ICT prices and ICT services: What do they tell us about productivity and technology?

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based on a paper by David Byrne and Carol Corrado

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Figure: U.S. ICT E&S Investment and Prices

(a) Private ICT investment, percent of GDP
(b) ICT real price change, annual rate

Notes: Excludes software R&D. ICT prices are relative to the GDP deflator. Source: Authors’ elaboration of data from U.S. BEA.
ICT narrative needs to account for services (i.e., cloud platform) + incorporate more plausible ICT price measures.

Figure: **U.S. NonICT producers’ spending** on ICT and ICT Prices

(a) ICT E&S investment + intermediate use

(b) ICT real price change, annual rate
Outline of Talk

- Summary of Framework
- Summary of Measurement Results
- Macroeconomic Implications
Oulton (2012) proposed an approach to analyzing ICT based on a two-sector model of an open economy where one-sector is an ICT-producing/supplying sector.

Approach is similar to multi-sector growth accounting in which relative growth of TFP in ICT production is a key driver of growth and relative ICT price change reflects the TFP growth differential.

When the Oulton model is expanded to include ICT services, it still retains this fundamental property.
Model solution

- Relative ICT price change equals relative sector TFP change
  \[ \Delta \ln p = \Delta \ln A_N - \Delta \ln A_T < 0 \]

- The ICT sector contribution to growth in output per hour =

\[
\bar{V}_K + \frac{\bar{N}_T}{\bar{V}_L} (\Delta \ln p) + \bar{w}_T (\Delta \ln p).
\]

Investment (use) and diffusion (productivity) effects

Production effect
Model solution, continued

- Real output per hour in the \( N \) sector grows less than real output per hour in the \( T \) sector—implying that real ICT services output grows faster than other services in real terms.
- Purchases of ICT services are flows of **ICT capital** services in this model.
- Their relative price can be linked to a user cost expression that transforms the volume of capital employed in producing the service to a value for its services (a flow), i.e., the ICT services relative price will decline in tandem with the underlying ICT assets used to produce them.
Declines in ICT asset prices are understated

Note: Real ICT asset price change is relative to the GDP deflator, in percentage points.
Key takeaways

- Relative ICT price change remains squarely in negative territory
- Late 1990s looks very different from prior and subsequent history
- ICT asset price declines are understated by nearly 6 percentage points per year since 2004
- ICT productivity differential in balanced growth is estimated to be about 10 percentage points
Differential should be unsurprising:

Rate of private domestic ICT R&D is eye-popping!
ICT output share ($\overline{w}_T$) of final products has been about constant at 5.6 percent for past ten years.
Summing up

Evaluate the model’s implications for the contribution of ICT to the growth of OPH in balanced growth yields:

Total ICT contribution to OPH growth, in percentage points

\[
\text{Total ICT contribution} = \text{Investment (use) effect} + \text{Diffusion via intermediates (productivity) effect} + \text{Production effect}
\]

\[
= [0.077 \times 9.9] + [0.036 \times 9.9] + [0.056 \times 5.7]
\]

= 1.4 percentage points
Summing up

Evaluate the model’s implications for the contribution of ICT to the growth of OPH in balanced growth yields:

Total ICT contribution to OPH growth, in percentage points

\[ = [\text{Investment (use) effect } ] + [\text{Diffusion via intermediates (productivity) effect}] + [\text{Production effect}] \]

\[ = [0.077 \times 9.9] + [0.036 \times 9.9] + [0.056 \times 5.7] \]

\[ = 1.4 \text{ percentage points} \]

- This is a large contribution.
- Excluding the consumer final spending and government IU channels, the contribution via private industry spending is still large at 1.0 percentage points per year.
ICT platform shift—when application workloads are shifted to the cloud (private or public):

- The demand for computing equipment falls (for a given volume of services) ... and the demand for the software developers and software products that enable cloud technologies increases.

- From adopters’ perspective, *effective* declines in prices of ICT assets > declines in observed quality-adjusted prices of ICT assets.

- Underlying mechanism that boosts OPH is a reduction in the underutilization of ICT assets and greater efficiency in application development.

- With co-investments in business processes (intangibles) needed to reap full efficiencies of the latest ICT platform change, total factor productivity gains are likely to surface only after the technology diffuses on a wide scale.
Conclusions

- Improved measurement suggests ICT innovation is alive and well
- ICT’s contribution to $\dot{OPH}$ is likely to continue to be substantial ...
  - The productivity differential is about 10 percentage points
  - The level of ICT penetration via both capital stocks and purchased services is high
  - In the United States, the production effect from software products and consumer services is not high but a stable contributor to growth
- Costs of adjusting to the cloud platform—or headwinds from the financial recession, or failure of BI apps to generate returns as yet—appear to have restrained post–2010 productivity growth among nonICT producers
- At the industry level, TFP growth has not improved along with increased ICT use....despite the fact that co-investments in intangibles have been made
Conclusions (2)

As to price measurement,

- This paper introduced new prices for computer servers, storage equipment, and enterprise software that, along with earlier work on communications equipment enabled the construction of an ICT investment deflator more up to the task of analyzing the latest developments in ICT.

- The paper also suggested that, under certain assumptions, prices for ICT services that are forms of marketed ICT capital services (e.g., telecommunications services, cloud computing services, software subscription services) should move in tandem with the relative prices of the underlying ICT assets used to produce them.

- Despite advances introduced in this paper, new research and thinking about measuring software asset prices is badly needed.
Thank you.
### Table: Real ICT Investment Price Change (annual rate)

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<td><strong>-9.9</strong></td>
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<td>-11.3</td>
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<td>4. Software</td>
<td>-5.8</td>
<td>-6.6</td>
<td><strong>-5.7</strong></td>
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**Contributions to line 1:**

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**Memo:**

*Line 1 less BEA:*

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<tr>
<td>8. ICT investment</td>
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Increase in productivity of quality-adjusted server stock due to virtualization—12 percent per year

Figure: Application workload of U.S. server stock (Source: IDC)
Virtualization increases workload, containerization speeds application development

Containers vs. VMs

Containers are isolated, but share OS and, where appropriate, bins/libraries
TFP growth has not been improving along with increased ICT use

NonICT-producing U.S. industries

Note. Relative intensity is the use rate averaged over period indicated relative to its trend over the previous decade. TFP estimates are from BLS (i.e. not corrected for misstatement of ICT asset and services use price change).
... despite co-investments in intangibles that are crucial in the installation phase of new ICT platforms

NonICT-producing U.S. industries

Note. Relative intensity is the use or investment rate averaged over period indicated relative to its trend over the previous decade.