SNA/M3.21/7.2

17th Meeting of the Advisory Expert Group on National Accounts,
15, 16 and 19 November 2021, Remote Meeting

Agenda item: 7.2

Measuring Cloud Computing in Macroeconomic Statistics

The attached paper provides background information on cloud computing and identifies conceptual and practical issues for measurement of transactions associated with cloud computing. It also recommends development of separate measures of cloud computing and suggests measurement techniques. A summary of the main points is as follows.

AWS defines cloud computing as “the on-demand delivery of compute power, database storage, applications, and other IT resources … via the internet with pay-as-you-go pricing.” Cloud computing enables services delivered over the internet to replace on-premises IT equipment and software. As a result, a considerable share of the IT capital stock has moved into the hands of cloud computing providers and large digital platforms.

Substitution of online access to IT hardware and software for on-premises capital stocks can raise questions of economic ownership. A cloud computing customer may have a service contract providing long-term access to a dedicated server. Financial accounting rules would treat this sort of contract as a financial lease. Also, the 2008 SNA treated software copies as fixed capital formation, but nowadays software users tend to access the software in the cloud or via a subscription to automatic updates delivered over the internet. Although such modes of access would normally be classifiable as intermediate consumption of services rather than fixed investment in software, the software user may have acquired a long-term license that would qualify as a software fixed asset.

Measuring cloud computing involves practical challenges. Two of these concern investment. Switching from on-premises computing to cloud computing requires expenditures on software and in training on the use of this software that may be missed. In the case of the cloud computing suppliers, the problem is hard-to-measure own-account investment in equipment: major cloud computing enterprises may design and fabricate their own servers and networking equipment to improve customization and reduce costs.

International trade in cloud computing services is a third practical measurement challenge. Multinational cloud computing enterprises are unlikely to respond to requests for detailed information on the source of supply of the services consumed in an economy or the residence of the users of the services that they produce in an economy. However, national accountants should be able to estimate the total consumption and total production of the enterprise’s cloud computing services in each economy and at least estimate the net flows required to balance demand and supply.

Questions for the AEG

1. What is appropriate to include in the definition of cloud computing? Is specifying pay-as-you-go pricing, as in the AWS definition, necessary for statistical purposes?
2. Should the cloud computing industry and its products be added to the industry and product classification systems?
3. What types of services should be included in cloud computing products? Business-process-as-a-service, which lets software automate certain labor-intensive processes, is often included along with the core cloud services of infrastructure-as-a-service (Iaas), function-as-a-service (FaaS), platform-as-a-service (PaaS), and software-as-a-service (SaaS). If a software publisher supplies a subscription to software that is run in the cloud or automatically downloaded to the user's computer, is that a cloud computing product?
4. Under what circumstances would a contract for dedicated access to a server hosted by a cloud computing provider make the user the economic owner of the server?
5. Does the nature of the software user's license determine whether software accessed in the cloud is fixed asset of the software user?
6. What are the prospects for measuring cross-border flows of cloud computing services on a gross basis? Should net international flows be imputed to cover imbalances between economies' production and consumption of cloud computing services?

Measuring Cloud Computing in Macroeconomic Statistics

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October 28, 2021

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Introduction

Cloud computing providers supply on-demand IT services via the internet. These services include infrastructure-as-a-service (IaaS), platform-as-a-service (PaaS), function-as-a-service[1] (FaaS), and software-as-a-service (SaaS) (Bryne, Corrado and Sichel, 2018). Discussions of cloud computing often also include specialized business process software run in the cloud, or Business Process as a Service (BPaaS).[2] While the core cloud services are replacements for capital stock ownership, BPaaS is a technology for automating labor-intensive tasks.

The history of cloud computing could be traced to the business process software and storage being supplied over the internet by the late 1990s. However, the real birth of cloud computing as revolutionary technology can be dated to the IaaS offered to the public by Amazon Web Services (AWS) in 2006, which leveraged computing technology that Amazon had previously developed to launch its third-party marketplace. Google, Alibaba Cloud Service, and Microsoft Azure followed with their own cloud computing services over the next few years.

The growth of cloud computing has been rapid. Gartner's reports on cloud computing put the industry's global revenue at almost $200 billion in 2018 (Table 1) and project that it will surpass $330 billion by 2021 (Table 1). 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*.[3]

This paper briefly analyzes some conceptual and practical issues in measuring cloud computing in national accounts, price statistics and international transaction accounts and recommends solutions. Many of these issues have been previously examined, often in more detail – see, for example, Byrne, Corrado, and Sichel (2018), Coyle and Nguyen (2018 and 2019) and Baer, Lee and Tebrake (2020).

The organization of this paper is as follows. It first discusses the definition of cloud computing and the economics driving the adoption of this technology. Next it reviews the current treatment of cloud computing in BEA's accounts. It then considers conceptual and practical issues for measurement, with a focus on investment in IT capital by the users and providers of cloud computing services. A brief discussion of measurement of price and volume indexes for cloud computing and products made possible by cloud computing follows. Last, the paper considers challenges for measurement of international transactions associated with cloud computing. A conclusion section summarizes the main findings.

[1] FaaS resembles PaaS because the user does not have to manage the deployment of a virtual server the way users of IaaS do. Alexa's skills are an example of a product enabled by FaaS (Baez, 2020).
[2] In the 2012 Economic Census, business process management services (NAPCS 70143000) accounted for 23 percent of the sales of the NAICS 518210, "Data processing, hosting, and related services".
[3] 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.

Table 1. Estimates of Cloud Computing Services Output in the U.S. and the World

(Billions of Current Year Dollars)

Source	Scope	2013	2017	2018	2019
Gartner press releases	Worldwide sales of Business Process as a Service (BPaaS), Saas, PaaS, IaaS, and cloud management and security services	N.A.	145.3	197.7	242.1
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
US Census Bureau Service Annual Surveys	Data processing, IT infrastructure provisioning and hosting products of NAICS industry 518210	85.8	111.2	126.2	133.9
Addendum:					
US Census Bureau Service Annual Surveys	NAICS 518210 (all products)	116.8	157.5	175.3	191.5

Definitions of Cloud Computing

The National Institute of Standards and Technology (NIST) defines cloud computing as a service offering "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." AWS has a more concise definition: "the on-demand delivery of compute power, database storage, applications, and other IT resources … via the internet with pay-as-you-go pricing."

However, specifying the pricing formula may make the definition too narrow for statistical purposes. The documentation for BEA's digital economy satellite defines cloud computing as:

> Computing services based on a set of computing resources that can be accessed on demand with low management effort, including remote and distributed hosting, storage, computing, and security services (Nicholson, 2021)

Cloud computing is not yet defined as a separate industry or product in official classification systems and business surveys. Surveys on IT services typically focus on consulting services and traditional data processing activities (Baer, Lee, and Tebrake, 2020), with cloud computing products contained in broader aggregates on data processing and other services. Because official business surveys have not collected separate data on on-demand IT services accessed over the internet, estimating cloud computing services requires assumptions and supplementing data from official sources with private data. For its digital economy satellite account, BEA uses private data from Statistica to fill gaps in official source data on cloud computing (Nicholson, 2020).

The sizeable scale and rapid growth of cloud computing make the cloud computing industry and cloud computing products appropriate to include in the updated international industry and product classification systems. Separately identifying cloud computing services would facilitate and encourage their inclusion in official economic surveys and in the detailed supply and use tables (SUTs).

The Rise of Cloud Computing

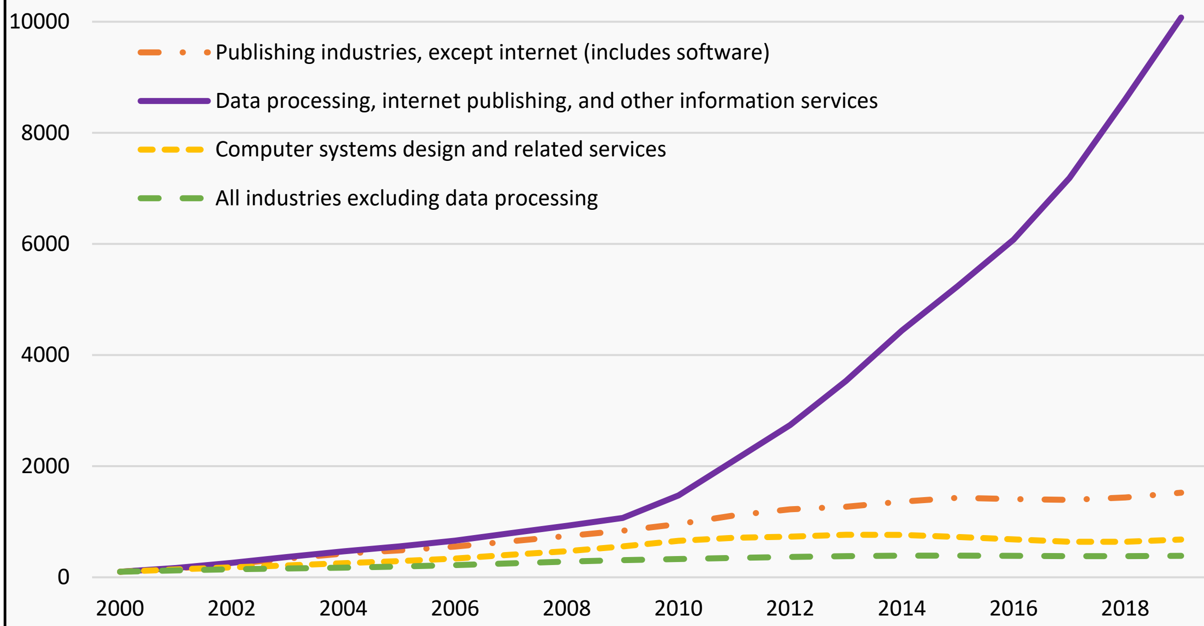
Cloud computing has changed how IT services are delivered. The substitution of cloud computing services for on-premises IT equipment is reflected in the relocation of the IT hardware capital stock reported in the *BEA-BLS Integrated Industry-level Production Account for the United States*. By one metric, the single industry group containing cloud computing accounted for half of the economy-wide growth of the hardware capital stock over the 10 years ending in 2019. This is because the real hardware stock of that industry group grew by a blistering 25 percent per year, while the real hardware capital stock of all the other industry groups averaged just 2.3 percent per year (Figure 1).

The rapid growth of cloud computing can be attributed to its advantages of lower cost, greater 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) enables much of the cost savings. Cloud computing servers' often have double the capacity utilization rate of conventionally managed servers. The economies of scale also enable savings on labor, as cloud computing customers can avoid significant labor costs are 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, without cloud computing Zoom would have been unable to accommodate the sudden 30-fold increase in demand that it experienced when the pandemic caused office workers to start working from home. 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.

The growth of cloud computing eventually will slow. Acquiring and operating their own IT equipment and is still economical for very large users of IT capital such as Dropbox. Also, cloud computing software cannot replace customized on-premises software for users who require unique features or capabilities. Finally, cloud storage of sensitive data may be perceived as riskier than on-premises storage.

Figure 1: Computer Hardware Real Capital Stock
(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.

Current Treatment of Cloud Computing in BEA's Accounts

The *Data Processing, Hosting, and Related Services* industry – NAICS 518200 in the detailed benchmark supply-use tables (SUTs) for 2012 is the main supplier of cloud computing, which is not shown separately. BEA classifies most payments from business and government to cloud computing providers as purchases of services for intermediate consumption. The intermediate uses of this industry's output amounted to $77 billion spread across many industries.[4] Large users of the intermediate services were government ($23 billion), the financial services sector ($9 billion) and the information sector ($4 billion).

A further $17 billion the industry's output by business and government was used for investment in software and other intellectual property assets. BEA treats subscription software as investment in software fixed assets, including subscription software that is accessed remotely. (Metered on-demand SaaS from cloud computing providers is treated as intermediate consumption). This approach to software subscriptions represents an adaptation of BEA's longstanding treatment of packaged software to a change in the technology for delivering software. Extending the treatment of packaged software to subscription software prevented an artificial break in the software investment series when software subscriptions began to supplant packaged software. BEA's treatment of packaged software and software

[4] Baer, Lee and Tebrake (2020) also note the widespread usage of cloud services by industries in OECD countries.

subscriptions is consistent with SNA (10.100 and 10.111) guidance on packaged software and licenses for use of intellectual property for more than a year, though international practices vary.

Finally, about $16 billion of the services of industry 518200 was consumed by persons (i.e., households and nonprofit institutions serving households – NPISH). Cloud computing services are part of this total, as NPISHs can be significant users of cloud computing, and many households use cloud storage.

BEA does publish separate estimates of output of cloud computing services in its digital economy satellite. These estimates bring together the relevant products of NAICS 518200 and other industries, as shown in the second row of Table 1. They show that US cloud computing output already surpassed $100 billion by 2017.

Measurement Questions and Challenges arising from Cloud Computing

Substitution of Cloud Computing Services for Investment in IT Fixed Capital

The tradition role of capital as a key in production is reflected in its first position in the usual formulations of the arguments of the production function. In these formulations, value added Y equals

$$Y = f(K,L),$$

or total output Y* equals

$$Y^* = f(K,L,E,M,S),$$

where K and L are primary inputs of capital and labor, and E, M, and S are intermediate inputs of energy, materials, and services. Yet cloud computing has reduced the primacy in production of capital by making intermediate inputs of services a highly competitive substitute for an IT capital stock. A further source of substitution of S for K is an emerging trend for non-IT capital equipment incorporating software and a connection to the internet to be supplied via an operating lease (a type of lease in which the equipment supplier is responsible for maintenance and upkeep). Equipment incorporating software can undergo quality improvements when the software is automatically updated. Under the operating lease treatment, the services supplied to the user of the equipment could be adjusted for such quality changes.

As in the more familiar case of outsourcing that replaces labor inputs, outsourcing the production of capital services inputs to cloud computing providers reduces value added. This can have implications for the interpretation of the growth of an industry's value added and labor productivity as measured by value added per hour worked. The industry composition of GDP could also be affected.[5] Information on spending on cloud computing services could help data users to interpret these statistics properly.

The substitutability of cloud computing services for IT capital stock ownership can also raise classification questions that affect the measurement of investment.[6] In financial accounting, a long-

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[5] Baer et al. (2020) discuss changes in the industry composition of GDP and other effects on the accounts of substitution of cloud computing services for investment in IT capital. Patterns of foreign trade could also be affected if cloud computing services are imported or exported.

[6] Cloud computing has also contributed to the rising importance of intangible assets, particularly software and data assets. Growing investment in intangibles is making overall investment and capital stocks harder to measure (Crouzet and Eberly, 2021 and Corrado et al. 2009).

term contract giving the cloud computing user access to a dedicated server would normally be considered a financial lease[7], making the user the economic owner. However, the SNA would not necessarily have to follow this approach; the SNA generally treats the party that bears the risk and that is responsible for the maintenance and upkeep as the economic owner, and this might be the cloud computing provider. Also, a special treatment for contracts for exclusive access to a server may not be feasible in practice.

The SNA implies that software licenses lasting more than a year are fixed assets. This guideline should still apply if the licensed software is hosted in the cloud.[8] If separate payments are made for a long-term software license and the computing time needed to utilize the hosted software, the license fee would represent the purchase of a fixed software asset and the computing time would represent purchases cloud computing services. Alternatively, if the cloud computing provider collects a single-use license fee as part of the changes for metered SaaS, the entire transaction should be treated as a purchase of cloud computing services. In this case, the software is an asset of the cloud computing provider, who will have purchased a license from the software publisher.

Software publishers may also host the software themselves. Purchases of licenses to use the hosted software that last for more than a year represent investment in software fixed assets, not purchases of intermediate services. However, software publishers may also distribute their software via subscriptions in which the user receives regular updates of the software. Frequent updates resemble the sort of maintenance that is characteristic of an operating lease, making the software subscription a type of software-as-a-service rather than an investment in software fixed assets. When the SNA 2008 was being prepared, software publishers distributed packaged software on physical media with a license that never expired. Purchasing this sort of software copy was hard to distinguish from investment in a tangible fixed asset. However, the way software is supplied has changed.

In addition to conceptual correctness, practical feasibility and the utility of the information that would be provided must be considered. Software subscriptions often come with the one-year licenses, just under the SNA (10.100) threshold of for the license to be a fixed asset. However, these licenses often renew automatically in the expectation of a multi-year period of use of the software. A treatment of the one-year licenses for subscription software as equivalent to purchases of software copies therefore seems to be an attractive pragmatic solution. A separate treatment of software licenses lasting less than a year, or of long-term contracts for dedicated access to a server may also turn out to be difficult to implement.

[7] In the SNA (17.301-17.309) financial leases are a financing mechanism while operating leases entitle the lessor to a flow of services.

[8] Financial accounting rules of U.S. GAAP also capitalize software licenses and on-premises (packaged) software.

Cloud Computing Implementation Costs

Business accounting guidelines capitalize cloud computing implementation costs – the costs involved in transitioning to cloud computing.[9] Investment in software to access and use cloud computing resources and employee training on the use of this software may be 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 classified as organizational capital intangible assets, a type of intangible asset that is out of scope for national accounts.

Cloud Computing Providers' Fixed Capital Investment

As noted above, cloud computing providers have rapidly expanded their capital stock of IT equipment. Consistent with this, AWS reports that over the 10 years ending in 2020 it invested $35 billion in data centers in northern Virginia alone, the bulk of which went to equipment.[10] Cloud computing providers have also invested in software, R&D, and structures, including datacenter buildings, land networks, and submarine cables.

One issue that could arise in measuring investment by cloud computing providers is where to record the investment in submarine cables. This investment should be attributed to the country of residence of the entity that owns the cable, which may be the headquarters of a multinational enterprise (MNE) or one of its foreign affiliates. If ownership of the submarine cable is shared among enterprises resident in different countries, the investment would be allocated in proportion to ownership shares.

Buildings that house cloud computing datacenters can also present issues of classification and inclusion in supplemental estimates of cloud computing investment because many of these buildings are leased. If the occupancy arrangement is a financial lease, the cloud computing provider must be deemed the economic owner of the datacenter structure, while if it is an operating lease, the structure is a rental from the Real Estate industry. SNA 2008 guidelines for distinguishing between operating and financial leases treat the party responsible for operations and maintenance and that bears the risk as the economic owner of the asset. Most leases for datacenter buildings appear to be operating leases under these criteria. As a result, investment in datacenter buildings by the real estate industry (specifically datacenter REITs) would have to be included in a complete measure of cloud computing investment.

Finally, a measurement problem that could cause underestimation of fixed capital formation and GDP comes from the significant amounts of own-account investment undertaken by major cloud computing providers and other operators of hyper-scale datacenters. Operators of hyper-scale datacenters produce considerable R&D, software, and equipment for their own use. Own-account investment in R&D and software is common, so statistical agencies should already have procedures in place to measure these types of investment by their cost. The own-account equipment investment is, however, usual enough to be easily missed. Statistical agencies generally assume that the equipment users do not design and manufacture their own equipment and estimate equipment investment from source data on shipments. However, major cloud computing providers can often improve equipment's performance and reduce its

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

[10] See https://d1.awsstatic.com/WWPS/pdf/aws-economic-impact-virginia.pdf. Spending on equipment accounts for most of the $35 billion, followed by spending on construction. However, a small portion of the $35 billion is really data center operating expenses, not investment as the term is defined in national accounts.

costs by designing and fabricating (sometimes with the help of a contract manufacturer) their own servers and networking equipment. In effect, self-produced equipment can be optimized for cloud computing workloads.

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 any other relevant expenses. To get an indication of the scale of the overlooked equipment investment, Byrne, Corrado and Sichel (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.[11]

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).

The economic welfare gains linked to cloud computing come partly from the new digital products made possible by this technology. In principle, quality adjusted price indexes could capture the gains from the new and improved products made possible by cloud computing, but this may not be possible in practice. The relative quality of a new product with distinctive features may be impossible to estimate without 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.

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 two hundred different services, some with complicated characteristics. Pricing formulas also tend to be complicated: charges for cloud computing include a combination of subscription fees and metered usage charges, and the packages offered have a range of price-determining characteristics (Baer, Lee, and Tebrake, 2020). Also, pricing formulas can change – for example, AWS switched from rounding IaaS compute time up to the nearest hour to rounding up to the nearest second. Finally, 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 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.

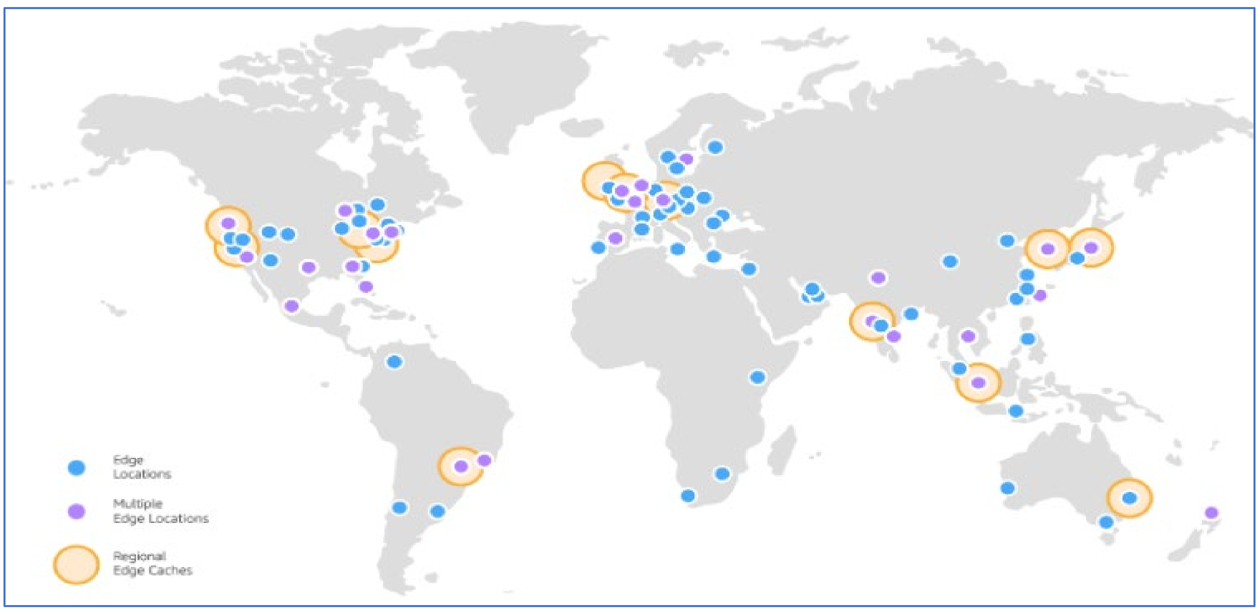
[11] BEA has since revised the estimates of cloud computing providers' investment in equipment.

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 of will distort industries' contributions to GDP growth but not GDP growth itself. Thus, in general, mismeasured deflators for cloud computing services would cause mismeasurement of GDP growth only if the services are exported or imported. Cloud computing may, however, have indirect effects on measurement of GPD growth. Many of the new services that have appeared in the digital economy rely on cloud computing. Adjusting the household consumption deflator for the benefits of these new digital services could raise estimated GDP growth.

International Transactions associated with Cloud Computing

Cloud computing services are consumed in every economy. Cloud computing enterprises supply services to this global market through cross-border data flows and by constructing and equipping local datacenters and edge locations. The cloud computing providers' foreign direct investment (FDI) has been substantial. AWS, for example, has over sixty owned or leased[12] datacenters in foreign locations. It also has 230 edge location facilities scattered across the globe (Figure 2).

Figure 2: AWS Edge Locations and Regional Edge Caches



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

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).

[12] The leased foreign datacenters may be owned by multinational REITs.

Commercially valuable international data flows often take place without payment, sometimes because they are between related parties.[13] Estimates of international trade in digitally delivered services, including computer services, omit these unpaid data flows. Unpaid cross-border data flows also complicate measurement of the location of production of cloud computing services. Cloud computing users whose own customers are in foreign locations may request that their computing tasks be assigned to the datacenter to closest their customer to minimize latency. In other cases, the cloud computing provider shifts tasks to foreign datacenters for workload balancing purposes or stores the data in a foreign location to ensure uninterrupted data accessibility in the event of a natural disaster or data center outage. Finally, software updates developed at an MNE's headquarters are often pushed out to datacenters around the world as a way of supplying SaaS. All these factors can make the physical location of production of a cloud computing service hard to determine.

Statistical agencies are likely to have limited success in collecting detailed information on cross-border consumption of cloud computing output. The output of a cloud computing MNE in each country could be measured using data on payments from cloud computing customers and on payments or transfers within the MNE and, if necessary, data on costs of production.[14] Every datacenter or edge location establishment should have at least enough income to at least cover its costs of production. If not, its output can be measured by its costs.

The total consumption of computing services by the customers in each country and the primary sources of supply of these services should also be feasible to measure. Taken together, the consumption and production occurring in each economy should allow derivation of a set of net international flows of cloud computing services that satisfy the constraints that the services produced in each country must all be consumed by someone and that services consumed in each country must all be produced by someone. International collaboration through a clearinghouse for this kind of data would be helpful for allowing national statistics offices to produce accurate, mutually consistent estimates.

Another problem in measurement of international trade and investment is the influence of tax avoidance behavior of MNEs on both their actual and their purported transactions. MNEs in industries with significant intellectual property (IP) assets often redomicile their IP and adjust their international transfer prices to allocate an exaggerated share of their global production to low tax jurisdictions. 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.

Conclusion

Cloud computing is a transformative technology that has allowed services delivered over the internet to replace on-premises IT equipment and software – inputs of IT capital services have, in effect, been

[13] Data flows may also be paid in-kind as part of a bartered exchange. Such barter transactions are conceptually in scope for trade statistics, but the gross values of the bartered services may be impossible to determine. In practice, a net monetary settlement may cover the imbalance between bartered services received and supplied, at least allowing the trade balance to be measured.

[14] Payments that an MNE makes on behalf of its local affiliate must be rerouted through the affiliate. This makes the cost of production a floor on the estimate of each countries' output.

outsourced. This has increased the share of the IT capital stock owned by cloud computing providers and major digital platforms.

Cloud computing poses both conceptual and practical questions for economic measurement. Conceptual questions of classification are raised by dedicated servers located in cloud computing datacenters, which could be viewed as financial leases, and licenses for software accessed in the cloud or supplied through a subscription to regular software updates. The practical questions include development of measures of a cloud computing industry and cloud computing products, capturing cloud computing providers' own-account production of IT equipment, and estimating the imports, exports, and local production of cloud computing services supplied by cloud computing MNEs.

Five conclusions and recommendations are worth highlighting. First, as fast-growing industry with annual output of US $300 billion and annual investment of US $150 billion, cloud computing has become important enough to incorporate explicitly in the international product and industry classification systems. This would facilitate collection and reporting of separate data on cloud computing, which would also be appropriate to prioritize. National accounts must keep up with changes in the economy.

Second, financial accounting rules would treat contracts that entitle the cloud computing user to exclusive access to a server as financial leases (i.e., as changes in economic ownership). This raises the question of whether a similar treatment would be appropriate in national accounts. Yet the SNA criteria of risk-bearing and responsibility for maintenance may argue against treating these contracts as financial leases.

Third, payments for software subscriptions may be appropriate to treat as purchases of a service rather than as purchases of software fixed assets. However, long-term licenses for software hosted in cloud computing datacenters are likely to represent software assets of the user.

Fourth, indexes of the prices of a subset of standardized cloud services imply price declines, highlighting the need to develop suitable deflators for cloud computing services. However, the complexity of the product offerings and the frequent introduction of new products and product features make it necessary to base the price index for cloud computing on a subset of standardized products.

Finally, the major suppliers of cloud computing have globe-spanning networks of computing facilities and clients. Precise measurement of the international transactions in cloud computing services across these networks may be impossible, but plausible estimates of the international flows may be implied by the estimates of each country's consumption and production of cloud computing services.

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