Cloud computing services – emerging trends during the times of pandemic

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Abstract — **Cloud computing services offer virtualization, meaning that users can access applications and services from any location with an internet connection. Different studies predicted and some reports confirmed that the adoption of cloud computing was neither slowed down nor sustained but accelerated during the covid-19 pandemic. This paper aims to find out if these conclusions are valid in the environment of the European Union and especially in the Czech Republic. We answer our main research question based on the data gathered by Eurostat within Digital economy and society surveys. Did the growth before the pandemic sustain, accelerate, or slow? We also focus on particular types of cloud computing services and compare results according to different sizes of companies and the domain they work.**

Keywords – cloud computing; covid-19; European Union; Czech Republic; Eurostat.

I. INTRODUCTION

Cloud computing is a game-changing technology transforming how businesses and individuals use and store data. It has been adopted rapidly because of its stability, flexibility, and cost-effective services. Cloud computing services have been growing in popularity over the years. The covid-19 pandemic has only accelerated this trend as organizations have increasingly relied on cloud computing to support remote work and enable business continuity [1]. Gartner report described that the worldwide end-user spending on public cloud services is forecast to grow 20.7% (total $591.8 billion) in 2023, compared to the 18.8% growth forecast for 2022 [2]. Zippia [3] stated that 94% of companies adopted cloud services in 2022.

Due to the COVID-19 pandemic and the necessity to work remotely, 61% of businesses migrated their workloads to the cloud [3]. The pandemic has also increased the adoption of cloud-based services like e-commerce, telemedicine, and online education. These services rely on the cloud to provide scalable and reliable infrastructure to handle the increased demand. According to Eurostat, 41 percent of EU enterprises used cloud computing mainly for email and file storage in 2021 [4]. According to Pujazon and Carr [5], cloud computing secures the smooth provision of financial services and the transition to new work models. It also enables the opportunity to provide additional new services simply and cost-efficiently.

Although the covid-19 pandemic has accelerated the adoption of cloud computing services, it has also created new challenges for businesses. Security, cost management, and network infrastructure are some challenges businesses must address to realize the benefits of cloud computing fully. With the increased demand for cloud computing services, network infrastructure has become a critical bottleneck. The pandemic has exposed the limitations of existing network infrastructure, and businesses are looking to invest in more robust and scalable networks. As cloud computing evolves, businesses and individuals must carefully evaluate its benefits and challenges to make informed decisions about its implementation.

This article aims to reveal trends in cloud computing adoption in the European Union, particularly in the Czech Republic. In order to fulfill this aim, we defined our main research question: Did the growth before the pandemic sustain, accelerate, or slow down? This question was then divided into four sub-questions:

1. What is the penetration level of cloud computing services in the EU, and how has it changed during covid-19 pandemic?
2. What is the penetration level of particular types of cloud computing services in the Czech Republic, and how did it change during covid-19 pandemic?
3. How do differ preferences between SMEs (small and medium enterprises) and big enterprises related to cloud computing services?
4. What level of sophistication of cloud computing services do companies use based on entrepreneurial activity?

The paper is structured as follows. The next section gives the overview of cloud computing services. Third section describes research methods together with data definition and the description of the data gathering process. Section 4 shows the results of a data analysis. Finally, the conclusion closes the paper and summarizes the significance of cloud computing in the EU.

II. CLOUD COMPUTING SERVICES

Cloud computing is a revolutionary technology that has transformed the way businesses and individuals use and store data [6], [7], [8], [9]. It provides a way to access applications, services, and storage over the internet without needing on-premises hardware or software. Cloud computing is based on the principle of virtualization, which allows multiple users to access a single server or set of servers. This statement means that users can access applications and services from any location with an

internet connection. The cloud computing model is composed of three main service models [10], [11], [12], [13], which are Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS).

IaaS is the foundation of cloud computing and provides users with basic computing infrastructure such as virtual machines, storage, and networking [14]. PaaS builds on IaaS and provides developers a platform to develop, test, and deploy applications without worrying about the underlying infrastructure [15], [16]. SaaS is the most popular cloud computing model [17], [18], [19], which provides users with access to applications over the internet, eliminating the need for local installation.

Cloud computing has many benefits [20], [21], [22], some of which include the following:

- Scalability – cloud computing allows businesses to scale up or down their computing resources on demand, giving them the flexibility to adjust to changing business needs.
- Cost-Effectiveness – cloud computing eliminates the need for businesses to invest in expensive hardware and software, providing them with cost-effective computing solutions.
- Accessibility – cloud computing allows users to access applications and services from any location with an internet connection, providing greater accessibility and flexibility.

However, cloud computing also comes with some challenges [7], [23], which include:

- Security -cloud computing can expose users to security risks, such as data breaches and cyber-attacks, if not implemented and managed correctly.
- Vendor Lock-In – users may become dependent on a specific cloud provider and find switching providers challenging.
- Lack of control – organizations may have less control over their data and applications in the cloud, which can increase the risk of security breaches.
- Data loss - can happen due to hardware failure or malicious attacks on the system. Data backup policies should be implemented to overcome this type of threat.
- Account or service traffic hijacking – it affects the confidentiality and integrity of the users. In addition, hackers can steal users' data, like bank credentials. Anti-phishing and fraud detection policies should be implemented to reduce these.

Saroha & Singh [24] worked on a qualitative analysis of all vulnerabilities and related threats corresponding to each service model. Jain et al. [25] argued that most attacks result from the cloud provider's shared data computation and multiple access problems. They stated that all stakeholders and actors must consider the risk and take adequate measures to mitigate it. To effectively mitigate the risk, they suggested building security at every level of a cloud computing platform and incorporating best practices and new emerging technologies to mitigate risks. Singh et al. [26] proposed the 3-tier security architecture to enhance cloud security. They discussed the three levels of cloud service systems and the critical security considerations of each level.

Fault tolerance techniques and cloud computing concepts, their components, service model, and deployment models are discussed in [27]. Alenezi [28] argued that security is a big issue and must be an elemental concern in implementing the cloud. To achieve the goal of providing stable cloud infrastructure, developers must fix specific security problems. This paper highlighted all the potential security problems in the cloud computing infrastructure. Parast et al. [29] stated that DoS/DDoS, shared technology, and session hijacking were among the most addressed risks in cloud computing.

III. METHODOLOGY

The study in this paper is based on the data gathered by Eurostat within Digital economy and society surveys [30]. Since 2002 the European Commission has established annual Information Society surveys benchmarking the ICT-driven development in enterprises and by individuals. In addition, Eurostat is responsible for coordinating two surveys that are conducted at the national level. The surveys are developed annually in close collaboration with Member States and the OECD and are adapted to the changing needs of users and policymakers. The data are a combination of primary statistics (two annual community surveys on ICT usage in households and by individuals as well as in enterprises) and secondary statistics (structural business statistics, national accounts, research and development, and labor force survey). This paper used only data about enterprises on two levels – European and Czech. The whole process of data processing is depicted in Fig. 1.

We obtained the data in the form of an MS Access database from Eurostat web pages (Eurostat, 2022). The first step in data processing was a selection of necessary tables and attributes for both views. For the EU comparison, we used only five attributes (ExpCountryCaption, Year, ExpIndicator = E_CC, ExpEntSize = (10-249) OR (GE250), Value). The extraction of CZ data was more complex as we also wanted to compare what types of cloud computing services companies use the most. Attributes selected were ExpCountryCaption, Year, ExpIndicator = (E_CC) OR (E_CC_PDEV) OR (E_CC_PCPU) OR (E_CC_PCRM) OR (E_CC_PEM) OR (E_CC_PERP) OR (E_CC_PFACC) OR (E_CC_PDB) OR (E_CC_PSOFT) OR (E_CC_PSEC) OR (E_CC_PFIL) OR (E_CC1_B) OR (E_CC1_I) OR (E_CC1_S), ExpEntSize = (10-249) OR (GE250), ExpActivity = (C-F) OR (G45-S951_X_K) OR (C10-S951_X_K), Value.

The next step, after data selection, was exporting data into MS Excel and preparing a graphical representation of data. In this step, we wanted to emphasize the level of cloud computing services in the selected period and the changes that led to this state. As the comparison among EU states required data from three time periods, we had to eliminate data from those states with missing values. Similarly, at the CZ level, we compared the change in the interest in particular types of cloud computing, so if some type (E_CC_PSEC, E_CC_PDEV) was not part of the previous survey, we had to omit it.

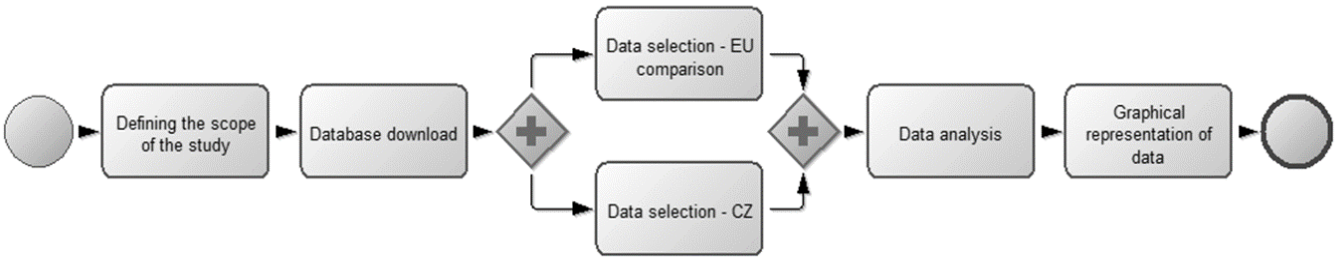

Figure 1. Data processing model

IV. RESULTS

Today's world is full of information about the implications of covid-19 pandemic in almost every aspect of people's life. Impacts on companies are mostly viewed from both sides, as the disaster or the opportunity. For the particular case of cloud computing, articles, and reports mostly take the side of opportunity. However, this time also brings a lot of misinformation or accurate information that can be interpreted differently. Therefore, researchers need trusted sources to verify the information. Such source offers Digital and economy surveys provided by Eurostat, forming our research's basis.

The first research question asked what the level of penetration of cloud computing services in the EU is and how it changed during covid-19 pandemic. Fig. 2 shows two graphs with these views. Each view compares the absolute penetration level of cloud computing services in 2021 with the change between 2020 and 2021. These are the years influenced by covid-19. The graphs show that the change in most countries was positive, but we can also find those with negative change. Mostly these are the countries with a low level of penetration of cloud computing services as Romania and Turkey. However, we can also see countries with very high penetration, indicating they have reached full saturation.

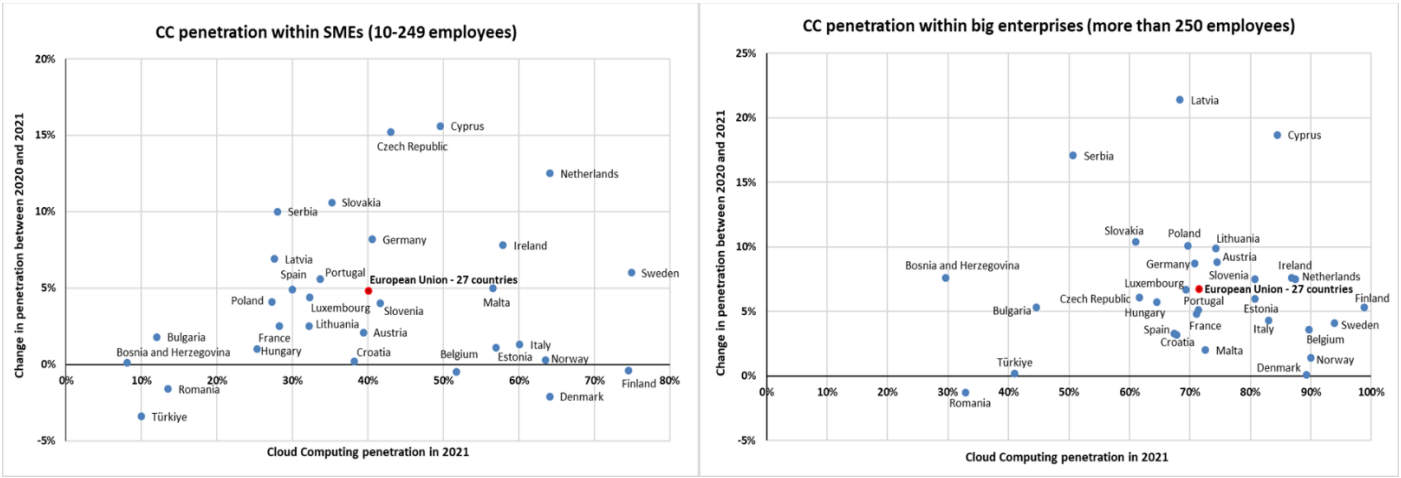

Figure 2. Comparison of the penetration of CC services and its change per EU country.

Different view offers the comparison of the rate of change in years before the pandemic and during the times of pandemic. We prepared the comparison between 2018 and 2020 as a control view to validate that the change was positive before the pandemic. As the data for 2019 were unavailable, we recalculated the growth to get the data per year. The assumption of positive change was confirmed in all cases. The range of growth per year was 0.05% – 18.45% for SMEs and 0.70% – 11.90% for big companies. However, the change was distinct; we could expect that the change without the pandemic hit would continue in this trajectory. Data about change before the pandemic can be found in Table I.

TABLE I. CHANGE IN CC PENETRATION BEFORE THE COVID-19 PANDEMIC (2018-2020) – RECALCULATED PER YEAR

	Size of the enterprise			Size of the enterprise	
	10-249	250 and more		10-249	250 and more
European Union - 27 countries	6,1%	5,9%	Hungary	3,5%	6,9%
Belgium	6,6%	3,8%	Malta	7,9%	4,1%
Bulgaria	1,2%	4,8%	Netherlands	2,2%	2,0%
Czech Republic	1,1%	5,4%	Austria	7,4%	7,9%
Denmark	5,6%	6,3%	Poland	6,4%	8,5%
Germany	5,4%	6,7%	Portugal	2,2%	3,4%
Estonia	11,3%	9,0%	Romania	2,7%	4,5%
Ireland	2,7%	8,9%	Slovenia	6,3%	4,4%
Spain	2,0%	4,6%	Slovakia	2,2%	4,8%
France	3,8%	3,3%	Finland	5,2%	0,7%
Croatia	4,0%	7,2%	Sweden	6,2%	3,7%
Italy	18,5%	10,6%	Norway	6,6%	4,3%
Cyprus	3,9%	11,9%	Serbia	1,7%	1,1%
Latvia	3,4%	4,2%	Türkiye	1,9%	6,3%
Lithuania	4,0%	4,9%	Bosnia and Herzegovina	0,1%	1,2%
Luxembourg	2,2%	4,3%			

Next part of the research considered only data from the Czech Republic. The comparison at the EU level revealed that cloud computing penetration in the CZ is slightly above the EU average (43% compared with 40.1 %) within SMEs. However, it is below the EU average (61.7 % compared with 71.6 %) within big enterprises. However, the change in both cases was positive. According to these results, we were interested to find out if the positive change happened for all cloud computing services or if there are some differences.

For the comparison between covid-19 years, we had to omit two types of services, but they are present in another view of the data. The results (see Fig. 3) show the same dynamics for SMEs and big companies, with slight differences. SMEs bought more financial and accounting software applications with almost no changes in CRM software. On the other side, big companies bought more hosting for enterprise databases and storage of files. An interesting type of cloud computing service is buying power to run the enterprise's own software. The change for big companies was -11.5 %, and for SMEs, it was -4.28 %. As the change is negative for all companies, it is a trend that deserves special attention in future research.

A different view on using particular types of cloud computing brings Fig. 4. In this figure, we can see all types evaluated in 2021. Adoption of most types in big companies is higher, except for Finance and accounting software and Security applications. It is obvious that security threats are not only the domain of large companies. On the contrary, while large companies have enough funds to solve security problems, for small and medium-sized companies, these problems could be fatal.

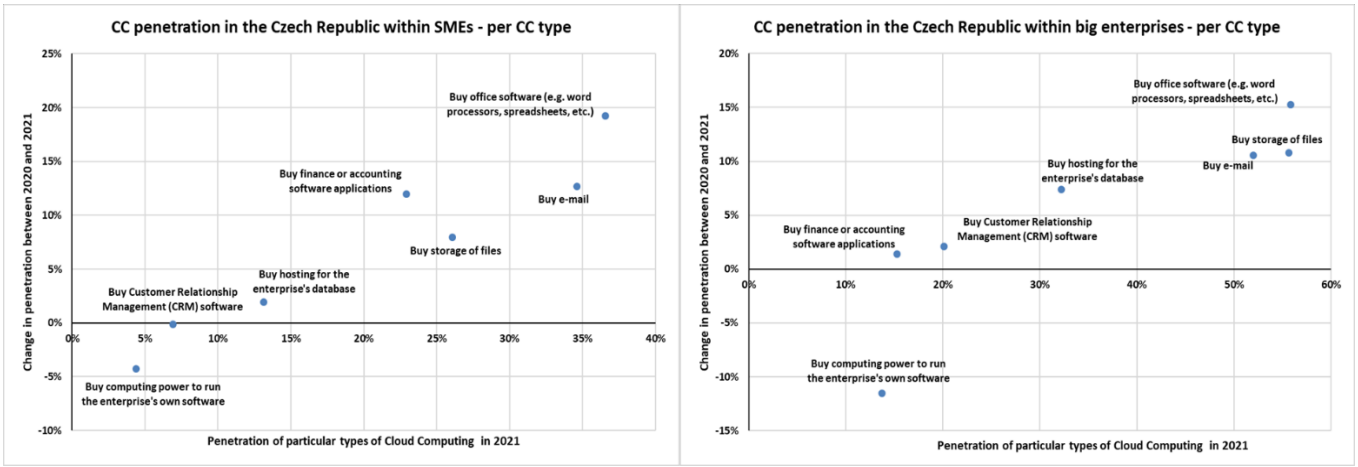

Figure 3. Comparison of penetration of CC services and its change per type of service

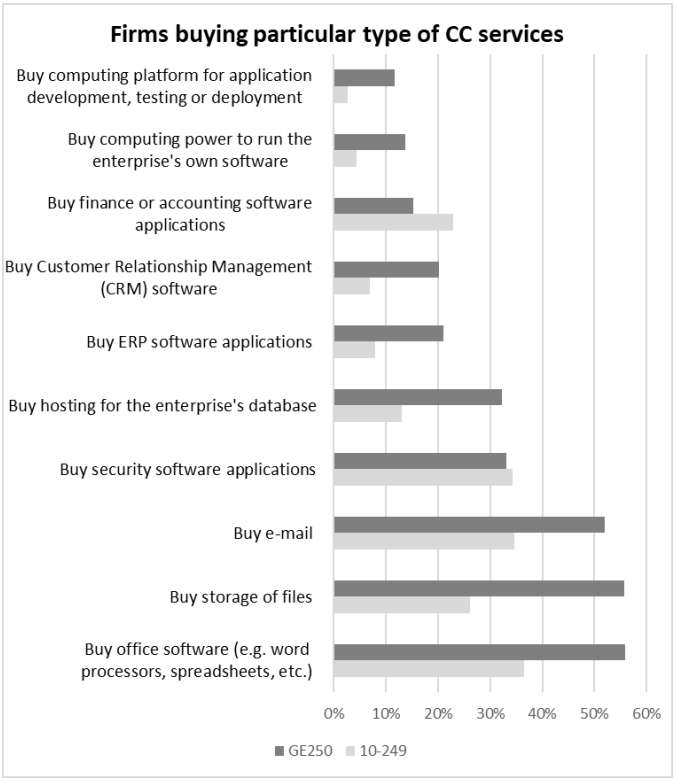

Figure 4. Cloud computing penetration in the Czech Republic – data per type of CC service

The last view of the data considers the sophistication of cloud computing services (see Fig. 5). Cloud computing services in the presented survey are further categorized as basic, intermediated, and sophisticated. Basic services are recognized by buying email, office software, files and storage, and computing power to run own applications. If the company has only these services (at least one), it is categorized into the basic level of cloud computing use. Intermediate services are finance and accounting applications, ERP applications, and CRM applications. Again, if the company has at least one service from this category, it is categorized into an intermediate level of cloud computing use. Finally, to be categorized into the sophisticated level of cloud computing use, the company has to use at least one of these services: security software application, hosting for an enterprise database, and computing platform for application development.

The presented results in figure 6 show that most companies, regardless of the field of business, use at least one sophisticated cloud computing service. However, the results also show that companies in the service domain are more mature than those engaged in manufacturing. On the level of SME, the results are only slightly different, but the graph depicting the sophistication of cloud computing services within big enterprises shows a more significant disproportion. 14.3 % of companies engaged in manufacturing use only basic cloud computing services compared with 8.8 % in the service domain. This result is surprising as the expectation would be that smaller firms buy basic cloud computing services and more significantly concentrate on more sophisticated ones.

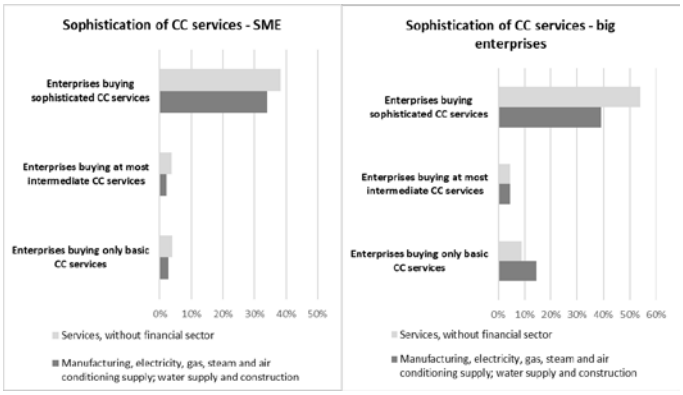

Figure 5. Level of sophistication of CC services – data per domain (manufacturing, services)

V. CONCLUSIONS

Utilization of cloud computing services has become a standard part of the life of businesses, the public sphere, and ordinary people. This research showed that developments in this domain were imminent before the pandemic hit. All evaluated countries in the EU were experiencing growth in the time period 2018 – 2020. As the data for 2019 were unavailable, we recalculated the growth to get the data per year. The main research question motivating this research was if this growth was sustained, accelerated, or slowed down. We found that only 43.3 % of SMEs in the EU experienced higher growth in penetration of cloud computing during covid-19 pandemic, in comparison with 60 % of big companies. This statistic shows that even though the growth in most countries continued during the pandemic, data are not convincing that there was quite a boom in this domain.

According to data in the Czech Republic, we can see a decrease in the buying of computing power to run own software, which can be identified as a trend because we identified this situation in both SMEs and big companies. The next revealed trend is buying security software applications. Finally, the last trend revealed is buying sophisticated cloud computing services.

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