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Szymon Dziubak M.A.
SGH Warsaw School of Economics
Collegium of Economic Analysis
e-mail: sdziuba@sgh.waw.pl
ORCID: 0000-0001-5475-6899

Cloud computing usage determinants in European Union countries

Determinanty użycia chmury obliczeniowej w krajach Unii Europejskiej

Keywords:
cloud computing, statistical modelling, technology adoption

Abstract: Cloud computing is growing technology that can offers many benefits for organizations. The purpose of this article is to explain cloud computing adoption determinants. According to literature review the principal factors influencing cloud usage are digital skills, cloud computing infrastructure, IT development in certain country, regulatory and regulatory quality, trust to innovative technologies, economic development, management styles, fund provision and uncertainly avoidance. According to presented statistical analysis based on data from 2020 and 2021, using cloud computing for personal purposes and regulatory quality are significant variables in linear regression model performed to explain cloud computing usage by organizations in EU member states. Those variables explain 92% of data variance. Governments and public institutions may use cloud computing in public offerings (for example healthcare and education) to introduce cloud computing to society and improve regulatory quality in order to boost cloud computing usage by organizations. This research is important from countries innovation and competitiveness perspective.

Słowa kluczowe:
chmura obliczeniowa, modelowanie statystyczne, adopcja technologii

Streszczenie: Chmura obliczeniowa jest rozwijającą się technologią oferującą wiele korzyści organizacjom. Celem tego artykułu jest wyjaśnienie determinant adopcji chmury obliczeniowej. Bazując na przeglądzie literatury najważniejsze czynniki wpływające na użycie chmury to umiejętności cyfrowe, infrastruktura chmury publicznej, rozwój technologii IT w danym kraju, regulacje i ich jakość, zaufanie do nowych technologii, rozwój gospodarczy, style zarządzania, dostęp do finansowania i niechęć do niepewności. Zgodnie z zaprezentowaną analizą statystyczną opartą na danych z lat 2020 i 2021, użycie chmury

obliczeniowej w celach prywatnych i jakość regulacji to dwa istotne statystycznie czynniki w modelu regresji liniowej użytej do wyjaśnienia poziomu użycia chmury obliczeniowej przez organizacje w krajach UE. Zmienne te wyjaśniają 92% zmienności w danych. Rządy i instytucje publiczne mogą używać chmury obliczeniowej w oferowanych przez nie usługach (np. w opiece zdrowotnej i edukacji) i poprawić jakość regulacji w celu zwiększenia poziomu użycia chmury obliczeniowej przez organizacje. To badanie jest ważne z perspektywy innowacyjności i konkurencyjności krajów.

JEL:
M15, L86, O33

Introduction

Cloud computing is essential technology in modern business because it delivers innovations, reduce time from idea to go live and it is disrupting the technology and business aspects of organizations [Hurwitz, Kirsch, 2020, pp. 21–28].

Mell and Grace [2011] define cloud computing as computing paradigm that provide access to pool of computing resources that can be quickly provisioned and released with on-demand delivery model. They distinguish 4 deployment options:

- public cloud, it is provided by external IT companies, and it is publicly available,
- private cloud, it is available only for one organization,
- community cloud, it is available for set of organizations but not publicly available,
- hybrid cloud, it is combination of other deployment models.

Cloud computing evolved in last years and it became the main IT infrastructure and services delivery model [Benlian et al., 2018]. Sunyaev [2020, p. 195] notice that cloud computing contribute also to development of services delivered to individuals. It is changing the way that individuals store their data, play online games, and write documents. Cloud provides infrastructure that is used in modern solutions for example big data, artificial intelligence and Internet of Things. Numerous benefits have to be confronted with challenges and threats related to this technology.

Tadapaneni [2020, p. 2] discusses security issues in cloud computing. It is one of the main challenge that organizations are encountering. Privacy protection is other crucial challenge of cloud computing [Sun, 2020, p. 3]. Recently, organizations that intended to use cloud computing are encountering more non-technical issues instead of technical ones. It is because cloud providers are spending more on creating secure and reliable technology however governments and organizations are struggling to adapt to new technologies. Recent research shows that building solutions that include multiple cloud providers can be challenged as cloud projects become more complex [Varghese,

Buyya, 2018, p. 4]. Survey conducted by Singh and Chatterjee [2017, p. 1] points out that other cloud challenges are related to cloud architecture and cloud technologies.

Marston et al. [2011] claims that cloud computing changes the root of IT services from technical and business perspective. However many organizations were reluctant to implement cloud computing services [Hsu, Ray, Li-Hsieh, 2014, p. 1]. It was because of business concerns leading to higher rate of private deployment models instead of using public cloud. Nowadays, cloud computing is used by organization more frequently [Vu, Hartley, Kankanhalli, 2020, p. 3]. Nevertheless, there are many obstacles that make difficult to use all cloud opportunities.

According to Gartner [Goasduff, 2019] between European countries there are significant differences in cloud computing perception and usage based on selected EU countries. They distinguish 3 categories: Tracking Countries (with highest cloud computing spendings as a percentage of total IT spendings and growth in cloud spendings), Lagging Countries and Resisting Countries (with the lowest percentages). In European Union states Tracking Countries are Poland and Netherlands, while Lagging Countries are France, Germany, Italy and Spain. In the research it is noticed that emerging markets have rapid growth of cloud computing spendings, while in developed markets this growth is lower. However developed ones are spending more on cloud computing as a percentage of total IT spendings.

Balland et al. [2021] analyse regions of EU that may contribute the most in know-ledge creation in cloud computing. Regions from Finland, Hungary, Ireland, France, Czech Republic and Germany have the most potential in this area. They notice that regions with high presence of innovative technologies and with larger population have high potential in Industry 4.0 development (including cloud computing).

This paper focuses on answering following research questions:
RQ1: What are the determinants of adopting cloud computing according to literature?
RQ2: What factors impact on cloud computing usage in EU countries according to statistical analysis?
RQ3: What can countries do to increase the rate of cloud computing usage by organizations?

Literature review and research method

Features preselection

In the research determinants of adopting cloud computing are analysed according to recent literature. Papers released after 2017 were analysed in order to get the most recent results. Cloud computing is rapidly changing technology, that is why literature

should be recent to disclude conclusions that may be outdated. All analysed papers are released in reviewed journals. 20 papers were analysed in order to list determinants that are important in the process of cloud computing adoption. The number of articles is limited by the niche of this topic as well as time limitation. However the number is providing adequate a set of determinants that will be included in further statistical modelling. Only determinants that can be described from entire country perspective were selected due to nature of this study, those that apply for selected organizations were rejected.

Table 1 describe determinants of cloud computing usage according to literature.

Table 1. Determinants of cloud computing adoption in selected articles

Article	Determinants
[Alkhalil et al., 2017]	management style, digitals skills, regulatory, uncertainty avoidance
[Amron et al., 2019]	trust, digitals skills, cloud computing infrastructure, personal IT development, regulatory
[Avram, 2014]	cloud computing infrastructure
[Bhatiasevi, Naglis, 2016]	trust, digitals skills
[Das, 2022]	digitals skills, uncertainty avoidance
[Dincă et al., 2019]	digitals skills
[Ghobakhloo, 2020]	digitals skills, regulatory
[Haddad, Hornuf, 2019]	economic development, personal IT development, provision of fund
[Hassan et al., 2017]	digitals skills, cloud computing infrastructure
[Kathuria et al., 2018]	cloud computing infrastructure, personal IT development
[Kshetri, 2016]	economic development
[Maroufkhani et al., 2020]	cloud computing infrastructure, personal IT development
[Mikalef et al., 2022]	regulatory
[Oke et al., 2021]	digitals skills
[Priyadarshinee et al., 2017]	trust, management style
[Riswanto et al., 2020]	regulatory
[Sarangi, Pradhan, 2020]	economic development, personal IT development, provision of fund, regulatory
[Schneider, Sunyaev, 2016]	cloud computing infrastructure, personal IT development
[Wong et al., 2020]	trust
[Yoo, Kim, 2018]	digitals skills

Source: autor's own study.

According to literature review, following determinants with corresponding number of occurrence are important:

- digital skills (9),
- cloud computing infrastructure (6),

- personal IT development (6),
- regulatory (5),
- trust (4),
- economic development (3),
- management style (2),
- fund provision (2),
- uncertainly avoidance (2).

This list is answering the first research question, what are the determinants of adopting cloud computing according to literature.

Based on papers reviewed, under category digital skills lies IT skills of employees and management team. Cloud computing infrastructure is the infrastructure located in certain countries from where cloud computing services are shared. More specifically it is the indicator pointing out the existence of public cloud data center in certain country or the number of data centers of public cloud in the country. Personal IT development is describing the level of IT usage by society and access to internet. Regulatory is about regulations and regulatory quality of IT related issues. Trust means the approach of society to IT technologies as well as how people trust technology. Economic development is characterized by bunch of economic development indicators. Management style is the method and effectiveness of management. Fund provision describes the accessibility of funding to business. Uncertainty avoidance is describing how societies are prone to risk.

Data sources

To examine the quantitative form of formulated problem, quantitative data needs to be searched and used. Data used in this research is from 2021 or from 2020 if collection for base year is not available.

Dependent variable – cloud usage is retrieved from Eurostat research titled Cloud computing services by NACE Rev.2 activity. Data was collected in 2021. Variable used in the research is named cloud_usage. It reflects the percentage of companies that bought cloud computing services in Internet. Those cloud computing services are mainly e-mail systems and cloud disks, however 73% of companies that bough cloud computing services used sophisticated cloud services like databases, security software applications or platforms for application development and deployment [Eurostat, 2022].

For digital skills percentage of persons with ICT education in entire population was used. Values for persons with ICT education were retrieved from Persons with ICT education by labour group Eurostat dataset was used. Values for population were obtained from Population, total dataset published by The World Bank [2021]. Variable used in the research is named it_specialists_pct.

For cloud computing infrastructure it was checked how many main cloud computing providers (Google Cloud, Amazon Web Services and Microsoft Azure) located its cloud infrastructure in certain country. This can have an integer values from 0 to 3, where 0 means that none of cloud providers located its infrastructure in country and 3 means that all of checked cloud computing providers located its infrastructure there. Data was collected from official websites of Amazon Web Services, Microsoft Azure and Google Cloud Platform [Amazon Web Services, 2021; Microsoft Azure, 2021; Google Cloud, 2021]. Variable used in the research is named datacenters_sum.

For personal IT development internet access and individuals use of Cloud Computing were used. The first one is from Level of internet access – households Eurostat dataset, while the second one is from Individuals – use of cloud services Eurostat dataset. By individuals using cloud computing, it meant the percentage of individuals that are sharing files, using email and personal websites in cloud. Variables used in the research are named internet_access and individuals_use_cc.

For regulatory data from The Worldwide Governance Indicator – regulatory quality was used [Kaufmann, Kraay, 2022]. This indicator was used by Dziubak [2023] in literature review and empirical study and it demonstrates high positive linear correlation value with cloud computing usage. Variable used in the research is named regulatory_quality.

For trust category following variables were used: use smartphone, data lost and data restriction from Trust, security and privacy – smartphones (2020 onwards) Eurostat dataset (columns correspondingly Individuals use a smartphone for private purposes, Individuals already lost information, documents, pictures or other kind of data on their smartphone as a result of a virus or other hostile type of programs and Individuals at least once restricted or refused access to personal data, when using or installing an app on the smartphone). Variables used in the research are named trust_use_smartphone, trust_data_lost and trust_personal_data_restriction.

Economic development category is divided into GDP growth and GDP per capita at purchasing power parity. This data is retrieved from Eurostat datasets. Variables used in the research are named gdp_growth and GDP_per_capita_PPS.

Managements styles are elaborated based on research done by Bloom et al. [2012, p. 8]. Management style overall, management style targets and management style monitoring were added to this research for each country. If the value was not available for certain country, extrapolation based on described characteristics were done. It has a form of positive float for analysed category. Variables used in the research are named management_styles_overall, management_styles_targets and management_styles_monitoring.

Data for fund provision was retrieved from Money market interest rates – monthly data from Eurostat dataset. Monthly data was aggregated to yearly by calculating average. Variable used in the research is named interest_rates.

Uncertainly avoidance is based on research done by Snitker [2010]. It gets positive continuous values for each country, the higher indicator value is, the more uncertain decisions are avoided by certain society. Variable used in the research is named uncertainly_avoidance.

Statistical analysis

Table 2 presents descriptive statistics of analysed variables.

Table 2. Descriptive statistics of analysed dataset

Variable	mean	std	min	Q25	Q50	Q75	max
cloud_usage	42.8	17.2	12.8	30.2	40.4	57.3	75.4
it_specialists_pct	0.76	0.30	0.27	0.56	0.67	0.88	1.56
datacenters_sum	0.78	1.09	0.00	0.00	0.00	2.00	3.00
internet_access	91.8	4.1	83.5	89.6	91.9	94.2	99.2
individuals_use_cc	38.6	11.3	24.2	30.0	34.3	45.1	64.4
regulatory_quality	1.12	0.51	0.31	0.77	1.22	1.56	1.92
trust_use_smartphone	79.6	8.8	60.0	76.0	77.9	87.4	93.2
trust_data_lost	4.34	2.71	1.41	2.81	3.73	4.64	14.88
trust_personal_data_restriction	48.5	11.8	25.3	40.8	48.5	55.2	68.4
gdp_growth	6.46	2.78	2.60	4.90	6.00	7.35	13.60
GDP_per_capita_PPS	33796	14920	18600	24300	29400	39000	87100
management_styles_overall	2.99	0.14	2.73	2.90	3.02	3.09	3.23
management_styles_targets	3.06	0.11	2.81	2.96	3.08	3.14	3.21
management_styles_monitoring	3.29	0.20	2.97	3.12	3.26	3.45	3.63
interest_rates	–0.27	0.50	–0.58	–0.48	–0.48	–0.48	1.30
uncertainly_avoidance	75.3	23.1	23.0	62.0	75.0	90.2	112.0

Source: autor's own study.

The highest cloud usage is in Scandinavian countries (Sweden: 75.4%, Finland: 75.3%) while the lowest is in Bulgaria (12.8%). Over 50% of countries do not have any public cloud data center located within their borders, while some countries have 3 out of 3 providers infrastructure located inside. Between individual usage of cloud computing there is visible dispersion, the lowest value means that every fourth citizen use this type of services while the highest one is significantly higher and equal to 64,4%. In some countries GDP growth exceeded 10% while in median European Union economies increased at a rate of 6%. Values for management styles categories are consistent, with low dispersion. The average cost of lending money in the vast majority of

countries was negative (mainly Euro area), while in Eastern Europe (Romania, Poland, Hungary, Czechia) it was relatively low but positive. Nations averse to risk are, among others, Greeks and Portuguese while Swedes, Danes and Irish are rather risk-loving.

Collinearity is a situation where independent variables are closely related to one another [Wilcox, 2022, p. 577]. After removing trust_personal_data_restriction, management_styles_monitoring and management_styles_overall from the set of independent variables, collinearity has significantly decreased.

The next step was to review the form of dependency between dependent variable and each independent variable. Following forms were analysed in order to define the character of dependency: logarithmic form (log base 2), square power form and form without transformation. After reviewing linear dependency for each dependent variable with each form following transformations were made:

- *trust_data_lost* transformed using log base 2 named *log_trust_data_lost*,
- *GDP_per_capita_PPS* transformed using log base 2 named *log_GDP_per_capita_PPS*,
- *interest_rates* transformed using square power named *pow2_interest_rates*,
- *individuals_use_cc* transformed using log base 2 named *log_individuals_use_cc*.

Automatic selection of variables can be done using forward selection and backward selection [Blanchet, Legendre, Borcard, 2008, p. 2]. Variables used in model were selected using both selection methods. Scoring metric used in selection process was Mean Absolute Error. Selection was done for number of features for range from 2 to 4. Higher number of features deteriorated model performance and properties. Model for selection was linear regression due to small research sample. Two features were selected: log2_individuals_use_cc and regulatory_quality.

Ordinary Least Squares linear regression was performed in order to resolve second research question of this study. The form of regression is presented in formula 1.

$$\hat{cloud\_usage} = 4.44 * log2\_individuals\_use\_cc + \\ +17.90 * regulatory\_quality \tag{1}$$

Coefficient for log2_individuals_use_cc is equal to 4.44 and the p-value is below 0.05 alpha level. Null hypothesis can be rejected so coefficient is significantly different than 0.

Coefficient for regulatory_quality is equal to 17.9 and p-value is below 0.05 alpha level. Null hypothesis can be rejected so coefficient is significantly different than 0.

Both variables are statistically significant thus these can be used in statistical inference.

Adjusted R-squared is computed without centering as model does not have intercept. This metric is equal to 0.92. That means that 92% of observed variation can be explained by the model.

Shapiro test points out that model residuals have normal distribution. P-value for this test is equal to 0.82 and means that null hypothesis cannot be rejected with selected alpha level.

White test is to detect homoscedasticity of the model. P-value for this test is 0.11, thus null hypothesis cannot be rejected with 0.05 alpha level. It means that residuals are equally dispersed so there is homoscedasticity present in the data.

All assumptions that apply are met, thus linear regression model is valid and can be applied and interpreted.

Results and discussion

This empirical study has indicated determinants important in the process of cloud computing adoption based on statistical data. Features were preselected based on literature review.

According to literature review, the most important factor determining cloud usage is level of digital skills. This statement is not valid in analysing this phenomenon, because it_specialist_pct (percentage of population that have IT educational background) is not statistically significant and have low Pearson correlation coefficient so linear form and any other of analysed transformation (that are general one) is not proper in the modelling process.

Correlation for datacenters_sum (cloud computing infrastructure) is equal to 0.37 that is low-to-moderate linear dependency. This variable is not significant in the model so it is removed.

Personal IT development is another important category according to literature review. In the research it is divided into 2 features individuals_use_cc and internet_access. In model presented logarithm with base 2 from individuals_use_cc has moderate-to-strong linear correlation with dependent variable. It is included in the model due to statistical significance.

Regulatory and regulatory quality is another feature included in model that have moderate-to-strong linear correlation with cloud usage and it is statistically significant. Moreover Dziubak [2023] is providing an in-depth analysis of this feature and study its positive linear impact on cloud computing adoption.

Variables from the rest of categories (trust, management style, economic development, fund provision and uncertainly avoidance) are not included in the model due to low dependency with cloud computing usage variable and lack of statistical significance.

Coefficient for log2_individuals_use_cc is equal to 4.44. That means that increasing this feature by 1 will lead to increase of cloud_usage by 4.44 caeteris paribus – using cloud computing services privately is improving digitalization through cloud computing

in organizations. Employees that are using cloud computing for personal purposes have better understanding and familiarity of this technology and are more eager to use it in organizations. However logarithm function is characterized by the property that as the value of individuals_use_cc increases (independent variable), cloud_usage (dependent variable) grows slower. Mathematically it is explained in formula 2.

$$if\ \Delta_1 = f(x_{12}) - f(x_{11})\ and\ \Delta_2 = f(x_{22}) - f(x_{21})\ and\ x_{12} > x_{11}\ and\ x_{22} > x_{21}$$
$$and\ \|x_{22} - x_{21}\| = \|x_{12} - x_{11}\|\ then\ \Delta_1 < \Delta_2 \quad (2)$$

To increase cloud computing usage it is especially important to increase private cloud computing usage if it has low values. For example increase of individuals_use_cc from 20 to 30 will lead to increase of cloud usage by organizations by 2.6 percentage points, where increase of individuals_use_cc from 80 to 90 will increase cloud computing usage by organizations by 0.75 percentage points.

Coefficient for regulatory_quality is equal to 17.9. Increasing regulatory quality indicator by 1 will lead to increase of cloud usage by 17.9 caeteris paribus. This means that improving regulatory quality will lead to increase in cloud computing usage. It is linear dependency, so change in independent variable will cause the same change in dependent variable regardless actual value.

Analysing important features in the cloud computing adoption process is helping to explain, what can be done to increase cloud computing usage. It is important to use cloud computing in education to familiarize young people with this technology [Zeqiri et al., 2017]. Cloud can be used to support education in the field of communication and sharing studying materials. Cloud can be also used in public sector offerings like healthcare and dealing with administrative matters. Government, local government units and public institutions can implement cloud computing to interact with society and familiarize people with cloud. Improving regulatory quality by government is important factor to boost cloud computing adoption. Governments should then carry about issuing proper law in high quality.

There is not available recent research that study quantitative approach to distinguish extensive scope of determinants of cloud computing adoption. There are many researches presented in Literature review and research method section. However these researches focus on single factors that make it hard to compare research results of all the factors as presented in this paper. Personal IT development was mentioned in 6 researches citied in Literature review while regulatory quality was in 5. Results of this research are then congruent with some researches, however most features are not significant.

Conclusions and further research questions

Cloud computing is a technology affecting societies and organizations. Organizations can benefit from public cloud offerings that are available on demand to boost economy development. That is why cloud adoption is important.

In this study, multiple determinants of cloud computing adopting in European Union countries were selected based on literature review. For each of these determinants corresponding dataset or datasets were downloaded in order to present results in quantitative way. Based on statistical analysis, features were selected and used in linear regression model to explain the significance and impact on cloud computing usage in EU states. All statistical assumptions were met, so model is valid.

In this paper three research questions have been defined.

The most important factions influencing cloud computing adoptions are digitals skills, cloud computing infrastructure, current IT development and regulatory and regulatory quality. Trust to new technologies, economic development management styles, fund provision and uncertainly avoidance were indicated in less than 25% of articles analyzed.

Factors that are important in cloud computing usage by organizations in EU member states are the percentage of people that are using cloud computing for personal purposes and regulatory quality. These two features are statistically significant and can explain 92% of variation. The dependency between cloud computing usage and regulatory quality is linear while for individuals cloud computing use it has logarithmic form. That is why increasing the number of individuals that are using cloud for private purposes is especially important if this number is low.

Governments, local governments and other institutions can offer public services using based on cloud computing to enable societies familiarize with cloud computing. Using cloud computing in education can be crucial because it is targeted to young people that are just entering labor market.

Further research questions may include analyzing how those determinants changed over time – multiple periods can be compared in order to check if determinants in other periods were the same like in 2021. If those determinants would be different, it will be worth to check why the change occurred. Data in this research is limited to European Union countries, thus research sample can be extended to all countries worldwide with an attempt to perform geospatial analysis. Data is aggregated to country level instead of organization level. More granular data may results in more detailed conclusions.

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