The Contribution of Cloud to Economic Growth in the Middle East and North Africa

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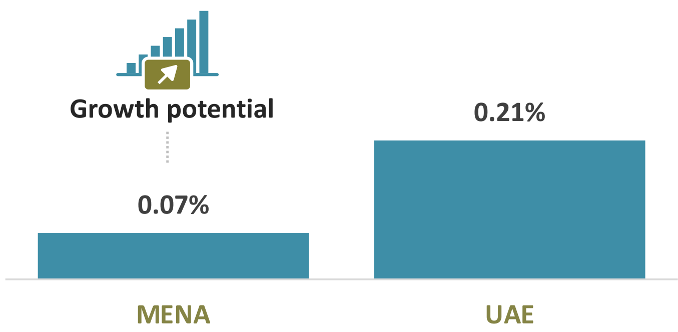
Spillover effects

Most of the economic impact of cloud adoption **(86%)** is driven by spillover effects. The remainder **(14%)** is driven by organizations' spending in cloud services.

86%

GDP growth impact of 1% adoption of cloud



As an economic accelerator, cloud contribute to economy up to 17% more than broadband does.

Impact of Public Cloud Adoption in MENA

Enabling Policies and Regulations

Promote adoption of cloud in public and private sectors.

26.5%

Cloud Adoption

26.5% of organizations in MENA adopt cloud services vs **49% in Western Europe** and **North America**.

Impact on MENA Economy

$34.8b

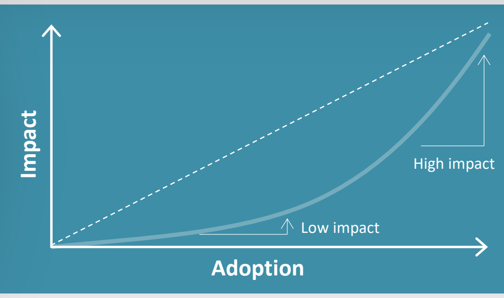
2021: 0.97% of the GDP
USD 34.8 billion economic value

$733b

By 2033: 1.14% of the cumulative GDP
USD 733 billion economic value

Increasing returns to scale

An increase in cloud adoption results in a more than proportional impact on GDP.



EXECUTIVE SUMMARY

This Report explores the contribution of cloud adoption to economic growth in the Middle East and North Africa (MENA). We define cloud computing as the on-demand delivery of IT resources via the internet with pay-as-you-go pricing. This means that, instead of buying, owning, and maintaining their own data centers and servers on premise, organizations remotely access computing power, storage, databases, and other services on an as-needed basis.

Economic research provides vast evidence of the efficiency gains cloud enables at the firm-level through increased agility, cost savings, and faster innovation. Some studies extrapolate efficiency gains at firm or industry level to estimate the aggregate impact of cloud on national productivity. However, no research thus far quantifies the causal relationship between cloud adoption and economic growth, as measured by the Gross Domestic Product (GDP). In other terms, how much GDP growth does 1% of cloud adoption yield?

To answer this question, we developed a macro-economic model using a state-of-the-art econometric approach and the latest publicly available data. Our model estimates GDP growth based on public cloud adoption in a worldwide sample of countries over 2014-2021. We calculate cloud impact as the sum of cloud spending of organizations and the efficiency gains enabled by cloud adoption throughout the entire economy, or so-called "spillover effects". Our model does not account for the construction effect of cloud infrastructure, i.e., the ripple effect of investment across sectors of the economy to build cloud infrastructure. We model the impact of access to cloud, regardless of whether cloud infrastructure is present in country or not.

We estimate that in 2021 alone, cloud adoption in MENA added 0.97% to regional GDP, amounting to USD 34.8 billion of economic value. More than 86% of this impact comes from spillover effects on the economy, while the remainder (14%) is driven by cloud spending from MENA public and private organizations.

In terms of spillovers, we find that an increase of 1% in cloud adoption by MENA organizations will yield an average GDP increase of 0.07%. UAE is the MENA country where cloud adoption has driven the highest economic growth, with 1% increase in cloud penetration yielding 0.21% increase in GDP growth, 3x more than the MENA average. As an economic accelerator, we find that cloud in MENA is up to 17% more powerful than mobile broadband.

Our research confirms that the economic impact of cloud is guided by a "return to scale" effect: cloud economic impact grows with the penetration of cloud. When cloud penetration is low, the economic impact of 1% cloud penetration is minimal. When cloud penetration reaches a critical level, cloud starts having proportionally more impact on the economy. The return to scale for cloud impact is consistent with prior research on the economic impact of digitization and broadband.

Only 26.5% of organizations in the MENA region adopted cloud computing in 2021, versus 49% in Western Europe and North America. The MENA region therefore has the potential to improve cloud penetration substantially. By doing so, the region will benefit from increasing returns to scale and unlock USD 733.1 billion of additional economic value over the next decade (2023-2033), representing 1.14% of MENA's cumulative GDP. Most MENA countries have ambitious plans to diversify their economies through digitization. However, unlocking the potential of cloud will require aggressive policy reforms to make public cloud available for all.

1. INTRODUCTION

Cloud computing represents the delivery of IT resources via the internet with pay-as-you-go pricing. Instead of buying, owning, and maintaining their own data centers and servers, private firms and public sector organizations can acquire technology such as computer power, storage, databases, and other resources on an as-needed basis. Cloud computing provides a remotely accessible environment with high reliability, agility, and scalability to large, small and microenterprises, start-ups, governments, and public agencies (Park and Ryoo, 2013; Ebadi and Jafari Navimipour, 2019; Naseri and Jafari Navimipour, 2019; Khayer et al, 2020). As originally defined by the US National Institute of Standards and Technology (NIST), the cloud service is conceived as,

> "…a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort of service provider interaction."
> (Mell and Grace, 2011)

From an infrastructure standpoint, it represents a combination of technological tools that allows the remote access of computing services through the internet, rather than using a firm's own IT infrastructure, containing a physical and an abstraction layer. The physical layer comprises the hardware resources, including servers, storage, and network components. The abstraction layer includes software deployed across the physical layer (Mell and Grace, 2011). The cloud platform relies on several technologies ranging from virtualization, grid computing, micro-services architecture, and high-speed broadband (Byrne at el., 2017). With regards to the last technology, the reduction of any network traffic limitations (from technological to regulatory barriers) multiplies the fundamental benefits of cloud computing.

According to PwC (2021) and Chen et al. (2022), the following cloud service characteristics are:

- On-Demand self-service: The consumer can unilaterally provision and manage computing capabilities without requiring human interaction.
- Metered Service: Providers and consumers can meter the units of computing capabilities utilized (units could be defined as bandwidth, time, memory, seats, etc.).
- Rapid Scaling: Computing capabilities can be quickly and automatically scaled up or down to meet business or consumer demand.
- Resource Pooling: Computing resources are pooled to serve multiple consumers and are dynamically assigned and reassigned to consumers based on demand.
- Broad network access: Computing capabilities are available over the network and can be accessed through different end-user devices.
- Enables access to cutting-edge technologies such as machine learning, quantum computing, and big data, among others.

There are different computing services that can be supplied within cloud platforms (Table 1-1).

Table 1-1. Cloud Computing Services

Technology type	Description	Consumer participation	Examples
Infrastructure as a Service (IaaS)	IaaS provides customers with the capability to procure and use processing, storage, networks, and other fundamental computing resources easily	Control over operating systems, storage, and deployed applications, and possibly some control of selected networking components	
Platform as a Service (PaaS)	PaaS provides a platform allowing software developers to develop, run, and manage applications without maintaining technology infrastructure	Control over deployed applications	AWS, Google, Azure
Function as a service (FaaS)	Sometimes conceived as a refined PaaS service	Consumer considers functions or code that are to be performed and the cloud services provider manages all other aspects of the infrastructure	
Software as a Service (SaaS)	SaaS is a software licensing and delivery model in which software is licensed on a subscription basis and is centrally hosted	Control over limited user-specific application configuration settings	Zoom, Microsoft Teams, Webex, cloud-supported CRMs

Source: Cohen (2017); Avram (2016); PwC (2021); Byrne at el. (2017)

Beyond these four offerings, a further distinction can be made among different cloud services regarding deployment models, depending on the location of the infrastructure, represented in Table 1-2 (PWC, 2021; Frontier Economics, 2022).[1]

[1] Some authors, such as Chen et al. (2022), group the deployment models into four categories: public, private, community, and hybrid cloud.

Table 1-2. Deployment models for Cloud Computing

Model	Definition
On-premises private cloud	In this model, the company applies cloud technologies to its privately owned IT infrastructure that is run in its own data center. This is the most complex model to be adopted by companies and is typically the costliest, since it does not result in economies of scale, except if the company itself is very large.
Managed Private Cloud	In this model, the company purchases a cloud service from a provider but asks the cloud provider to dedicate certain resources only for the company's use. All characteristics of a cloud service are in place in this model except that resource pooling is limited.
Public cloud	In this model, the cloud provider manages all the computing infrastructure and sells the cloud service to its customers. The customer uses the cloud services according to a contractual agreement. When people talk about the cloud, this model is what they are usually referring to.
On-premises shared cloud	This model is an extension of the on-premises private cloud. The difference is that, in this model, the computing resources are shared with external parties outside of the company. Companies using this model may be charging their users, and therefore become a cloud provider to their users.
Hybrid cloud	This is a deployment model that combines two or more of the models described above. A typical example might be the combination of an on-premises private cloud and a public cloud model. This hybrid model is usually adopted to address some constraints that prevent the company from adopting only one deployment model.

Source: PwC (2021)

Some of the implied benefits of cloud computing are: (i) the ability to deploy hundreds or even thousands of servers in minutes and deprovision them without risk; (ii) cost savings by allowing adopting organizations to focus on variable rather than fixed costs; (iii) elasticity (i.e., ability to scale up and down); and (iv) innovation, (i.e., customers focus their IT resources on developing applications).

Given cloud computing importance in terms of the support it provides for the digital transformation of organizations and for delivering access to foundational technologies, it is critical to understand its aggregate macroeconomic impact. However, most research conducted so far has focused on the microeconomic impact of cloud adoption on firm's performance (i.e., rate of innovation, cost efficiency). Without denying the value of the evidence in this last domain, a relevant related question that needs to be addressed is the macroeconomic impact of an infrastructure which is so central to the digital economy. In other words, it is critical to understand what value the public cloud adds to a country's economy in quantitative terms such as its contribution to GDP growth. This is even more important in countries where the digital economy represents a critical engine for economic development.

The following study addresses these needs by presenting an estimation of the public cloud's contribution to GDP growth in Middle East and North Africa (MENA) countries. The scope of detailed quantitative analysis covers all Gulf Cooperation Council countries (Saudi Arabia, United Arab Emirates, Qatar, Kuwait, Oman, and Bahrain), and other MENA states (Jordan, Egypt, Turkey, Morocco, Algeria, and Tunisia).

To estimate the GDP contribution of public cloud in the MENA region, the study begins by reviewing the existing research on this topic in Chapter 2. Next, the methodology used to estimate cloud enterprise adoption for MENA countries is detailed in Chapter 3. Using cloud adoption data as a starting point, it presents the econometric model used to estimate the spillover effects of public cloud to GDP in Chapter 4. In Chapter 5, the revenues generated and spillover effects are combined to estimate cloud's overall GDP contribution. The implications of the study findings are presented in Chapter 6.

2. PRIOR RESEARCH ON THE ECONOMIC IMPACT OF CLOUD COMPUTING

Investment in cloud technology is crucial for the development of the digital economy. Modern production systems are increasingly based on connectivity between people, machines, and real-time data. In this context, limited cloud infrastructure can be assumed to be a barrier for digital transformation (AWS, 2021). The research findings until now regarding the economic impact of cloud computing have primarily focused on understanding the impact of the public cloud on firm performance, although a few studies already provide evidence on its contribution to macroeconomic growth.

2.1. Microeconomic benefits of cloud computing

Cloud services present the advantage that users can access technology services on an as-needed basis from a cloud provider (Frontier Economics, 2022). When cloud computing was not available as a commercial service, enterprises requiring these resources had to build their own data centers, purchase the required hardware and software, and hire skilled workers for its development and operations. As a result, most companies, particularly in emerging countries, were unable to enjoy the benefits of this technology.

With the commercial availability of cloud services, these infrastructures became reachable to many firms, especially micro, small and medium enterprises. Moreover, this technology provided convenient access to powerful computing resources at minimal incremental cost for organizations and individuals (Marston et al, 2011; Sheikholeslami and Navimipour, 2017; Khayer et al, 2020). In addition, market entry barriers were lowered by allowing firms immediate access to cloud-supported services, rather than incurring months or years as required to build their own infrastructure.

For a firm, adopting cloud computing services can add value at both strategic and operational levels, increasing revenues and minimizing costs (Carcary et al., 2014). These benefits have been identified by some authors as improved organizational flexibility, higher IT capabilities, and shared resources and collaboration environment, which enable firms to achieve better performance (Armbrust et al., 2010; Chen and Yu, 2012; Wang et al., 2016; Chen et al., 2022). Flexibility in accessing data enabled by cloud technology can be crucial for firms, not only in terms of specific decentralized functions, but also to facilitate employees access from anywhere, something that is particularly important in today's hybrid working world (Frontier Economics, 2022). In addition, cloud adoption can prompt the transformation of firms' IT departments, moving their primary emphasis from regular data center operations and maintenance to business assistance, thereby improving both intra- and inter-firm collaborations, and facilitating innovation (McAfee, 2011; Berman et al., 2012; Luo et al., 2018; Chen et al., 2022). As a result of all these effects, Berman et al. (2012) consider that cloud computing can basically shift the competitive landscape of industries.

Frontier Economics (2022) also argue about the potential of cloud to improve organizational resilience, by means of additional security support, offered through dedicated staff, and infrastructure support. Moreover, cloud's back-up capabilities can offer protection against disruption caused by shock events or cybersecurity threats.

In addition, cloud computing can help businesses achieve IT efficiency (Oliveira et al., 2014), due to the use of scalable technical resources (Marston et al., 2011), improving efficiency in work (Low et al., 2011) and increasing service availability (Armbrust et al., 2010). On the other hand, cloud computing is expected to increase business agility, because of the capacity to deploy mass computing technology quickly, minimizing capital costs and responding rapidly to market changes (Oliveira et al., 2014).

All in all, the microeconomic benefits of cloud computing are categorized according to those emerging in the short, medium, and long term (Table 2-1).

Table 2-1. Benefits of adopting Cloud Computing

Short-term outcomes	Medium-term outcomes	Impacts
• Ease of increasing scale • Lower fixed costs • Greater organizational flexibility, including enhanced data sharing • Increased organizational resilience and enhanced cybersecurity • Access to developer tools and software maintenance • Regular and more timely updates of hardware and infrastructure • Increased utilization of servers and greater energy efficiency of data centers	• Greater use of internal digital solutions • Greater use of advanced data analytics • Improved user experience of existing digital services and wider offer of services • Greater confidence in cybersecurity • Improved coordination of services	• Increased efficiency and effectiveness • Increased access to services • Increased productivity • Reduction in carbon-emissions per megabit of data

Source: Frontier Economics (2021)

However, the success of cloud computing in improving firm performance can be conditioned by certain internal factors. As pointed out by Khayer et al (2020), cloud's successful implementation depends on the quality of the system, on the firm's organizational IT capability and on the positive feedback from end-users. Similarly, some authors argue that the adoption of cloud computing requires some internal organizational transformation to maximize its impact, such as training workers (Armbrust et al., 2010; Chen et al., 2022).

2.2. Empirical research on the microeconomic impact of cloud computing

Most empirical studies of the economic impact of cloud computing have been conducted at the firm-level, and in many cases focused on specific economic sectors. The selected variables to measure firm performance vary by study, being in some cases productivity, innovation, or other metrics based on financial indicators.

Schniederjans and Hales (2016) rely on transaction cost economics and examine how cloud computing supports adequate supply chain collaboration and is positively associated with the economic and environmental performance of firms. Data for this study was generated from 247 survey responses by IT and supply chain professionals and was analyzed using structural equation modelling. The authors found that, with interoperability, cloud computing positively improves collaboration among supply chain partners and drives a firm economic performance. Similarly, Loukis et al. (2019) conducted a survey of 102 Dutch firms and concluded that both operational and innovational benefits of SaaS cloud technologies can yield a positive impact on business performance, as measured by improved operations and the rate of innovation. Their contribution, however, is that the magnitude of impact is mediated by the firm's "absorptive capacity", defined as a company's ability to recognize, acquire, and incorporate useful new knowledge from the external environment, and to make valuable innovations in processes, products, and services. Coincidentally, Chou et al. (2017) analyzed a sample of 165 firms in the IT, travel, tourism, finance, and banking industries in Taiwan, finding a positive association of cloud adoption with service innovation. In particular, the study identified cloud services as "effective technological platforms for a firm and its business partners to share, integrate, and reciprocate information, knowledge, and experience for service innovation." Bolwin et al. (2022) conducted a large-scale survey of 1,504 companies in Germany aimed at quantifying the impact of AWS cloud computing in business performance. By extrapolating the survey results to the overall firm population, the authors estimate that 1.25 million companies in Germany rely on the cloud, realizing added value growth of Euros 11.2 billion by using AWS services. In addition, as a result of business growth, AWS provided cloud computing contributed to the growth of employment of 16.9 % between 2020 and 2022.

In a similar vein, other authors have focused on analyzing which are the necessary factors that enhance impact of cloud at the firm level. For example, Garrison et al. (2015) analyzed a survey of 302 Korean businesses with a structural equation modelling methodology and found that managerial, technical, and relational IT capabilities can be factors which positively contribute to cloud computing's impact on firm performance. However, managerial capability, defined as "the extent to which IT managers have the necessary business acumen and technical skills to foresee emerging technologies and leverage them effectively in the alignment of business processes with organizational goals," appeared to have the largest contribution.

As better datasets were developed, research on the microeconomic benefit of cloud computing has extended to emerging countries as well. For example, Kathuria et al. (2018) analyzed a survey of 147 Indian firms, finding that firms can capitalize on cloud computing to enhance performance and propose a strategic value appropriation path for adopters to improve their business performance. In particular, the authors highlighted cloud technological and integration capability, cloud service portfolio capability, and business flexibility as enablers of cloud's impact on firm performance. In turn, Dalenogare et al. (2018) analyzed the impact of several digital services, including cloud computing, on some firm performance metrics for a sample of Brazilian firms (product, operational and side-effects expected benefits), finding a positive link. Finally, using structural equation modelling, Khayer et al. (2020) found a positive impact of a cloud computing construct on a firm performance construct for a sample of Chinese firms during the period 2018-2019. In particular, the authors argued about the relevance of external factors, such as end-user satisfaction, which contributes to firm performance.

On a worldwide scale, Chen et al. (2022) estimated for a world sample of firms during the period 2010-2016 the link between cloud computing and some firm-level performance metrics (such as ROA and Tobin's Q[2]). The study addressed three research questions: (i) Can cloud computing, as an innovative IT delivery model, affect firm performance? (ii) What is the magnitude of the short- and long-term impact of cloud service adoption on firm performance? and (iii) Can cloud computing have heterogeneous performance impact on firms with different characteristics? They address these questions using Difference-in-Difference econometric techniques, finding a positive relation: firms adopting cloud computing experience significantly improved profitability and market value, as measured by ROA and Tobin's Q, respectively. In addition, the authors identified differences in cloud computing performance impact by industry type and firm size. Manufacturing firms have significantly higher level of profitability after adopting cloud computing than service firms, while the effect of cloud computing on market value is significantly stronger for firms in service industries than in manufacturing. Finally, small firms accomplish higher improvement in profitability than big firms, whereas big firms achieve significantly higher market value than small firms.

2.3. Aggregate macroeconomic impact of cloud computing

While most empirical research on the economic impact of cloud computing has been conducted with firm-level data for specific industries and countries, some studies have been able to analyze the effects at a more aggregated level. A relevant contribution is that of Gal et al. (2019), who estimated the impact of cloud computing (among other technologies) on multifactor productivity[3] growth for a sample of 20 European countries, using a combination of firm-level and industry-level data, sourced from Eurostat and the Orbis database and applying it to a Neo-Schumpeterian growth approach that links innovation and technology diffusion. Their results suggest that a 10-percentage point increase in adoption of cloud computing would translate into an increase in multifactor productivity growth by 0.9 percentage points. The authors found that productivity gains are strongest for high productivity firms, which would indicate that digital adoption in an industry has contributed to the increasing productivity dispersion across firms. An interesting result from this study is that cloud computing presents the strongest impact on productivity performance for the case of the smallest firms, which can avoid the fixed costs of investing in data storage and processing facilities; in other words, a way to acquire "scale without mass", according to the authors.

[2] Tobin's Q, also known as the Q ratio is calculated by dividing the market value of a company by its assets' replacement cost.
[3] Multifactor productivity is a measure of economic performance that compares the amount of output to the amount of combined inputs, which includes labor, capital, energy, materials and purchased services.

The results found in Gal et al. (2019) were later used in other studies to highlight the link between cloud computing and productivity. That is the case of Sorbe et al. (2019) policy paper. By relying on the differential effect of cloud computing (among several digital technologies) on firm productivity estimated in Gal et al. (2019), the authors argue for several policy prescriptions to enhance the digitization of less productive firms. However, the recommendations are more generic and relate to regulation and financial constraints for start-ups.

Similarly, Frontier Economics (2022) used a conservative approach based on Gal et al. (2019) results to find out that a 10% increase in the adoption of cloud in the Irish public sector could generate productivity benefits in the order of €473 million in the first year alone following adoption. Their estimate assumes that the productivity effect is going to be "half" (0.45%) of the one estimated by Gal et al. (2019). By multiplying the productivity growth by firms' sales, they calculate the economic benefit cited above.

Beyond the impact on national productivity, there is limited quantification of the aggregate effects on variables such as GDP at a national level. One reason for the limited research is that cloud computing constitutes an intermediate input to sector output and, as such, is not measured in national accounts or input/output tables. However, estimates were conducted by factoring in the impact of cloud investment on overall sector output. For example, AWS investment in Indonesia between 2022 and 2037 (USD 5 billion) is estimated to generate USD 11 billion in spending on construction, labor, materials, specialized software, and personnel, as well as additional value to the country's information sector.[4]

In turn, PWC (2021) studied the effects of cloud computing on productivity in Indonesia, by applying a methodology based on Yusuf (2020). Their research uses a recursive-dynamic multi-regional computable general equilibrium model and applies sector-specific labor productivity shocks to it, representing the effect of the new technological changes on the economy. Overall, they estimated that the cumulative productivity benefit to the Indonesian economy of cloud adoption will be USD 10.7 billion over the period 2021 - 2025.

In sum, in the context of limited research on the aggregated macroeconomic impact of cloud computing, we have identified either its contribution to multifactor productivity outlined in Gal et al. (2019) original work based on econometric modelling, the contribution of cloud investment within an input-output model (AWS, 2021), and the calculation of cloud investment within a previously developed general equilibrium model for Indonesia (PWC, 2021). These findings point out the need to develop additional work in assessing cloud computing's economic contribution relying on rigorous econometric analysis with a cross-national sample of countries: this is the purpose of the current study.

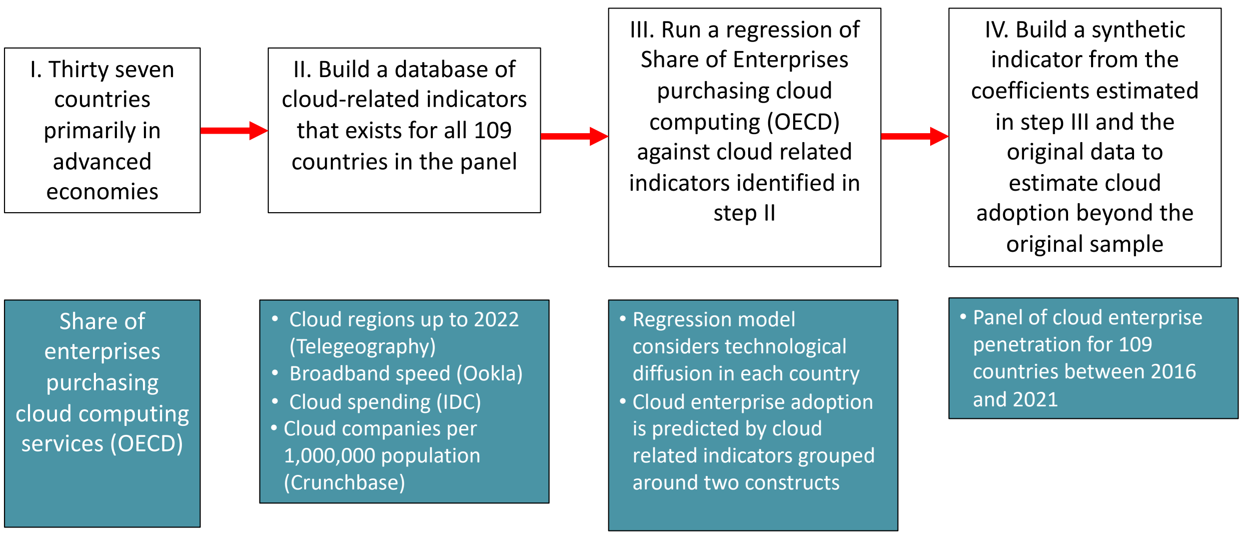
[4] This analysis was conducted using the country's input-output tables provided by Statistics Indonesia (AWS Economic Impact Study: AWS Investment in Indonesia, 2021).

3. MEASURING CLOUD COMPUTING ADOPTION IN THE MIDDLE EAST AND NORTH AFRICA

According to IDC, the 2021 Middle East and Africa (MENA) public cloud market amounted to USD 3.5 billion, and grew by 18.8% in 2022, a trend being largely unaffected by COVID-19. In fact, the pandemic disruption accelerated the use of digital technologies by citizens and enterprises, as people needed to telework, to buy online, and to rely further on digital tools to counteract the isolation policies. In this context, several firms accelerated public cloud adoption as organizations have enhanced new digital service creation and migrate applications from private to shared infrastructure.

That said, the pace of cloud development within the MENA region is uneven. As there are no public datasets covering cloud penetration throughout MENA, we had to approximate the values for some countries. To do so, we first developed a logistic diffusion function to explain current cloud enterprise penetration for thirty-seven countries where data is available (Source: OECD Statistics, see Table A-4 in Appendix), and later made estimates based on the explanatory variables to expand the dataset into MENA countries (see Figure 3-1)

Figure 3-1. Method for the calculation of cloud adoption for MENA countries



Source: Telecom Advisory Services

Starting with OECD cloud adoption data panel, we compiled data on cloud related indicators for the countries included in the panel:

- Cloud regions up to 2022 (Source: TeleGeography)
- Broadband speed (Source: Ookla)
- Cloud spending (Source: IDC)
- Cloud companies per 1,000,000 population (Source: Crunchbase)

With these variables and the OECD data on enterprise penetration, we used factor analysis through a principal component's methodology (PCA) to build three cloud constructs related to cloud development. The selected constructs jointly explain

98.96% of all the information provided in the original variables, while it resolves multicollinearity issues as they are orthogonal to each other. These constructs were included in a logistic diffusion function to explain current cloud penetration.

$$\log(CLOUD) = \frac{(\gamma_0 + \gamma_1 CLOUD1 + \gamma_2 CLOUD2 + \gamma_3 CLOUD3)}{1 + exp^{(-\beta(s)(t-\delta))}}$$

In this function we assume the speed of diffusion of cloud services to depend on broadband speed. The results for the non-linear regression are presented in the Table 3-1.

Table 3-1 Nonlinear regression of Cloud diffusion

Dep. variable: CLOUD penetration	
γ_0	30.756***
	[2.713]
γ_1	4.654***
	[0.867]
γ_2	5.791**
	[2.181]
γ_3	6.201***
	[2.138]
β	0.000
	[0.000]
δ	5.056***
	[1.415]
R-squared	0.89
Observations	151

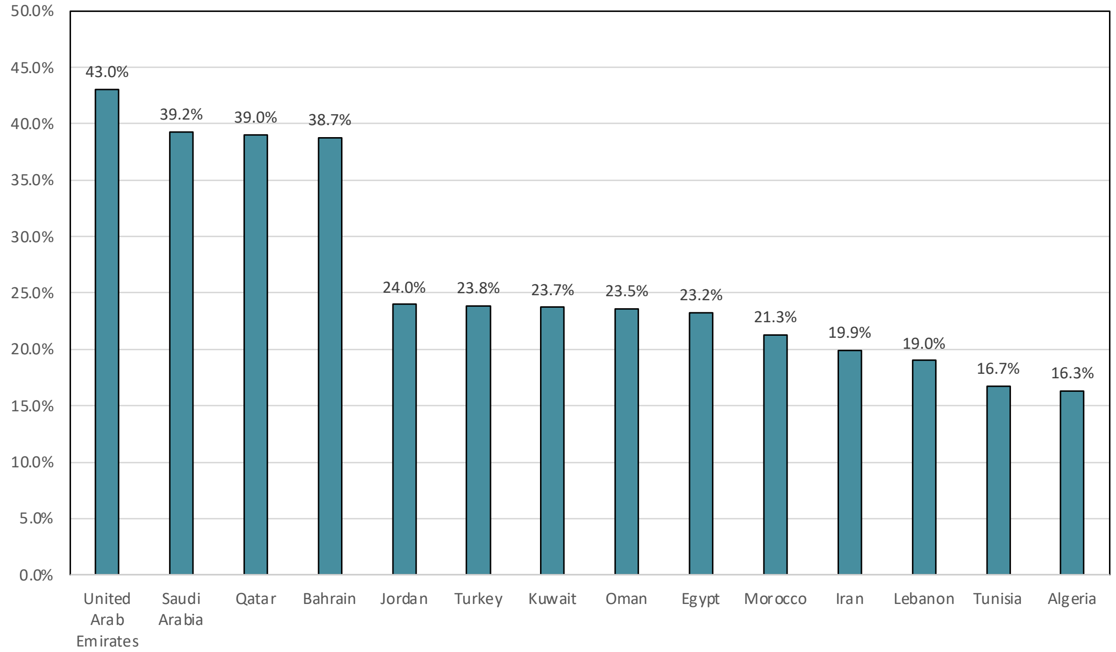
*Note: ** p<5%, *** p<1%.*

Source: Telecom Advisory Services analysis

All three constructs are positive and significant to explain actual cloud penetration values. In addition, the R-squared takes a value of 0.89, thus performing reasonably well in predicting the real cloud values. Once the coefficients were estimated, we obtained predicted cloud penetration values for MENA countries with a complete set of explanatory variables, allowing us to expand considerably the data sample.

As for 2021, our estimates suggest two groups of MENA countries; a first group of those who are presenting cloud penetration levels of approximately 40% of enterprises (United Arab Emirates, Saudi Arabia, Qatar, and Bahrain), and a second group who are exhibiting penetration levels below 25% (Graphic 3-1). Considering that there are disparities in the relative development of cloud in each country, we can expect differences as well in the degree of economic impact generated by its diffusion.

Graphic 3-1. Cloud enterprise penetration as estimated for MENA countries (2021)



Note: For the case of Qatar, we assumed for 2021 the effect of cloud zones formally launched in 2022 based on feedback from industry specialists.
Source: Telecom Advisory Services analysis

Once cloud enterprise penetration was estimated for MENA countries, we could proceed to calculate its economic contribution.

4. ESTIMATING CLOUD COMPUTING SPILLOVER ECONOMIC CONTRIBUTION

The aggregated economic contribution of public cloud on GDP is measured through revenues generated of cloud providers and spillover effects of the service throughout the economy. The revenues refer to the spending of public and private organizations purchasing cloud services, and the spillover effects are the effects of cloud services on the entire economy. The revenues are a measure of market demand that can be met through cloud providers based within the country or beyond the nation's borders. The spillover effect measures the impact that cloud purchasing has on the overall economy productivity and business performance. This section focuses on estimating of the spillover economic impact.

4.1. Model for estimating cloud computing spillover contribution

The model is estimated through the 3-stage least squares procedure for a worldwide sample of countries[5], including the MENA region (detailed list of countries included in the table A-5 in the Appendix). The results that incorporate the predicted cloud variables are presented in Table 4-1. In the Table A-6 of the Appendix, we present a similar model but using only cloud data from OECD countries as a robustness test.

Table 4-1. Econometric results

Dependent variable: Log (GDP)	
Log(K)	0.477** (0.234)
Log(L)	0.554* (0.335)
Log (BB)	0.299** (0.144)
Log (BB)*Cloud	0.001** (0.000)
Dependent variable: Log (BB)	
Log (P_{BB})	-0.570*** (0.090)
Log (HK)	0.186 (0.171)
Log (GDP per capita)	0.881*** (0.064)
Urban	0.000 (0.000)
Dependent variable: Log (BB inv.)	
Log (P_{BB})	-0.079 (0.074)
HHI	-1.862*** (0.438)
Dependent variable: log (BB/L.BB)	
Log (BB inv.)	0.000 (0.006)
Dependent variable: Log (Cloud)	
Log (P_{CLOUD})	-0.020 (0.013)
Log (HK)	1.535*** (0.446)
Log (GDP per capita)	0.988*** (0.171)
Urban	0.000 (0.000)
Dependent variable: Log (Cloud inv.)	
Log (P_{CLOUD})	-0.130 (0.090)
Cloud companies	0.005*** (0.000)
Cloud zones	0.100*** (0.258)
Dependent variable: log (Cloud/L.Cloud)	
Log (Cloud inv.)	-0.105 (0.077)
Country Fixed Effects†	YES
R-squared†	0.99
Observations	172

*Note: * p<10%, ** p<5%, *** p<1%. †Refers to first equation of the structural model.*
Source: Telecom Advisory Services analysis

[5] Detailed explanation of model structure can be found in the Appendix A.1.2.

The model in Table 4-1 behaves as expected, with positive and significant coefficients for capital, labor, broadband and cloud in the first equation. In the secondary equations, the results are also in line with expectations. A negative effect on price (elasticity effect) and a positive one from income were found in the demand equation; competitive intensity drives investment in the supply equation, while cloud adoption depends positively on income and on human capital. In turn, cloud investment depends critically on the number of cloud companies operating and on the development of local cloud regions. Returning to the coefficients of interest on the main equation, these results point to a broadband penetration coefficient of 0.299, while on the other hand, the interacted cloud coefficient is 0.001. This is strong evidence of the relevance of cloud's macroeconomic effect. This coefficient is in line with the estimate conducted using only data from OECD countries, presented in table A-6 in the Appendix.[6] Therefore, we can conclude it is an accurate estimate.

4.2. Calculating cloud computing spillover contribution in the Middle East and North Africa

The coefficients presented above cannot be interpreted directly as elasticities, as some further algebra is needed. For this purpose, we calculate the derivative of GDP with respect to cloud computing in the first equation of the model, and replace $\delta = 0.001$ as estimated in Table 4-1:

$$\frac{\partial \log(GDP_{it})}{\partial \mathrm{CLOUD}_{it}} = 0.001 * \log(BB_{it})$$

from where the elasticity between GDP and cloud penetration can be easily obtained:

$$\frac{\partial GDP_{it}}{GDP_{it}} \frac{\mathrm{CLOUD}_{it}}{\partial \mathrm{CLOUD}_{it}} = 0.001 * \log(BB_{it}) * \mathrm{CLOUD}_{it}$$

According to it, the elasticity will depend on the estimated coefficient (0.001), and on the actual penetration levels of broadband and cloud. This means that each country will have its own elasticity level to determine the magnitude of the spillovers. We can conclude that, **for the average MENA country during the period 2017-2019 (simple average of broadband adoption and cloud penetration), an increase of 1% in cloud penetration will yield a GDP increase of 0.07%.** In order to highlight the impact for each MENA country, in Table 4-2 we calculate the elasticity using the respective average values of cloud and broadband penetration for the period under analysis using the formula described above.

[6] The model run for the OECD country sample included cloud penetration by economic sectors. The model depicted a positive and complementary relationship between cloud and broadband.

Table 4-2. Increase in GDP after Cloud adoption increase

Region	Elasticity - Increase in GDP (%) after 1% increase in cloud adoption	Increase in GDP (USD million) after 1% increase in cloud penetration
Algeria	0.05%	$ 86.18
Bahrain	0.10%	$ 35.50
Egypt	0.05%	$ 132.44
Iran	0.05%	$ 200.03
Jordan	0.06%	$ 26.95
Kuwait	0.05%	$ 63.86
Lebanon	0.05%	$ 26.54
Morocco	0.05%	$ 58.50
Oman	0.07%	$ 64.31
Qatar	0.10%	$ 169.51
Saudi Arabia	0.09%	$ 717.44
Tunisia	0.05%	$ 19.35
Turkey	0.07%	$ 589.73
UAE	0.21%	$ 854.72
Total	**0.07%**	**$ 3,045.06**

Note: Averages for broadband and cloud penetration for every country for the period under analysis were used in the calculations.
Source: Telecom Advisory Services analysis

Table 4-2 shows that the economic impact varies considerably by country. We find that those countries which are advanced in broadband and cloud development such as UAE, Saudi Arabia, Qatar, and Bahrain exhibit much larger spillover effects than the regional average, while countries with lower broadband and cloud development present more modest economic impact. Here we highlight some of the cases:

- The UAE is the country with the highest elasticity, reaching a 0.21% GDP increase after a 1% increase in cloud penetration (equivalent to USD 855 million). This is explained as it is the country with the largest penetration of this technology (43%) and presents the largest fixed broadband penetration (subscriptions account for more than 100% of households). The elasticity registered in the UAE is 3x more than in the average MENA country. As an economic multiplier, cloud adoption is 17% more powerful than the 0.18 percent average impact of mobile broadband deployment on GDP, as indicated in prior research conducted by the authors for the Arab States (Katz and Callorda, 2020)[7].

- Qatar, Bahrain, and Saudi Arabia are the countries that follow UAE in terms of elasticity, reaching in a 0.10% GDP increase after a 1% increase in cloud penetration. This is because these countries present a significant adoption of cloud services (39% of enterprises on average), while on the other hand, fixed broadband subscriptions account for 100% of households.

[7] Katz, R. & Callorda, F. (2020). *The economic contribution of broadband, digitization, and ICT regulation Econometric modelling for the Arab States region*. Geneva: International Telecommunication Union.

- Oman and Turkey follow next, reaching a 0.07% GDP increase after a 1% increase in cloud penetration. Both countries have an average adoption of cloud technology (penetration levels of 23.5% and 23.8%, respectively), although they present a high diffusion of fixed broadband networks, with subscriptions accounting for 73% of households during the period analyzed.

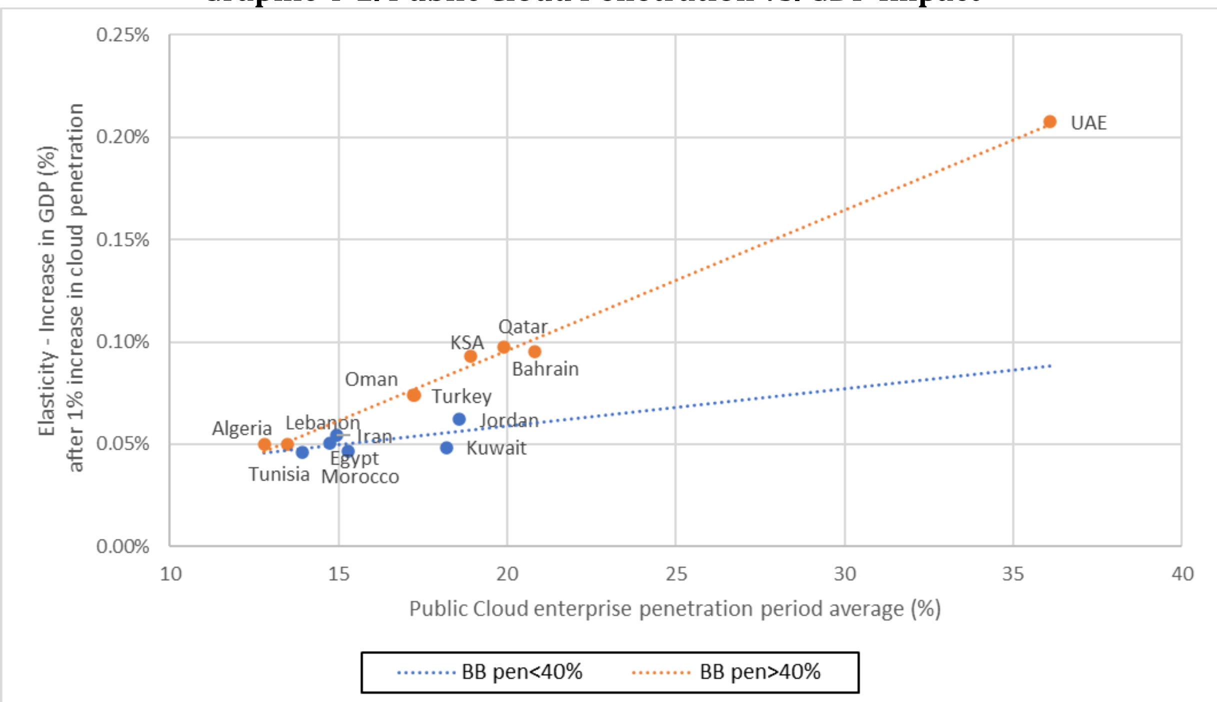
- Jordan will reach a 0.06% GDP increase after a 1% increase in cloud penetration. Despite having relatively low fixed broadband penetration (28% average in the period), the country has been expanding cloud technology, reaching a penetration of 24% of enterprises in 2021).

- Lebanon and Algeria present in both cases a 0.05% GDP growth after a 1% increase in cloud penetration. This is because both countries present a relatively good development of broadband infrastructure (above 40% of household penetration), combined with low levels of cloud penetration (19% and 16.3%, respectively).

- The remaining countries of the region reach an elasticity of 0.05%, mainly because they present less development in both technologies.

As implied in the estimation model of table 4-1, cloud's economic impact is closely related to the degree of development of broadband networks. This is clearly depicted in Graphic 4-1.

Graphic 4-1. Public Cloud Penetration vs. GDP Impact



Source: Telecom Advisory Services analysis

The interrelationship between fixed broadband and cloud's economic impact is clear. If broadband penetration is less than 40%, the impact of public cloud on GDP is driven by a slower pace, while if broadband adoption is higher than 40%, the impact of public cloud increases at a faster pace. Broadband is the primary technology that enables access to cloud services. Adopting organizations require a well-developed infrastructure to access central data processing units.

In addition to fixed broadband penetration, spillover cloud contribution is also related to differences in cloud penetration. The disparity in the degree of cloud adoption by firms is mainly explained by differences in human capital and income, as highlighted in the regression presented in Table 4-1. In addition, we can also expect cloud adoption to be affected by the presence of regulations that restrict cloud services availability, and high connectivity costs which reduce cloud service benefits, among others.

Having estimated the spillover impact of cloud computing for each MENA country, we now move to calculating its total contribution for each nation.

5. CLOUD COMPUTING OVERALL CONTRIBUTION IN THE MIDDLE EAST AND NORTH AFRICA

In this chapter we analyze the cloud contribution for the MENA region during year 2021 and estimate its impact between 2023 and 2033. When combining revenues and spillover effects on GDP, we found out that public cloud services generated a significant contribution to the aggregate MENA economy in 2021: on average 0.97% of the GDP. For comparative purposes, this amount of economic value is close to the 2021 MENA automobile market.[8] However, some relevant differences arise in the magnitude of effects across countries. In Table 5-1, we present the detailed results of the spillover effects generated by public cloud penetration growth in 2021 and the revenues generated in the same year.

Table 5-1. Total economic contribution of Cloud in 2021

Item	Concept	Saudi Arabia	United Arab Emirates	Qatar	Oman	Kuwait	Bahrain	Egypt	Turkey	Rest of MENA	Source
1	Cloud spending 2021 ($ M)	$ 545.50	$ 852.30	$ 138.61	$ 21.25	$ 146.35	$ 48.99	$ 423.84	$ 390.90	$ 2,229.86	IDC / Statista
2	GDP ($M)	$ 833,541	$ 419,762	$ 179,677	$ 85,869	$ 135,761	$ 38,869	$ 404,143	$ 819,035	$ 720,075	IMF / WB
3	Cloud revenue (% GDP)	0.07%	0.20%	0.08%	0.02%	0.11%	0.13%	0.10%	0.05%	0.31%	(1)/(2)
4	Spillovers	0.92%	2.05%	0.97%	0.73%	0.48%	0.94%	0.50%	0.69%	0.36%	Calculated from elasticities
5	Spillover contribution ($ M)	$ 7,690	$ 8,621	$ 1,743	$ 630	$ 652	$ 366	$ 2,015	$ 5,674	$ 2,576	(4)*(2)
6	Total contribution	$ 8,236	$ 9,473	$ 1,881	$ 651	$ 798	$ 415	$ 2,439	$ 6,065	$ 4,806	(1)+(5)
7	Total contribution (% GDP)	0.99%	2.26%	1.05%	0.76%	0.59%	1.07%	0.60%	0.74%	0.67%	(6)/(2)

Note: Annual spillovers were calculated using MENA's growth rate of cloud penetration in 2021.
Source: Telecom Advisory Services analysis

- Overall, the country with largest public cloud contribution to GDP is UAE (USD 9.5 billion), followed by Saudi Arabia (USD 8.2 billion), Egypt (USD 2.4 billion), Qatar (USD 1.9 billion), while Oman, Kuwait, Bahrain, and the remaining MENA economies are further behind. This is a significant increase in GDP for these economies, that will translate into more jobs, lower poverty, and higher government's revenue, with improved public services as a result.

[8] The 2021 MENA market for automotive products is USD 44,966.80 million (Source: HIS Markit).

- In terms of revenues, UAE presents the largest contribution, both in absolute value ($ 852 M) and in relative terms (0.2% of GDP). This is explained as the UAE is the largest regional hub for the development of cloud regions in MENA.

- In terms of spillover effects, because of its high development in broadband and cloud penetration, the UAE also presented the highest value (USD 8.6 billion), followed by Saudi Arabia (USD 7.7 billion), Egypt (USD 2.0 billion), Qatar (USD 1.7 billion), and Oman (USD 0.6 billion).

If MENA organizations increase their public cloud adoption over the next decade, economic gains will be significant. First, increasing the average current cloud penetration from 26.54% in 2021 to the average penetration level of North America and Western Europe in the same year (49.29%) will generate average annual spillovers of USD 59.2 billion, which for the next decade yields an accumulated economic value of USD 651.7 billion. In addition, cloud spending will also increase (we assume a compound annual growth rate similar of that of cloud penetration, 5.29%), reaching an accumulated value of $ 81.4 billion. Considering both revenues and spillovers, over the next decade (2023-2033), the MENA region has a potential to unlock USD 733.1 billion of economic value (equivalent to 1.14% of the cumulative 2023-2033 GDP[9]) if it catches up with the advanced digital countries in terms of cloud penetration (See Table 5-2).

Table 5-2. MENA: Simulation of contribution of Cloud in 2023-2033

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Cloud spending (USD B)	$ 5.40	$ 5.73	$ 6.09	$ 6.46	$ 6.85	$ 7.27	$ 7.72	$ 8.19	$ 8.69	$ 9.23	$ 9.79
Average Cloud penetration (%)	27.20%	28.87%	30.63%	32.51%	34.50%	36.61%	38.86%	41.24%	43.76%	46.44%	49.29%
Average Broadband penetration (%)	65.69%	66.56%	67.45%	68.35%	69.26%	70.19%	71.13%	72.07%	73.04%	74.01%	75.00%
Percentual increase in GDP after a 1% increase in cloud penetration	0.11%	0.12%	0.13%	0.14%	0.15%	0.16%	0.17%	0.18%	0.19%	0.20%	0.21%
Spillovers (% GDP)	0.70%	0.74%	0.79%	0.84%	0.90%	0.95%	1.02%	1.08%	1.15%	1.22%	1.30%
GDP (USD B)	$ 4,142	$ 4,421	$ 4,718	$ 5,035	$ 5,374	$ 5,735	$ 6,121	$ 6,532	$ 6,971	$ 7,440	$ 7,940
Spillovers (USD B)	$ 28.88	$ 32.82	$ 37.28	$ 42.36	$ 48.13	$ 54.68	$ 62.13	$ 70.59	$ 80.19	$ 91.11	$ 103.51
Total economic value (USD B)	$ 34.29	$ 38.55	$ 43.37	$ 48.82	$ 54.98	$ 61.96	$ 69.85	$ 78.78	$ 88.89	$ 100.34	$ 113.30

Source: Telecom Advisory Services analysis

[9] GDP over the next decade is calculated considering IMF predicted growth rates.

The overall economic contribution can be broken down as follows, considering the weight of each country in overall MENA economic value generated by Cloud in 2021 (see Table 5-3).

Table 5-3. Public Cloud GDP Contribution (2023-2033)

Country	Total contribution (USD billion)
Saudi Arabia	$ 191.84
UAE	$ 181.62
Turkey	$ 127.90
Egypt	$ 51.44
Qatar	$ 39.67
Kuwait	$ 16.83
Oman	$ 13.72
Bahrain	$ 8.75
Rest of MENA	$ 101.33
Total	$ 733.12

Source: Telecom Advisory Services analysis

The increasing economic value of Saudi Arabia over the next decade reflects the enormous potential implied by new cloud investments in the kingdom, and the digitization emphasis of Vision 2030.

6. CONCLUSION AND IMPLICATIONS

In recent years, cloud computing has become an essential tool for the delivery of IT-based services, With the progress of these technological advances, the interest in studying the economic effects of cloud computing increased, although evidence is still scarce and fragmented. In this study we contributed to fill a research literature gap as previous research had not yet been able to identify macroeconomic impact for MENA countries.

The econometric results for the sample point to a positive economic impact of both broadband adoption and cloud penetration, although we found some country-level heterogeneities, as the economic impact for cloud turned out to be larger in more digitally advanced economies within the region.

According to the results found, the elasticity that links GDP growth with cloud penetration varies by country, depending on the relative development of this technology coupled with broadband adoption. On an average MENA country, we can conclude that an increase of 1% in cloud penetration will yield a GDP increase of 0.07%. If cloud penetration increases by 10% (from an average of 26.54% to 29.29 %) in the entire MENA region, this would yield economic spillover effects of USD 25.5 billion.

Finally, we were able to calculate the overall effects (revenues created + spillover) for the specific cases of Saudi Arabia, United Arab Emirates, Qatar, Oman, Kuwait, Bahrain, Egypt, and the rest of the region's countries grouped together for year 2021. On average, the overall economic effect associated to cloud approximates to 0.97% of the GDP, although the UAE present a much larger direct contribution. The UAE is followed by Bahrain, Qatar, Saudi Arabia, while Oman, Egypt, Kuwait, while the rest of MENA countries lag further behind.

These results support the need to create the regulatory conditions to accelerate cloud adoption. Stimulating cloud adoption will require to embark in policy reforms to address the barriers to service penetration. This means creating the conditions for reducing broadband connectivity costs, removing stringent data localization obligations, issuing Cloud First policy for governments, putting in place cloud procurement frameworks, and promoting the development of a cloud computing IT workforce.

In fact, an advanced regulatory framework is crucial for driving the digital ecosystem growth and, consequently, accelerating the economic impact of cloud computing. This is consistent with previous empirical studies that have found that an improvement of the regulatory framework can be a key driver to increase telecommunications investment and to accelerate the development of the digital ecosystem.[10]

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[10] Katz, R. & Jung, J. (2021). *The impact of policies, regulation, and institutions on ICT sector performance.* Geneva: International Telecommunication Union; Katz, R. & Callorda, F. (2018). *The economic contribution of broadband, digitization, and ICT regulation*. Geneva: International Telecommunication Union.

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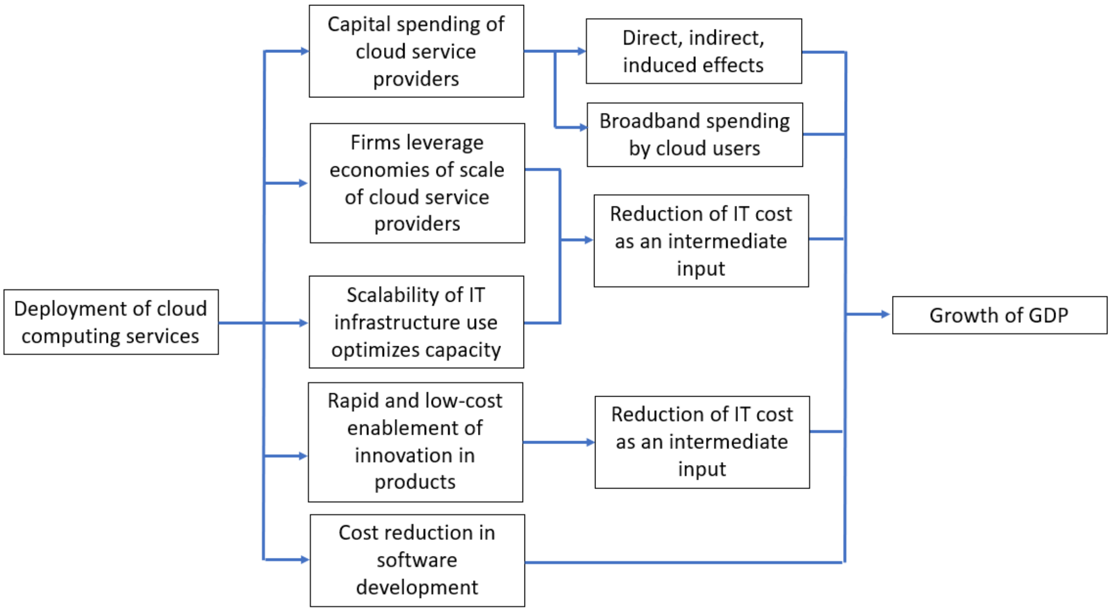
APPENDICES

A.1. THEORETICAL FRAMEWORK AND EMPIRICAL STRATEGY

A.1.1. Macroeconomic impact channels of cloud computing

Before attempting to estimate the impact of cloud computing on GDP it is important to synthesize existing research reviewed above and formalize a set of hypotheses that allows understanding why it is possible to causally link cloud computing to GDP growth. Figure A-1 presents the set of factors that explain why the adoption of cloud computing can be linked to GDP growth.

Figure A-1. Casual links between Cloud Computing and Economic growth



Source: Telecom Advisory Services

The first effect, consisting in the impact of capital spending of cloud providers, is associated to conventionally understood infrastructure deployment investment. The investment linked to the construction of data centers in an economy drives direct, indirect, and induced effects, as calculated through input-output models. In the first place, data center construction drives investment to build and operate the facility. In addition, data center construction and operation have an impact on indirect spending through business-to-business transactions. Finally, the household consumption based on the income generated from direct and indirect jobs drives induced economic effects. This is precisely the analysis of impact of AWS' investment on the Indonesian economy (AWS, 2021).

The second effect of cloud computing on GDP consists in firms leveraging economies of scale and scalability of IT use as a result of cloud adoption. It is derived from the microeconomic benefit of the service on organizations (private enterprises and government agencies) acquiring the service. Cloud computing provides these customers with advantages in cost reduction, flexibility, and scalability. The opportunity is then to automatically scale storage and software use to quickly up and down in response to load to save resources (Armbrust, et al, 2010). A reduction in resource spending has an impact on firms' margins and consequently monetary value, which translates into a contribution to GDP.

The third effect focuses on rapid and low-cost innovation generated because of cloud adoption. It has been studied through survey data proving that SaaS has an impact on firms ICT-enabled innovation (Chou et al., 2017; Kathuria et al., 2018; Chen et al., 2022), although the effect appears to be moderate, according to Loukis, et al. (2019(, and PWC (2021).

Finally, cloud services have an important economic contribution to software development. As stipulated by Byrne et al. (2017), when cloud vendors adopt technologies that enable them to develop products and offer services with greater abstractions, the work of software development in organizations purchasing cloud services is simplified. As a result, they can focus only on code programming and its deployment, lowering development costs. This, in turn, leads again to higher margins and, potentially an increase in sales.

In sum, a combination of all four effects has an impact on GDP growth. This should be added to actual spending in cloud service providers in the national economy.

A.1.2. Empirical strategy

The empirical strategy selected for this research is supported by a theoretical model that differentiates direct (sales) and spillover effects on the GDP of public cloud adoption. These should not be confused with the direct, indirect, and induced effects derived from an initial investment in cloud (the so-called "construction effect"). In this case, our purpose is to tease out the different economic effects that occur once cloud providers have deployed infrastructure in a country. Under this scenario, direct effects include all revenues of cloud companies when they offer their services in an economy, while the spillover effects of cloud services capture the impact on the rest of the economy. 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.

The direct effects are relatively easy to quantify as they refer to the revenues of cloud providers (or alternatively, to the spending in cloud of all sectors of the economy). On the other hand, spillover effects are more complex to calculate as they refer to cloud's contribution the rest of the economy. To estimate the spillover effects of cloud computing, we start with an empirical model based on an augmented Solow framework, where economies produce according to a Cobb–Douglas production function:

$$GDP_{it} = A_{it}K_{it}^{\alpha}L_{it}^{\beta} \quad (1)$$

where *GDP* represents gross domestic product, *K* is the physical capital stock, and *L* is labor. Subscripts *i* and *t* denote, respectively, countries and time periods. The term *A* represents total factor productivity (TFP), which reflects differences in production efficiency across countries over time.

Naturally, TFP is expected to depend on digital technologies. However, if we were to replace this variable with only a cloud-related variable, it would result in the problem of omitted variable bias. In other words, the contribution of cloud computing would capture the effects of other digital technologies, such as broadband, which needs to be isolated. On the other hand, if we were to introduce separately a cloud and a broadband variable, it could lead to multicollinearity, as both are expected to be largely correlated. Therefore, we propose a different approach, modeling broadband as an enabler of the economic impact of cloud adoption. This is reasonable as both technologies are largely complementary; in fact, without broadband, cloud is not expected to yield any economic impact.

Therefore, we expect TFP to depend on broadband adoption (denoted by BB), and beyond it, we can assume that a higher cloud penetration (CLOUD), as a variable measuring adoption, will enhance that impact. As a result, TFP is proposed as:

$$A_{it} = \Omega_i BB_{it}^{\Phi+\delta CLOUD_{it}} \tag{2}$$

Accordingly, TFP depends on country-specific characteristics represented by fixed effect Ω_i, a term reflecting time invariant idiosyncratic productivity effects, which may make some economies more productive *per se* because of unobserved characteristics. As it is assumed that broadband connectivity contributes to increased productivity, *A* is considered to depend positively on the level of broadband adoption, denoted by *BB*. Thus, we expect a positive value for Φ indicating the economic gains derived from broadband. Another important aspect that could shape the impact of broadband on country-level productivity is cloud penetration. Therefore, the empirical exercise will consist in identifying the sign and significance level of the parameter δ. If, as suspected, we verify that $\delta > 0$, this means that CLOUD enhances the positive impact of broadband. In other words, for two countries with the same broadband penetration, we expect to observe a larger economic impact for those with higher adoption of cloud services. Inserting Equation (2) into (1), we obtain:

$$GDP_{it} = \Omega_i BB_{it}^{\Phi+\delta CLOUD_{it}} K_{it}^{\alpha} L_{it}^{\beta} \tag{3}$$

Applying logarithms for linearization, and after some rearrangements, we get:

$$\log(GDP_{it}) = \mu_i + \alpha\, log(K_{ist}) + \beta log\,(L_{ist}) + \Phi log\,(BB_{ist}) + \delta CLOUD_{ist} log\,(BB_{ist})$$

where $\mu_i = \log(\Omega_i)$ is a country-level fixed effect. Thus, we understand that the evolution of *GDP* depends on specific unobserved local characteristics, on physical capital stock, on labor, on broadband adoption and, most importantly, on public cloud adoption.

From the last equation, we can calculate the economic impact of broadband, which is expected to depend on the adoption of cloud services:

$$\frac{\partial \log(GDP_{it})}{\partial \log(BB_{it})} = \Phi + \delta CLOUD_{it}$$

Similarly, we can directly calculate the economic contribution of CLOUD because of the spillover effects on the economy's productivity:

$$\frac{\partial \log(GDP_{it})}{\partial \mathrm{CLOUD}_{it}} = \delta \log(BB_{it})$$

This means that the impact of CLOUD on the GDP is expected to depend on the advancement of broadband infrastructure. In other words: if there is no broadband connectivity, the impact of cloud is zero. More importantly, if broadband adoption is constrained by high telecommunications prices, the positive impact of cloud is diminished.

A common critique of the estimation based on models such as those presented above is that the results for the ICT effects could determine correlation rather than causality because adoption of digital technologies may be considered as a driver, but also a consequence of productivity and economic growth.[11] This means that both broadband penetration and cloud computing may be potentially endogenous. This likely reverse causality may arise due to three factors: (i) individuals and firms in high-income countries may also have higher resources to pay for ICT (and therefore cloud), (ii) policy interventions are aimed to stimulate deployment, and (iii) use of ICT might depend on the level of development of each country because digital adoption can run in parallel to other technological advances (Czernich, 2011[12]).

To address these concerns, we propose to estimate the effect of cloud adoption with a structural multi-equation model, as other authors have previously done (Roller and Waverman, 2001[13]; Koutroumpis, 2009[14]; Katz and Callorda, 2018[15]). This system of equations effectively endogenizes broadband infrastructure and cloud penetration because it involves the supply and demand of these infrastructures (see Table A-1).

The broadband demand equation states that broadband penetration is a function of the average income per country, the price of a standard service for the connection to the network, the degree of human capital endowment, and the percentage of the

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[11] Cardona, M., Kretschmer, T., & Strobel, T. (2013). ICT and Productivity: conclusions from the empirical literature. *Information Economics and Policy*, 25, 109-125.
[12] Czernich, N., Falck, O., Kretschmer, T., & Woessman, L. (2011). Broadband infrastructure and Economic Growth. *The Economic Journal,* 121, 505-532.
[13] Röller, L. H. & Waverman, L. (2001). Telecommunications infrastructure and economic development: a simultaneous approach. *American Economic Review,* 91, 909-923.
[14] Koutroumpis, P. (2009). The economic impact of Broadband on growth: a simultaneous approach. *Telecommunications Policy*, 33, 471-485.
[15] Katz, R. & Callorda, F. (2018). *The economic contribution of broadband, digitization and ICT regulation*. Geneva: International Telecommunications Union.

population that lives in densely populated areas. The supply equation links the aggregate broadband investment to broadband price levels and competition intensity in the telecom market. These variables affect the dynamic of the supply side of the broadband market. The infrastructure equation models the annual change in broadband as a function of broadband investment.

Table A-1. System of simultaneous equations

Aggregate production equation		$Y_{ist} = f(K_{it}, L_{it}, BB_{it}, CLOUD_{it})$
Broadband equations	Demand equation	$BB_{it} = g(INCOME_{it}, P_{it}, HK_{it}, URBAN_{it})$
	Supply equation	$BB\ INV_{it} = h(P_{it}, COMP_{it})$
	BB infrastructure production	$\Delta BB_{it} = j(BB\ INV_{it})$
Cloud equations	Demand equation	$CLOUD_{it} = k(INCOME_{it}, P_{it}, HK_{it}, URBAN_{it})$
	Supply equation	$CLOUD\ INV_{it} = v(P_{it}, COMP_{it})$
	Cloud infrastructure production	$\Delta CLOUD_{it} = z(CLOUD\ INV_{it})$

Note: i and t denote respectively country and year.

Source: Telecom Advisory Services

From now on, we mirror the approach followed for the case of broadband, to endogenize cloud penetration as well. This means that we are introducing specific equations linked to cloud demand, cloud supply and cloud infrastructure production. In that sense, cloud demand is expected to depend on the average income, on cloud prices, on the degree of human capital, and on the degree of urbanization. As for cloud supply equation, it links cloud investment as a function of cloud prices and the competitive intensity in the local cloud sector. Finally, the variation in cloud penetration is modelized to depend on cloud investment.

Finally, if we add the spillover effects generated from cloud services (the spillover effect) derived from the econometric analysis to the spending in cloud services (the direct effect) we obtain a measure of the overall economic contribution (see table A-2).

Table A-2. Revenue and spillover contribution of cloud services to GDP

Item	Indicator	Source
(1)	Revenue created: Spending in Cloud Service	Public secondary sources
(2)	Spillover effect: Spill-over effect of cloud services	Estimated from the econometric analysis
(3)	Total impact of cloud services to the GDP	(1) + (2)

Source: Telecom Advisory Services

Having formalized the models to be used, we will now describe the data to be used in the analyses. The data required for running the models presented above was compiled from the following sources (see table A-3).

Table A-3. Data sources

code	Description	Source
GDP	Gross domestic product, current prices (USD)	IMF
K	Capital stock at current prices (USD)	Penn World Tables / IMF
L	Number of persons engaged	Penn World Tables / IMF
BB	Fixed broadband penetration (% households)	ITU
Price BB	BB price - fixed broadband basket	ITU
Price Cloud	Average based on the price of the mean broadband commercial plan and the price of Local Access all metro area cost of a Fast Ethernet (100 Mbs circuit) for 0-5km range	TeleGeography
BB investment	Telecommunications investment (USD)	ITU
Cloud investment	Cloud companies' investment (USD)	Oxford Economics / IMF
HK	Mean years of schooling, population 25+ years	UNESCO
HHI	Herfindhal Hirshman Index for fixed broadband	OVUM / TAS
Urban	Urban population (% of total population)	World Bank
Revenue	Revenue from all telecommunication services (USD)	ITU
Cloud companies	Number of cloud companies	Crunchbase
Cloud zones	Number of cloud regions (every 1 million inhabitants)	Telegeography

Source: Telecom Advisory Services analysis

Table A-4. OECD data: Share of Enterprises purchasing Cloud Services

	2014	2015	2016	2017	2018	2019	2020	2021
Australia	29.77	..	44.51	..	59.48	..	71.27	..
Austria	11.67	..	17.05	21.03	23.27	..	38.13	40.40
Belgium	21.24	24.62	28.46	39.59	40.25	..	53.23	52.96
Canada	..	..	..	52.90	..	25.03	..	..
Czech Republic	15.13	..	18.00	22.03	26.48	..	28.89	43.75
Denmark	37.67	36.65	41.60	50.53	55.62	..	66.90	64.82
Estonia	14.85	..	22.84	..	33.91	..	56.32	57.54
Finland	50.78	53.45	56.92	65.64	65.26	..	75.49	75.29
France	11.91	..	17.11	..	19.42	..	26.86	29.35
Germany	11.29	..	16.26	..	22.43	..	33.32	41.60
Greece	7.60	9.37	9.21	11.03	12.83	..	16.70	22.36
Hungary	8.08	10.56	12.19	16.34	18.01	..	25.21	26.41
Iceland	43.13	..	..	..	..	..	..	..
Ireland	27.60	35.24	36.08	..	45.18	..	50.90	58.79
Israel	..	..	..	..	..	..	50.85	..
Italy	40.10	..	21.51	..	22.53	..	59.14	60.47
Japan	38.70	44.60	46.88	56.80	58.70	20.93	68.70	..
Korea	12.90	12.90	..	17.19	22.70	23.50	24.94	..
Latvia	5.69	8.31	8.37	12.04	14.53	..	21.31	28.55
Lithuania	13.47	16.24	16.64	23.17	22.56	..	30.77	33.58
Luxembourg	12.52	..	18.83	..	24.54	..	29.09	33.48
Mexico	..	..	..	..	..	..	..	..
Netherlands	27.65	..	34.53	..	48.25	..	52.56	64.94
Norway	29.31	37.56	39.74	48.02	50.66	..	63.73	64.02
Poland	5.76	7.28	8.17	10.00	11.48	..	24.42	28.70
Portugal	12.56	..	17.95	22.60	24.68	..	29.00	34.70
Slovak Republic	19.32	20.41	17.89	22.21	21.14	..	25.57	36.14
Slovenia	15.42	17.49	22.17	22.07	26.28	..	38.60	42.69
Spain	14.04	14.56	18.34	23.54	21.99	..	26.15	30.92
Sweden	39.44	..	48.16	..	57.21	..	69.51	75.39
Switzerland	..	23.40	..	21.74	..	43.44	..	..
Turkey	..	..	10.33	..	10.09	..	14.09	10.83
United Kingdom	23.97	..	34.66	..	41.86	..	53.03	10.83
United States	..	..	..	52.20	44.29	..	..	..
Brazil	..	44.60	..	40.50	..	53.92	..	62.18
Bulgaria	7.72	5.36	6.70	8.01	8.35	..	10.85	12.79
Croatia	22.20	22.44	22.61	31.21	30.71	..	38.95	39.15
Romania	4.86	8.17	7.29	10.79	10.29	..	15.73	14.14

Source: OECD

The model was specified with data from the following countries.

Table A-5. Countries included in the econometric model

Argentina	Hungary	Pakistan
Australia	India	Peru
Austria	Indonesia	Philippines
Bangladesh	Ireland	Poland
Belgium	Islamic Republic of Iran	Portugal
Brazil	Israel	Romania
Canada	Italy	Singapore
Chile	Japan	Slovak Republic
China	Jordan	Slovenia
Colombia	Kenya	South Africa
Costa Rica	Korea	Spain
Croatia	Kuwait	Sri Lanka
Cyprus	Luxembourg	Sweden
Czech Republic	Malaysia	Switzerland
Denmark	Malta	Thailand
Ecuador	Mexico	Turkey
Egypt	Morocco	Ukraine
Estonia	Netherlands	United Arab Emirates
Finland	New Zealand	United Kingdom
France	Nigeria	United States
Germany	Norway	Vietnam
Greece	Oman	

Source: Telecom Advisory Services analysis

Table A-6. Econometric results for the principal equation using OECD data

Dep. variable: Log (GVA)		
Log(K)		0.400***
		[0.011]
Log(L)		0.448***
		[0.019]
Log (BB 30 Mbps)		0.300**
		[0.137]
Log (BB 30 Mbps) * Cloud		0.001*
		[0.000]
Fixed Effects†	Country	YES
	Year	YES
R-squared†		0.95
Observations		516

*Note: * p<10%, ** p<5%, *** p<1%. † Refers to first equation of the structural model.*

Source: Telecom Advisory Services analysis