
Measuring Cloud Computing in Macroeconomic Statistics

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Outline of the Presentation

Growth/importance of cloud computing in the digitalized economy

Defining cloud computing industry and products

Measurement issues

- Replacement of capital stock ownership with purchased services and related questions of economic ownership

- Capital stock of cloud computing providers

- Prices and volumes of cloud services and services that they enable

- International flows of cloud computing services and FDI

Concluding thoughts

Growth of Cloud Computing

The Internet enabled remote delivery of computing services in late 1990s, but transformative cloud computing technology emerged with AWS in 2006

Cost, agility, and security advantages spurred rapid growth

- Costs are lower because of virtualization technology and economies of scale

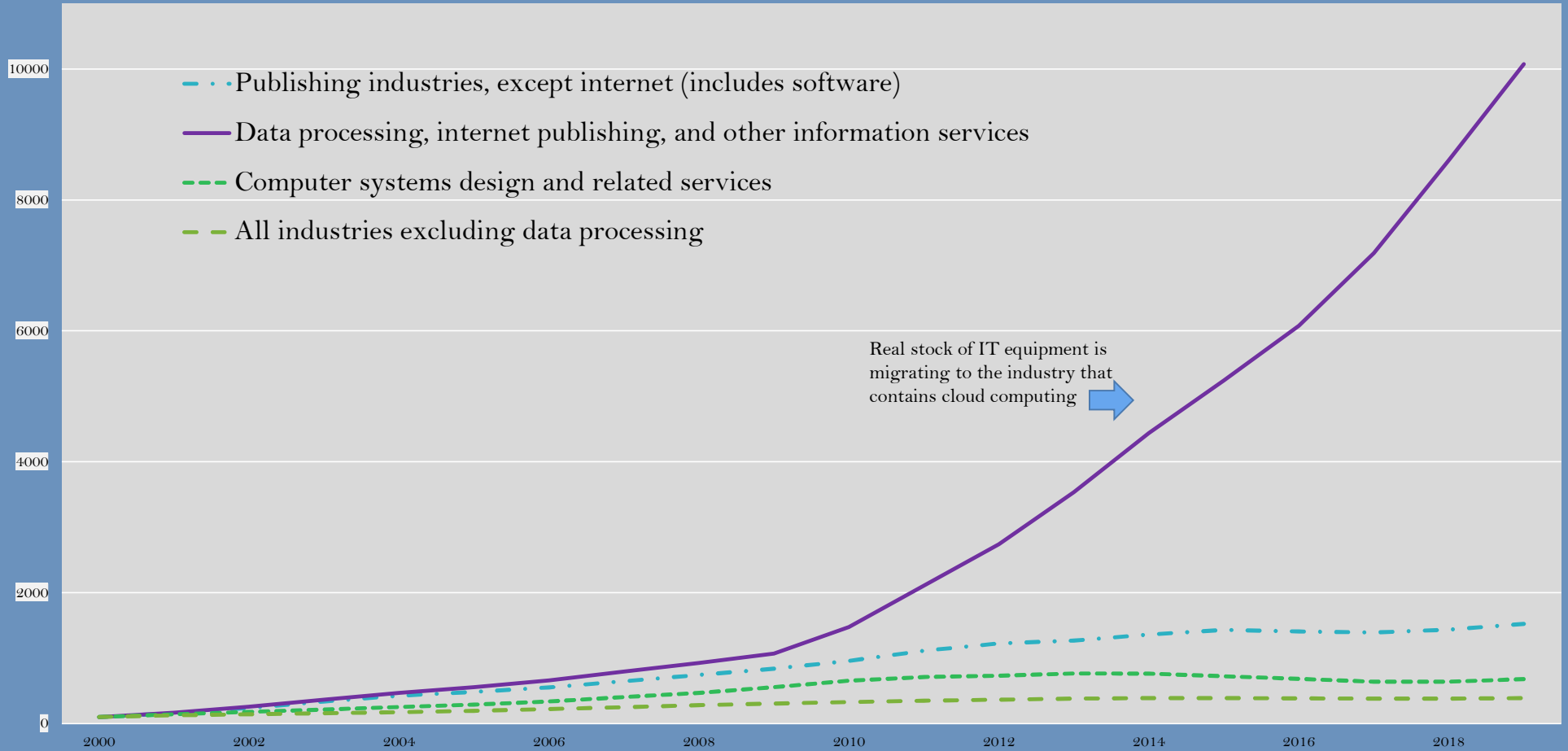
Gartner predicts worldwide revenue will exceed \$300 billion in 2021

Synergy Research Group predicts worldwide investment will be \$150 billion

BEA's KLEMS accounts imply that half the growth of stock of IT hardware occurred in cloud computing & related industries

Suggest need to add cloud computing industry and products to classification systems

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



Real stock of IT equipment is migrating to the industry that contains cloud computing →

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.

Definitions of Industry and Products

AWS definition of cloud computing: “The on-demand delivery of compute power, database storage, applications, and other IT resources ... via the internet with pay-as-you-go pricing.”

- Pricing formula not important for statistical purposes

Definition in BEA’s satellite account: “computing resources that can be accessed on demand with low management effort”

Cloud Computing Products:

Infrastructure-as-a-service (IaaS)

Platform-as-a-service (PaaS)

Function-as-a-service (FaaS)

Software-as-a-service (SaaS), which includes Business-process-as-a-service (BPaaS)

Can debate whether to include BPaaS and *software subscriptions* in cloud computing SaaS

Measurement Issue 1: Purchased services replacing capital stock ownership

Capital has always been a key input in production

- It the first input in the production function $f(K,L,E,M,S)$

Cloud services are leading to substitution of S for K

Hard to analyze the role of capital in production when cloud users' on-demand access to a vast capital stock could be considered a kind of virtual capital stock

Leads to questions of economic ownership: under appropriate circumstances long-term contracts for access to IT resources could represent financial leases

- Many cloud computing users have contractual control over a server
- Software user is economic owner of a long-term license for software accessed in the cloud
- But subscriptions to software (and equipment) seem like operating leases
 - Updates of the software may be pushed out frequently

Measurement Issue 2: Investment and capital stock of cloud computing providers

Investment/capital assets of cloud computing providers presents two measurement problems

1. Major cloud computing providers (and major digital platforms) have significant own-account investment in equipment, software, and R&D (Byrne, Corrado and Sichel, 2018)
The own-account investment in software and R&D should be captured by standard procedures for measuring cost-of-production
But the industry's own-account investment in equipment may require new procedures
Cloud computing providers design -- and sometimes fabricate -- their own servers, networking equipment and chips to customize them and to reduce their cost
2. Data center structures are often leased from specialized real estate owners
 - The leases are likely to qualify as operating leases

Data Center Ecosystem Leaderboard

– H1, 2021 –

	NORTH AMERICA	EMEA	OCEANIA	ASIA	LATAM
1	EQUINIX	DIGITAL REALTY	EQUINIX	EQUINIX	EQUINIX
2	DIGITAL REALTY	EQUINIX	NEXT DC	NTT Communications	DIGITAL REALTY
3	CORESITE	LUMEN	VOCUS	中国电信 CHINA TELECOM	LUMEN
4	LUMEN	KDDI	TELSTRA	sunvision	navegalo
5	cologix	NTT Communications	GLOBAL SWITCH	ST Telemedia Global Data Centres	IO
6	CyrusOne	Telia Carrier	Spark	sify	AMERICAN TOWER
7	DATABANK	gtt	DATACOM	DIGITAL REALTY	中国移动 China Mobile International
8	Cyxtera	BT	FUJITSU	GPX	marecatel
9	verizon	GLOBAL SWITCH	i s e e k DATA CENTRES • CLOUD • CONNECTIVITY	GLOBAL SWITCH	#matrix
10	FLEXENTIAL	verizon	macquarie DATA CENTRES	@Tokyo	transtelco

See the full results at cloudscene.com/news

Cloudscene's H1 2021 Data Center Ecosystem
Leaderboard

Measurement issue 3: *Price and volume change*

Measuring the relative quality of inventions like cloud computing as a substitute for on-premises computing requires strong assumptions

- New digital services enabled by cloud computing pose a similar problem

Challenges in constructing quality-adjusted price indexes for cloud services include lengthy and complex product menus and changing characteristics

Practical solution is to construct a quality-adjusted (e.g., hedonic) price index for a basket of the more straightforward products

Research indexes of cloud computing prices show substantial price declines

Most cloud services are for intermediate uses, which just matter for the **composition** of GDP, but price indexes for those that are traded affect GDP

Measurement Issue 4: *International transactions related to cloud computing*

Among the measurement problems from unpriced cross-border data flows is the constant shifting of the location of production of cloud services that these flows enable

MNE cloud computing providers can't report on detailed cross-border service flows

But they can provide information on economies' consumption and production of services

Can assume that output of establishments owned by MNEs \geq production expenses

Net flows of cloud services can be imputed to ensure that every economy's consumption is all produced somewhere, and every economy's production is all consumed somewhere

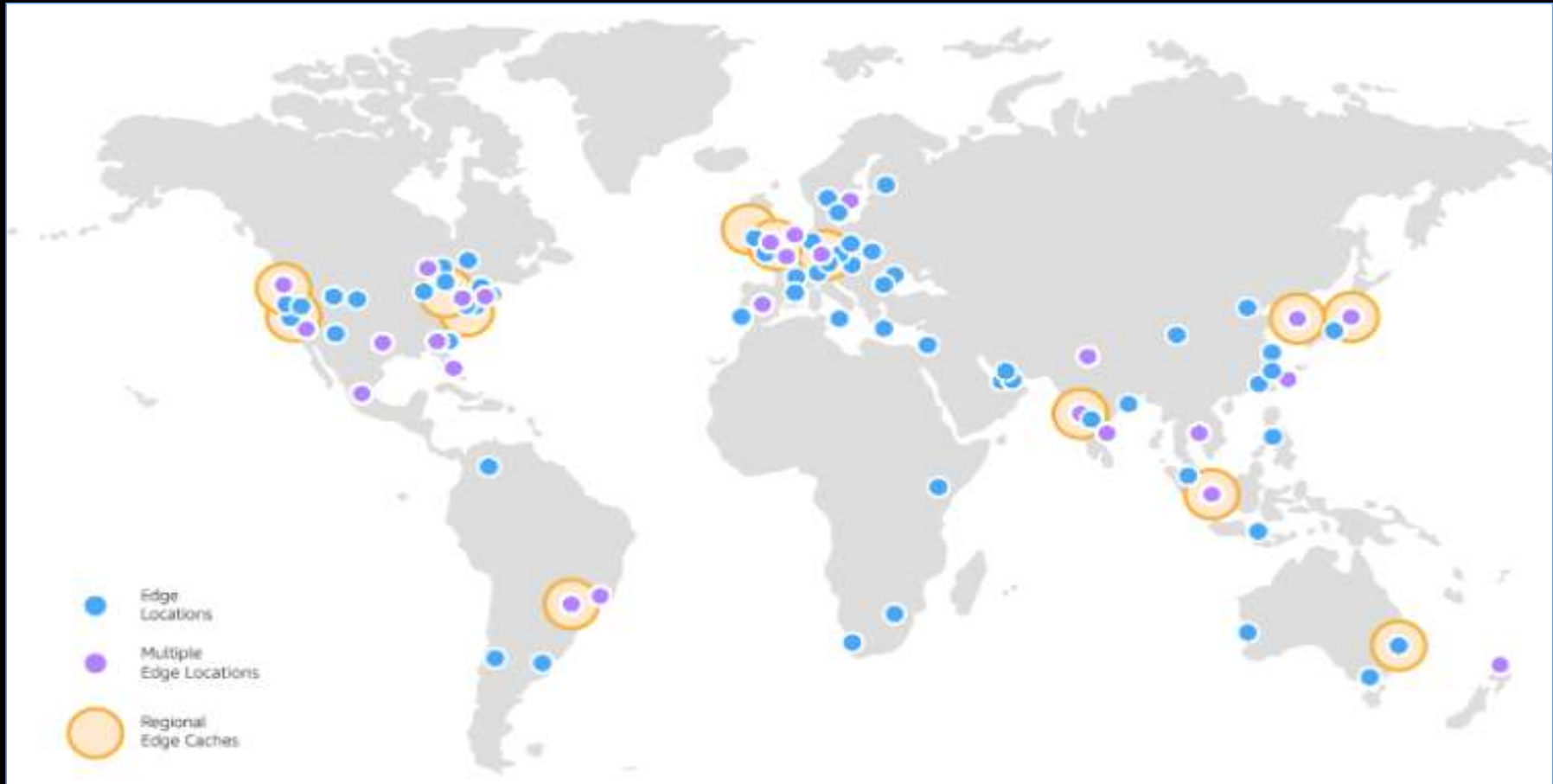
FDI related to cloud computing (equipment, software and structures) is significant

Investment in submarine cables should be allocated in proportion to ownership shares

Tax optimization by MNEs affects actual and reported locations of production of IT services

Ireland and Netherlands account for 53% of computer services exports (Baer et al., 2020)

AWS Edge Locations



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

Summary and Highlights

Cloud computing is growing fast and enables many digital services

Agreed definition and industry/product classification needed to support measurement and reporting

Substitution of S for K can lead to questions of economic ownership of resources hosted in the cloud (what to treat as a financial lease, software subscriptions, ...)

Cloud computing providers have significant own-account investment in equipment

No obvious way to measure cross-border flows of cloud computing services, but the net flows within a cloud computing MNE should be possible to estimate

Questions for the AEG

What is appropriate to include in the definition of cloud computing?

Has the time arrived to add cloud computing to our classification systems?

Should BPaaS and software subscriptions be included in cloud SaaS?

When should a contract for dedicated access to a hosted server be treated as a financial lease?

How to treat licenses for software run in the cloud, and subscription software?

Should net international flows be imputed to cover imbalances between economies' production and consumption of cloud computing services?