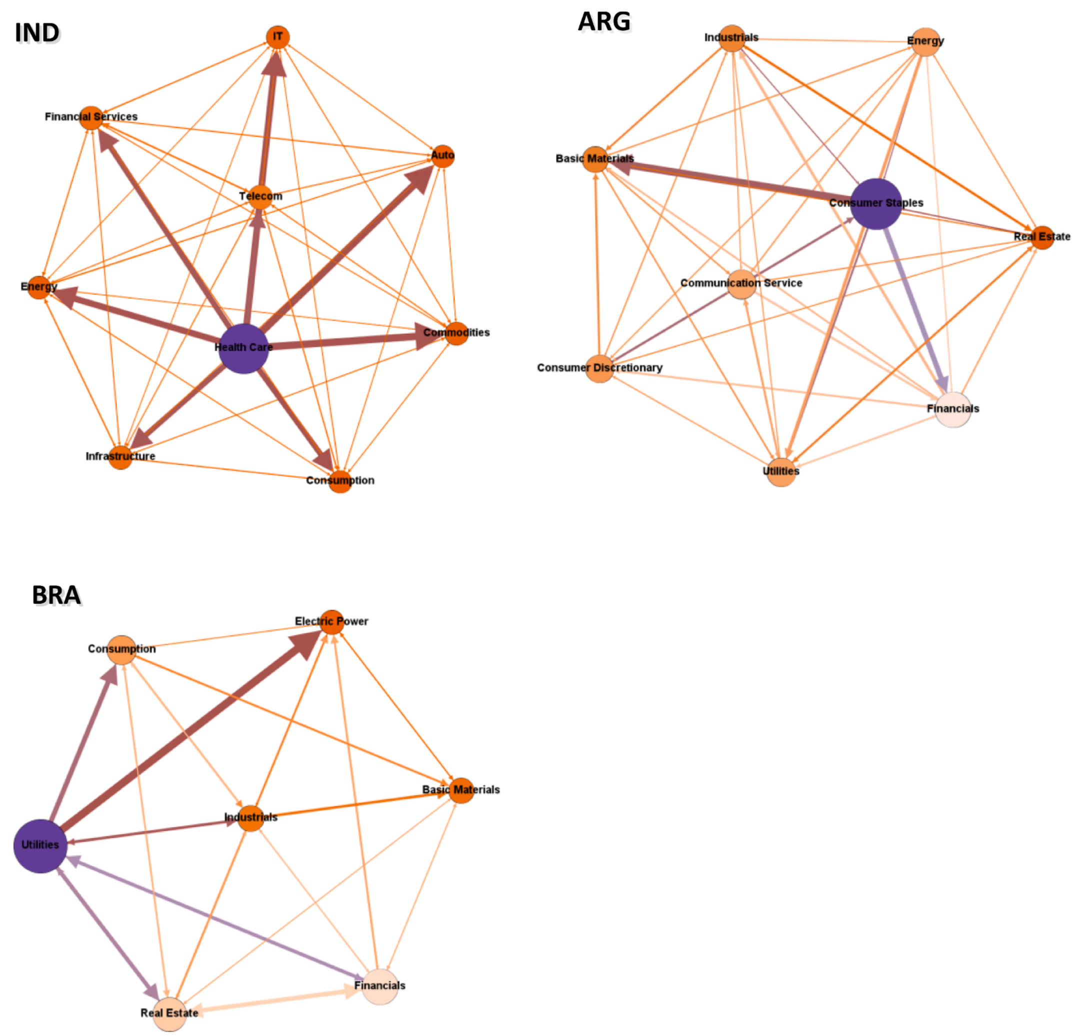


**Fig. 6.** (*continued*).

Italy industry intensity, the absorptive intensity of utilities and chemicals is relatively high, while the absorptive intensity of banks, energy, and travel industries is relatively low. According to the results of India industries, the auto and health care have the lowest absorptive ability, while the financial and infrastructure present relatively high absorptive ability. From the results of the Argentina market, the utilities industry has the highest absorptive intensity, while the financials has the lowest intensity. From the results of the Brazil market, the real estate intensity is the lowest and the consumer goods intensity is the highest. Overall, the trends of absorptive intensity vary across industries and countries. From the perspective of industry, the health care intensity shows a different trend from other industries, indicating the strongest shock absorptive ability. Moreover, the intensity of non-cyclical industries such as utilities and consumer staples is high, while the intensity of cyclical industries such as finance, banking, real estate, and energy is low. Such findings, to some extent, are consistent with those in Ramelli and Wagner (2020).

We turn to the results of the absorptive duration of stock price indices. The absorptive duration for various markets and industries, illustrated in Fig. 3, varies over time, which aligns with absorptive intensity. However, the volatility of the absorptive duration is much greater than in Fig. 2. From Fig. 3, we can observe that the Argentina stock price index has the shortest duration and shows a slow upward trend. The US stock price index also has a relatively short duration and shows a W-shaped trend. Short duration means the stock price index can absorb the COVID-19 shock in a short period of time. The duration of the France stock index also shows an upward trend during the sample period, however, the duration of the India and Brazil stock indices shows an inverted U-shaped structure.

According to the results of the absorptive duration of the industries in the US market, we can observe that the real estate, finance, and energy industries show a relatively long duration, while the health care and consumer discretionary industries have a short duration. From the UK stock market, the duration of the electricity and telecommunications industries have a shorter duration and greater volatility, while the aerospace and defense and real estate industries present long duration. Overall, the absorptive duration of the industry indices shows a significant upward trend in the France stock market, with the health care and technology industries

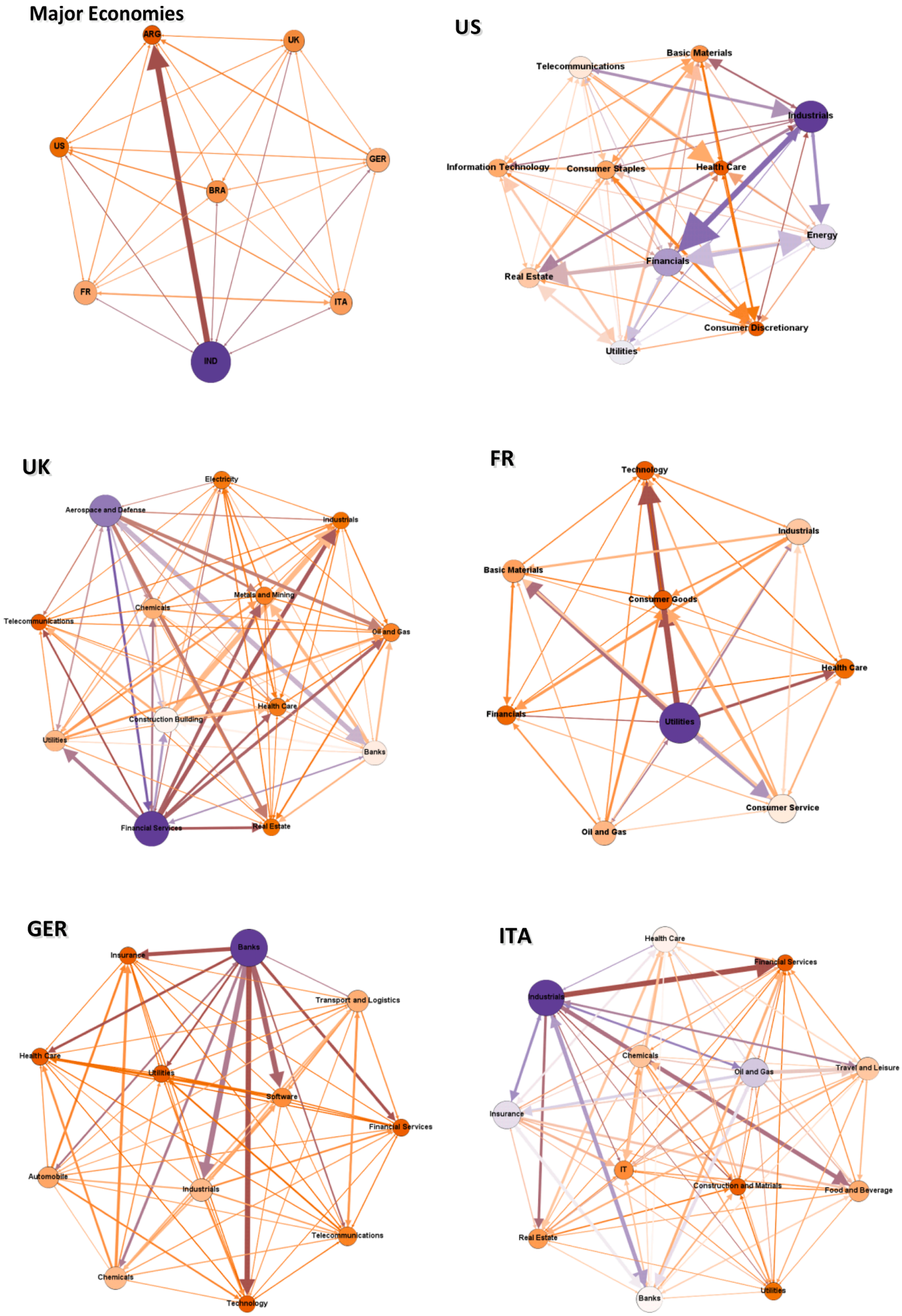


**Fig. 7.** Spillover networks of stock price absorptive duration.

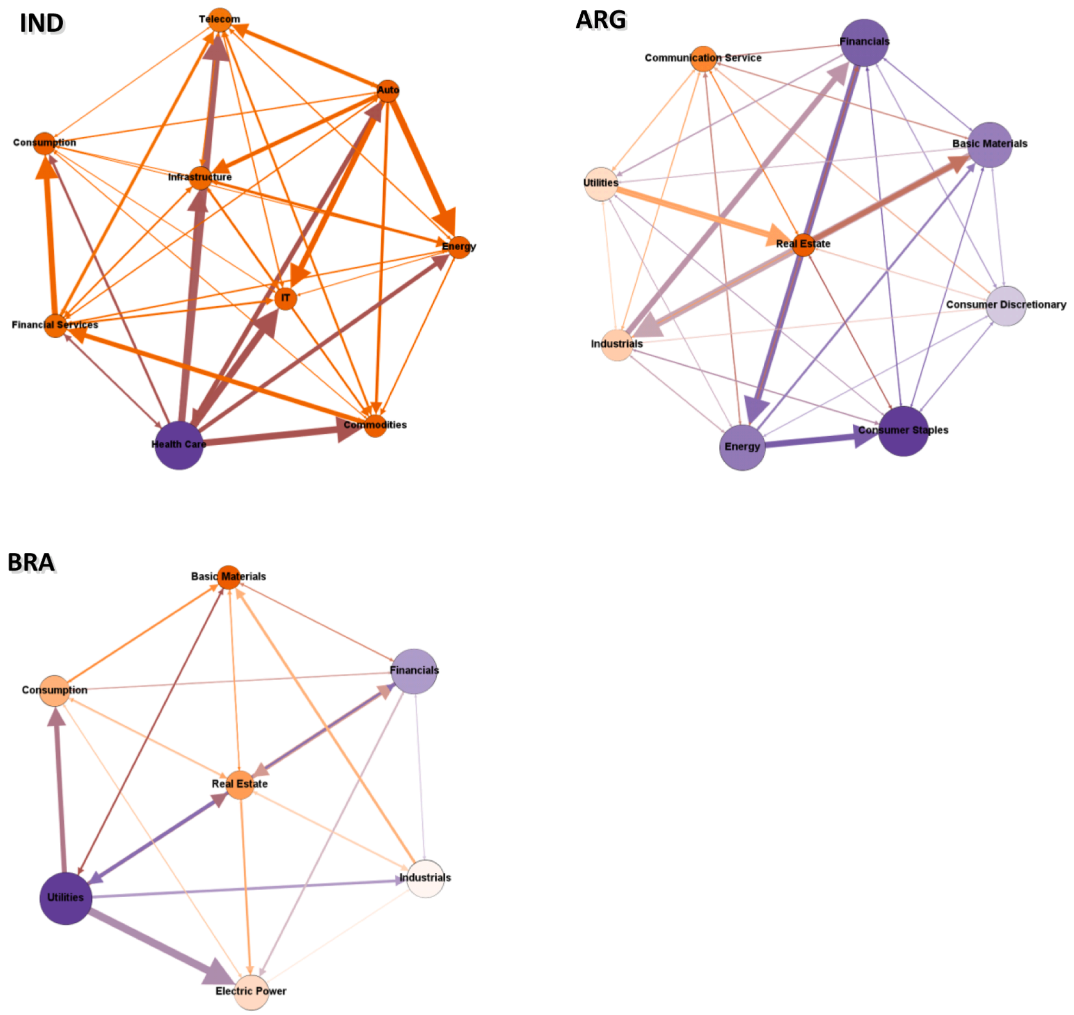


**Fig. 7.** (*continued*).

having relative low duration. According to the results of the absorptive duration of the industries in the Germany market, the duration of the auto and transport indices show a significant decline trend, while the finance and utilities present a high duration. In the Italy stock market, the real estate industry has a longer duration, and the utilities has a lower duration. In the India stock market, the duration shows an upward trend, and the volatility is relatively large in the early stage of the sample. The financial industry has lower duration, while the auto, energy and health care industries have high duration. On the whole, in developed financial markets, real estate, financials, and utilities stock price indices have higher durations, while in emerging markets these industries have lower duration. The health care industry shows lower durations in developed markets, while presenting higher duration in emerging markets.

### 4.2. *Results of causality tests*

To demonstrate a preliminary understanding of the relationship between stock price resilience, we conduct the Granger causality test. Fig. 4 plots the causality results for stock price absorptive intensity. The variables on the lateral axis are the causal variables, with the effect variables on the vertical axis. The blue zones indicate vertical variables that have significant impacts on the lateral axis variables. To mitigate the impact of trading time on the results, we use the 2-day moving average of stock price data for empirical analysis.

From Fig. 4, the shock absorptive intensity of the UK significantly Granger causes the intensity of Germany, France, and Italy. However, the shock absorptive intensity of the US has fewer causal effects on the European countries, except for the UK. The shock absorptive intensity of India significantly Granger causes the intensity of Argentina. From the results of the US industries, the absorptive intensity of health care is the Granger cause for the absorptive intensity of other industries, while other industries do not Granger cause the health care industry. The industrials and utilities industries are the main drivers of changes in the absorptive intensity of the other industries. In the UK stock market, the absorptive intensity of real estate, financial services, and health care is the Granger cause for most industries. In the France stock market, the absorptive intensity of utilities and health care are the Granger causes for other industries. In the Italy stock market, the causality among industries is significantly weaker than that in other countries. In the India stock market, the absorptive intensity of health care and financial services is the Granger cause for other major industries. In the Argentina stock market, the absorptive intensity of utilities and real estate is the Granger cause for other industries. The causality among industries in the Brazil stock market is particularly striking.

Fig. 5 plots the causality results for stock price absorptive duration. From the figure, we see that the shock absorptive duration of the UK, India, and Brazil has significantly caused that of the other countries. However, the shock absorptive duration of the US has fewer causal effects on the other countries, except for Argentina. From the results of the US industries, the absorptive duration of health care, energy, and financials Granger causes that of other industries. In the UK stock market, the absorptive duration of financial services and aerospace and defense significantly causes that of the other industries. In the France stock market, the absorptive duration of utilities and health care does Granger cause that of other industries. In the Italy stock market, the absorptive duration of the chemicals, insurance, and oil and gas industries has significant effects on that of the other industries. In the India stock market, the causal relationship among industries is striking. In the Argentina and Brazil stock markets, the absorptive duration of consumption is the Granger cause for other industries.

### 4.3. Results of the absorptivity spillover network

To enhance our understanding of the mechanism by which stock price resiliency is affected by others, we extend our analysis to calculate the spillover matrix and plot the spillover network for these measures. We display the absorptivity spillover connectedness for different measures using the network topology approach of Diebold and Yilmaz (2014).

Fig. 6 displays the spillover networks of absorptive intensity across countries and industries. From the results, we can observe that the UK, India, and the US stock markets are the most influential absorptive intensity transmitter, which aligns with the results of the causality tests. The Germany stock market also plays an important role in explaining the variations in other countries. The Argentina and the Brazil stock markets are the main recipients of the absorptive intensity spillover network.

According to the results of the spillover network of industry absorptive intensity, we can see that, in the US stock market, the utilities and industrials are the main intensity transmitters, which is consistent with the results of the Granger causality tests, while the real estate and basic materials are the main intensity recipients. The aerospace and defense industry is the most important intensity transmitters in the UK market, while the oil and gas and telecommunications are the main intensity recipients. As expected, the automobile industry plays a key role in the network in the Germany market. From the Italy and India markets, the health care industry is the center of the spillover network. In the Argentina market, the consumer staples is the most influential absorptive intensity transmitter. For the France and Brazil markets, the utilities acts as the most important transmitter in their own networks. Overall, the non-cyclical industries such as health care, utilities, and consumer staples are the main absorptive intensity transmitter, while the cyclical industries such as financial services, banking, real estate, and energy are the main recipients.

Fig. 7 illustrates the spillover networks of absorptive duration across countries and industries. From the results, we can observe that the India stock market is the most influential absorptive duration transmitter. The Germany stock market also plays an important role in explaining the variations in other countries. The Argentina stock market is the main duration recipient in the spillover network. According to the results of the spillover network of industry absorptive duration, we can see that, in the US stock market, the utilities, energy, financials, and industrials are the main duration transmitters, while the health care and consumer discretionary industries are the main intensity recipients. The aerospace and defense and financial services industries are the most important duration transmitters in the UK market, while the oil and gas and real estate are the main duration recipients. The banks industry plays a key role in the duration network in the Germany market. From the Italy and India markets, the IT industry is the main duration recipient. In the Argentina market, the financials and consumer staples are the most influential absorptive duration transmitter. Consistent with the results in Fig. 6, the utilities industry, in the France and Brazil markets, acts as the most important duration transmitter in their networks. On the whole, the non-cyclical industries such as utilities and consumer staples are the main absorptive duration transmitter, while IT and telecommunications are the main duration recipients.

### 4.4. Robustness checks

In this section, we analyze the robustness of our baseline measures for stock price resiliency by substituting important variables and applying different model specifications. First, we repeat the estimation by setting different periods of impulse response with 16 and using a TVP-VAR lag of 1. The results of the measures are reported in Figs. A1, A2, A3, and A4. As can be seen from the figures, the trajectories and the order of most stock price absorptive intensity and duration are consistent with the original results reported in Figs. 2 and 3. Thus, we can conclude that the findings reported are generally robust to variations in the lag of TVP-VAR model and periods of impulse response. Moreover, we replace the main shock variable infection cases with death cases. The new results are reported in Figs. A5 and A6. We can observe that most results are consistent with the baseline results, except for the absorptive duration of the Germany and the UK stock markets. On the whole, our results are robust to a different core variable and other model specifications.

### 4.5. Policy implications

We find that the US stock price index is not the most important resiliency transmitter, while the UK and the India stock price indices are the two most important resiliency spillovers. However, the US stock price resiliency plays an important role in driving the UK stock price resiliency. Such findings mean that when the COVID-19 worsens or the virus mutates, investors need to pay more attention to the performance of the UK and India stock markets. Meanwhile, we find that in the India stock market, the health care industry is the most important transmitter in both absorptive intensity and duration. Therefore, investors need also to focus on the performance of the health care industry in the India stock market. Furthermore, our results show that the intensity of the non-cyclical industries such as utilities and consumer staples is high, while the cyclical industries such as banking, real estate, and energy have lower absorptive intensity. Such findings mean that when the pandemic worsens, the government can take some stimulus measures such as issuing consumer coupons to stimulate consumption and reducing the taxation of utilities companies to stimulate utilities and the consumer industries, thus stabilizing the market.

## 5. Conclusion

This paper studies the resiliency of stock price indices to COVID-19 shocks by constructing two measures: absorptive intensity and duration. We then employ the Granger causality test and a network topology approach to investigate the interactions of stock price absorptivity across industries and countries. Our results show that stock price absorptivity varies over time and across countries and industries. The US and Brazil stock indices have relatively high absorptive intensity while short durations. The health care industry shows a distinctive trend in absorptive intensity from the other industries. The intensity of the non-cyclical industries such as utilities and consumer staples is high, while the cyclical industries such as banking, real estate, and energy have lower absorptive intensity. Moreover, the utilities, consumer staples, and financials industries are the main resiliency transmitter.

Our results suggest that most of the national stock price resiliency to absorb COVID-19 shocks has improved during the sample period. The interesting finding that stock price absorptivity varies across industries suggests that stock price absorptivity is tied to real fundamentals. There are several meaningful ways to elaborate upon our results. First, although we have found evidence of an increasing absorptivity of stock price indices when facing COVID-19 shocks, whether the observation holds for other assets is not clear; after all, a stock is simply one among many assets. Second, the calculated time-series measures can be used to assess the determinants of stock price resiliency through a panel data model. Third, the method proposed in this paper can be used to estimate the resiliency of time-series variables to an external shock.

*CRediT authorship contribution statement*

**Xu Zhang:** Conceptualization, Methodology. **Zhijing Ding:** Data curation. **Jianqin Hang:** Writing – original draft. **Qizhi He:** Writing – review & editing.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

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## Appendix Figures

(See Figs. A1-A6).

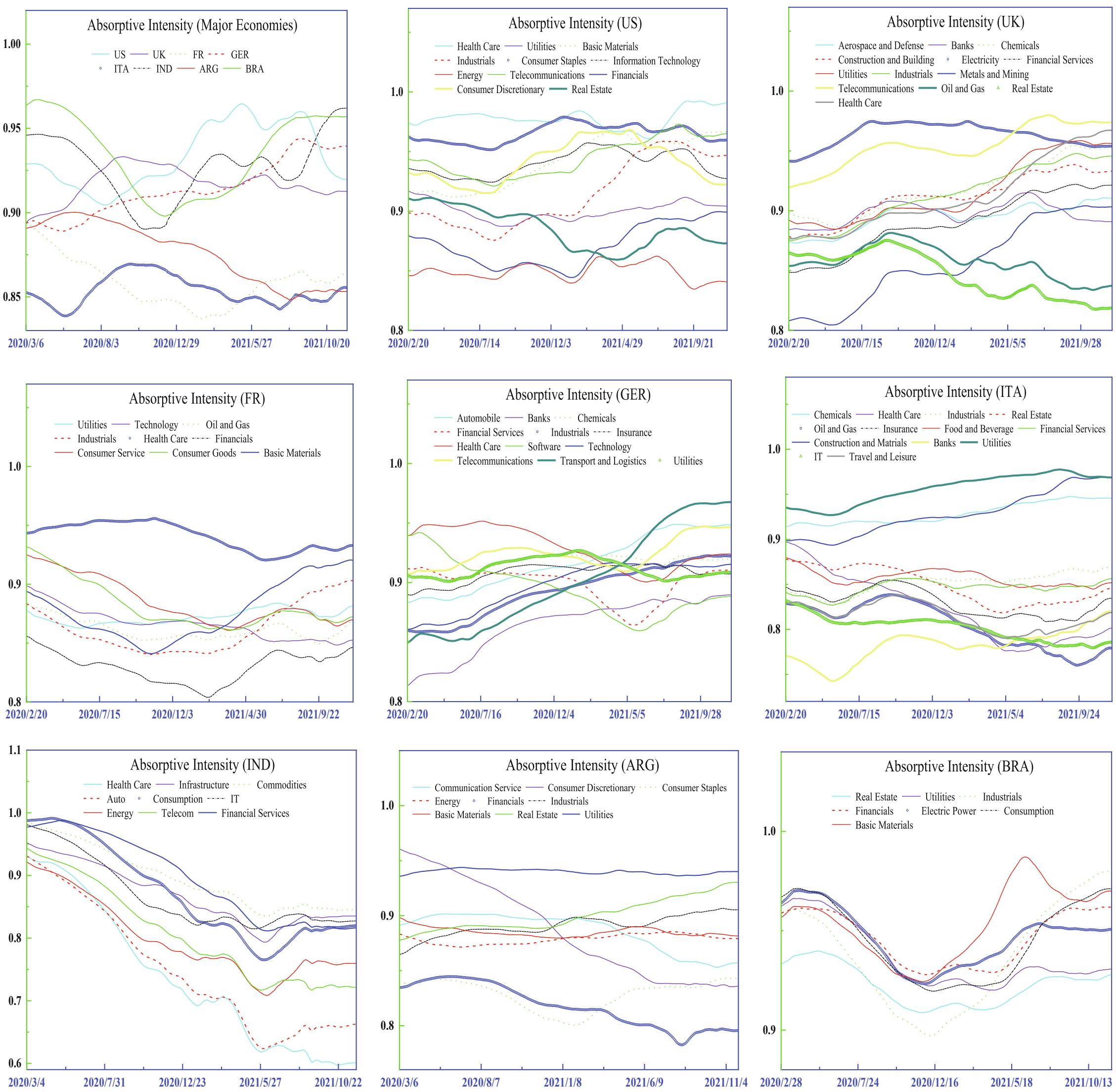

**Fig. A1.** Absorptive intensity of stock price indices (16-period impulse response).

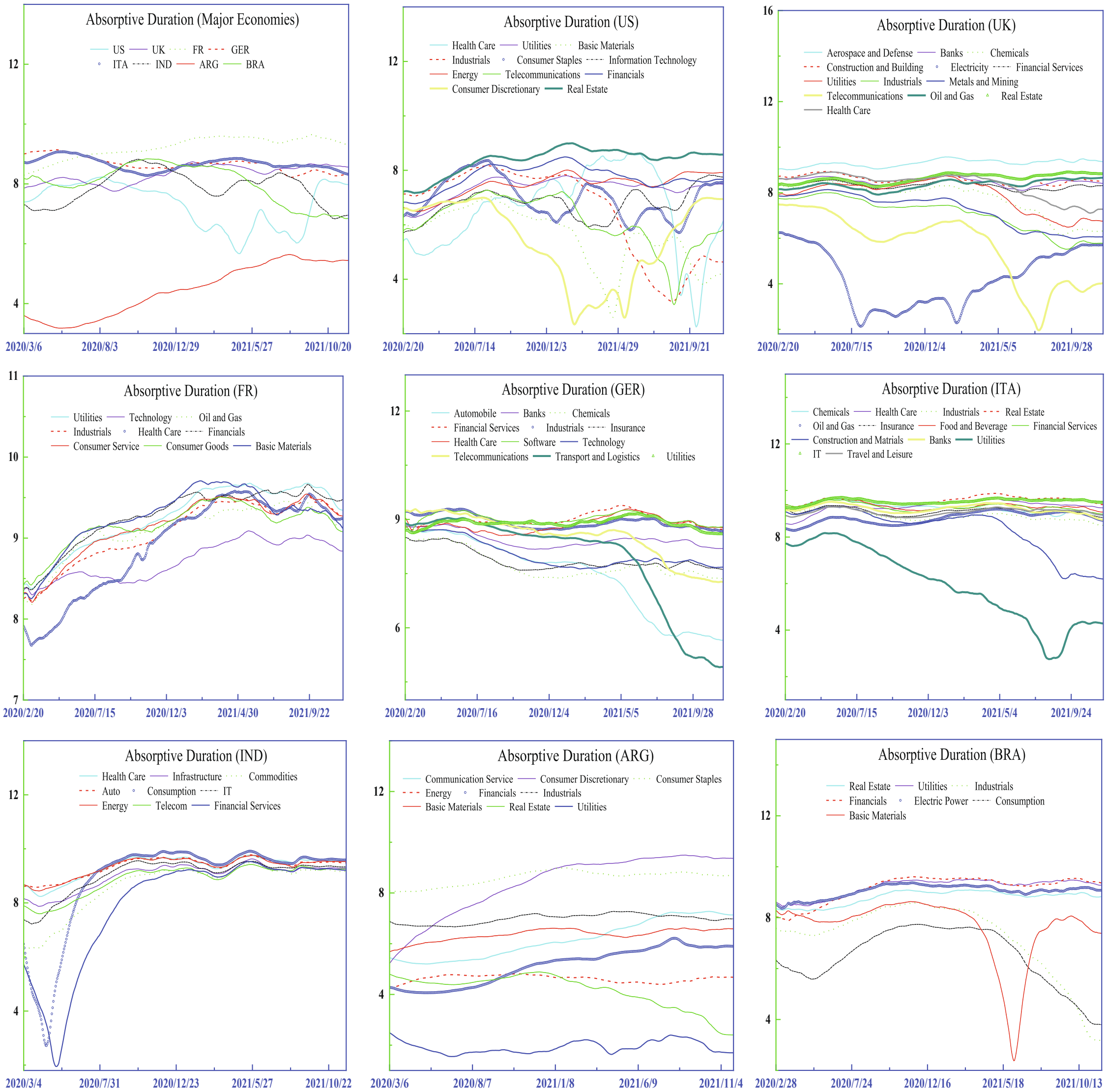


**Fig. A2.** Absorptive duration of stock price indices (16-period impulse response).

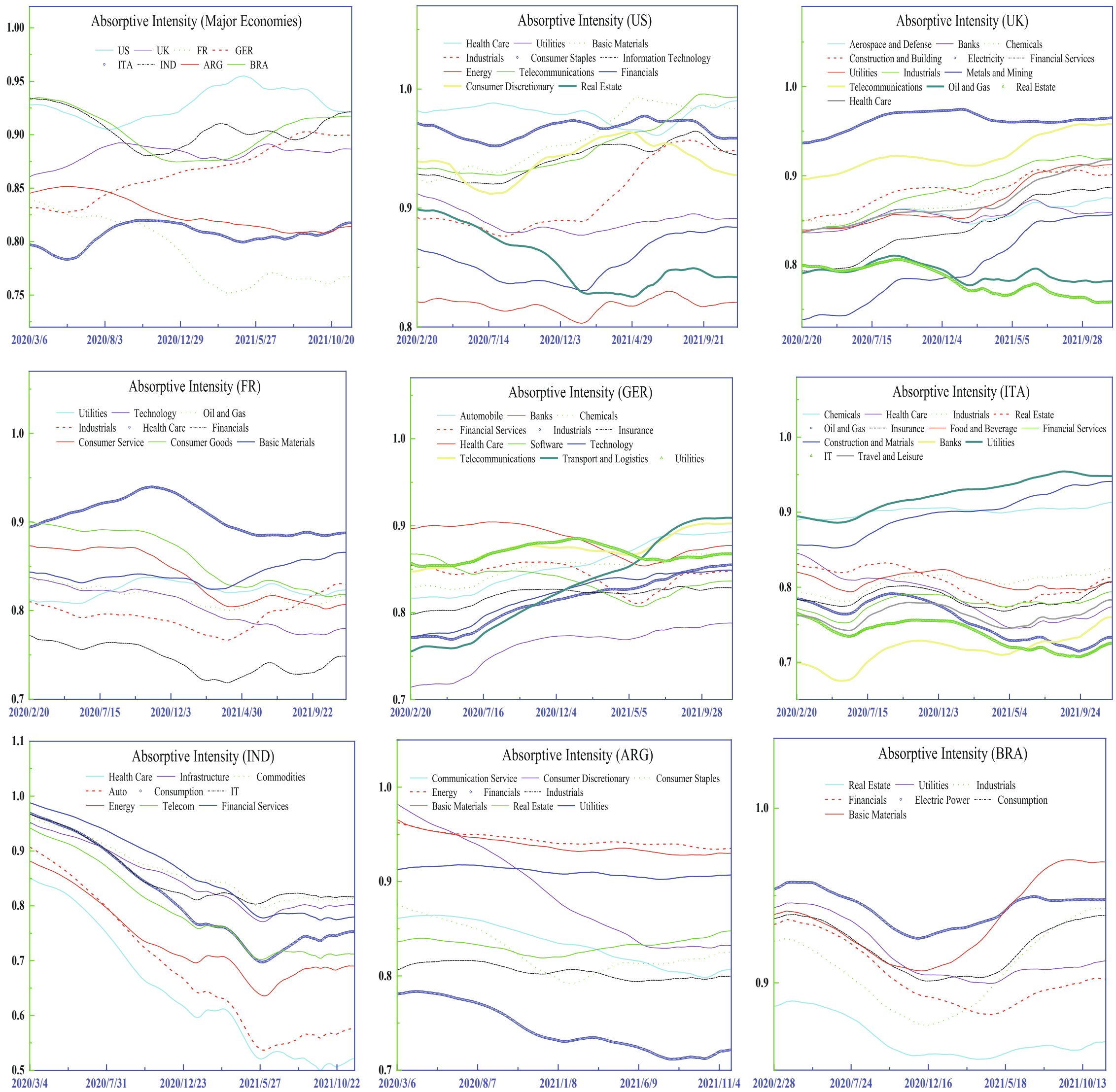

**Fig. A3.** Absorptive intensity of stock price indices (1-lag VAR).

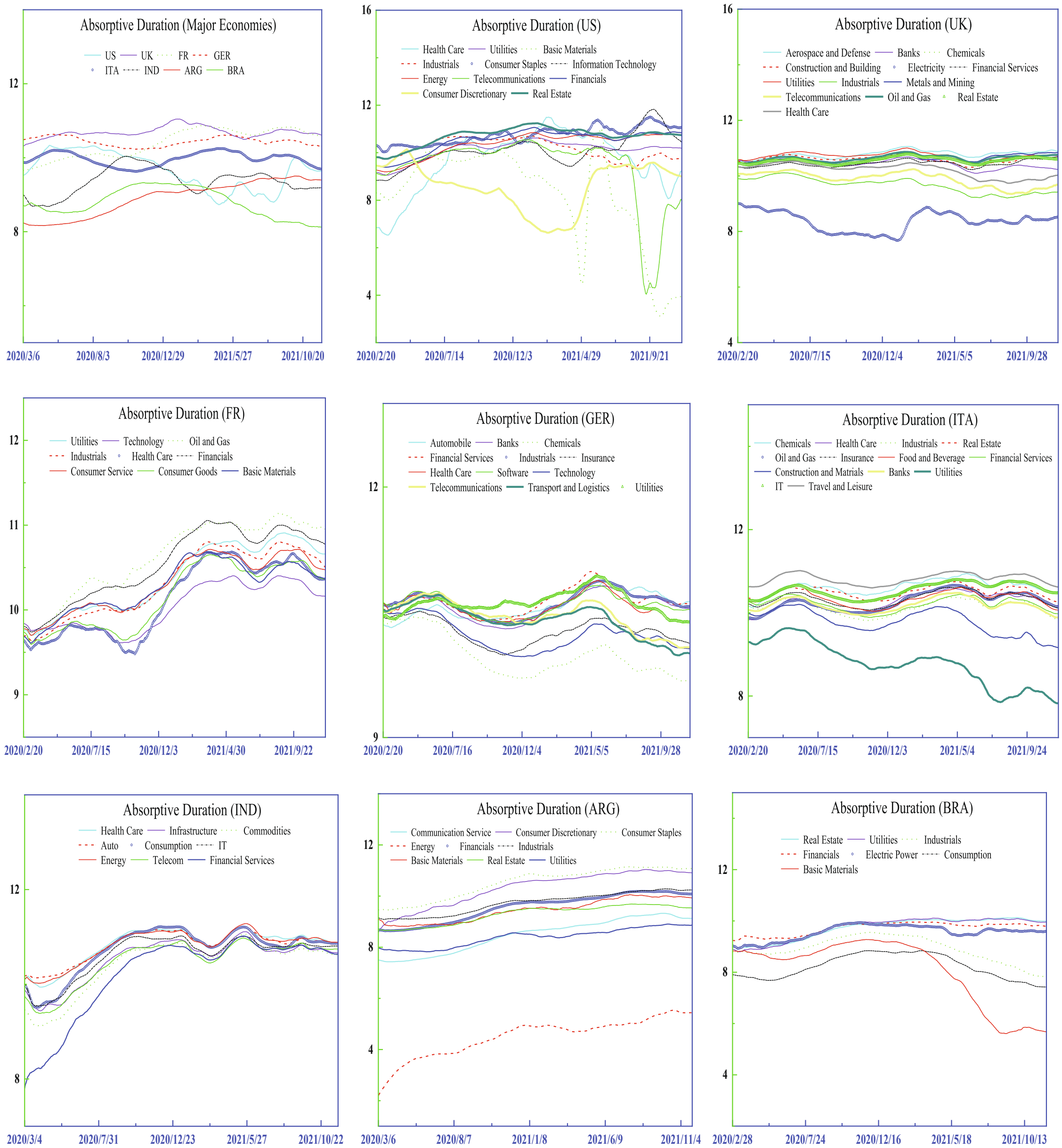


**Fig. A4.** Absorptive duration of stock price indices (1-lag VAR).


Fig. A5. Absorptive intensity of stock price indices (death cases).

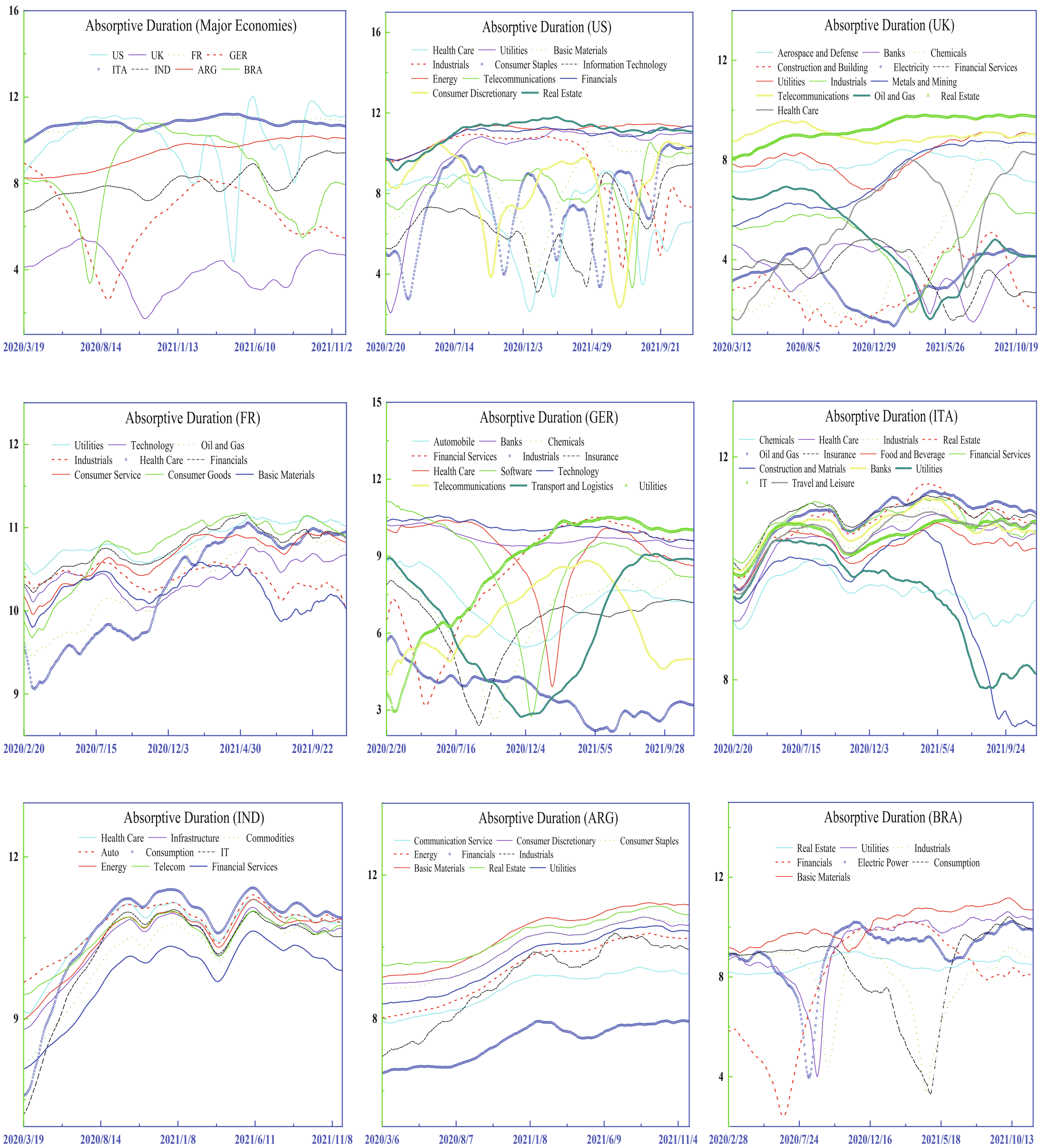


**Fig. A6.** Absorptive duration of stock price indices (death cases).

## References

Albuquerque, R., Koskinen, Y., Yang, S., & Zhang, C. (2020). Resiliency of environmental and social stocks: An analysis of the exogenous COVID-19 market crash. *The Review of Corporate Finance Studies, 9*, 593–621.

Baek, S., Mohanty, S. K., & Mina, G. (2020). COVID-19 and stock market volatility: An industry level analysis. *Finance Research Letters, 37*, Article 101748.

Baig, A. S., Butt, H. A., Haroon, O., & Rizvi, S. R. (2021). Deaths, panic, lockdowns and US equity markets: The case of COVID-19 pandemic. *Finance Research Letters, 38*, Article 101701.

Chiah, M., & Zhong, A. (2020). Trading from home: The impact of COVID-19 on trading volume around the world. *Finance Research Letters, 37*, Article 101784.

Diebold, F. X., & Yilmaz, K. (2014). On the network topology of variance decompositions: Measuring the connectedness of financial firms. *Journal of Econometrics, 182*, 119–134.

Engelhardt, N., Krause, M., Neukirchen, D., & Posch, P. (2021). Trust and stock market volatility during the COVID-19 crisis. *Finance Research Letters, 38*, Article 101873.

Fahlenbrach, R., Rageth, K., & Stulz, R. M., 2020. How valuable is financial flexibility when revenue stops? Evidence from the Covid-19 crisis. NBER Working Paper Series.

Fernandez-Perez, A., Gilbert, A., Indriawan, I., & Nguyen, N. H. (2021). COVID-19 pandemic and stock market response: a culture effect. *Journal of Behavioral and Experimental Finance, 29*, 100454.

Ferreruela, S., & Mallor, T. (2021). Herding in the bad times: The 2008 and COVID-19 crises. *The North American Journal of Economics and Finance, 58*, Article 101531.
Heyden, K. J., & Heyden, T. (2021). Market reactions to the arrival and containment of COVID-19: An event study. *Finance Research Letters, 38*, Article 101745.
Izzeldin, M., Muradoglu, G., Pappas, V., & Sivaprasad, S. (2021). The impact of Covid-19on G7 stock markets volatility: Evidence from a ST-HAR model. *International Reviewof Financial Analysis, 74*, Article 101671.
Just, M., & Echaust, K. (2020). Stock market returns, volatility, correlation and liquidity during the COVID-19 crisis: Evidence from the Markov switching approach. *Finance Research Letters, 37*, Article 101755.
Landier, A., & Thesmar, D. (2020). Earnings Expectations during the COVID-19 Crisis. *The Review of Asset Pricing Studies, 10*, 598–617.
Li, M., & Zhao, X. (2016). Neighborhood effect on stock price comovement. *The North American Journal of Economics and Finance, 35*, 1–22.
Li, Y., Zhuang, X., Wang, J., & Dong, Z. (2021). Analysis of the impact of COVID-19 pandemic on G20 stock markets. *The North American Journal of Economics and Finance, 58*, Article 101530.
Liu, X., Zhang, X., & Li, S. (2021). Measurement of China's macroeconomic resilience: Evidence from the perspective of systemic risk. *Social Sciences in China, 1*, 12–32.
López-Espinosa, G., Moreno, A., Rubia, A., & Valderrama, L. (2015). Systemic risk and asymmetric responses in the financial industry. *Journal of Banking & Finance, 58*, 471–485.
Matos, P., Silva, C., Santos, D., & Reinaldo, L. (2021). Credit, default, financial system and development. *The Quarterly Review of Economic and Finance, 79*, 281–289.
Nakajima, J. (2011). Time-varying parameter VAR model with stochastic volatility: An overview of methodology and empirical applications. *Monetary and Economic Studies, 29*, 107–142.
Primiceri, G. E. (2005). Time varying structural vector autoregressions and monetary policy. *Review of Economic Studies, 3*, 821–852.
Rahman, M. L., Amin, A., & Mamun, M. A. A. (2021). The COVID-19 outbreak and stock market reactions: Evidence from Australia. *Finance Research Letters, 38*, Article 101832.
Ramelli, S., & Wagner, A. F. (2020). Feverish Stock Price Reactions to COVID-19. *The Review of Corporate Finance Studies, 9*, 622–655.
Rehman, M. U., Kang, S. H., Ahmad, N., & Vo, X. V. (2021). The impact of COVID-19 on the G7 stock markets: A time-frequency analysis. *The North American Journal of Economics and Finance, 58*, Article 101526.
Sergi, B. S., Harjoto, M. A., Rossi, F., & Lee, R. (2021). Do stock markets love misery? Evidence from the COVID-19. *Finance Research Letters, 42*, Article 101923.
Sun, Y., Wu, M., Zeng, X., & Peng, Z. (2021). The impact of COVID-19 on the Chinese stock market: Sentimental or substantial? *Finance Research Letters, 38*, Article 101838.
Takyi, P. O., & Bentum-Ennin, I. (2020). The impact of COVID-19 on stock market performance in Africa: A Bayesian structural time series approach. *Journal of Economics and Business, 12*, Article 105968.
Tissaoui, K., Hkiri, B., Talbi, M., Alghassab, W., & Alfreahat, K. I. (2021). Market volatility and illiquidity during the COVID-19 outbreak: Evidence from the Saudi stock exchange through the wavelet coherence approaches. *The North American Journal of Economics and Finance, 58*, Article 101521.
Topcu, M., & Gulai, O. S. (2020). The impact of COVID-19 on emerging stock markets. *Finance Research Letters, 36*, Article 101691.
Uddin, G. S., Bekiros, S., & Ahmed, A. (2018). The nexus between geopolitical uncertainty and crude oil markets: An entropy-based wavelet analysis. *Physica A, 495*, 30–39.
Xu, L. (2021). Stock Return and the COVID-19 pandemic: Evidence from Canada and the US. *Finance Research Letters, 38*, Article 101872.
Yong, H. H., & Laing, E. (2021). Stock market reaction to COVID-19: Evidence from U.S. Firms' International exposure. *International Review of Financial Analysis, 76*, Article 101656.