The Rise of Cloud Computing: Minding Your P’s and Q’s (and K’s)

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Bureau of Economic Analysis Advisory Committee

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Overview

• Definition of the cloud.

• How prevalent is cloud computing? (Q)

• How fast are cloud prices falling? (P)

• How large is investment by the cloud providers? (K)
Definition of the Cloud

NIST, 2011:
a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources.

Image source. Wikipedia. Created by Sam Johnston.
Definition of the Cloud: Cloud Services

**Software as a service (SaaS)**
Vendor-developed software

**Platform as a service (Paas)**
User-developed applications
(e.g. database program)

**Infrastructure as a service (IaaS):**
Basic computing
(virtual machines, storage)
Definition of the Cloud: Cloud Services

**Software as a service (SaaS)**
Vendor-developed software

Salesforce, ADP, Oracle, SAP, SAS

**Platform as a service (Paas)**
User-developed apps
(e.g. database program)

AWS Elastic Beanstalk
Microsoft Azure
Google App Engine

**Infrastructure as a service (IaaS):**
Basic computing
(virtual machines, storage)

Amazon Web Services, Microsoft,
Google Compute Engine, IBM
How prevalent is cloud computing? (Global)

Public Cloud Quarterly Revenue Flows
Q2 2015

Cloud Build
(hardware & software)
$7.0B
26% y/y growth

Colocation
(data center lease)
$2.8B
9% y/y growth

Public Cloud

Cloud Infrastructure Services
(IaaS, PaaS, Private/Hybrid)
$5.5B
49% y/y growth

Software as a Service (SaaS)
$6.6B
29% y/y growth

Also supporting
Internet Services
(Search, Social Networking, Email, E-Commerce Platforms, etc.)
>$100B
25% y/y growth

Source: Synergy Research Group

Note. Figures are global revenues.
How prevalent is cloud computing? (Global)

Figures include

- “cloud services” & internet services
- traffic between & within data centers
- public & private data centers

Source: Cisco Global Cloud Index, Forecast and Methodology, 2015-2020 and earlier editions.
How prevalent is cloud computing? (Domestic)

• A wide net to get an (imperfect) indicator of cloud company footprint in the domestic economy

• Company establishments may appear in multiple industries

• BEA Input-Output “industries” (groups of NAICS industries)

  • **514** Data processing, internet publishing and other information services

  • **5415** Computer systems design and related services

  • **511** Publishing industries, except internet (includes software)

  • 2015 gross output = **$903 billion**

*Compare broadcast & telecom $846 billion*
How Fast are Cloud Prices Falling? Data

- Prices and characteristics
  - Web scraped using Web Archive
  - 3 products each from 3 vendors

- Cloud Service Products
  - **Compute** (renting virtual machines)
  - **Storage** (renting storage)
  - **Database** (user-developed apps)

- Prices by Vendor
  - **2009**: Amazon Web Services (AWS)
  - Early 2014: Microsoft Azure
  - Late 2014: Google Cloud

### Amazon Prices: 2013-2016

<table>
<thead>
<tr>
<th>Product</th>
<th>Observations (prices)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compute (EC2)</td>
<td>4,079</td>
</tr>
<tr>
<td>Database (RDS)</td>
<td>5,340</td>
</tr>
<tr>
<td>Storage (S3)</td>
<td>445</td>
</tr>
</tbody>
</table>
How Fast are Cloud Prices Falling? Methodology

• **Compute:**
  - Hedonic adjacent-quarter regressions
  - Controls: *quantity of* processor power, memory, storage plus *fixed effects* for region, operating system, bus width, solid state drive

• **Database:**
  - Hedonic adjacent-quarter regressions
  - Controls: *quantity of* processor power, memory, input-output plus *fixed effects for* region, type of database software

• **Storage:**
  - Matched-model
  - Models distinguished by volume, access speed, region
### How Fast are Cloud Prices Falling? Results

<table>
<thead>
<tr>
<th>Prices for AWS Cloud Service Products (percent change, annual rate)</th>
<th>2009-2013</th>
<th>2014-2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compute (EC2)</td>
<td>-5.1</td>
<td>-10.5</td>
</tr>
<tr>
<td>Google</td>
<td></td>
<td>-11.4</td>
</tr>
<tr>
<td>Database (RDS)</td>
<td>-3.3*</td>
<td>-22.6</td>
</tr>
<tr>
<td>Storage (S3)</td>
<td>-12.1</td>
<td>-25.1</td>
</tr>
</tbody>
</table>

* Sample for RDS starts 2010:Q2

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* Prices for AWS Services

![Prices for AWS Services Graph](image)
How large is cloud investment?

- Cloud companies:
  - Amazon, Microsoft, Google, IBM, Rackspace (60%)
  - Adobe, ADP, Intuit, Oracle, Salesforce (5%)
  - LinkedIn, Facebook, Twitter, Yahoo!, eBay, Apple (35%)

- Telecom service providers
  - AT&T, Verizon, Sprint Nextel, T-Mobile, Century Link, and related companies

Source: Company financial filings.
How large is cloud investment?

- NIPA IT investment tracked the telecom boom
- But not the cloud boom
- A puzzle?

- Possible resolutions
  - Global v. domestic
  - Not all capex is IT
  - Unmeasured investment
  - Cloud is efficient

Source: Bureau of Economic Analysis. Company financial reports.
Note: IT investment includes communications equipment, computers and peripherals, and software.
How large is cloud investment?

• Recall industry focus
  • 514 Data processing, internet publishing, and other information services
  • 5415 Computer systems design and related services
  • 511 Publishing industries, except internet (includes software)

• NIPA fixed asset investment by type

• **Equipment and software investment has increased moderately since 2009.**
How large is cloud investment?

**Surge in electronic components use?**

- Output of 334 (computer & electronic prod.)
  - Boards, MPUs, memory, disk drives
  - Intermediate use not investment.
  - Make table => no final electronics produced by these industry groups

- How are the electronic components being used?
  - final processing performed on site before they can be employed?
  - Microsoft, Google contacts confirm some assembly takes place, essential proprietary software is added
How large is cloud investment?

Is full value of cloud equipment in investment?

- Value of equipment = Design + Software + Hardware
- Software: Own-account software included in software investment
- Design: IT design services included in computer investment.
- Hardware: value omitted?

Consider augmenting investment by value of components...
Conclusions: P’s

- Rapid price declines
- Indicate rapid technical progress
Conclusion: Q’s

• Quantity of cloud services is soaring
• Purchased IT services deserve attention in growth accounting
Conclusions: K’s

• Capital spending by cloud companies is enormous

*IF not be fully captured in the accounts*
• Investment understated.
• Productivity analysis affected
Summary: P’s, Q’s, and K’s

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Global Data Traffic by Datacenter Type

Prices for AWS Services

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