

A Study on the Influence of the COVID-19 Pandemic on Digitalization

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This paper examines the key changes in terms of digitalization inflicted by the COVID-19 pandemic. Governments imposed restrictions as a consequence of the global pandemic, resulting in significant changes in people's daily lives as well as in professional environments. A significant number of people faced difficulties continuing their previous activities and in order to adapt, they often had to rely on using information technology. Our hypothesis is that the COVID-19 pandemic has accelerated digitalization on a global scale. We divided the technologies into two categories: traditional and modern and studied each one separately. We compared the results of several indicators in 2020 with their forecasted values based on previous years when the pandemic had no (significant) influence yet. The results show a significant increase for both studied categories for the values of the indicators from 2020 compared to the forecasted ones, which validates our hypothesis.

Keywords: Digitalization, Information Technology, COVID-19, Industry 4.0

1 Introduction

The global pandemic caused by the new coronavirus, SARS-CoV-2, took humanity by surprise. People have been deeply affected on both personal and professional levels due to the health crisis and the related global restrictions. In this context, information technologies started to be used more and more so people could continue their activities. This article focuses on those digital changes generated by the pandemic.

We chose several technologies and split them into two categories: traditional and modern. Traditional technologies refer to the software and hardware that have already been used by the general public in the past years, such as internet services, social media, e-commerce, e-learning platforms, video conferencing, health, etc. Being forced to spend more time at home, it was relatively natural for many people to switch their day-to-day offline activities to digital ones.

However, it is not intuitive whether the modern technologies adoption speed will increase in the pandemic times compared to the previous years. Therefore, we consider it very important to study the evolution of Industry 4.0 technologies' evolutions such as artificial intelligence, cloud computing, cybersecurity, blockchain, internet of things (IoT), or big data.

Related work

The effect of the pandemic on information technology is a subject of interest in many articles. In our research, we first looked at general papers published on digitalization, then looked at each group and category separately. We identified paper [1] as a starting point since it synthesizes the state-of-the-art for August 2020. The article splits the information technologies into software and hardware, identifying 50 software technology types and 15 hardware technology types used to cope with the pandemic. Several other papers discuss the general impact of COVID-19 measures towards IT, such as [2], [3]. Other articles, such as [4], [5] have a slightly different approach and discuss the effects of information technologies on combating the pandemic.

By analyzing the outcomes of Information Technology used during the SARS pandemic, paper [6] examines the potential of digitalization to combat the negative economic impact of the COVID pandemic. Their findings show that during the 2003 SARS pandemic, countries with higher broadband adoption handled economic losses more effectively than other countries.

While some of the measures are only temporary, in order to allow operations to resume, others will be kept in place until the pandemic is over. Article [7] discusses the implications of the restrictions regarding tech-

driven work. It describes the transition process towards an efficient work environment. Also, it analyzes to what extent these changes will be useful after the end of the pandemic.

Many other papers discuss the implications of global restrictions for organizations. Paper [8] illustrates the importance of digital maturity in companies and identifies the main aspects that a company must consider in order to be prepared during a pandemic. Paper [9] identifies the most important IT solutions that can contribute to better pandemic management. Article [10] discusses the main changes inflicted by COVID-19 towards technology and innovation from a management perspective. It discusses the challenges and the solutions based on digitalization to ensure a good efficiency among organizations in the context of the imposed restrictions. Since traditional marketing strategies were limited, [11] draws attention to the fact that any company should have a primary focus on “how to approach digital marketing strategies”.

This section presents the literature review related to digitalization evolution during the pandemic. Section 2 classifies IT technologies into two categories, modern and traditional, and analyses the evolution of each subcategory. In section 3 we test and validate our hypothesis regarding the connection between COVID-19 and digitalization.

2 The analysis of the COVID-19 pandemic impacts on modern and traditional technologies

This section analyzes the main changes caused

by the pandemic on both traditional and modern technologies. We included only the technological domains/subdomains in which the pandemic had a significant impact.

In order to provide a more efficient split, we classified as traditional the following areas:

- internet services;
- social media;
- e-commerce;
- e-learning;
- video conferencing;
- digital news platforms;
- digital entertainment technologies;
- digital healthcare;
- e-government applications;

In order to provide a clearer understanding of the trends, some of the charts presented hereinafter contain both actual and forecasted values. The forecast was realized based on previous data and as a calculus method, we used linear regression. More details about the forecasting methods are presented in section 3.

Internet services

In terms of internet services, our primary focus was the internet adoption rate. Data provided by Statista [12] suggests that the number of internet users around the world has increased from 4.53 billion in 2019 to 4.88 billion in 2020. The increase was slightly higher than the forecast in relation to the COVID-19 pandemic, as a linear regression conducted on data between 2009-2019 forecasted 4.76 billion users in 2020. Figure 1 presents the difference between the actual and forecasted values in terms of worldwide internet users.

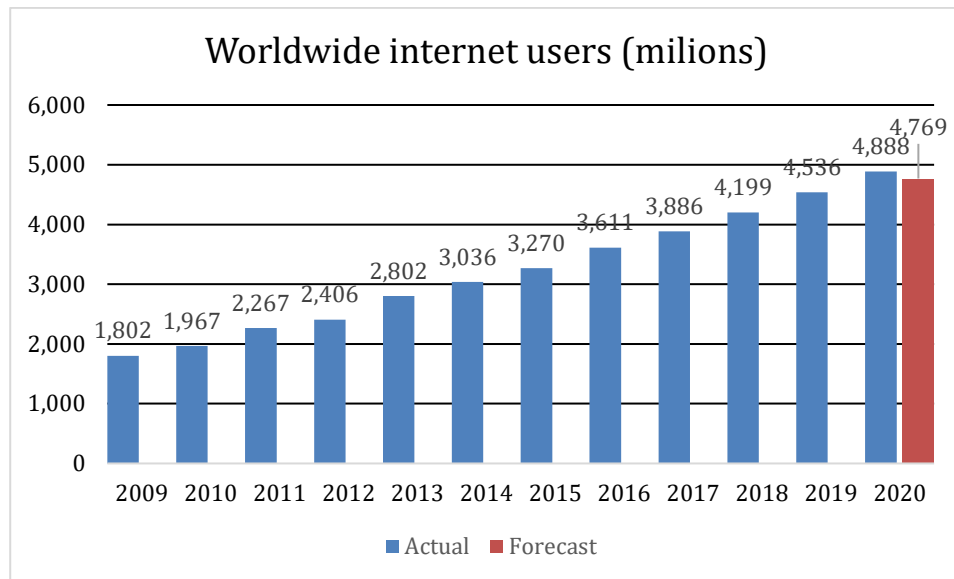


Fig. 1. Worldwide internet users [12]

Digital entertainment

Entertainment activities play an important role in people's lives, especially ever since restrictions were imposed. Statistics indicate that since the start of the pandemic, the use of entertainment platforms has increased dramatically. As more lockdown measures have been imposed around the world along with stay-at-home campaigns, they consumed more digital content. Therefore, evidence [13] proves that movie platforms such as Netflix, Prime Video, or YouTube have become more popular and their usage rate has grown.

However, digital entertainment is not limited to movie streaming platforms, therefore we also took into consideration live video streaming platforms, such as Twitch, which is mainly used by gamers and also by people who offer online talk shows, programmers, or even computer builders who like to live stream their activities. Section 3 presents the rate of growth for

Twitch, having an almost 50% difference between forecasted concurrent viewers and actual values.

Social media

During the COVID-19 pandemic, social media has played an important role in people's lives. From keeping up to date with the news around the world to staying in touch with friends and relatives, people have spent more time on social media platforms. Data provided by Eurostat, which can be seen in figure 2 suggests that the number of people involved in social media activities has increased by 10 percentage points for the general population and also by 10 percentage points for people aged between 65 and 74 years, which may be explained by the fact that the elderly were in the highest risk group and were constantly recommended to stay in and not to expose themselves.

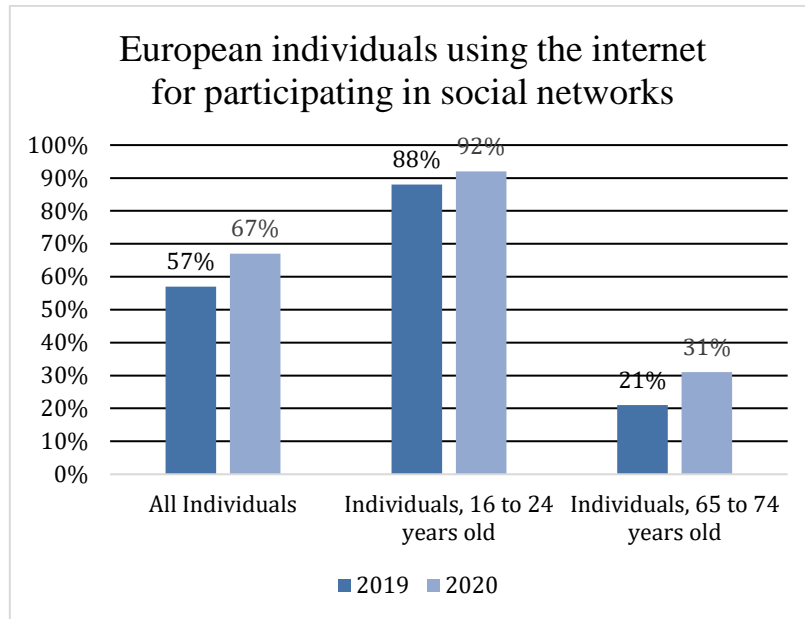


Fig. 2. European individuals using the internet for participating in social networks [14]

Delivery platforms

Lockdowns and curfews have also led to higher adoption and usage of delivery platforms for food, groceries, and household goods. The fact that restaurants were closed and forced to work only with takeaway and delivery platforms has created a new business opportunity for such platforms which was reflected in the number of jobs posted related to the delivery field.

Evidence [15] suggests that the number of people that use food delivery services increased by 25% in 2020. Figure 3 represents the evolution of food delivery applications revenue in European markets, expressed in USD billions. As it can be seen in the figure, the revenue has increased from 14.2 USD billions in 2019 to 18.9 USD billions in 2020.

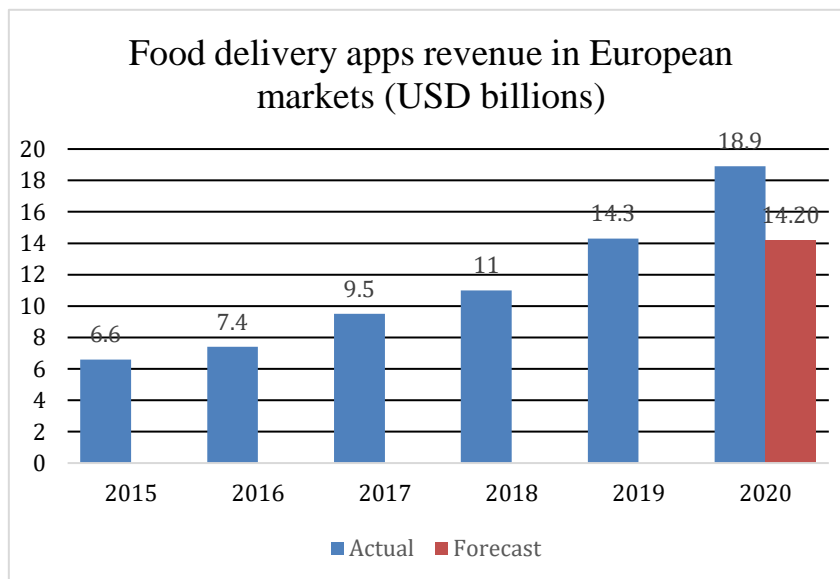


Fig. 3. Food delivery applications revenue in European markets [16]

E-learning

Many articles discuss the implications of the pandemic on e-learning, such as [17], [18]. Paper [19] analyzes the impact of the COVID-19 pandemic on the day-to-day lives of students around the world. As per the cited article, on April 9th, 2020 there were over 1.5 billion students around the world that could not attend school. Therefore, educational institutions were forced to find new ways to continue their activities considering social distancing and restrictive measures. This has created an unprecedented push to online learning and in many cases, the solution to this problem was joining ed-tech platforms. Thus, the COVID-19 pandemic represented an opportunity for ed-tech companies to promote their solutions and a considerable amount of them offered free solutions for a certain period of time.

Furthermore, paper [20] analyzes the measures taken shortly after schools were closed and emphasizes the asynchronous interaction between teachers and students. As per the cited article, asynchronous learning works best with electronic formats and loosens the coupling between teachers and students in terms of how

and when they share materials. Thus, asynchronous working gives a certain degree of flexibility to teachers in terms of how they post the study materials and also lets students have a more balanced home-school interaction. Moreover, the most preferred material is represented by video lessons, and based on this, FutureLearn, a digital education platform that offers free courses and degrees from top universities, has optimized its approach to remote learning in order to balance accessibility and effectiveness.

A significant number of students around the world have switched to remote learning, using dedicated platforms, such as Google Classroom or multiple applications, which combined, would replace the traditional way of teaching. Evidence [21] suggests that 98% of institutions moved the majority of their traditional courses online, the University of Washington being the first major university to close and move classes and exams online for approximately 50,000 students. Moreover, the number of people joining online courses platforms has increased, as can be observed in figure 4.

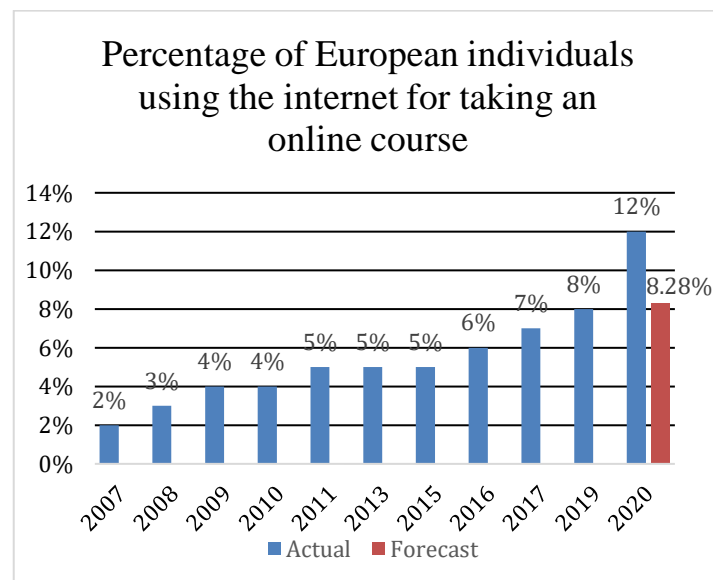


Fig. 4. Percentage of European individuals using the internet for taking an online course [22]

From the software platforms' perspective, both the demand and usage have grown for technologies used in work-related activities, such as video conferencing, communication, collaboration and software integration, and also for technologies used in remote schooling

activities, such as video conferencing and communication and e-learning platforms.

Video conferencing

In terms of technologies used, Zoom, a video conferencing platform, has known the highest

growth in its category. Used in companies, education institutions as well as for day by day activities, Zoom has set the new standard for video conferencing. Offering free services during the pandemic [23], it was adopted by a significant number of organizations in different countries and industries. However, besides Zoom, other platforms used for video conferencing were impacted as well. WebEx, a solution offered by Cisco and Google Meet has also seen a growth in usage, Google Meet being used also for remote teaching and learning,

being integrated into Google Classroom. In terms of communication in all fields, Microsoft Teams represents the most used software platform [24], representing an instant messaging application available for different devices, such as laptops, tablets, or mobile phones. However, besides Microsoft Teams, other several platforms and applications, such as Slack or DingTalk were adopted by organizations across the globe. Figure 5 represents the growth of Microsoft Teams in terms of revenue and active users' number.

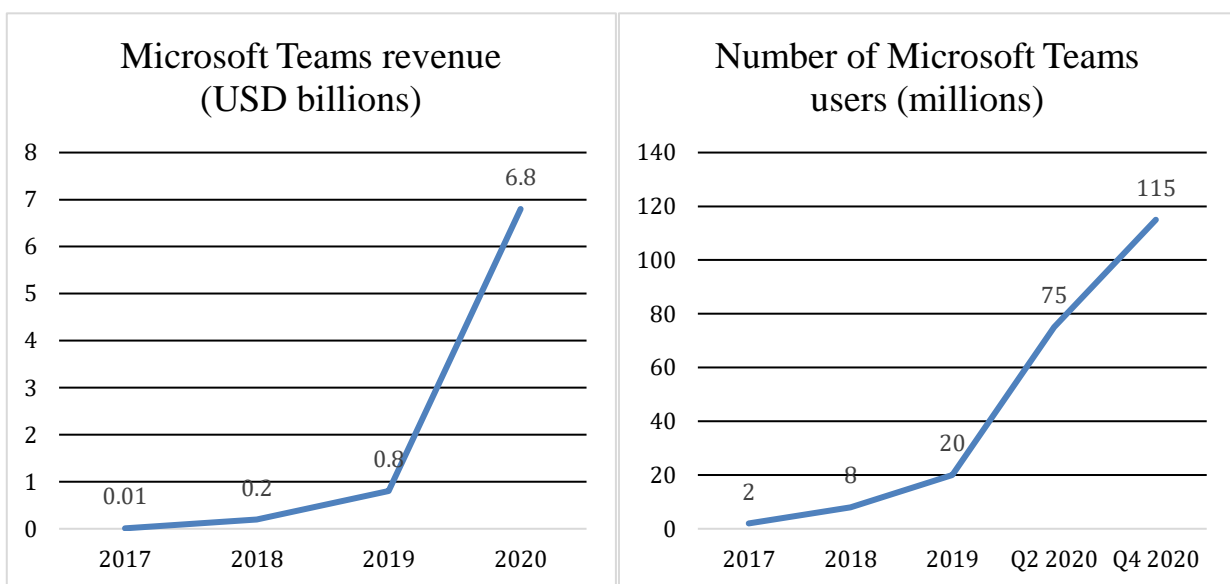


Fig.5. Microsoft Teams revenue and number of users [25]

The usage of collaboration platforms has also grown in terms of usage. Google G-Suite and Microsoft Office 365 represent the most used applications when it comes to the full package of applications used by professionals. Both applications offer email services, cloud storage, video conferencing services, calendar synchronization across different applications, editing capabilities for text documents, tables, and presentations.

People's personal lives have also changed when the ones that could make the switch to teleworking have done it and their children have switched to remote learning. Even though this could be translated into more time spent

together, this has also created some imbalances in terms of work-life boundaries.

Digital healthcare

Even though the COVID-19 pandemic has represented a public health issue, the evolution of internet usage related to health-related information is not significantly different from the forecasted values. Figure 6 shows that the percentage of people who seek information related to health has grown from 53% in 2019 to 55% in 2020. Chapter 4 analyses how the actual data differs from forecasted values and according to that analysis, the growth rate has been following the trend.

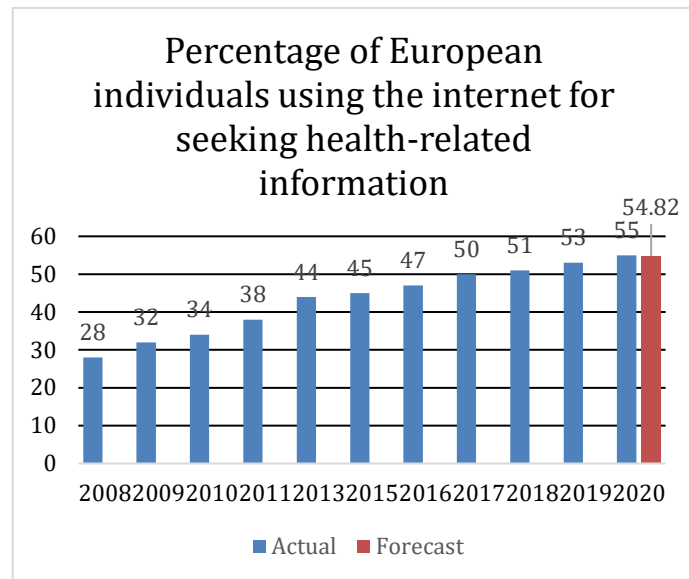


Fig. 6. Percentage of European individuals using the internet for seeking health-related information [26]

Moreover, the paper [27] analyses how digital healthcare could help to fight against the COVID-19 pandemic. The focus points covered in the paper are tracking the high-risk subsets likely to be infected with the new coronavirus, telehealth systems, and their applications in the COVID-19 pandemic, offering diagnostic support, and using Artificial Intelligence for diagnostics.

As per the cited paper, digital DHIS2 based solutions can help identify passengers who travel from high-risk countries to facilitate active COVID-19 surveillance. Governments around the world are now working closely with agencies to develop such systems. Moreover,

the article discusses the creation of telemedicine systems that are able to take over the traditional interaction between patients and healthcare workers where social distancing and self-quarantine are in place.

E-government

Since authorities have imposed restrictive measures in order to stop the spread of the new coronavirus, people generally spent less time interacting with the authorities in the traditional way. Therefore, the percentage of people that have used the internet for interacting with authorities has grown from 53% in 2019 to 56% in 2020, as seen in Fig. 7.

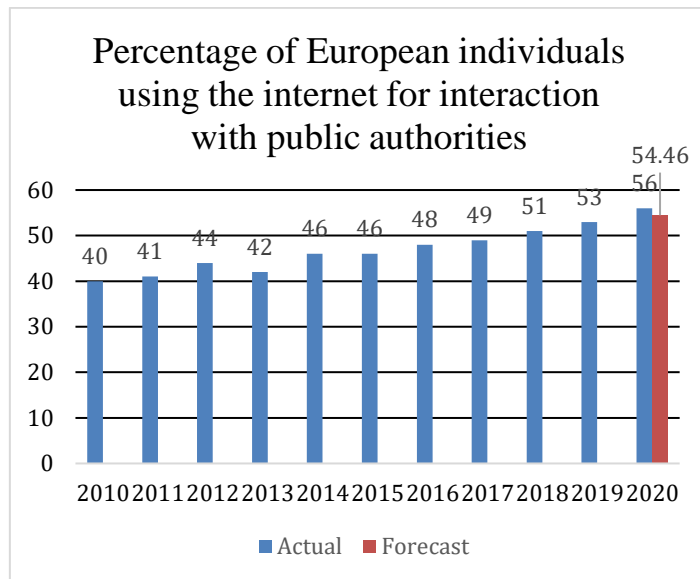


Fig. 7. Percentage of European individuals using the internet for interaction with public authorities [28]

Furthermore, the paper [29] analyses the importance of e-government solutions during current times, when social media and word of mouth play an important role in spreading the information around the world and the main conclusions of the article were that the role of e-government and COVID-19 word of mouth positively impacted online social presence.

Modern technologies

Besides the traditional areas, we identified several modern technologies, below we discuss their evolution during the pandemic. Those technologies are:

- cloud computing;
- cybersecurity;
- artificial intelligence;
- blockchain;
- internet of things;
- augmented reality (AR) and virtual reality (VR);
- big data;
- 3D printing.

Cloud Computing

After the start of the COVID-19 pandemic, many companies were forced to relocate their employees from the office to work from home. However, the transition was not an easy one since many of the activities depended on the company's infrastructure. One of the most efficient solutions consisted of the migration to

cloud computing. Paper [30] emphasizes the importance of cloud technologies for companies all over the world during the pandemic, calling cloud computing the “unsung hero”.

Articles [30], [31] analyse the influence of the COVID-19 pandemic over cloud computing applications and according to them, cloud computing technologies have increased in terms of usage and adoption among business entities. Moreover, with a significant number of enterprises adopting cloud computing services, the field has reached a market capitalization of \$2 billion in 2020, which represents a record for the aforementioned indicator. Satya Nadella, the CEO of Microsoft, which has previously led several divisions related to cloud technologies, declared that we have assisted at two years’ worth of digital transformation in just two months. His statement refers mainly to remote working and learning and all the activities that can be performed remotely [32].

Cybersecurity

Sudden changes in companies after the start of the pandemic in terms of the use of technology, as well as the general increase in IT usage, led to a significant increase in the number of cyberattacks [33]. Some of the most common cyberattacks during pandemic involve ransomware [34], phishing, remote desktop protocol attacks, brute-force attacks [35], data

exfiltration [36], and card-skimming [37]. Figure 8 presents the dynamic of ransom paid by companies from Q3 2018 to Q3 2020. As can be observed, from Q2 and Q3 2020 there has

been a massive increase of approximately 60% in Q2 compared to Q1 and 30% in Q3 compared to Q2.

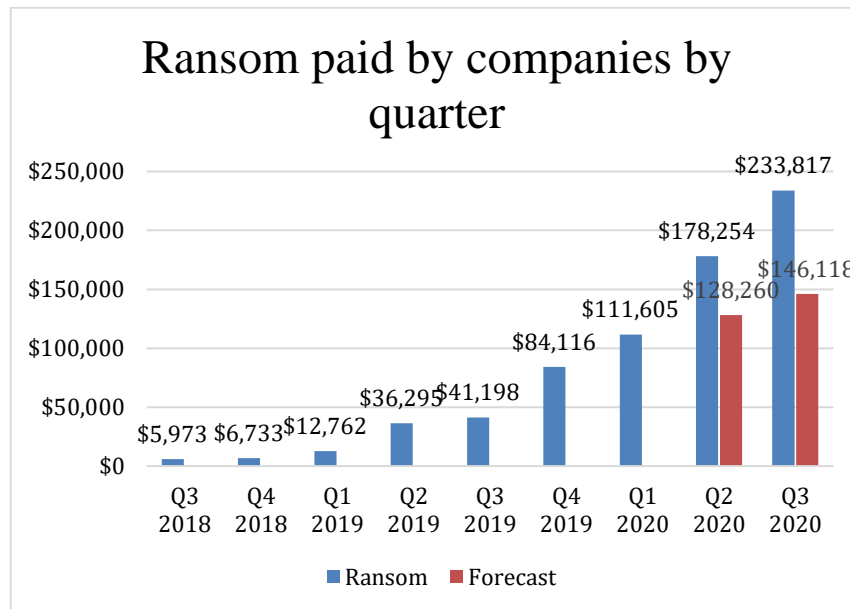


Fig. 8. Ransom paid by companies quarterly [38]

In this context, most of the companies increased their budgets [39], and according to [40] they are planning to continue increasing investments in cybersecurity.

Artificial intelligence

Paper [41] analyzes the impact of artificial intelligence applications over the COVID-19 pandemic and vice-versa. The main key points to be extracted from that paper are that AI has contributed to more precise detection and diagnosis and also for reducing the workload on healthcare by moving the research and development to AI-powered systems.

Furthermore, paper [42] analyses possible applications of artificial intelligence and big data for the management of the ongoing COVID-19 outbreak and the main key points to be extracted from it are that artificial intelligence could provide rapid identification of outbreaks by collecting and analyzing epidemiological data in real-time and it could also provide forecasts of COVID-19 cases. In terms of research, AI could help with identifying potential therapeutic options by analyzing existing medication.

Blockchain

Paper [43] provides a review of how the new technologies, such as the Internet of Things, Artificial Intelligence, Drones, Blockchain, and 5G helped in managing the impact of COVID-19 pandemic. In terms of blockchain technology, the main usage is represented by organizations that face the challenge of integrating verified data sources.

Moreover, another paper [44] provides an analysis of how blockchain technology could help people in the event of a pandemic, such as the COVID-19. The paper covers several uses of blockchain and the advantages it provides when discussing transparency and data integrity. The article proposes a centralized case reporting system built on blockchain, the main benefits being that data is stored more securely and also its integrity would not be compromised. Moreover, the cited paper proposes using blockchain as backing technology for donations and news creation, therefore both could become completely transparent and immutable.

Internet of Things

The article [43] talks about concepts such as the Internet of Things and Internet of the Medical Things and the main usages of these concepts are represented by monitoring patients from a remote location, tracking medication orders, and also using wearable technology to facilitate transmitting health information to the healthcare professionals. Moreover, the article discusses using drone technology in order to limit human interaction and also to provide coverage to less accessible areas. More applications of drones are represented by crowd surveillance, public announcements, screening masses, spraying disinfectants and delivery of medical supplies and other essentials.

Moreover, the paper [45] provides a more extended analysis on how IoT applications could help to fight against COVID-19 from the healthcare standpoint. The cited paper presents the major IoT scraped mentions concerning the COVID-19 pandemic. Therefore, IoT provides the infrastructure needed so that medical devices can be connected to the internet and in the event of a critical situation, they are able to notify responsible workers. Furthermore, IoT is a tool for screening a potentially infected person, thus keeping the spread of the new coronavirus under control.

AR/VR

Virtual reality and augmented reality represent two emerging technologies that are discussed in [46] and [47]. The first paper discusses significant applications of virtual reality in relation to the COVID-19 pandemic and the main conclusions that can be taken out of it are that this technology is useful for patient treatment, disease awareness and medical training and learning and also that this technology is helpful for physical rehabilitation and pain management of an infected patient during the treatment process. The second article discusses the idea of using augmented reality for relaunching tourism in the post-COVID-19 era. The key point to be extracted from this paper is that augmented reality will provide the opportunity of traveling while respecting social distancing measures.

Big Data

When it comes to big data in relation to the COVID-19 pandemic, paper [48] analyses the challenges encountered when operating Geospatial Information Systems (GIS) that generate significant amounts of data. The highlight of the article is that big data showed significant progress in analyzing the epidemic transmission and prevention decision-making support. The rapid development of the epidemic requires GIS and big data technology to allow rapid responses and analyses.

Moreover, big data plays an important role in the healthcare industry, as presented by paper [49]. The aforementioned paper analyzes the impact of big data in healthcare in China and the security risk factors that arise in each stage of the life cycle. With an ever-increasing number of medical institutions, medical personnel, and insured people, hospitalization costs are also on the rise year after year, and data collection, storage, analysis, and destruction all carry a low risk of security breaches. Higher risks emerge during the application and analysis phases, requiring the development of a risk prediction framework for healthcare big data in order to obtain greater control over data.

3D printing.

Papers [50] and [51] analyze the help provided by 3D printing technology during the COVID-19 pandemic. The main applications of 3D printing were related to the medical field. When the outbreak started, the demand for medical devices, such as masks, face shields, collection kits, and ventilator valves was significantly bigger than the offer and therefore it raised the challenge of finding such products. Therefore, organizations started to look for alternative ways of covering those high levels of demand and 3D printing had the opportunity of filling the gap between demand and supply.

3 Evidence that the digitalization acceleration was mainly inflicted by the pandemic

This section studies the pandemic influence on the key domains identified and discussed in section 2. Our hypothesis is that the COVID-19 pandemic measures led to the acceleration of

digitalization of both traditional and modern technologies.

Methodology

Relevant data were gathered for both traditional and modern technologies in order to understand the natural evolution of the selected domains in the absence of the pandemic. Annual time series were used. We used linear regression to predict the corresponding value for 2020 which we subsequently compared to the actual data. A confidence interval of 95% was used.

Data

15 relevant time series have been selected for our study. Each data series is presented below, along with an explanation of why it is important for our analysis. All selected indicators have a positive trend, an expected aspect, as the IT field is constantly growing.

- **Internet services**

We gathered the worldwide number of internet users from 2009 to 2020 [12]. This can be considered the main indicator regarding digitalization since all the information technologies selected depend directly on internet services.

- **Digital entertainment**

Two time series were used, the number of Netflix paid subscribers [52] and the average concurrent viewers on Twitch [53]. Netflix is currently the most popular movies and TV series streaming service, while Twitch is by far the most used live streaming platform for gamers.

- **Social Media**

We selected data regarding the number of Facebook active users from 2009 to 2020 [54]. Facebook is the most used social media platform.

- **Delivery platforms**

We selected the evolution of food delivery applications revenue in European markets from 2015 to 2020 [16], as well as relevant data for the most used global food delivery platform Uber Eats [16].

- **Video conferencing**

Data about the two most popular video conferencing platforms were analyzed:

Microsoft Teams [25] and Zoom [55].

- **E-commerce**

We gathered data regarding the evolution of e-commerce market size between 2015 and 2020 [56].

- **E-learning**

We studied the percentage of European individuals using the internet for taking online courses for the time interval between 2007 and 2020 [22].

- **Digital healthcare**

Data regarding the percentage of individuals who use the internet for seeking health-related information for the 2007-2020 time frame was used [26].

- **E-government**

One of the top priorities among European Union countries is to increase the degree of digitalization of public organizations. Data regarding the percentage of European individuals using the internet for interaction with public authorities was gathered for the 2010-2020 time frame [28].

- **Cloud computing**

Since cloud computing was one of the key solutions for companies to successfully continue the operational activities, we selected the percentage of companies that buy cloud computing services from 2014 to 2020 [57].

- **Cybersecurity**

We gathered data regarding ransomware attacks starting with Q3 2018 until Q3 2020 [38]. This time series is relevant for a couple of reasons: (1) ransomware was one of the most popular types of cyberattacks in 2020 and (2) since companies were eager to pay a bigger ransom, this indicates that they were also willing to spend more money on cybersecurity.

Limitation

Our study was not applied for all the selected domains since data was not always available. However, we managed to gather relevant data for eight domains out of nine traditional technologies and two out of eight modern technologies. In the future, we will complete the study with indicators for which data were not yet available for 2020.

Results

Table below illustrates the comparison between the forecasted values obtained by using linear

regression and the actual values of the selected indicators for the year 2020.

Table 1. A comparison between the forecasted and actual values of the indicators for the year 2020

No.	Subcategory	Indicator	Period	Forecasted data for 2020	Actual data for 2020	Unit	The relative difference between actual and forecasted data
1	Video conferencing	Zoom - number of business customers	Q4 2018 - Q4 2020	104829	433700	-	313.72%
2	Video conferencing	Microsoft Teams - number of users	2017-2020	28.22	115	millions	307.51%
3	Delivery Platforms	Uber Eats users	2016-2020	26	66	millions	153.85%
4	Delivery Platforms	Uber Eats earnings	2017-2020	2.6	4.8	billions	84.62%
5	Cybersecurity	Average ransom paid by companies	Q3 2018 - Q3 2020	146117.70	233817	USD	60.02%
6	Digital entertaining	Average Concurrent viewers on Twitch	2015-2020	1.437	2.117	millions	47.32%
7	E-learning	Percentage of Individuals from EU using the internet for doing an online course	2007-2020	8.28%	12.00%	-	44.93%
8	Cloud Computing	Percentage of enterprises that buy Cloud Computing services	2014-2020	26.48%	36.00%	-	35.95%
9	Delivery Platforms	Food delivery apps revenue in European markets	2015-2020	15.74%	18.90%	-	20.08%
10	E-commerce	World e-commerce market size	2015-2020	2252.65	2534.81	USD billions	12.53%
11	Digital entertaining	Number of Netflix paid subscribers	2011-2020	194.95	203.66	millions	4.47%
12	E-government	Percentage of European individuals using the internet for interaction with public authorities	2010-2020	54.46%	56.00%	-	2.83%
13	Social Media	Number of Facebook Active Users	2009-2020	2641	2710	billions	2.61%

No.	Subcategory	Indicator	Period	Forecasted data for 2020	Actual data for 2020	Unit	The relative difference between actual and forecasted data
14	Internet services	Worldwide internet users	2009-2020	4.769	4.888	billions	2.50%
15	Digital healthcare	Individuals using the internet for seeking health-related information	2007-2020	54.82%	55.00%	-	0.33%

Studying the 15 time series, we came to the conclusion that the real value in 2020 is higher than the forecasted one for every single one data series. The biggest difference between forecast and real value was obtained for the video conferencing data (over 300%). This was to be expected, as people were forced to switch from their physical encounters towards online meetings. Another intuitive result consists in the growth of delivery platforms since in the context of restrictions, people have resorted to these solutions. The same applies to e-commerce, which registered an increase of over 20% more than the forecast. Another important growth consists in the use of e-learning platforms since many educational institutions were forced to switch from traditional to online learning.

Regarding the impact on companies' activities, the most important changes were registered in the cloud computing and cybersecurity field. Since working in a physical office was restricted, organizations implemented work from home strategies. Thus, many companies migrated their operations to the cloud. Cybersecurity is another area that registered significant growth.

The smaller digital acceleration was registered in e-government, social media, internet services, and digital healthcare. Regarding e-government and digital healthcare, a relevant aspect consists in the fact that the identified data are about the European Union, where the technology adoption was already very high before the

pandemic.

Regarding the internet services growth, the small growth can be attributed to the maturity of the technology. The same applies to the adoption of Facebook, which can also be considered the most mature social platform. As can be observed, all the 15 data series studied and presented in table 1 had bigger real data than the forecasted ones for the year 2020, which validates our hypothesis.

4 Conclusions and future work

The COVID-19 pandemic had implications for all sectors and information technology made no exception. However, although the economies were severely affected, there is also a positive aspect consisting in the acceleration of digitalization.

This paper discussed some of the main information technology areas where the pandemic had a significant impact. We classified these areas into two categories: traditional and modern. However, our study shows an acceleration in digitalization in both categories.

In the future, we will study the effects of the pandemic on other information technologies, as new data becomes available. Also, we will study for how long this digital accelerated development will continue, as the pandemic will be brought under control and at some point, will be stopped.

Last but not least, we want to study the potential of digitalization to support the recovery of other sectors and implicitly of the economy.

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