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Original Research

The Relationship between Technology of Higher Education in the Case of European Countries, a Panel Approach

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Abstract

The educational system of the twenty-first century is student-centered. Students are the generation that has seen firsthand the enormous expansion of online media represented by the Internet, virtual reality, and artificial intelligence, which has increased the relevance of digital competence in higher education. This is because they are the ones who have grown up with the rapid development of computer networks and who have firsthand knowledge of those technologies. Additionally, the epidemic has raised public awareness of the need ~~of~~ for digital literacy. The increasing digitalization and modernization of every area of our lives to satisfy the needs of modern education is creating new chances for both teaching and learning. The world over, more and more technology is being used to improve training and education, which eliminates the need to take into account regional factors that are associated with traditional education. More and more educational establishments are using technology to improve instruction. The paper's primary objective is to pinpoint the internet-related and digitalization-related variables that have an impact on higher education in European nations using the following indicators: patent applications, resident population, high-tech exports, research and development spending, and school enrollment at the tertiary level (% gross). Due to data availability, the sample includes 40 nations over the period 1996-2020. The World Bank database is the source of the information. Panel-data VAR and panel Granger causality were the methodologies we used. Our findings suggested that the Internet and digitalization considerably impact higher education because high-technology exports represent both the internet and digitalization.

Keywords: digitalization, patent applications, resident population, high-tech exports, panel - data VAR, panel Granger

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Introduction

New opportunities for teaching and learning are emerging as a result of the growing modernization and digitization of all aspects of our lives to meet the demands of contemporary education [1]. The use of technology to enhance education and training is increasing globally, eliminating the need to consider geographical issues related to conventional education [2-5]. Information and communication technology (ICT) is being used more often in higher education, universities, and other institutions throughout the globe for administrative, learning, and teaching tasks as well as for developing curricula [6-8]. A growing number of educational institutions are embracing the use of technology to enhance learning. The use of digital technology in teaching and learning has had a profound impact on education in general and higher education in particular [9-11]. To provide their students with a comfortable, secure, and adaptable learning environment, many institutions and organizations are updating their instructional techniques [12-14]. In higher education, the importance of digital competency is becoming more and more widespread, and the Covid-19 has raised social awareness of the need for digital skills [15, 16]. Overall, it can be said that this kind of development of higher education is a realistic expectation of the target audience, therefore it should appear as a priority of institutional interest and a fundamental strategic development direction in the management's approach. The Internet, virtual reality, artificial intelligence, and the rapid rise of computer networks are examples of the incredible growth of online media that students attending institutions in the twenty-first century have seen [17-19]. The addition of these apps to the teaching-learning process would also be very beneficial for today's tech-savvy aspirant teachers. These individuals are digital natives who utilize technology on a daily basis. Since most studies examining the connection between the internet and higher education were conducted in the past [11, 20-22] to our knowledge, no studies examining this topic have been published. Our research fills this gap by stressing the significance of the internet and digitalization for higher education in this setting. This poses a novelty. This study contributes to the corpus of knowledge on the components of higher education by taking the internet into account as a factor of impact. Given that the pandemic influenced every activity, this study also has a substantial impact on businesses and decision-makers. However, it should be noted that although a lot of digital technologies are available and accessible to everyone, after the end of the pandemic, most institutions returned to the usual operating order of frontal education and examinations. This article proceeds as follows. Section 2 reviews the literature on technological revolution and digitalization aspects. In Section 3, we identify the factors related to the Internet and digitalization influencing higher education in European countries by panel-data VAR and panel Granger causality. Section 5 presents the empirical results. Section 6 presents the discussion and conclusion.

Literature Review

The 21st century saw another technological evolution that gave rise to what is now known as Web 2.0 technologies that constituted a fundamental change in the production, dissemination, and access of information, even if many of the intrinsic teaching and learning affordances of ICT were still intact [23-25]. Openness, personalization, collaboration, social networking, social presence, and user-generated content are some of the characteristics that have come to define Web 2.0 [26-29]. Online education is becoming more and more commonplace in schools [30], rather than just a fad that affects colleges. Learning is no longer limited to the conventional in-class and on-campus settings, which lends weight to this idea. Online business education is becoming more popular in response to the growing needs of a changing student body and increased competition on the education market. In comparison to their more conventional classroom equivalents, e-learning and online teaching businesses face particular difficulties. Promoting an agile organization from the managers' viewpoint is a key component of effective online education. Along with everyday planning, instructors and students need to prepare and receive training [31]. Higher education institutions are increasingly using digital tools like social media and virtual learning environments to improve the educational experience of their students and aid them in achieving their individual educational objectives. Technology provides many chances to study, educate more effectively, and contribute to the creation of new information. But at the same time, ICT advancements pose difficulties for the educational sector. According to literature and field research, the following three concerns are the major stumbling blocks to the potential value addition that technologically improved teaching and learning methods might provide to the educational system. Digital technology may support innovative learning strategies and successfully support the successful acquisition of information and skills, particularly those that are necessary in today's environment. By leveraging audience response systems or digital presentations to graphically portray difficult processes, for example, digital technologies provide potential to assist and improve on-site learning. They also enable technology-enhanced distant learning [32]. Modern education has incorporated digital technologies into regular tasks, and formal learning spaces also anticipate their usage. Examples include subject-specific learning resources, interactive whiteboards, desktop or mobile videoconferencing, mobile apps, gaming consoles, tablets, and smartphones. Additionally, learning management systems (LMSs) like Moodle and Blackboard have lately acquired prominence as crucial tools in the area of education, despite the fact that they are already in use [33,34]. The lockdown has had a detrimental influence on several aspects of daily life, but the impact on education has been particularly severe given the nature of the situation [35]. Many changes were brought about by the closing of educational institutions, one of which was the shift toward an education that was more technologically focused [36,37].

More than 65 percent of students have had mixed experiences, and the remaining students are still not particularly impressed [38]. Less than one-fourth of students in higher education (HE) say their HE experience exceeded their expectations. The results of the survey suggest that one reason for the poll's abysmal ranking is how little support students get while they work to achieve their HE goals. The poll findings indicate that one factor contributing to such a dismal rating is the little assistance students get while they strive to meet their HE objectives.

Material and Methods

In order to identify the factors related to the Internet and digitalization influencing higher education in European countries, we used the following variables: Patent applications, residents, High-technology exports, Research and development expenditure, and School enrollment, tertiary (% gross). Because of the availability of data, the sample spans the years 1996-2020 and includes 40 nations: Albania, Austria, Belgium, Bulgaria, Bosnia and Herzegovina, Belarus, Switzerland, Cyprus, Czech Republic, Germany, Denmark, Spain, Estonia, Finland, France, United Kingdom, Greece, Croatia, Hungary, Ireland, Iceland, Italy, Lithuania, Luxembourg, Latvia, Moldova, Malta, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, Serbia, and Slovak Republic.

The variable description is presented in Table 1 The World Bank database provides the information.

As methodology, we considered panel-data VAR and panel Granger causality. For panel data, the first step consists of verifying the cross-section dependence and Unit root tests [39, 40]. The cross-section dependence was performed using the Lagrange Multiplier, Pesaran's CD test Friedman's and Frees' test. For testing the stationarity are utilize, ADF-Fisher Chi-Square, and PP-Fisher Chi-Square tests. To detect Granger causality in panel datasets, the appropriate model's number of delays was chosen by considering the minimum values for AIC (Akaike information criterion), BIC (Bayesian information criterion), and HQ (Hannan-Quinn information criterion) [41].

The Panel-data VAR (Vector Autoregressive) methods represent a mixed econometric methodology, introduced by Sims [42] to examine the variable time-series property [43]. It considers the variables to be endogenous, including a fixed effect [44].

An additional dimension known as the cross-section is added by considering the variables as both endogenous and interdependent. The panel VAR has the following form:

$$Y_{it} = A_{0i}(t) + A_i(l)Y_{t-j} + u_{it}$$

Where i = 1,40, t = 1996,2020, Y_{it} is a vector of G X 1, G represents the number of variables for country i, and Y_t is the stacked version of y_{it}.

Vector Error Correction Model (VECM) [45] is a form of VAR, implying restriction due to the variables being non-stationary, but cointegrated. Thus, VECM reflects a long term relationship between non-stationary variables and a short-run relationship between the variable dynamic and the lag effect. The 4-variable panel VAR is used to establish the dynamic connection between variables, demonstrating the effects of a perturbation shock on the variables for impulse response function analysis while assuming the other variables remain constant [46]. The analysis was performed using the Eviews Student version.

Empirical Results

We applied the panel VAR, ideal for addressing interconnected economic issues. The descriptive statistics for the data used in the research are presented in Table 2.

As it can be observed from Table 2, the average value for the number of patent applications for the

Table 1. Variables description.

Variables	Description	Unit of measure
Patent applications, residents	Patent applications reflect the inventions, both product or process in order to provide solutions to a problem.	Number
High-technology exports	High-technology exports refers to products with high R&D intensity.	Current US$
Research and development expenditure	Gross domestic research and development spending, which includes fundamental research, applied research, and experimental development.	% of GDP
School enrollment, tertiary (% gross)	School enrollment tertiary education is the share of people at the secondary level.	% gross enrollment

Source: own research

Table 2. Summary Statistics of the Variables.

Variables	Patent applications, residents	High-technology exports	Research and development expenditure	School enrollment, tertiary
Mean	3523.122	$5.49*10^{14}$	1.444	68.360
Min.	2.000	4246458	0.193	10.607
Max.	48480.00	$2.16*10^{16}$	3.734	148.531
Std. Dev.	7928.27	$2.95*10^{15}$	0.885	17.223

Source: own research

countries in the sample is 3523.12, ranking between 2 and 48480, with a standard deviation of 7928.27. The minimum value for High-technology exports is 4246458 US$, the maximum value is $2.16*10^{16}$ the mean value is $5.49*10^{14}$ and standard deviation is $2.95*10^{15}$. Regarding Research and development expenditure, the countries in the sample register have values varying from 0.193% to 3.734%, with an average value of 1.44% and a standard deviation of 0.885%. The smallest value registered for the School enrollment, tertiary is 10.61% and the biggest value is 148.53%. The mean value is 68.36% and standard deviation is 17.22%. According to the Jarque-Bera test, all the variables are normally distributed.

According to Table 3, the variables are not reporting a very high correlation. In addition, Patent applications, residents show a positive correlation with all the variables (strong correlation with High-technology exports and a weak correlation with Research and development expenditure and School enrollment, tertiary), High-technology exports present a positive, but weak correlation with Research and development expenditure and a negative correlation with School enrollment, tertiary. Research and development expenditures indicate positive and weak correlations with all the variables. An important step in our modeling is identifying the cross-sectional dependence between variables, for this we perform the Pesaran cross-sectional dependence test (Table 4). The findings demonstrated the absence of cross-sectional dependency, demonstrating that there is no correlation between the variables.

Table 4. Results from cross-sectional dependence test.

Test	Statistic	Prob.
Breusch-Pagan LM	2880.305	0.0000
Pesaran LM normal	53.177	0.0000
Pesaran CD normal	51.638	0.0000

Source: own research

Unit root tests, including the enhanced Dickey-Fuller, LLC, PP-Fisher Chi Square, Im, Pesaran, and Shin tests for unit roots, were employed to assess the stationarity among the factors. The results presented in Table 5 indicated all variables are stationary at level. According to those tests, the variables School enrollment, tertiary (% gross) - level and High-technology exports are stationary at level and the variables Patent applications, residents and Research and development expenditure are stationary after the first.

The cointegrating relationship was tested using the Pedroni and Kao cointegration tests, with the results (Table 6) confirming the existence of a cointegration relationship between the variables in the study: School enrollment, tertiary, High-technology exports, Patent applications, residents and Research and development expenditure.

In order to select the appropriate model, we used likelihood-based criteria; the results are presented in Table 7. The smallest likelihood-based criteria (AIC, SC, and HQ values) indicated the most stable model was the model with the two lags.

Table 3. Correlations.

	Patent applications, residents	High-technology exports	Research and development expenditure	School enrollment, tertiary
Patent applications, residents	1	0.685	0.227	0.033
High-technology exports	0.685	1	0.253	-0.033
Research and development expenditure	0.227	0.253	1	0.262
School enrollment, tertiary	0.033	-0.033	0.262	1

Source: own research

Table 5. Unit tests for the whole sample.

Variables	Levin, Lin&Chu		Im, Pesaran & Shin W-Stat		ADF-Fisher Chi-Square		PP-Fisher Chi-Square	
	Statistic	Prob.	Statistic	Prob.	Statistic	Statistic	Statistic	Prob.
Patent applications, residents - level	-0/797	0.213	0.362	0.641	88.610	0.153	96.635	0.055
Patent applications, residents - first difference	-7.721	0.000	11.949	0.000	300.634	0.000	595.947	0.000
High-technology exports - level	-15.424	0.000	-2.772	0.003	102.580	0.045	133.839	0.000
Research and development expenditure - level	1.732	0.958	4.673	1.000	59.135	0.924	60.946	0.896
Research and development expenditure - first difference	-5.559	0.000	-8.738	0.000	236.151	0.000	447.102	0.000
School enrollment, tertiary - level	-4.353	0.000	1.242	0.893	83.243	0.321	102.053	0.035

Source: own research

Table 6. Cointegration tests.

Test	Statistic	Prob.
Pedroni cointegration test		
Panel v statistic	0.433	0.332
Panel Rho statistic	1.928	0.973
Panel PP statistic	-7.210	0.000 ***
Panel ADF statistic	-6.957	0.000 ***
Group Rho statistic	4.867	1.000
Group PP statistic	-6.3733	0.000 ***
Group ADF statistic	-0.013	0.495
Kao cointegration test	t-stat	Prob.
ADF	0.484	0.0001***

Source: own research
*** a 1% significance level statistical rejection of the null hypothesis of no cointegration

The cointegration test's findings suggest that the variables taken into account in the model have long-term linkages. The maximum Eigenvalue test and trace test are used as the only likelihood estimators for the cointegration rank, in accordance with the Johanson cointegration test (Table 8).

For a 5% degree of significance, there is one cointegrating equation for the Trace statistic and two cointegrating equations for the Eigenvalue. As a result, the hypothesis that the model has a cointegrating link is supported, and the hypothesis that there is no cointegration is rejected. Due to the fact that there is a long-run relationship between the variables, VECM can be applied to the short-run adjustment being examined. Table 9 presents the panel VECM estimation result. The Johanson cointegrating relationship indicated there is a long-run relationships between the variables of interest in the study. These findings are used to estimate VECM, taking into account how quickly the long-term balance transitions to the short-run equilibrium.

Under the long-run scenario of High-technology exports and Patent applications, residents have significant influences on School enrollment, tertiary. In addition, High-technology exports are generating a decrease, and Patent applications, residents are generating an increase in School enrollment, particularly tertiary. Comparatively, while High-technology exports and Patent applications are statistically significant, Research and development expenditure is statistically insignificant in influencing School enrollment and tertiary education in the countries in the sample. The findings showed that the short-run situation's divergence from long-run equilibrium is adjusted with a 0.3% adjustment speed. In the near term, a growth

Table 7. Selection Criteria for Lag Orders.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-4567.140		$3.94*10^{29}$	79.498	79.594	79.537
1	-3509.472	2023.364	$5.35*10^{21}$	61.382	61.860	61.576
2	-3473.048	67.147	$3.75*10^{21}$*	61.027*	61.886	61.376*

Source: own research
* shows the lag order that the criteria chose.

Table 8. Johanson Cointegration Test Result.

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized no. of CE(s)	Eigenvalue	Trace Statistic	0.05 critical value	Prob.
None*	0.276	113.970	47.856	0.000
Trace test indicates 1 cointegrating equation at the 0.05 level *denotes rejection of the hypothesis of the 0.05 level				
Unrestricted Cointegration Rank Test (Trace)				
Hypothesized no. of CE(s)	Eigenvalue	Max-Eigen statistic	0.05 critical value	Prob.
None*	0.276	88.645	27.584	0.000
At most 1*	0.076	21.646	21.132	0.042
The level 0.05 threshold shows the presence of cointegrating equations for two, according to the Max-Eigen statistic. * indicates that the 0.05 level's hypothesis was rejected.				

Source: own research

Table 9. Estimation of the Panel VECM.

Variable	Coefficient	SE	t statistic
Long-run scenario			
High-technology exports	$-3.85*10^{-14}$	$6.4*10^{-15}$	6.033
Patent applications, residents	0.030	0.002	13.398
Research and development expenditure	-8.030	13.274	-0.605
Short-run scenario (error correction)			
Cointegrating equation	-0.0003	0.0001	0.321
High-technology exports	$2.88*10^{12}$	$4.3*10^{11}$	6.623
Patent applications, residents	-1.470	0.146	-10.090
Research and development expenditure	$5.9*10^{-6}$	$4.1*10^{-5}$	0.143
Constant	0.324	0.139	2.332
R^2: 0.374			

Source: own research

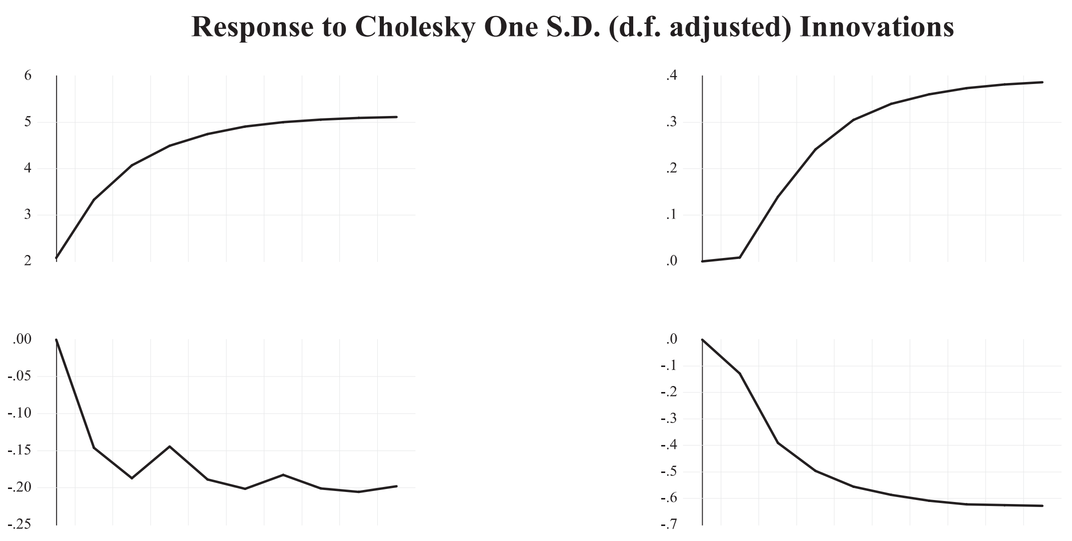

Fig. 1. Responses of School enrollment, tertiary. Source: own research

in tertiary school enrolment of 2.88*1012% is often correlated with changes in high-technology exports as a percentage. For the patent applications, the resident coefficient, a percentage increase, generates a 147% decrease in School enrollment, tertiary on average in the short run. Research and development expenditure have no significant influence on School enrollment, both in the short and long run, being statistically insignificant for robust adjustment to equilibrium. The diagnostic test results indicated no serial correlation, all the variables are normally distributed, and the model errors are homoscedastic. In the least European countries, the impact of High-technology exports and Patent applications on School enrollment is negative and significant. Instead, Research and development expenditures impacted School enrollment and tertiary education in a positive manner (Fig. 1).

As High-technology exports reflect internet and digitalization, our results indicated that internet and digitalization significantly influence higher education. If, in the long run, the internet and digitalization lead to a decrease in higher education, in the short-run internet and digitalization lead to an increase in higher education. This can be explained by the fact that, in the short term, the internet and digitalization positively impact higher education because the lag is not so big. Instead, in the long term, due to the big lag between the time periods and volatility regarding the internet and digitalization, the impact has become negative.

Discussion and Conclusion

Every aspect of our lives has been changed by the internet, including education [47]. The university system underwent a considerable transformation as a result of the educational system's quick shift [13]. A vision of teaching reform is beginning to take shape thanks to the interactive integration of Dig Data and Internet technology, which accelerates human society's transition from the industrial to the information eras. ChatGPT and other artificial intelligence technologies are made available for use in the classroom.

Our results highlighted that Internet use represents an effective tool for university teaching in the short term, which is similar to the results found in the existing literature. Beyth-Marom et al. (2003) claim [48] that the growth of the internet has greatly improved distant learning, and blended learning [49, 50] have significantly benefited from internet expansion. Grabarski et al. [51] and authors Zhang and Mao studied the evolution of the internet in university teaching [52].

According to a poll conducted by Motiwalla and Tello [53] students are happy with the online learning environment. It is not appropriate for digitalization to be seen as a fashion trend that conventional educational methods would oppose, marked by the creation of online courses or the purchase of new hardware or software. Therefore, universities should embrace change by allowing themselves to benefit from digitization without sacrificing the human element of education [54-56].

There are also studies according to which the internet has no positive influence on higher education. For example, according to Chen et al. [57], Feng et al. [58], Rana et al. [59], connected technology or tools generate distraction problems in the case of students. Gogus and Saygın [60] and Kurt [61] highlighted privacy issues and frustration caused by errors on platforms or bad connections.

In the long term, Internet use generates a decrease regarding higher universities due to the existing lag between the two periods of time. In a network society, the Internet and higher education do not consider the changed conditions of knowledge, being necessary new directions allowing to make technology and pedagogy choices in order to achieve education suitable to a network society [62, 63].

Most of the studies analyzing the internet and higher education are old; to our knowledge, there are no existing studies in the literature analyzing the impact of the internet on higher education. In this context, our study fills the gap in the literature, highlighting the influence and importance of the internet and digitalization on higher education. As a result, by considering the internet as a component of influence, this study expands the amount of research on aspects of higher education. Taking into account how the pandemic affected all activities, this paper also has a significant impact on industry and policymakers. The study limitations rely both on data and relevant research. Regarding literature in the field, there is a lack of papers related to our theme, and most of them are old. The limitations, according to the data, are limiting the availability of the data and not existing relevant data regarding internet use in the case of higher education. Future research directions will focus on the influence of the internet on higher education in pandemic time. Thus, we will consider data regarding blended learning, distance learning, and the internet's impact.

Conflict of Interest

The authors declare no conflict of interest.

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