Pandemics uncertainty and informational globalization in CEE countries: The role of innovation diffusion

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ABSTRACT

The Covid-19 pandemic has dramatically changed how information is shared and processed worldwide. The COVID-19 pandemic has profoundly affected the globalization of information, causing shifts in communication, information dissemination, and technology. This paper investigates the impact of pandemics-related uncertainty on the index of de facto informational globalization (the measure based on high-technology exports, international patents, and used internet bandwidth). The paper uses the panel dataset of 18 Central and Eastern European (CEE) countries from 1990 to 2020. The results indicate that pandemics-related uncertainty negatively affects the informational globalization level in the CEE economies. The findings are robust in utilizing different estimation techniques and considering NATO member CEE countries.

1. Introduction

The Covid-19 pandemic has dramatically changed how information is shared and processed worldwide. The COVID-19 pandemic has profoundly affected the globalization of information, causing shifts in communication, information dissemination, and technology [1]. E-commerce has also seen a boost as people have been forced to shop online due to lockdowns and restrictions on physical shopping [2].

The Covid-19 pandemic has profoundly affected the global economy, leading to an unprecedented economic slowdown [3]. Governments and businesses have had to develop innovative solutions to keep their economies stable. This issue has led to the development of new financial technologies, such as digital currencies and blockchain, and the adoption of new business models, such as e-commerce and remote work [4].

There are significant negative and positive effects of the COVID-19 pandemic on the globalization of information. Firstly, the Covid-19 pandemic increased the reliance on digital communication and technology. With lockdowns and physical distancing measures in place, people have had to find new ways to communicate and access information [5]. This issue has significantly increased digital technologies, such as cloud computing, online collaboration tools, social media, and video conferencing [6].

Secondly, the Covid-19 pandemic has accelerated the trend of remote work. During the Covid-19 pandemic, remote work has also become the norm for many industries. This has led to a new reliance on digital communication to increase labor productivity and

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connection with colleagues [7]. Remote work was already rising before the COVID-19 pandemic, but the need for physical distancing has accelerated its adoption [8]. As a result of the Covid-19 pandemic, businesses have had to quickly adapt to support remote work.

Thirdly, the Covid-19 pandemic has caused disruptions to traditional news media and the rise of misinformation [9]. The sudden shift to digital communication has created new opportunities for misinformation to spread quickly, leading to concerns about the accuracy of information. This issue has pressured traditional news media to adapt to the changing landscape and find new ways to verify and disseminate information [10].

Fourthly, the Covid-19 pandemic has led to an expansion of online education and virtual events. With lockdowns and physical distancing measures, schools and universities have quickly transitioned to online learning [11]. Virtual events have also become more prevalent, allowing people to connect and participate in events from the comfort of their own homes. This issue has created new opportunities for students to access education worldwide [12]. Still, the COVID-19 pandemic has also highlighted the digital divide and the need for equal internet and technology access [13].

Finally, the pandemic has heightened concerns over privacy and cybersecurity. The increased reliance on technology and digital communication has created new data privacy and security risks. With more sensitive information being shared and stored online, there is a greater need for robust privacy and security measures to protect corporate and personal data [14].

In addition, the Covid-19 pandemic has also had a profound impact on innovation across the world. It has accelerated the adoption of new technologies and innovations in several industries, as businesses and individuals had to adapt to the new reality of a world in lockdown. The COVID-19 pandemic has also highlighted the need for new technologies and innovations to help prevent the spread of the coronavirus and improve public health [15]. One of the most significant effects of the COVID-19 pandemic on innovation has been in the field of technology. Companies have had to quickly develop and implement new technologies (e.g., video conferencing) to allow employees to work from home [16]. With millions of people forced to work and study from home during the COVID-19 pandemic, the demand for technology enables remote work. The Covid-19 pandemic promotes online learning [8]. The COVID-19 pandemic has also accelerated the development of virtual and augmented reality technologies, which enhance remote work and online learning experiences [17].

Another area where the COVID-19 pandemic has significantly affected healthcare innovation [18]. The COVID-19 pandemic has spotlighted the need for better healthcare technologies and innovations to help prevent the coronavirus's spread and improve public health. Governments and private organizations have invested heavily in the development of new diagnostic tools and treatments, as well as in the production of vaccines. The COVID-19 pandemic has also accelerated the adoption of telemedicine, with more people turning to virtual consultations and remote monitoring technologies to receive medical care [19].

Given these backdrops, this paper investigates the effects of pandemics-related uncertainty on the indices of de facto informational globalization (a measure based on high-technology exports, international patents, and used internet bandwidth). For this purpose, the paper uses the panel dataset of 18 Central and Eastern European (CEE) countries from 1990 to 2020. Our informational globalization measure is based on the de facto KOF index of informational globalization, introduced by Ref. [20]. This index uses the data of high-technology exports, international patents, and internet bandwidth to measure informational globalization. Meanwhile, the primary variable of interest is the World Pandemics Discussion Index (WPDI) introduced by Ref. [21]. The World Pandemics Discussion Index captures the pandemics-related uncertainty across 18 CEE economies from 1990 to 2020.

The paper finds that per capita income positively relates to de facto informational globalization. Still, the impact of the age dependency ratio on de facto informational globalization is negative. The novel evidence is that the World Pandemics Discussion Index decreases de facto informational globalization. The results are robust enough to utilize different estimation techniques, such as the fixed effects and the Bias-corrected Least-squares Dummy Variable (BLDV) estimators. The results indicate that pandemics-related uncertainty negatively affects informational globalization in the panel dataset of CEE economies from 1990 to 2020.

The remainder of the paper is structured as follows. Section 2 reviews the previous articles on the relationship between technological innovation and informational globalization and the determinants of informational globalization. Section 3 provides the data and the model. Section 4 argues the empirical findings, and Section 5 delivers the concluding remarks.

2. Literature review

2.1. Technological innovation and informational globalization

Technological innovation has significantly increased informational globalization since the early 1990s [22]. The rise of informational globalization with technological innovation has several dimensions. First is the increase in internet speed and bandwidth capacity. For instance, Tim Berners Lee invented the World Wide Web in 1989, and the Internet became a global phenomenon in the early 1990s [23]. The Internet has changed entertainment dynamics and lifestyles around the globe and enhanced business communication and productivity [24]. By the 21st century, the Internet had been one of the most important inventions in history.

The second dimension is the rise of international patents around the globe. Thanks to the significant role of domestic innovation diffusion, patents promote economic growth and international technology transfer in developed and developing economies. Information globalization makes patent applications and management more accessible, and this issue promotes firms' efficiency and performance.

The third dimension is high-technology exports. Several developing economies (e.g., China) have upgraded their export baskets by including new products with high technology [25]. Then, these countries export high-technology products all around the globe. Meanwhile, informational globalization promotes high-technology products [26,27].

It is noteworthy to note that the COVID-19 pandemic has also affected these dimensions of internet speed, bandwidth capacity,

international patents, and high-technology exports. For instance, remote work became essential during the COVID-19 pandemic as much work has been done online [6,28]. At this stage, internet access with good speed has been an important determinant of workers' productivity during the COVID-19 pandemic [7,29]. The COVID-19 pandemic has also increased the supply of patented products, especially pharmaceuticals [30]. However, high technology exports have declined during the Covid-19 pandemic due to the restrictions on international trade [31].

2.2. Previous papers on informational globalization

Information globalization is the primary driver of investments, given that significant informational asymmetries exist among investors [32,33]. Informational globalization decreases corruption [34]. In addition [35], examined the impact of information globalization (de facto and de jure indices), the benchmark measure of information globalization, on institutional quality. The results from eight ASEAN member economies indicated that information globalization (de facto and de jure indices) promotes institutional quality. The authors controlled the role of economic growth, fiscal expenditures, and human capital.

Previous papers have examined the determinants of information globalization. However, previous articles have focused on the different main variables of interest. For instance, according to Refs. [36,37]; and [38]; migration is the primary source of information spread across different countries, and it promotes information globalization [39]. find that telephone traffic is the primary driver of information spread and the main source of informational globalization [40]. indicate that internet access is the primary driver of informational globalization. Generally speaking, cultural indicators, such as speaking the same language, having a common legal origin, or experiencing a colonial past, provide a similar culture which also increases information spread and, thus, information globalization [41–48].

3. Data and model

This paper uses the panel dataset of 18 countries (Albania, Belarus, Bosnia Herzegovina, Bulgaria, Croatia, the Czech Republic, Hungary, Latvia, Lithuania, Moldova, North Macedonia, Poland, Romania, Russia, the Slovak Republic, Slovenia, Ukraine, and Turkey) from 1996 to 2020. The start date is 1996, and it is due to the issue of data availability. We consider the yearly data.

Following the models in Refs. [44,49]; we estimate the following model by utilizing the fixed effects and the BLDV estimators of [50,51].

$$lnIG\_DF_{i,t} = \alpha_0 + \alpha_1\ WPDI_{i,t} + \alpha_2\ X_{i,t} + \tau_i + \omega_t + \varepsilon_{i,t} \tag{1}$$

$$lnIG\_DF_{i,t} = \beta_0 + \beta_1 IG\_DF_{i,t-1} + \beta_2\ WPDI_{i,t} + \beta_3\ X_{i,t} + \tau_{i,t} + \omega_{i,t} + \varepsilon_{i,t} \tag{2}$$

In Eq. (1) and Eq. (2), $IG\_DF_{i,t}$ and $IG\_DF_{i,t-1}$ are the current and the lagged de facto informational globalization index in the natural logarithmic form, $WPDI_{i,t}$ is the World Pandemics Discussion Index, $X_{i,t}$ captures the vectors for control variables. Note that i represents countries, and t indicates the year. Meanwhile, τ_i and ω_t represent the country and the time-fixed effects in the estimations. Note that $\varepsilon_{i,t}$ signifies error terms. At this stage, Eq. (1) is estimated by the fixed effects estimations, and Eq. (2) is estimated by the BLDV estimators, where the bias correction is initialized by Ref. [52] estimation procedure.

The dependent variable is the de facto informational globalization index, comprising high-technology exports, international patents, and internet bandwidth usage. Following [53]; the de facto informational globalization index is used in the natural logarithmic form. The related index is proposed in the KOF Globalization Index (version 2022) by Ref. [20]. The income effect is captured by per capita gross domestic product (GDP), which uses the constant 2010 USD price in the natural logarithmic form. The age-dependency ratio captures the demographic effect. The per capita GDP and the age-dependency ratio data are obtained from the [54]. The model suggests the positive impact of per capita income and the negative impact of the age dependency ratio on the de facto informational globalization index.

Furthermore, the primary variable of interest is the World Pandemics Discussion Index, and its data are provided by Ref. [21]. The World Pandemics Discussion Index measure implements text-mining approaches on country reports and editorial articles in the Economist Intelligence Unit. The text-mining methods are based on searching for specific words, such as "pandemics" and "uncertainty." At this stage [21], suggest that the World Pandemics Discussion Index measure significantly models uncertainty shocks related to pandemics in developing and developed economies.

At this stage, Table 1 summarises descriptive statistics of all indicators used in the estimations.

Table 1
A summary of descriptive statistics.

Variable	De Facto Information Globalization	Log GDP Per Capita	Age Dependency Ratio	World Pandemics Discussion Index
Mean	4.139	8.936	45.61	0.232
Maximum	4.493	10.21	63.35	11.75
Minimum	3.388	7.254	34.76	0.000
Standard Deviation	0.248	0.718	4.864	1.201
Observation	450	450	450	450
Data Source	[20]	[54]	[54]	[21]

Note that Table 2 also reports the pairwise correlation matrix.

Table 2 indicates a positive correlation between per capita income and the de facto informational globalization index. However, the correlation between the World Pandemics Discussion Index and the age dependency ratio with the de facto informational globalization index is negative. Still, the correlation between the per capita GDP, age dependency ratio, and the World Pandemics Discussion Index is negative. The correlation between per capita GDP and the age dependency ratio is positive. These correlations align with the theoretical expectations.

4. Empirical findings

4.1. Findings of the fixed effects estimations: all CEE countries

Table 3 provides the results of the fixed effects estimations to analyze the impact of the World Pandemics Discussion Index on the de facto informational globalization index in the panel dataset of 18 CEE economies from 1996 to 2020.

Column (I) reports the results where only the World Pandemics Discussion Index is included. In addition, Column (II) consists of the per capita GDP with the World Pandemics Discussion Index. Column (III) consists of the age dependency ratio with the World Pandemics Discussion Index in the estimations. Finally, the results with all variables are reported in Column (IV) in Table 3.

Regarding findings, it is found that the average World Pandemics Discussion Index coefficient is around −0.012. The related coefficients are statistically significant at the 5 % level. This evidence indicates that the pandemic uncertainty adversely affects the de facto informational globalization index in the panel dataset of 18 CEE economies. Regarding the controls, it is found that the per capita income promotes the de facto informational globalization index. The related coefficients are statistically significant at the 1 % level. However, the age dependency ratio is negatively associated with the informational globalization index. The coefficients of age dependency are also statistically significant at the 1 % level.

4.2. Findings of the BLDV estimations: all CEE countries

Table 4 reports the findings of the BLDV estimations to examine the impact of the World Pandemics Discussion Index on the de facto informational globalization index in the panel dataset of 18 CEE economies from 1996 to 2020.

Column (I) provides the findings where only the World Pandemics Discussion Index is included. In addition, Column (II) consists of the per capita GDP with the World Pandemics Discussion Index. Column (III) consists of the age dependency ratio with the World Pandemics Discussion Index in the BLDV estimations. Finally, the findings with all variables are reported in Column (IV) in Table 4.

Regarding results, it is observed that the average of the World Pandemics Discussion Index coefficient is around −0.012. The related coefficients are statistically significant at the 1 % level. This result shows that the pandemic-related uncertainty decreases the de facto informational globalization index in the panel dataset of 18 CEE countries. Regarding the controls, the per capita income increases the de facto informational globalization level. The related coefficients are statistically significant at the 1 % level. In addition, the age dependency ratio is negatively related to the de facto informational globalization index. The related coefficients are statistically significant at the 5 % level. The lagged dependent variables are also statistically significant at the 1 % level in each estimation.

4.3. Findings of the fixed effects estimations: NATO member CEE countries

We also focus on 13 North Atlantic Treaty Organisation (NATO) member CEE countries in the panel data sample: Albania, Bulgaria, Croatia, the Czech Republic, Hungary, Latvia, Lithuania, North Macedonia, Poland, Romania, the Slovak Republic, Slovenia, and Turkey. Therefore, we exclude five countries and re-estimate the models with the fixed effects and the BLDV estimation procedures. We suggest that NATO member CEE countries would have better access to tools for informational globalization.

Table 5 reports the findings of the fixed effects estimations to show the impact of the World Pandemics Discussion Index on the de facto informational globalization index in the panel dataset of 13 NATO member CEE countries from 1996 to 2020.

Column (I) provides the findings where only the World Pandemics Discussion Index is included. In addition, Column (II) adds the per capita GDP to the World Pandemics Discussion Index. Column (III) consists of the age dependency ratio with the World Pandemics Discussion Index in the estimations. Finally, the results with all variables are provided in Column (IV) in Table 5.

When we look at the results in Tables 5 and it is observed that the average World Pandemics Discussion Index coefficient is around −0.013. The related coefficients are statistically significant at the 1 % level. This evidence shows that the pandemic-related uncertainty

Table 2
Pairwise correlation matrix.

Variable	De Facto Information Globalization	Log GDP Per Capita	Age Dependency Ratio	World Pandemics Discussion Index
De Facto Information Globalization	1.000			
Log GDP Per Capita	0.574	1.000		
Age Dependency Ratio	−0.301	0.006	1.000	
World Pandemics Discussion Index	−0.121	−0.111	−0.003	1.000

Source: The authors' calculations.

Table 3
Fixed effects estimation results.

Indicator	(I)	(II)	(III)	(IV)
Log GDP Per Capita	–	0.663*** (0.017)	–	0.653*** (0.023)
Age Dependency Ratio	–	–	−0.025*** (0.003)	−0.008*** (0.001)
World Pandemics Discussion Index	−0.012** (0.006)	−0.009** (0.004)	−0.013** (0.006)	−0.012** (0.005)
Intercept	4.142*** (0.011)	−3.667*** (0.203)	5.318*** (0.139)	−1.296*** (0.254)
Observation	450	450	450	450
Countries	18	18	18	18
Adjusted R-squared (Within)	0.004	0.782	0.151	0.701

Notes: The dependent variable is the KOF de facto information globalization index. The standard errors are in parentheses. ***$p < 0.01$ and **$p < 0.05$.
Source: The authors' estimations.

Table 4
Bias-corrected least-squares dummy variable (BLDV) estimation results.

Indicator	(I)	(II)	(III)	(IV)
Lagged De Facto Information Globalization Index	0.958*** (0.027)	0.971*** (0.037)	0.931*** (0.021)	0.966*** (0.038)
Log GDP Per Capita	–	0.137*** (0.026)	–	0.127*** (0.027)
Age Dependency Ratio	–	–	−0.028** (0.012)	−0.003*** (0.001)
World Pandemics Discussion Index	−0.007*** (0.002)	−0.012*** (0.003)	−0.009*** (0.003)	−0.020*** (0.003)
Observation	432	432	432	432
Country Sample	18	18	18	18

Notes: The dependent variable is the de facto information globalization index. The bootstrapped standard errors are in parentheses. ***$p < 0.01$ and **$p < 0.05$.
Source: The authors' estimations.

Table 5
Fixed effects estimation results: NATO member CEE countries.

Indicator	(I)	(II)	(III)	(IV)
Log GDP Per Capita	–	0.663*** (0.028)	–	0.674*** (0.026)
Age Dependency Ratio	–	–	−0.026*** (0.004)	−0.007*** (0.001)
World Pandemics Discussion Index	−0.014*** (0.004)	−0.011*** (0.003)	−0.014*** (0.004)	−0.013*** (0.004)
Intercept	4.574*** (0.013)	−3.856*** (0.217)	5.203*** (0.151)	−1.425*** (0.361)
Observation	325	325	325	325
Countries	13	13	13	13
Adjusted R-squared (Within)	0.006	0.791	0.177	0.713

Notes: The dependent variable is the KOF de facto information globalization index. The standard errors are in parentheses. ***$p < 0.01$.
Source: The authors' estimations.

adversely affects the de facto informational globalization index in the panel dataset of 13 NATO member CEE countries. Regarding the control variables, it is observed that the per capita income increases the de facto informational globalization index. The related coefficients are also statistically significant at the 1 % level. However, the age dependency ratio is negatively related to the informational globalization index. The coefficients of age dependency are also statistically significant at the 1 % level.

Table 6
Bias-corrected least-squares dummy variable (BLDV) estimation results: NATO member CEE countries.

Indicator	(I)	(II)	(III)	(IV)
Lagged De Facto Information Globalization Index	0.944*** (0.020)	0.949*** (0.035)	0.927*** (0.023)	0.954*** (0.045)
Log GDP Per Capita	–	0.126*** (0.023)	–	0.125*** (0.024)
Age Dependency Ratio	–	–	−0.029** (0.014)	−0.003** (0.001)
World Pandemics Discussion Index	−0.009*** (0.003)	−0.011*** (0.003)	−0.010*** (0.003)	−0.018*** (0.003)
Observation	312	312	312	312
Country Sample	13	13	13	13

Notes: The dependent variable is the de facto information globalization index. The bootstrapped standard errors are in parentheses. ***$p < 0.01$ and **$p < 0.05$.
Source: The authors' estimations.

4.4. Findings of the BLDV estimations: NATO member CEE countries

Table 6 provides the results of the BLDV estimations to investigate the impact of the World Pandemics Discussion Index on the de facto informational globalization index in the panel dataset of 13 NATO member CEE countries from 1996 to 2020.

Column (I) reports the results where only the World Pandemics Discussion Index is included. In addition, Column (II) adds the per capita GDP to the World Pandemics Discussion Index. Column (III) consists of the age dependency ratio with the World Pandemics Discussion Index. Finally, the findings with all variables are provided in Column (IV) in Table 6 in the BLDV estimations.

When we look at the findings, it is found that the average of the World Pandemics Discussion Index coefficient is around −0.012. The related coefficients are statistically significant at the 1 % level. This finding indicates that the pandemic-related uncertainty decreases the de facto informational globalization index in the panel dataset of 13 NATO member CEE countries. Regarding the controls, the per capita income promotes the de facto informational globalization level. The related coefficients are statistically significant at the 1 % level. In addition, the age dependency ratio is negatively associated with the de facto informational globalization index. The related coefficients are statistically significant at the 5 % level. The lagged dependent variables are also statistically significant at the 1 % level in each result. In short, the results remain robust when the panel dataset of 13 NATO member CEE countries is considered.

The COVID-19 pandemic has profoundly affected informational globalization across the CEE countries. The Covid-19 pandemic has accelerated the adoption of new technologies and innovations in several industries, highlighting the need for new solutions to address the challenges posed by the Covid-19 pandemic. The COVID-19 pandemic has significantly changed the CEE region's economy, leading to further financial technologies and business models. While the COVID-19 pandemic has brought about many challenges, it has also created new opportunities for informational globalization. It has opened up new avenues for growth and development in CEE countries.

5. Concluding remarks

The Covid-19 pandemic has significantly affected the globalization of information. It has increased the reliance on technology and digital communication, accelerated the trend of remote work and e-commerce, caused disruptions to traditional news media and the rise of misinformation, expanded online education and virtual events, and heightened concerns over privacy and cybersecurity. The pandemic has accelerated the trend towards a more interconnected yet digital and remote world of information exchange, with long-lasting effects on how people communicate, access information, and do business.

Given these backdrops, this paper analyzed the impact of pandemics-related uncertainty, measured by the World Pandemics Discussion Index of [21]; on the de facto informational globalization index of [20]. The paper uses the panel dataset of 18 CEE economies from 1996 to 2020. It is observed that per capita income promotes de facto informational globalization. However, the age dependency ratio is negatively related to the measure of informational globalization. The novel finding in the paper is that the World Pandemics Discussion Index reduces the capacity of informational globalization. The results remain robust to consider different estimation procedures, such as the fixed effects and the BLDV estimations.

Finally, our panel data sample is limited to 18 CEE countries from 1996 to 2020. Hence, future studies can enhance the number of countries in the panel data sample. The time dimension of the panel data should be updated until 2023 to capture the role of the COVID-19 pandemic in the relationship between pandemics-related uncertainty and informational globalization all around the globe.

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Zhou Lu: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization, Funding acquisition, Supervision. **Yajie Huang:** Writing – review & editing, Formal analysis, Validation. **Peiliang Du:** Methodology, Data curation, Validation. **Fang Li:** Data curation, Methodology, Validation. **Zhenhui Li:** Supervision, Project administration, Funding acquisition, Conceptualization, Writing – original draft.

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.

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