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DZ.8 Measurement of Cloud Computing in National Accounts

Digitalization Task Team

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1. Introduction

Cloud computing providers supply on-demand information services over a network. These services include computing infrastructure-as-a-service (IaaS), platform-as-a-service (PaaS), and software-as-a-service (SaaS).[1] Private estimates of the size of the cloud computing market also include specialized business process software run in the cloud, or Business Process as a Service (BPaaS), but BPaaS could be distinguished as a special category of cloud computing service.

The history of cloud computing begins with specialized software and data storage accessed over the internet in the late 1990s. Almost a decade then passed before public cloud computing emerged as a service with the potential to replace for ownership of an IT capital stock. In 2006, Amazon Web Services (AWS) extended the innovations that Amazon had developed to support its third-party to make a suite of IaaS products available to the public. Shortly thereafter, Google, Alibaba Cloud Service, and Microsoft Azure entered the cloud computing market with IaaS, PaaS and SaaS products, and many smaller suppliers of these and related products, including private and hybrid clouds and support services for cloud computing, began to enter the industry. Cloud computing has now become a global industry with extensive international transactions, and an estimated global output of 270 billion US dollars in 2020 (Annex A). Cloud computing also accounts for a sizeable share of IT investment and is an essential input for many of the products of the digital economy.

Their wide use makes cloud computing services important to include in the digital supply and use tables intended to bring additional visibility to the digital economy (Digitalization Task Team, 2020). A discussion of cloud computing is therefore appropriate to include in the digitalization chapter of the updated SNA. Previous research on measuring cloud computing, which provides additional detail on these issues, includes Byrne, Corrado, and Sichel (2018), Coyle and Nguyen (2018 and 2019) and Baer, Lee and Tebrake (2020), and Ker (2021).

This guidance note recommends definitions of cloud computing and of a broader aggregate containing computing services accessed remotely over a network. It then briefly reviews the economics of the adoption and impact of cloud computing technology on investment and international transactions. Next, it considers the issues arising from cloud computing for the measurement of investment by the users and suppliers of this service, the measurement of prices and volumes, and the measurement of international transactions. A summary of the main findings and recommendations is provided in the concluding section.

2. Definition of Cloud Computing

Existing definitions of cloud computing vary in the amount of technical detail they specify. The definition from the US National Institute of Standards and Technology (NIST) describes the technology in enough detail to exclude services that lack the key advantages of cloud computing. The NIST definition is:

[1] Function-as-a-service (FaaS) is sometimes also listed as a type of cloud computing service (e.g., Byrne, Corrado and Sichel, 2018), but this service can also be viewed as a special type of PaaS. Alexa's skills are an example of a product enabled by FaaS (Baez, 2020).

> 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 or service provider interaction. (Pell and Grance, 2011).

The NIST definition goes on to identify five essential characteristics of cloud computing technology, and a recent OECD paper on cloud computing also lists these five features (Ker, 2021). They are:

- on-demand self-service,
- broad network access,
- resource pooling,
- rapid elasticity, and
- measured service.

On-demand means that the service is supplied when ordered, with no need for human intervention. Broad network access means that the service can be accessed remotely from many locations. Resource pooling means that workloads can be automatically shifted between locations, preventing the customer from knowing the exact location of the provided resources. Rapid elasticity means that resources deployed can be scaled up or down quickly without management intervention. Measured service means that the resource use is monitored, controlled, and reported, with the metered use frequently charged on a pay-per-use basis.

A 2014 OECD paper considers the NIST definition and an earlier definition of cloud computing and recommends a definition of cloud computing as

> a service model for computing services based on a set of computing resources that can be accessed in a flexible, elastic, on-demand way with low management effort.

A simplified version of this definition could omit the first four words.

Like the discussion accompanying the NIST definition, the OECD paper notes that the cloud service spectrum consists of IaaS, PaaS, SaaS, with delivery models of private, public, hybrid, and community clouds. The paper lists network access and pricing based on resources used, which converts up-front capital expenses into operating expenses, as among the general characteristics of cloud computing services.

Because of its technical purpose, the NIST definition contains more detail on technology than is needed in a definition for statistical purposes. AWS provides a definition of cloud computing that focuses on the aspects of greatest interest to customers. This definition mentions on-demand service, pricing based on resources used, and network access, though it identifies the network as the internet. The AWS definition of cloud computing is:

> The on-demand delivery of compute power, database storage, applications, and other IT resources … via the internet with pay-as-you-go pricing."

The SNA definition of cloud computing should not limit the network used to access the service to just the internet. The simplicity of the AWS definition is, however, appealing. and on-demand delivery is worth highlighting in the SNA definition of cloud computing because it helps make access to cloud computing a near-perfect substitute for on-premises IT capital. An SNA definition that would capture the key characteristics of cloud computing is:

> **Cloud computing services consist of computing, data storage, software, and related IT services accessed remotely over a network, supplied on demand and with measured resource usage.**

In the definition, network bandwidth is a common type of related IT service. Also, measured resource usage allows charging based on actual resource usage (pay-per-use charging) or based on predetermined limits on the IT resources (such as storage space) to which the user has access. Most cloud computing services are charged on a pay-per-use basis. For cloud storage space, however, fixed charges for the right to use up to a predetermined limit for a specified period of time are also common. In addition to allowing charges to be based on actual consumption or consumption limits, measured resource usage allows efficient management of pooled resources.

Including on-demand delivery in the definition of cloud computing services means that access over a network is not sufficient for a service to be cloud computing. Services delivered under contracts for a fixed period of access, such as a year, are ordered in advance, not supplied "on-demand." Software subscriptions, for example, involve a license to access the software over a fixed time period. Software subscriptions are also excluded from cloud computing because the supplier of the service is the software publisher, not a supplier of computing services.

Access over a network is also worth highlighting in the definition of cloud computing because this feature of cloud computing allows the service to be produced remotely, potentially even in a foreign location. The prevalence of cross-border delivery of cloud computing services is an important aspect of the problem of measuring cloud computing.

Furthemore, access over a network can be used to define a broader class of IT services accessed over a network that also includes hosting of IT resources such as servers and software in remote datacenters and colocation of servers. Hosting of servers and software[2] and co-location of servers fall outside the definition of cloud computing because the resource is owned by the user but, as noted by Ker (2021, p. 12), the hosting may include an internet connection with the rapid elasticity that is characteristic of cloud computing. Thus, network access represents a cloud computing element of the bundle supplied to hosting customers.

Combined data on cloud computing and hosting services is needed for insight into remotely accessed IT services (or data center computing) as a phenomenon. Cloud computing and hosting/colocation services can be combined for purposes that require a measure of data center computing general. In the Eurostat Classification of Products by Activity (CPA) for example, the product subclass *63.11.1 Data processing, hosting, application services and other IT infrastructure provisioning services* contains cloud computing services as part of data processing, and also contains hosting and colocation services. Furthermore, hosting services have enough in common with cloud computing to be included in the cloud computing estimates of BEA's digital economy satellite account (Nicholson, 2021) and hosting services are also appropriate to include in the cloud computing component of the digital supply and use tables (SUTs).

The treatment of cloud computing and related services in product and industry classification systems is reviewed in Ker (2021). Further collaboration with classification experts to clarify guidelines on the detailed activities and products included in cloud computing would be useful. For example, management and support services for cloud computing, including advice and software to implement and utilize the core cloud computing services, seem appropriate to include in cloud computing in the digital SUTs and in the

[2] These services can be distinguished from website hosting. Ker (2021, p. 17) treats the available estimates of website hosting services as likely to contain cloud computing services.

cloud computing industry. These services help firms to implement and manage cloud computing and to protect the security of their data and applications. Furthermore, although BPaaS appears to be within the boundary of cloud computing as a special type of SaaS, its treatment would be worth clarifying. BPaaS is a significant activity – in the US Economic Census of 2012, business process management services (NAPCS 70143000) accounted for 23 percent of the sales of the NAICS 518210, "Data processing, hosting, and related services". Unlike most cloud computing services, which replace inputs of capital services, BPaaS replaces labor inputs by automating labor-intensive tasks. Because BPaaS combines outsourcing of business processes with software services, it could be viewed as a business process service produced with IT inputs. A detailed breakdown of cloud computing services separately identifying BPaaS would help provide a complete picture of cloud computing products. Breaking out the detailed activity of cloud computing from the detailed activity of hosting and colocation services would also provide important information on the structure of computing services accessed over a network.

Finally, it is important to distinguish services produced with cloud computing inputs, such as audio and video streaming, from cloud computing services. Cloud computing is often combined with other inputs to produce or deliver an output. That output is not considered to be a cloud computing product. However, data providing visibility into the uses of cloud computing in production would be of analytical interest for understanding digitalization.

3. The Economics of Cloud Computing

Cloud computing services are used by a wide range of industries (Annex B) and, as discussed in Annex C of the OECD-WTO-IMF *Handbook on Measuring Digital Trade*, they are replacing ownership of on-premises IT capital.[3] Connected devices with artificial intelligence (AI) capabilities and many digitally intermediated services have also been made possible by access to cloud computing. Except for cloud storage used by households, cloud computing products are almost always used for intermediate consumption purposes by enterprises, government and nonprofit institutions serving households. Because of the importance of intermediate consumption of cloud computing services, cloud computing is one of the digital products shown separately in the proposed digital SUTs (Digitalization Task Team, 2020). The large impact of cloud computing on patterns of IT fixed capital formation capital assets also adds to the importance of the information on use of cloud computing in the digital SUTs.

IT capital stocks are increasingly owned by cloud computing providers and other major digital enterprises. An indication of the extent of substitution of cloud computing services for on-premises IT equipment is the relocation of the IT hardware capital stock reported in the *BEA-BLS Integrated Industry-level Production Account for the United States*. The industry group that contains cloud computing saw volume growth in its IT hardware stock of 25 percent per year over the 10 years ending in 2019, while all other industry groups averaged just 2.3 percent per year (Figure 1). By one metric, the industry group containing cloud computing accounted for half of the economy-wide growth of the hardware capital stock over these years.

The rapid growth of cloud computing can be attributed to its cost advantages, agility, and, in many cases, greater security. The large gap between the low utilization rate of on-premises servers and software and the high utilization rate that cloud computing data centers can achieve by taking advantage of scale economies and virtualization (Cisco, 2018) helps enable the cost savings. Cloud computing servers' often have double the capacity utilization rate of conventionally managed servers. The economies of scale also

[3] Growth of hosting services is also contributing to the movement off premises of servers and software, but not to the changing ownership of IT capital.

enable savings on labor, as cloud computing customers can avoid significant labor costs when installing and managing servers and software becomes someone else's responsibility. Finally, because of their size, major cloud computing providers have market power as purchasers of IT capital assets and can engage in own-account production not only of software but also of IT equipment.

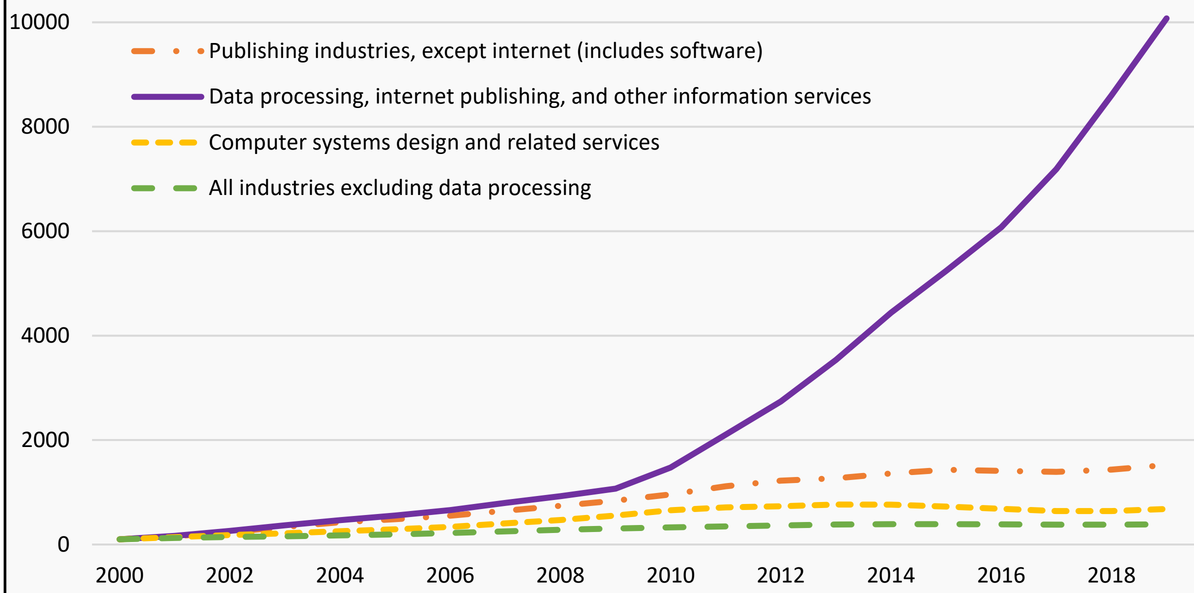
Cloud computing also enables agile adaptation to changing scale and capacity requirements. For example, the elasticity of cloud computing enabled Zoom to accommodate a sudden 30-fold increase in demand at the start of the COVID-19 pandemic. Cloud computing also enables new firms to launch and scale up quickly and cheaply and enables firms of all ages to avoid risky irreversible investment as they grow. Moreover, specialized software and computing capacity that would be uneconomic to buy may be affordable to use as an on-demand service or to experiment with to see what works best. Jin and McElheran (2019) attribute improvements in survival and growth of young firms that use cloud computing to opportunities to experiment with a wide range of cloud computing products. However, cloud computing software cannot replace customized on-premises software for users who require unique features or capabilities, and ownership of their IT capital stock is still economical for major users of IT resources.

Replacement of own-account production of IT services by services delivered over a network (tends to reduce an industry's ratio of value added to output and could also change the industry composition of GDP (Baer et al., 2020). (A similar effect occurs when outsourced services replace labor inputs.) Furthermore, if the cloud computing services are supplied from (or to) foreign locations, trade could be affected. Information on intermediate consumption of cloud computing services may therefore be needed to understand the growth of industry value added and labor productivity.

The rise of cloud computing has also affected other aspects of the economy. It has contributed to the rising importance of intangible assets by increasing the feasibility of accumulating data assets and R&D assets and the value of those assets. Growing investment in intangibles is making overall investment and capital stocks harder to measure (Crouzet and Eberly, 2021 and Corrado et al. 2009). In addition, cloud computing has also contributed to growth of international trade in digital services both as a direct participant in this trade and a facilitator of other parties' transactions. Trade in computer services (which include cloud computing services) has grown rapidly: US exports of computer services grew at an average annual rate of 14.3 percent between 2010 and 2017, and 28 European countries' exports of computer services grew at a rate of 7.5 percent (Baer et al., 2020).

Free access to limited amounts of cloud storage is often bundled with consumer products, and free trials of cloud computing services may be offered for marketing purposes. Free products supplied by market producers are discussed in guidance note DZ.3 on free products in the core national accounts. These free products are supplied as a part of a bundle whose priced components cover the cost of producing the bundle or help sell other products that carry mark-ups. Another question concerns the effect of changes in consumption of free products on measures of price and volume growth. However, the value of free cloud services would be too tiny to matter for measurement of cloud computing price and volume growth.

Figure 1: Computer Hardware Real Capital Stock in the US
(2000=100)



Source: BEA-BLS industry-level production account, expanded capital detail (2021 release). Author's calculations of the index for all industries ex. data processing use capital compensation as weights.

4. Recommendations and Clarifications on the Classification and Recording of Cloud Computing in national accounts

4.1 Needs for Added Detail on Cloud Computing and Hosting Services

At an aggregate level, cloud computing and hosting services have a place within existing industry and product classification systems as part of *Data processing, hosting, and related services* or *Data processing, hosting, application services, and other IT infrastructure provisioning services*. Similarly, the fixed assets of cloud computing enterprises can be recorded as part of existing categories of fixed assets. However, the rapid growth of cloud computing calls for development of more refined products and activity detail. Detailed classifications allowing for breakouts of cloud computing services, and of hosting and colocation services should therefore be developed in collaboration with experts on classification. Similarly, IT capital assets are increasing located in large data centers as part of the capital stock of cloud computing providers and large digital platforms or as part of the IT capital stock that is housed off-site in leased space in a colocation or hosting data center. Development of detailed data on IT fixed capital of cloud computing suppliers and on IT fixed capital assets that are owned by the end user but remotely located would help elucidate these changing patterns of IT investment.

4.2 Fixed Capital Formation of the *Users* of Cloud Computing Services

Boundary between Purchased Services and Ownership of IT Fixed Capital

Dedicated access to remotely located IT assets as a substitute for owning an on-premises IT capital stock that can raise questions for the measurement and interpretation of IT investment. In business accounting, long-term contracts with a cloud computing provider for access to dedicated IT assets such as servers are likely to be treated as financial leases.[4] In other words, the long-term lease would be treated as a change in ownership of a server. The appropriate treatment in national accounts of a contract for dedicated access to a remotely located server or other IT asset is also likely to be as a financial lease, making the user the economic owner of the IT asset. However, the criteria for identifying a financial lease are narrower in national accounts than in business accounting. The SNA treats the party that bears the operating risk as the economic owner of the asset. The SNA criteria should be used to ascertain the economic ownership of IT assets subject to long-term contracts with cloud computing providers.

The SNA also implies that software licenses lasting more than a year are fixed assets. Having the software hosted in a cloud computing datacenter does not change the ownership of the license as a software asset.[5] A user of remotely accessed software may purchase a license from a software publisher as a software asset and separately purchase the cloud computing infrastructure services of the processing time and storage needed to utilize the hosted software.

Cloud computing transactions that include software usage charges should be classified as SaaS. Cloud computing users who do not have their own software license incur pay-per-use software license charges when they run software in the cloud. The entire fee for accessing the software is retained by the cloud computing enterprise if it owns the software (either because it is the software developer or because it has acquired all rights to the software) or has purchased a license from the software publisher that includes rights to offer pay-per-use software rentals. In these cases, the software original or software copy is a fixed asset of the cloud computing enterprise. In other cases, the cloud computing provider passes on a portion of the pay-per-use software license fees to the software publisher and receives margin income from reselling software services supplied by the software publisher. However, it may be more practical to treat the cloud computing enterprise as purchasing intermediate inputs of services from software publisher and supplying software services to the cloud computing users than as supplying distributing software services on margin.

Software subscriptions and software licenses

Subscriptions from software publishers are not cloud computing or hosting services even if the publisher delivers the software via remote access over a network. Software publishers often take advantage of remote access to distribute regular updates, making the product seem like software-as-a-service. Software-as-a-service would be normally recorded as intermediate consumption, but if the user has purchased a long-term software license, the subscription should be recorded as a software asset of the license holder (i.e., the user of the software), and the periodic software updates should be viewed as maintenance of this asset. For example, a license to use Microsoft Office 365 over a period lasting more than a year would be a software fixed asset even if the software is frequently updated during the term of the license. This treatment allows continuity with the earlier treatment of software copies as assets.

[4] In economic terms a financial lease is a mechanism for financing the acquisition of the asset by its user (SNA, 17.301-17.309.)
[5] Financial accounting rules of U.S. GAAP also capitalize software licenses and on-premises (packaged) software.

Furthermore, software updates are also provided to purchasers of connected equipment, and these updates should not prevent the recording of the equipment acquisition as fixed capital formation.

The typical duration of software licenses also poses a dilemma. Software subscriptions often come with one-year licenses. These one-year licenses are a borderline case just under the SNA (10.100) threshold to be a fixed asset. Although the conceptually appropriate treatment of the borderline case of a one-year software licenses is probably as a software rental (i.e., as a purchased service used for current consumption), this treatment may not give the most analytically useful picture of investment in software copies, and it may not be feasible in practice. As a practical matter, the available source data on software licenses often fail to include enough information to distinguish one-year licenses from longer licenses. Also, these licenses often renew automatically, and multi-year use of the software is frequently the expectation when initially acquiring the software. Thus, the inclusion of one-year software licenses in software investment is likely to be an attractive pragmatic solution in many cases.

Cloud Computing Implementation Costs

Business accounting guidelines capitalize cloud computing implementation costs – the costs involved in transitioning to cloud computing.[6] Investment in software to access and use cloud computing resources and employee training on the use of this software are probably the main cloud computing implementation expenses. These software investment expenses must be included in national accounts estimates of software investment. Cloud computing implementation costs are also likely to include planning costs that could be classified as organizational capital intangible assets, a type of intangible asset that is out of scope for national accounts.

4.3 Fixed Capital Formation of Cloud Computing Suppliers

As noted above, cloud computing providers have rapidly expanded their stocks of IT equipment.[7] They have also invested in structures such as datacenter buildings, networks, and submarine cables and in software and R&D. The equipment and structures present noteworthy measurement issues.

Own Account Investment

Major cloud computing providers have high levels of own-account investment in R&D and software. They also undertake significant amounts of own-account investment in equipment, often by designing the equipment in-house and having a contract manufacturer handle the fabrication or assembly.

Own-account investment in R&D and software is common enough for statistical agencies to already have procedures in place to measure them by their cost. The design of customized equipment may therefore be captured in own-account R&D investment. However, at least some of the own-account equipment investment is likely to be missed by standard procedures for measuring equipment investment from source data on shipments. Major cloud computing providers can often improve performance and reduce costs by designing and fabricating (often via a contract manufacturer) their own servers and networking equipment. The estimates of own-account investment in equipment based on costs should include parts and materials from which the equipment is constructed, the compensation of the engineers and technicians who design and build the equipment, and the equipment assembly services. In the case of the United States, to gauge the scale of the overlooked equipment investment, Byrne, Corrado and Sichel

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[6] Both IFRS and U.S. GAAP follow this approach. See EY (2020) and Deloitte (2019).

[7] For example, AWS reports investing US $35 billion on datacenter equipment and structures in northern Virginia over 10 years ending in 2020 (https://d1.awsstatic.com/WWPS/pdf/aws-economic-impact-virginia.pdf).

(2018) identify over $58 billion of the output of the Computer and Electronics Manufacturing sector (NAICS 334) in 2015 as potentially representing parts used to produce servers and other equipment for own use by cloud computing providers and other hyperscale datacenter operators.[8]

Structures and Equipment

The treatment of cloud computing structures also requires clarification. The investment in inter-continental and other cross-border undersea cables should be attributed to the country of residence of the owner of the cable. If ownership of the undersea cable is shared among enterprises resident in different countries, the investment should be allocated in proportion to ownership shares, as outlined in SNA 4.13 and 26.35 and in BPM6 4.41-4.44 and the UNECE *Guide to Measuring Global Production*.

Second, suppliers of cloud computing services often occupy a leased datacenter building, and end users of computing services also sometimes lease an entire data center building from a supplier of colocation services. If the legal owner of the building bears the risk and is responsible for operating and maintaining the building – as is generally the case with colocation services – the lease should be treated as an operating lease. A complete measure of investment in supplying cloud computing and hosting/colocation services may therefore need to include investment in datacenters by the real estate industry. However, in some cases, cloud computing tenants have leases that give them ownership of the building at the conclusion of the lease. In these cases, the cloud computing enterprise is likely to be the party that bears the risk and that has acquired economic ownership of the data center building via a financial lease. A notional resident unit may also need to be established to record foreign direct investment (FDI) if the datacenter is located in a different economy from the cloud computing enterprise.

Third, suppliers of colocation services may invest in equipment such as server racks space on which can be leased to customers. (These colocation service suppliers typically own the data center structure, as well.) In addition, providers of hosting services that supply dedicated access to servers may be the party that bears the risks, making them the economic owner of the servers.

4.4 Prices and Volumes of Cloud Services and Services Enabled by Cloud Computing

The Guidance Note on *Price and volume measurement of goods and services affected by digitalization* of the Digitalization Task Team discusses measurement of prices and volumes of cloud computing services. Quality-adjusted price indexes for selected cloud computing services have also been constructed by Byrne, Corrado and Sichel (2018) and Coyle and Nguyen (2018).

In constructing price indexes for cloud computing as an existing activity, a practical challenge is the complexity of the menu of products offered by major cloud computing providers. For example, AWS offers more than 200 different services, some with complicated characteristics. The pricing formulas for billing packages of cloud computing services may include both subscription fees and metered usage charges and adjust for a range of price-determining characteristics (Baer, Lee, and Tebrake, 2020). Adding to the complexity, pricing formulas can change – for example, AWS switched from rounding IaaS compute time up to the hour to rounding up to the second – and cloud computing providers frequently introduce new products and product improvements.

A practical, though imperfect, solution to all this complexity is to base the price index for cloud computing on a few core services with relatively simple characteristics and price structures. Byrne, Corrado and Sichel (2018) and Coyle and Nguyen (2018) follow this approach and find rapid declines in the prices of core IaaS and PaaS products of AWS, suggesting that official deflators for the sector that

[8] BEA has since revised the estimates of cloud computing providers' investment in equipment.

contains cloud computing may be overstated. Price indexes that accounted for the growth of variety of cloud computing services offered and appearances of new kinds of services would undoubtedly show even larger declines.

Most cloud computing services are used for intermediate consumption. If these services are produced and consumed in the same economy, an overstatement of their deflator will distort industries' contributions to GDP growth but not GDP growth itself. However, mismeasured deflators for exported or imported cloud computing services would affect measurement of GDP growth. Consistency between countries in the measurement of prices and volumes of cross-border flows of computing services is important for international comparability.

Finally, products produced with cloud computing inputs also present challenges for price and volume measurement. Many of the new services that have appeared in the digital economy rely on cloud computing. If the deflators could be adjusted for the benefits of these new digital services, the impact on the estimates of consumption growth could be significant. However, quantifying the relative quality of novel products with distinctive features may require assumptions that are impossible to verify. Quantifying the gains from the replacement of on-premises computing by cloud computing may also require speculative assumptions. Consequently, the gains from the invention of cloud computing cannot be fully captured in the growth and productivity statistics.

This guidance note recommends that these issues be further explored and that guidance beyond the SNA be developed, for example in the various manuals for measuring prices.

4.5 International Transactions associated with Cloud Computing

The major suppliers of cloud computing services are multinational enterprises (MNEs) with customers and operations in many countries. Cloud computing enterprises supply services to this global marketplace both through cross-border data flows and by investing in local datacenters and other facilities linked by global cable networks that include subsea cables. As of 2021, for example, AWS had over 60 owned or leased datacenters outside of the US and 230 edge locations scattered across the globe (Figure 2).

The growth of cloud computing has generated considerable foreign direct investment (FDI). The FDI associated with cloud computing does not appear to present any measurement problem that is not already covered by the SNA and balance of payments manual (BPM6). For example, the measurement principles applicable to subsea cables are covered in BPM6 4.41-4.44.

Measuring gross cross-border flows of cloud computing services may be more of a challenge, as these services may not be produced in the country where they are consumed, and customers can place orders with a multinational cloud computing enterprise for computing services to be produced or used in a third country. Most cloud computing services are inputs into the production of something else, such as a digital service (e.g., streaming video, ridesharing, telecom services), a non-digital service (e.g., insurance, education, government services), or R&D and software assets.[9] The consumption of these cloud computing services takes place in the location of the production process into which they are an input. For

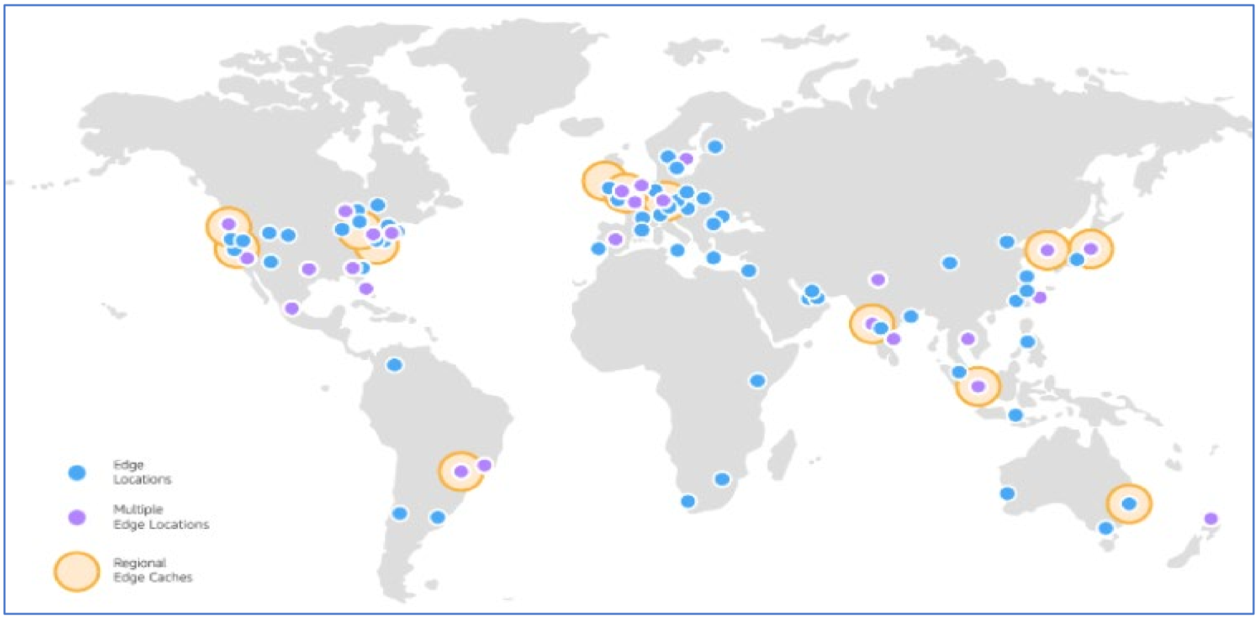
[9] Contino lists 100 enterprises and government agencies engaged in a diverse range of activities that use the services of AWS. See https://www.contino.io/insights/whos-using-aws.

example, if a business in country A purchases computing services from a cloud computing establishment in country B, the computing services will be an export of country B and an import of country A.

The resource pooling aspect of cloud computing technology could complicate the measurement of detailed trade flows when the supplier of the cloud computing services is an MNE with establishments in multiple countries and the purchaser of the computing service does not specify the location of the datacenter where the work must be done. Cloud computing providers may shift tasks to foreign datacenters for workload balancing purposes or store the data copies in foreign locations to ensure uninterrupted accessibility in the event of a data center outage or natural disaster. Finally, software updates developed at an MNE's headquarters or at a software development center may be pushed out to datacenters around the world as a way of supplying SaaS. The unpriced international data flows that allow cloud computing tasks to shift seamlessly between locations can be seen as part of the broader measurement problem of international flows of commercially valuable data between related parties taking place without payment.

Experiments with developing consistent estimates of gross cross-border flows of cloud computing services and country totals of production and consumption of these services would shed useful light on the detail and completeness of the data on their cross-border services that global cloud computing enterprises are willing and able to report. Payments within the MNE to each local establishment (with payments on behalf a local establishment rerouted through that establishment) must at least cover the establishments' costs of production. Thus, at a minimum cloud computing MNEs should be able to supply breakdowns by country of aggregate production and aggregate consumption of cloud computing services. If they can also provide data on the gross flows of cloud computing services, precise estimates of international transactions in cloud computing services can be developed. Research on measurement of investment in servers and software hosted in foreign locations by users of hosting services would also be useful.

Figure 2: AWS Edge Locations and Regional Edge Caches as of 2021



Source : https://aws.amazon.com/cloudfront/features/?whats-new-cloudfront.sort-by=item.additionalFields.postDateTime&whats-new-cloudfront.sort-order=desc#Global_Edge_Network

Global suppliers of cloud computing services are likely to be able to provide enough information on their sales to develop at least a partial picture of gross exports and imports of cloud computing services. In some cases, however, the cloud computing enterprise might only be able to report enough detail on the international production and consumption of its services to allow net cross-border flows of its services to be derived by applying output allocation principles for seamless multi-territorial enterprises of the 2008 SNA 26.35 and BPM6 4.41-44. International collaboration could also help national statistics offices to produce mutually consistent estimates.

Another problem in measurement of international trade and investment by MNEs supplying cloud computing services is the effect of tax considerations on both their actual and purported transactions. MNEs in industries with significant intellectual property (IP) assets often allocate an exaggerated share of their global production to low tax jurisdictions by redomiciling the IP assets and by distorting international transfer prices. Computing services appear to be one of the affected products: Baer et al. (2020) report that the tax-advantaged locations of Ireland and the Netherlands (which account for 2 percent of OECD countries' GDP) accounted for 53 percent of OECD countries' exports of computer services in 2016.

International collaboration between national accounts experts and experts on balance of payments statistics is needed to develop shared guidelines on international transactions involving remotely accessed computing services providers and the global cloud computing industry. (See the UNECE *Guide to Sharing Economic Data in Official Statistics* for further discussion of international data sharing to improve measurement of MNEs and international transactions in general.)

5. Conclusions and Recommendations

Cloud computing technology is allowing on-demand services delivered over a network to replace on-premises IT equipment and software. As a result, IT capital stocks are increasingly located remotely in cloud computing datacenters, and increasingly owned by cloud computing enterprises. This shift highlights the importance of the information on cloud computing services included in the proposed digital supply and use tables for understanding the changes in the organization of production caused by the replacement of broad-based IT investment by services delivered over a network. A summary of the main conclusions and recommendations is as follows.

First, cloud computing services are defined as *computing, data storage, software, and related IT services accessed remotely over a network, supplied on demand and with measured resource usage*. "Measured" refers to the measurement of the resources, which allows pay-per-use charging or charging for access to IT resources (such as storage) up to a predetermined limit and which also facilitates efficient allocation of pooled IT resources. The definition is accompanied by a discussion of the attributes of cloud computing services, including resource pooling and rapid elasticity, and of the types of services offered and modes of delivery. The discussion also notes that management and support services for cloud computing are an important part of the cloud computing industry, and that hosting of servers and software is a related activity that could be aggregated with cloud computing. Finally, additional collaboration with classification experts on refinement of classifications for the cloud computing and hosting/colocation industry and its products is recommended.

Second, this note clarifies the treatment of software licenses and software subscriptions. Long-term licenses and subscriptions should be recorded as fixed assets of the software user regardless of whether the software is hosted in the cloud. Furthermore, subscriptions from software publishers are not included in cloud computing, even if the software is accessed over a network.

Third, although the investment related to cloud computing poses no novel problems of a conceptual nature, applying the SNA and BPM6 principles regarding own-account production, economic ownership, and residency to cloud computing investment may involve practical compilation challenges. Large cloud computing enterprises engage in significant own account investment in IT equipment that may be hard to measure. Questions of economic ownership may arise from long-term contracts for dedicated access to servers or other resources in a cloud computing datacenter that could qualify as financial leases. The terms of cloud computing provider's lease of buildings housing datacenter equipment can also raise questions of economic ownership.

Fourth, cross-border flows of cloud computing services are likely to be important in many economies and may be challenging to measure. Ordering, production, and use of cloud computing services can potentially take place in different countries. Experiments on collecting data from major cloud computing enterprises on gross flows of cross-border cloud computing services could shed useful light on the potential measurement challenges. However, unpaid cross-border data flows may make the sourcing of at least some consumption of cloud computing services, or the destination of some cloud computing production difficult to ascertain. International collaboration between national accountants and experts on balance of payments statistics is recommended to develop shared guidelines on international transactions involving remotely accessed computing services providers and the global cloud computing industry.

Fifth, issues related to price and volume measures of cloud services and services enabled by cloud computing should be further explored and guidance beyond the SNA should be developed.

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Annex A: The Growth of Cloud Computing

Cloud computing has grown rapidly since its 2006 emergence. Reports on cloud computing from Gartner put the industry's global revenue at $270 billion in 2020 (Table 1) and project that it will reach $411 billion in 2021. The capital investment supporting the worldwide grow of this industry is also quite substantial: the Synergy Research Group estimates that it exceeded US $110 billion in 2018, rising to US $150 billion in the four quarters ending in Q1 of 2021.

A significant share of the industry's global revenue comes from the US: BEA's digital economy satellite account puts US output of cloud computing services in 2018 at about $108 billion, and the US Census Bureau's *Service Survey* shows revenue of $126.2 billion in 2018 from data processing and hosting products for NAICS industry 518210 – *Data processing, hosting, and related services.*[10]

Table 1. World and U.S. Cloud Computing Services Output

(Billions of Current Year Dollars)

Source	Scope	2013	2017	2018	2019	2020
Gartner press releases	Worldwide sales of Business Process as a Service (BPaaS), SaaS, PaaS, IaaS, and cloud management and security services. Desktop as a service included in 2021	N.A.	145.3	197.7	242.1	270.3
BEA Digital Economy Satellite Account (2021 release)	US – relevant products of NAICS industries: 511210 Software publishers 518210 Data processing, hosting, and related services 5191301 Internet publishing 5191302 Web search portals 5414 Specialized design services 541511 Custom computer programming 541512 Computer systems design services 541513 Computer facilities management 541519 Other computer related services	76.8	100.7	107.9	109.0	161.8
US Census Bureau Service Annual Surveys	Data processing, IT infrastructure provisioning and hosting products of NAICS industry 518210	85.7	110.1	125.1	135.0	146.4
Addendum:						
US Census Bureau Service Annual Survey, 2020	NAICS 518210 (all products)	116.7	157.5	175.1	193.2	205.9

[10] Hooton (2020) considers both direct output of cloud computing participants and multiplier effects and arrives at estimate of direct and indirect output of 181.4 billion dollars in the US in 2012.

Annex B: Intermediate and Final Uses of Cloud Computing and Related Output

Baer, Lee and Tebrake (2020) note the widespread usage of cloud services by industries in OECD countries. In BEA's detailed benchmark supply-use tables (SUTs) for 2012, the main supplier of cloud computing services is the *Data Processing, Hosting, and Related Services* industry – NAICS 518200. Intermediate uses accounted for most of this industry's output of the US $110 billion, followed by investment in intellectual property assets such as software. Intermediate consumption of these services amounted to US $77 billion, of which $23 billion was used by governments, $9 billion was used by the financial services sector, $4 billion was used by the information sector. Uses of the remaining $41 billion were spread across a wide variety of industries. An additional $17 billion of this industry's output was used for investment in software and other intellectual property assets, and $16 billion was consumed by households and nonprofit institutions serving households.