Telecom Advisory Services

ECONOMIC IMPACT OF CLOUD COMPUTING IN GERMANY

May 2024

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This report was commissioned by Amazon Web Services. All of the study's content, including its conclusions, are the independent outcome of the analysis conducted solely by the authors and Telecom Advisory Services.

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1. INTRODUCTION

Deep economic transformations have been triggered by the development and diffusion of digital technologies over the past few decades, especially for businesses, where new procedures, reduced expenses, and improved operations have resulted in significant changes in production processes and operating models. These developments have made possible for organizations using information technology to improve their performance, which has, in turn, led to overall economic growth. Among the most recent technological innovations, cloud computing is a powerful tool for organizations looking to execute significant production model changes, accomplish their strategic goals, and remain competitive. Along these lines, cloud computing has become a key lever of national competitiveness and economic growth.

In this context, the purpose of this study is to analyze the contribution of cloud computing to Germany's economy. Research on **the macro-economic contribution of cloud computing has concluded that, driven by its impact on capital efficiency and stimulus of product development, it represents an engine of economic growth.** The aggregate economic contribution of cloud to GDP is composed of: (i) the domestic revenues generated by cloud service providers and (ii) the spillover effects of cloud services on the total economy. The revenues represent the spending of public and private organizations purchasing cloud services,[1] while the spillover effects are the benefits generated by cloud computing in terms of IT cost efficiencies, productivity, new product development, support for incubation of startups and the like.[2]

The study is structured as follows. In chapter 2, we present a brief description of the current state of adoption of cloud computing in Germany. Following this, chapter 3 introduces the theoretical model of an aggregate production function to estimate the economic growth of cloud computing. In chapter 4, we present the estimates of economic contribution in the aggregate for the whole country and disaggregated by industry. In chapter 5, we present estimates on the impact of cloud on job creation. Finally, in chapter 6 we conclude with the study principal findings. Appendix A presents the regression analysis used to link cloud spending and adoption, while Appendix B presents the dataset and the econometric models.

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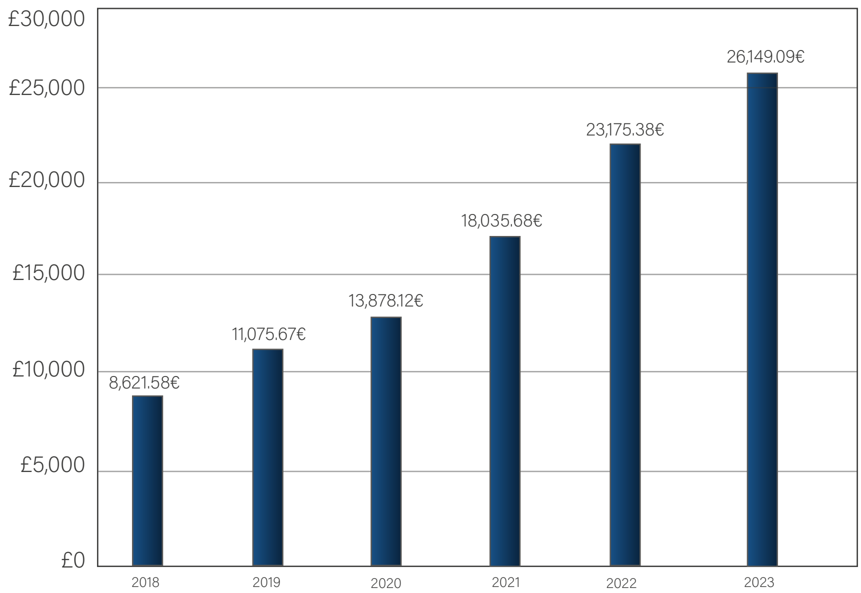
[1] *The revenues are a measure of market demand that can be met through cloud providers based within the country or beyond the country's borders.*
[2] *For example, when cloud services enable the adoption of IT services in the SME sector, which benefits from the scalability of IT state-of-the-art, that is considered to be a spillover effect.*

2. THE STATE OF DEVELOPMENT OF CLOUD COMPUTING IN GERMANY

Cloud computing spending in Germany is the second largest in Europe, accounting for € 26 billion in 2023 and representing the 21% of the total spending of the continent.[3] (see graphic 2-1).

Graphic 2-1. Germany: Cloud computing constant vendor revenues (in € million) (2018-2023)



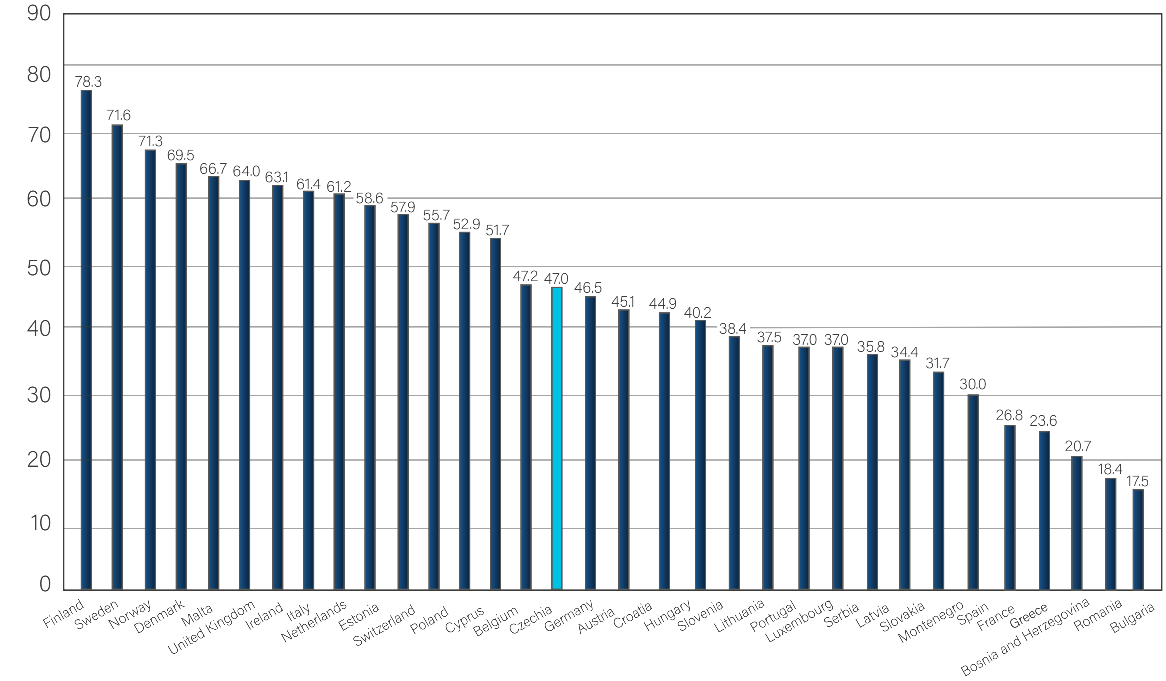
Note: AI Platforms excluded from cloud service provider revenues
Source: IDC Semiannual Public Cloud Services Tracker (2023H1 Release)

Since 2018, the cloud computing market in Germany has been growing at 24.9% CAGR, a similar growth rate than the world demand. At current levels, cloud spending represents 0.7% of the 2023 German's GDP.

Latest cloud adoption figures published for Germany point to 47% of firms relying on this technology in 2023 (source: Eurostat). That figure is only slightly above the European mean of 45.2% since several countries in Europe exhibit larger cloud adoption than Germany (see graphic 2-2).

[3] *Source: IDC. Software and Public Cloud Services Spending Guide. This data excludes the spending in AI platforms when delivered by CSP.*

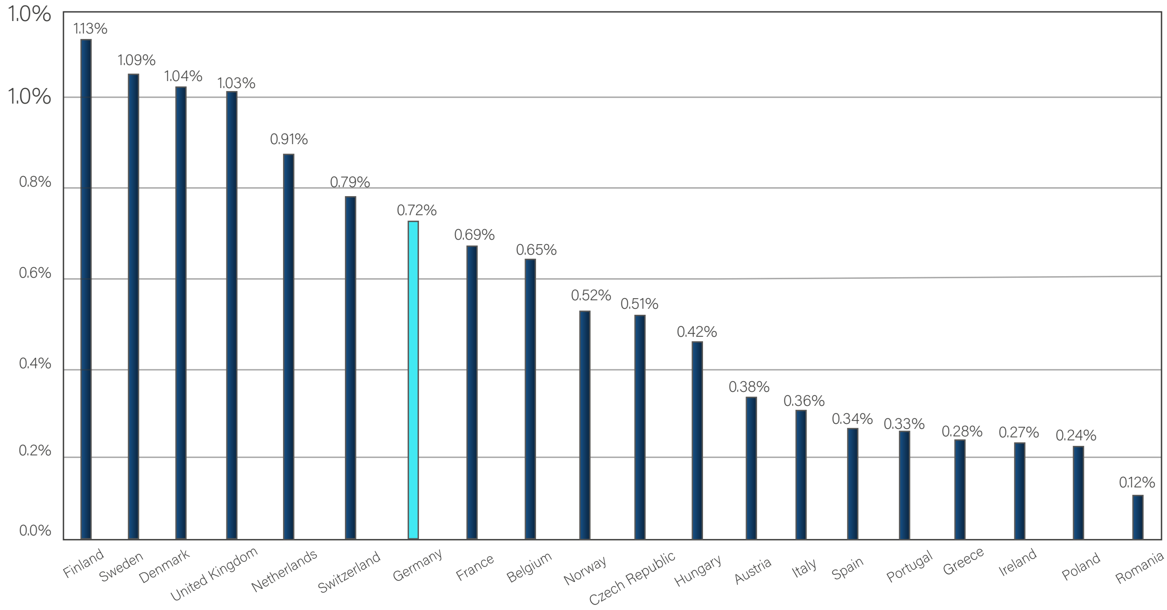
Graphic 2-2. Europe: Cloud enterprise adoption (Percent of employer firms) (2023) (%)



Source: Eurostat, Telecom Advisory Services analysis.

Correlated with cloud adoption, cloud spending as a share of GDP in 2023 in Germany is below Finland, Sweden, Denmark, UK, Netherlands, and Switzerland (see graphic 2-3).

Graphic 2-3. Europe: Cloud spending as percent of GDP (2023) (%)



Source: IDC; IMF; Telecom Advisory Services analysis

Beyond cloud spending, a more significant value creation takes place through economic spillovers, which can be measured on the basis of econometric models presented in chapters 3 and 4.

3. METHODOLOGY

The focus of this chapter is to present the methodology for assessing the economic contribution of cloud computing as a general-purpose technology. The empirical strategy selected for this research is supported by a theoretical model that estimates spillover effects in economic output derived from cloud enterprise adoption. The model proposed will be empirically tested for a sample of European countries, given the lack of enough observations to estimate statistically significant results only based on German data.

To estimate these effects, we start with an empirical model where output is explained through a Cobb–Douglas production function:

$$GVA_{is} = A_{is} K_{is}^{\alpha} L_{is}^{\beta} \qquad \textbf{(1)}$$

In equation (1), GVA represents gross value added, K is the physical capital stock, and L is labor. Subscripts i, and s denote, respectively, country, and economic sector. The term A represents the Total Factor Productivity (TFP), reflecting differences in productive efficiency across industries and countries.

We expect TFP to depend on cloud enterprise adoption (denoted by CLOUD), and beyond it, we assume that higher artificial intelligence (AI) use will enhance cloud impact. This is reasonable, as literature suggests that both technologies are interdependent.[4] As a result, TFP is proposed as:

$$A_{is} = \Omega_i \zeta_s CLOUD_{is}^{\Phi + \delta AI_{is}} \qquad \textbf{(2)}$$

According to it, TFP depends on country-level time-invariant characteristics represented by a fixed effect Ω_i , capturing idiosyncratic productivity effects. In addition, ζ_s reflects sector-level unobservables that make some industries more productive than others.

As it is assumed that cloud enterprise adoption contributes to increased productivity, we expect $\Phi > 0$. Although not the focus of this study, the parameter δ will capture the specific effects of AI as interdependent to cloud[5]. Inserting equation (2) into (1), we obtain:

$$GVA_{is} = \Omega_i \zeta_s CLOUD_{is}^{\Phi + \delta AI_{is}} K_{is}^{\alpha} L_{is}^{\beta} \qquad \textbf{(3)}$$

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[4] *Research evidence indicates that artificial intelligence is complementary to and interdependent with cloud computing. See for example, Pop 2016), Makridakis (2017), Yang (2022), and Brynjolfsson et al. (2018), Katz et al. (2024).*

Applying logs to linearize, we get the final empirical specification for the output equation:

$$\log(GVA_{is}) = \mu_i + \eta_s + \alpha\log\left(K_{is}\right) + \beta\log(L_{is}) + \Phi\log(CLOUD_{is}) + \delta AI_{is}\log(CLOUD_{is})$$

where $\mu_i = \log(\Omega_i)$ is a country-level fixed effect, and $\eta_s = \log(\zeta_s)$ represents the sector unobservables. In sum, we understand that the evolution of GVA depends on some specific unobserved characteristics, on the capital stock, on labor, on cloud enterprise adoption and, on the interdependent use of cloud and AI.

From the last equation, we can calculate the economic impact of cloud, which is expected to depend on the intensity of AI use:

$$\frac{\partial\log(GVA_{is})}{\partial\log(CLOUD_{is})} = \Phi + \delta AI_{is}$$

In addition, the production function can be transformed to represent productivity measures rather than overall output. Assuming constant returns to scale on capital and labour, $\alpha + \beta = 1$ output is therefore expressed as:

$$GVA_{is} = \Omega_i\zeta_s CLOUD_{is}^{\Phi+\delta AI_{is}} K_{is}^{\alpha} L_{is}^{1-\alpha}$$

This means we can modify this equation to represent it as:

$$\left(\frac{GVA_{is}}{L_{is}}\right) = \Omega_i\zeta_s CLOUD_{is}^{\Phi+\delta AI_{is}}\left(\frac{K_{is}}{L_{is}}\right)^{\alpha}$$

So effectively, labor productivity (measured as GVA per worker) can be expressed as a function of the unobservable factors, cloud, and AI adoption, plus the physical capital stock per worker. Applying logs for linearization, we get the empirical specification for the productivity equation:

$$\log\left(\frac{GVA_{is}}{L_{is}}\right) = \mu_i + \eta_s + \alpha\log\left(\frac{K_{is}}{L_{is}}\right) + \Phi\log(CLOUD_{is}) + \delta AI_{is}\log(CLOUD_{is})$$

The estimation of the productivity equation is relevant as these different output measures explain various perspectives on firm performance: while GVA is a metric of aggregate production (minus the consumption of intermediate inputs), labor productivity measures the value added for the average worker, thus representing a measure of efficiency. These models would allow us to estimate cloud's contribution to GVA and productivity.

The baseline contribution of cloud to GVA is estimated through the parameter $\boldsymbol{\Phi}$ estimated through the output equation, that represents the elasticity: a 1% increase in cloud enterprise adoption will yield an increase in GVA of $\boldsymbol{\Phi}$**%**.The contribution of cloud to productivity is estimated through the elasticity provided by the parameter $\boldsymbol{\Phi}$ resulting from the econometric regression of the productivity equation.

4. ESTIMATING THE ECONOMIC IMPACT OF CLOUD COMPUTING

4.1. ECONOMIC CONTRIBUTION OF CLOUD IN 2023

The aggregate economic contribution of cloud to GDP is composed of: (i) the domestic revenues generated by cloud service providers due to customer spending, and (ii) the spillover effects of cloud services on the total economy. The revenues represent the spending of public and private organizations purchasing cloud services,[5] while the spillover effects are the benefits generated by cloud computing in terms of IT cost efficiencies, new product development, support for incubation of startups and the like.[6] By adding the economic benefits generated from the use of cloud services (the spillover effect) to the spending in cloud services (the direct effect), we obtain a measure of the total economic contribution (see table 4-1).

Table 4-1. Revenue and spillover contribution of cloud services to GDP

ITEM	Indicator	Source
(1)	Cloud spending by public and private sector	From Chapter 2
(2)	Spillover effect: Spill-over effect of cloud services	Calculated from elasticities in Appendix B
(3)	Total impact of cloud services to the GDP	(1) + (2)

Source: Telecom Advisory Services

Direct spending includes all revenues of cloud companies when they offer their services in the country.[7] Considering the estimated elasticity and cloud enterprise adoption growth between 2022 and 2023, we estimated the spillovers associated to them. To reiterate results from the model included in Appendix B, 1% increase in cloud enterprise adoption is associated with an increase of 0.135% of the GVA. By adding both terms, the total economic contribution of cloud computing for Germany was calculated (see table 4-2).

Table 4-2. Germany: Total economic contribution of cloud computing (2023) (in € million)

ITEM	Indicator	Value
(1)	Cloud spending by public and private sector	26,149.09 €
(2)	Spillover effect: Spill-over effect of cloud services	28,514.00 €
(3)	Total impact of cloud services to the GDP	54,663.09 €

Source: Telecom Advisory Services analysis

[5] *The revenues are a measure of market demand that can be met through cloud providers based within the country or beyond the country's borders.*
[6] *For example, when cloud services enable the adoption of IT services in the SME sector, which benefits from the scalability of IT state-of-the-art, that is considered to be a spillover effect.*
[7] *The revenues derived from offering AI platforms are excluded from the estimate.*

In conclusion, the total economic impact of cloud in Germany in 2023, comprising cloud spending and its spillovers on the economy, is sizable: € 54.66 billion.

4.2. ECONOMIC CONTRIBUTION 2023-2030

In addition to estimating the impact for 2023 for cloud, we forecast economic contribution for the seven-year interval through 2030. To estimate the spillovers from cloud enterprise adoption growth in future years, we projected cloud adoption by considering IDC forecasts on spending and the regression that links adoption and spending (see Appendix A). Aggregated values for the seven-year interval under this baseline scenario are presented in table 4-4.

Table 4-4. Germany: Economic contribution of cloud computing and AI (2023-2030) (€ million)

ITEM		2023	2024	2025	2026	2027	2028	2029	2030
Cloud computing	Spending	26,149.09 €	31,499.57 €	37,569.46 €	44,412.50 €	52,162.84 €	59,166.13 €	64,151.40 €	65,960.95 €
	Spillover	28,514.00 €	28,529.27 €	26,920.28 €	25,685.74 €	23,944.48 €	19,546.12 €	14,092.42 €	8,804.15 €
	Total	54,663.09 €	60,028.84 €	64,489.74 €	70,098.24 €	76,107.32 €	78,712.25 €	78,243.82 €	74,765.10 €
	per worker	1,283.59 €	1,411.61 €	1,514.63 €	1,644.30 €	1,783.03 €	1,841.77 €	1,828.53 €	1,745.06 €

Note: The decline in economic impact from in the outyears is driven by a decrease in the cloud adoption growth rates, a driver of spillovers.
Source: IDC Semiannual Public Cloud Services Tracker- 2023H1 Forecast; Telecom Advisory Services analysis

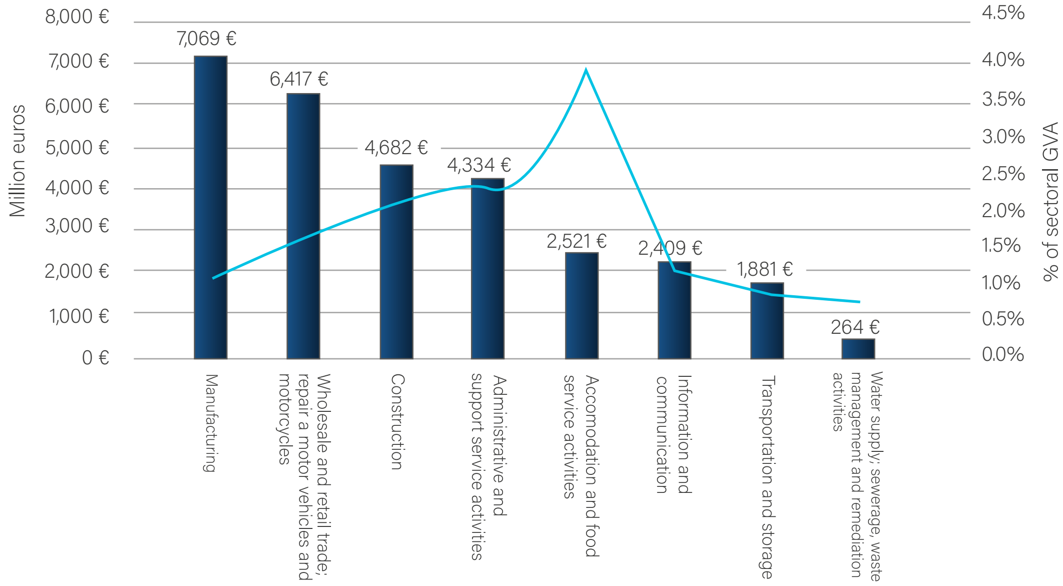
During the seven-year timeframe (2024-30), the economic impact of cloud in Germany will be significant, reaching € 502 billion, representing 1.49% of the forecasted cumulative GDP. In terms of productivity, the economic gains due to cloud computing account for € 1,283.59 per worker in 2023, increasing to € 1,745,06 in 2030.

4.3. ESTIMATING ECONOMIC IMPACT BY SECTOR

Based on the estimates presented above for 2023, we estimated the differential economic impact across industries. Strictly speaking, differences in economic impact could be traced back to the variance in cloud adoption, on the number of firms adopting cloud by sector, and on the growth rates of cloud spending.

The estimates were calculated for a selected list of sectors as represented in Graphic 4-2. Results suggest the largest economic impact takes place in the manufacturing sector, followed by wholesale and retail trade, and construction. As a share of the sector GVA, it is in the accommodation and food service sector where the largest effects are found (3.86% of its GVA). Lowest impact levels are identified for the water supply industries.

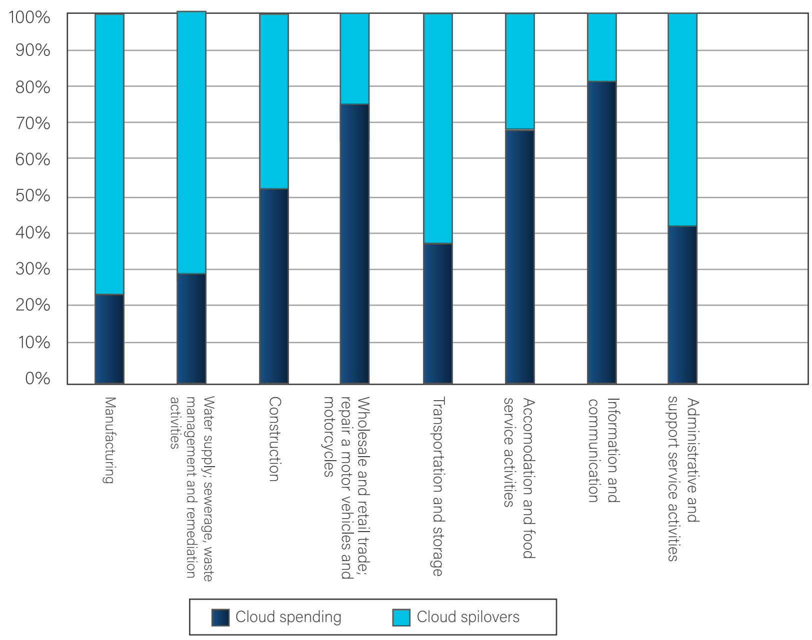
Graphic 4-2. Germany: Economic impact of Cloud Computing in selected sectors (2023)



Source: Telecom Advisory Services analysis

However, the composition of the effect in each sector varies largely, depending on the growth rate of adoption levels, and the number of firms adopting cloud (Graphic 4-3).

Graphic 4-3. Germany: Economic impact of Cloud Computing in selected sectors by source of impact (2023)



Source: Telecom Advisory Services analysis

In some industries, the main contribution is linked to direct spending (e.g.: wholesale and retail trade, or information and communication), while in other sectors, the spillovers are the main source of economic impact (manufacturing).

5. THE IMPACT OF CLOUD COMPUTING ON JOB CREATION

To estimate the impact of cloud services on employment, we built two models covering OECD countries (Table 5-1). We employed two dependent variables: the number of employed persons as a proportion of the labor force and the unemployment rate. As explanatory variables beyond cloud adoption, we introduced GDP per capita, to control for economic development, and inflation, to account for the effects usually represented through the Phillips curve. [8]

Table 5-1. Cloud computing spillover effects on employment

Dependent variable:	Log (Employment/Labor Force)	Log (Unemployment rate)
Log (Cloud adoption)	0.025***	-0.254***
	[0.008]	[0.056]
Log (GDP per capita)	0.025	-0.492**
	[0.023]	[0.184]
Inflation	0.220*	-2.944**
	[0.129]	[1.383]
Country fixed effects	YES	YES
Inflation	0.329	0.457
Inflation	229	229

*Note: *** p<1%, ** p<5%, * p<10%. Robust standard errors in brackets*
Source: Telecom Advisory Services analysis

The results point to a significant effect of cloud adoption on increasing employment and reducing the unemployment rate. Notably, we can state that a **1% increase in cloud adoption will yield a 0.025% increase in the employment share of the labor force.**

We employed the coefficients in Table 5-1 to simulate the expected increase in new jobs in the German economy during 2023. A projected increase in cloud adoption of 6.3% should yield a rise of 0.16% in the employment ratio (Table 5-2).

[8] *The data was compiled from statistics provided by the OECD.*

Table 5-2. Germany: Overall contribution to employment by the cloud (2023)

Category	Estimate	Source
1. Employment in 2022	42,810,285	World Bank
2. Labor Force in 2022	44,198,105	World Bank
3. Employment in 2022 (as a % of Labor Force)	96.860%	(1)/(2)
4. Cloud adoption in 2022	44.220%	Eurostat / TAS
5. Cloud adoption in 2023	47.000%	Eurostat
6. Increase in Employment ratio due to 1% increase in Cloud adoption	0.025%	Table 5-1
7. Increase in Cloud Adoption 2023	6.287%	((5)-(4))/(4)
8. Increase in Employment ratio for 2023 due to Cloud adoption	47.000%	Eurostat
9. Employment in 2023 (as a % of Labor Force) - due to Cloud Computing	97.010%	(3)*(1+(8))
10. New jobs in 2023 due to Cloud Computing	66,450	((9)-(3))*(2)

Source: Telecom Advisory Services analysis

As highlighted in Table 5-2, the employment ratio for 2023, including the new jobs created as a result of spillover effects related to the increase in cloud computing adoption, is estimated to be 97.01%. Therefore, **the growth in cloud adoption in 2023 represented an increase of approximately 66,450 employed individuals in Germany.**

During the seven-year timeframe (2024-30), a total of approximately 316,000 new jobs would be created in Germany according to the projections presented in Table 5-3.

Table 5-3. Germany: Contribution to employment by cloud (2023-2030)

ITEM	2023	2024	2025	2026	2027	2028	2029	2030
Cloud adoption (%)	47.0%	49.6%	52.2%	54.9%	57.5%	59.8%	61.6%	62.9%
Increase in Employment ratio due to 1% increase in Cloud adoption	0.025%	0.025%	0.025%	0.025%	0.025%	0.025%	0.025%	0.025%
Increase in Employment ratio due to Cloud adoption	0.16%	0.14%	0.13%	0.12%	0.12%	0.10%	0.07%	0.05%
Employment (as a % of Labor Force) - due to Cloud Computing	97.0%	97.1%	97.3%	97.4%	97.5%	97.6%	97.7%	97.7%
New jobs due to Cloud Computing	66,450	59,065	55,980	53,530	50,839	42,916	32,196	21,465

Source: Telecom Advisory Services analysis

5. CONCLUSIONS

The purpose of this study has been to assess the economic contribution of cloud computing in Germany. Germany is the second most mature European cloud computing market, accounting for € 26 billion in 2023 and representing 21% of the total spending of the continent.

The estimated empirical models conducted for Germany allowed us to draw the following conclusions:

- **The total economic impact of cloud in Germany in 2023, comprising cloud spending and its spillovers on the economy, accounts for € 54.66 billion.**
- **In terms of productivity, the economic gains in 2023 due to cloud computing accounts for € 1,283.59 per worker.**
- **The average seven-year economic contribution of cloud for Germany projected for the period 2023-2030 is significant, accounting for 1.49% of the GDP.**
- **In some industries, the main contribution is linked to direct spending (e.g.: wholesale and retail trade, or information and communication), while in other sectors, the spillovers are the main source of economic impact (manufacturing)**
- **During the seven-year timeframe (2024-30), a total of approximately 316,000 new jobs would be created in Germany due to cloud adoption.**

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APPENDIX A. LINK BETWEEN CLOUD SPENDING WITH ENTERPRISE ADOPTION

Table A-1. Fixed Effects estimate linking cloud enterprise adoption with spending

Dep. var.: log (CLOUD)	
Log (CLOUD REVENUE)	0.255***
	[0.042]
Country Fixed Effects	YES
Sector Fixed Effects	YES
Observations	199
R-squared	0.918

*Note: *** p<0.01. Robust standard errors in brackets.*
Source: Telecom Advisory Services analysis

APPENDIX B. DATASET AND ECONOMETRIC RESULTS

B.1. THE DATASET

The sample for the econometric analysis consists of 9 economic sectors across 26 European countries during the year 2021. The economic sectors included in the sample are detailed in Table B-1.

Table B-1. Economic sectors included in the empirical analysis

• Accommodation and food service activities	• Professional, scientific, and technical activities
• Administrative and support service activities	• Transportation and storage
• Construction	• Wholesale and retail trade; repair of motor vehicles and motorcycles
• Information and communication	• Water supply; sewerage, waste management and remediation activities
• Manufacturing	

Source: Telecom Advisory Services analysis

The variables to be used in the empirical analysis are detailed in Table B-2.

Table B-2. Variables to be used in the empirical analysis

Item	Description	Source
Y	Gross Value Added (in current million euros)	Eurostat
K	Total fixed assets (net)-- current replacement costs, million	Eurostat
L	Total employment (thousands of jobs)	Eurostat
CLOUD	Cloud enterprise adoption (business purchasing cloud services every 100 enterprises). Missing values addressed through industry averages.	Eurostat
CLOUD PRICE	Cloud ARPU (as a share of average revenue per firm)	Statista / Eurostat
CLOUD REVENUE	Cloud ARPU multiplied per the number of firms using cloud services (in current million euros)	Statista / Eurostat
CLOUD COMPANIES	Cloud companies per million inhabitants	Crunchbase / TAS
AI	AI adoption, measured as enterprises using AI services (every 100 enterprises). Missing values addressed through industry averages.	Eurostat
AI PRICE	AI ARPU (as a share of average revenue per firm)	Statista / Eurostat
AI REVENUE	AI ARPU multiplied per the number of firms using AI services (in current million euros)	Statista / Eurostat
AI COMPANIES	AI companies per million inhabitants	Crunchbase / TAS
SOFTWARE ERP	Enterprises using ERP software (every 100 enterprises)	Eurostat
SOFTWARE CRM	Enterprises using CRM software (every 100 enterprises)	Eurostat
URBAN	Urban population (%)	World Bank
HK	Enterprise employed ICT/IT specialist (%)	Eurostat

Source: Telecom Advisory Services analysis

Most variables are extracted from Eurostat. The AI variables to be used for the purpose of the interaction with cloud are specified as a dummy depending on the relative position of each observation in the overall distribution of AI use. From this perspective, the sample is divided into two. We identify a dummy variable named "AI > mean", taking values of 1 in all cases in which the observation relies above the median of the distribution of AI adoption (0 in other case). The baseline scenario, the firms with low AI use, are those situated below the median.

Two approaches were used to test the interdependent economic impact of AI and cloud: (i) a fixed effects OLS based on a Cobb Douglas function, and (ii) a structural model used to mitigate the reverse causality concerns resulting from simple OLS single-equation estimations.

B.2. FIXED EFFECTS OLS MODEL

Table B-3 presents the results for the fixed effects estimate of the output and productivity equations, with robust standard errors clustered at the country-level. We first assume cloud and AI to be exogenous. All estimates include country and sector fixed effects.

Table B-3. Fixed Effects estimate of output and productivity equations

Dep. var.: log(Y)	log(Y)	log(Y/L)
log(K)	0.285***	
	[0.053]	
log(K/L)		0.295***
		[0.051]
log(L)	0.647***	
	[0.077]	
Log (CLOUD)	0.135*	0.145*
	[0.079]	[0.080]
Log (CLOUD)#AI > MEDIAN	0.043***	0.044***
	[0.014]	[0.014]
AI	0.002	0.001
	[0.005]	[0.005]
Country Fixed Effects	YES	YES
Sector Fixed Effects	YES	YES
Observations	185	185
R-squared	0.985	0.920

*Note: ***p<0.01, *p<0.1. Robust standard errors in brackets.*
Source: Telecom Advisory Services analysis

The results reported in the first column of Table B-3 are in line with the expectations, with both physical capital and labor coefficients being positive and significant, and close to the assumption of constant returns to scale. The estimated α, that measures the share of capital returns over income, is close to the usual 1/3 typically arising from national accounts (slightly below).

In addition, cloud computing presents a positive and statistically significant direct effect on output. Also, the interaction with AI use seems to be relevant to increase the economic effects of cloud, thus validating the main hypothesis of complementarity between the two technologies of this study. The baseline scenario (low AI use) represents the case of lower economic impact from cloud computing.

According to this estimation, **a 1% increase in cloud enterprise adoption is associated with an increase of 0.135% of the GVA, regardless of the level of AI use. For those observations with higher than median AI use, the elasticity increases to 0.178% (resulting from adding the baseline coefficient of 0.135 plus the effect associated to the AI > MEDIAN variable, 0.043).**

In the second column of Table B-3 we present the results for the productivity equation. In this case, the estimates present a slightly worse, although still acceptable, model fit.

The results verify again the economic relevance of cloud enterprise adoption to enhance productivity, and the significant role of its complementarity with AI. This means that cloud computing and AI are relevant not only to explain aggregate output, but also to drive productivity. The estimated elasticities are similar to those estimated for the output equation.

B.3. STRUCTURAL MODELS

In this model, we relax the assumption of cloud and AI being exogenous. The approach to be used in this case is inspired on Roller and Waverman (2001) and Koutroumpis (2009, 2019), consisting of a structural econometric model with a production function and a supply and demand framework that endogenizes ICT related variables. To control for the concern that both cloud computing and AI may be potentially endogenous, the framework proposed by Roller and Waverman (2001) and Koutroumpis (2009, 2019) captures these two-way relationships between economic output and ICTs, by explicitly accounting for these effects in a simultaneous equations model.

To disentangle the effect of ICT-related variables on output, and its inverse, the following micromodel is formalized beyond the aggregated production equation (Table B-4).

Table B-4. System of simultaneous equations

Aggregate production equation		$Y_{is} = f(K_{is},\ L_{is},\ CLOUD_{is},\ AI_{is})$
Cloud equations	Demand equation	$CLOUD_{is} = g(Y/FIRM_{is}, CLOUD\ PRICE_{is},\ HK_{is},\ SOFTWARE_{is},\ URBAN_{is})$
	Supply equation	$CLOUD\ REVENUE_{is} = h(CLOUD\ PRICE_{is},\ Y_{is},\ CLOUD\ COMP_{is})$
	Cloud infrastructure production	$\Delta CLOUD_{is} = j(CLOUD\ REVENUE_{is})$
AI equations	Demand equation	$AI_{is} = k(Y/FIRM_{is}, AI\ PRICE_{is},\ HK_{is},\ SOFTWARE_{is},\ URBAN_{is})$
	Supply equation	$AI\ REVENUE_{is} = v(AI\ PRICE_{is},\ Y_{is},\ AI\ COMP_{is})$
	AI infrastructure production	$\Delta AI_{is} = z(AI\ REVENUE_{is})$

Source: Telecom Advisory Services analysis

In this case, cloud demand ($CLOUD_{is}$) is expected to depend on the average income per firm ($Y/FIRM_{is}$), on cloud prices ($CLOUD\ PRICE_{is}$), on the degree of human capital (HK_{is}), on the degree of software use ($SOFTWARE_{is}$), and on the degree of urbanization($URBAN_{is}$) . As for the cloud supply equation, it links cloud output ($CLOUD\ REVENUE_{is}$) as a function of cloud prices ($CLOUD\ PRICE_{is}$) and the competitive intensity in the local cloud sector ($CLOUD\ COMP_{is}$). Finally, the variation in cloud enterprise adoption ($\Delta CLOUD_{is}$)is modelized to depend on cloud output ($CLOUD\ REVENUE_{is}$). A similar approach is taken for the AI-related equations.[9]

Results for the output equation and productivity equations are presented in Table B-5. The estimation is conducted through 3-Stage Least Squares (3SLS) simultaneous equation approach. In both estimates we are including country and sector fixed effects in the main equation.

Table B-5. 3SLS estimate of simultaneous equation model

Dep. var.:	log(Y)	log(Y/L)
log(K)	0.283***	
	[0.034]	
log(K/L)		0.294***
		[0.033]
log(L)	0.659***	
	[0.057]	
Log (CLOUD)	0.393**	0.350*
	[0.190]	[0.189]
Log (CLOUD)#AI > MEDIAN	0.031**	0.033**
	[0.015]	[0.015]
AI	0.002	0.002
	[0.005]	[0.005]
Dep. var.: log (CLOUD)		
Log (CLOUD PRICE)	-0.362***	-0.358***
	[0.061]	[0.061]
Log (Y/FIRM)	0.067	0.064
	[0.052]	[0.052]
Log (SOFTWARE ERP)	-0.022	-0.022
	[0.092]	[0.092]
Log (SOFTWARE CRM)	0.312***	0.316***
	[0.106]	[0.106]
Log(URBAN)	0.659***	0.656***
	[0.221]	[0.221]

[9] *Variables ($CLOUD_{is}$) and (AI_{is}) are designed as the ratio between penetration and the respective country average.*

Log (HK)	0.061	0.062
	[0.089]	[0.089]
Dep. var.: log (CLOUD REVENUE)		
Log (CLOUD PRICE)	0.903***	0.921***
	[0.037]	[0.035]
log(Y)	0.963***	0.994***
	[0.042]	[0.035]
CLOUD COMPANIES	0.180***	0.178***
	[0.032]	[0.031]
Dep. var.: log(ΔCLOUD)		
Log (CLOUD REVENUE)	0.084***	0.085***
	[0.022]	[0.022]
Dep. var.: log (AI)		
Log (AI PRICE)	-0.453***	-0.451***
	[0.124]	[0.124]
log(Y/FIRM)	0.022	0.021
	[0.112]	[0.112]
Log (SOFTWARE ERP)	0.344**	0.342**
	[0.145]	[0.144]
Log (SOFTWARE CRM)	0.295*	0.297*
	[0.158]	[0.158]
Log (URBAN)	0.332	0.338
	[0.336]	[0.336]
Log (HK)	-0.134	-0.132
	[0.133]	[0.133]
Dep. var.: log (AI REVENUE)		
Log (AI PRICE)	0.813***	0.823***
	[0.095]	[0.088]
log(Y)	0.970***	1.011***
	[0.106]	[0.084]
AI COMPANIES	0.022	0.021
	[0.029]	[0.029]
Dep. var.: log(ΔAI)		

Log (AI REVENUE)	0.279***	0.272***
	[0.038]	[0.037]
Country Fixed Effects	YES	YES
Sector Fixed Effects	YES	YES
Observations	178	178
R-squared	0.982	0.912

*Note: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in brackets.*
Source: Telecom Advisory Services analysis

In the first column of Table B-5 we estimate the output model. The results for the main equation are in line with the expectations, with cloud computing presenting a positive and significant effect. The elasticity is higher than in the model that presented in section B.2, Therefore, for conservative purposes, we will take as the valid reference the elasticities reported in Table B-3.

As for the remaining equations, results are in line with the expectations. Particularly, cloud demand depends positively on the degree of firm's CRM software use, while it depends negatively on the service price. The coefficient for income per firm is not significant, suggesting demand insensitiveness to income differentials. In addition, both income, prices and number of providers drive positively cloud revenue, as reflected in the supply equation. On the other hand, the larger the expenditure in cloud, the bigger the variation of adoption levels with respect to the respective country average, as expected.

As for the AI-related equations, demand seems to depend positively on firm's software use (both CRM and ERP), while the coefficient for price is negative and significant. As for AI revenue, it depends positively on prices and income. Finally, the larger the expenditure in AI, the bigger the variation of adoption levels with respect to the respective country average, as expected.

In the second column of Table B-5 we turn to the labor productivity estimate. The estimated α remains almost unchanged with respect to the previous estimations. As expected, labor productivity depends positively on both cloud and AI, while the complementarity between both technologies again generates positive economic spillovers. No major changes arise in the secondary equations of the model.

B.4. CONCLUSIONS

The results presented above provide robust evidence of the significant effect that cloud computing has on economic output and productivity levels. The coefficients generated in the econometric model specified section 4.1 will be used to calculate the economic contribution of cloud for 2023.