Information Technology and the Economy: Where Are We and Where Do We Go From Here?

Erik Brynjolfsson
Center for Digital Business
MIT Sloan School of Management

Overview

- ( Mostly ) Good News: IT & Productivity
  - Past and Present
  - Future
- Concerns
  - Inequality
  - Turbulence
  - Innovation Incentives
  - Mismeasurement: Beyond Productivity
- Policy Implications

U.S. Labor Productivity

Source: Bureau of Labor Statistics
IT and Productivity: The Data Speak

Computers are associated with greater productivity...

...But what explains the substantial variation across firms?

Complementarities: More than computers alone

The “old” vs. “new” Johnson & Johnson

<table>
<thead>
<tr>
<th>Old</th>
<th>New</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass production</td>
<td>Flexible Manufacturing</td>
</tr>
<tr>
<td>Managers make decisions,</td>
<td>All employees make decisions</td>
</tr>
<tr>
<td>workers are laborers</td>
<td></td>
</tr>
<tr>
<td>Piece rates</td>
<td>Team incentives/ownership</td>
</tr>
<tr>
<td>Hierarchy</td>
<td>Flat design</td>
</tr>
<tr>
<td>Few Standard products, long</td>
<td>Product diversity, short runs</td>
</tr>
<tr>
<td>runs</td>
<td></td>
</tr>
</tbody>
</table>

Cost Structure of a Large IT Project

<table>
<thead>
<tr>
<th>Category</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardware</td>
<td>$0.8</td>
</tr>
<tr>
<td>Software (ERP)</td>
<td>$3.2</td>
</tr>
<tr>
<td>Implementation</td>
<td>$9.3</td>
</tr>
<tr>
<td>Deployment</td>
<td>$7.5</td>
</tr>
<tr>
<td>Start-up Costs Total</td>
<td>$20.5</td>
</tr>
</tbody>
</table>

Source: Gormely et al.

Computerization > Computers

IT Capital (10%)

Technological Complements (15%)

Intangible Assets are more important in the Information Economy

Image by Ralph Clevenger
Interactions Between IT and Digital Organization

Puzzle: Why Did Productivity Accelerate Even More After 2000?

- Post-2000 Surge caught most people by surprise
  - Simple growth accounting explanations of faster growth in the 90s do not work well

The Story

- IT investment associated with very large intangible organizational capital investments: up to 10x size of computer investments (Brynjolfsson & Yang, 2002)
  - Business process redesign, training, implementation, market and product strategy innovation
- Organizational investments are mostly “expensed” (Brynjolfsson & Fitoussi, 2005)
  - This shifts productivity from present to the future
- Businesses moved from “sowing” to “harvesting” after 2001
  - IT and BPR investment way down; big focus on cost cutting and realizing potential gains vs gold rush of exploring opportunities in late 1990s

=> Consistent with data that show 5 year lags before peak productivity gains from IT (Brynjolfsson & Hitt, 2001)

Implications of Story

- Standard growth accounting is wrong
  - Major investments have been treated as expenses
- Productivity surge in 2001-2004 was unsustainable because it reflects harvesting of past investments, and lack of future investments
- Productivity is dipping back below trend now as a result

The Future of Productivity Growth

- Baumol’s Disease and Carr’s Complaint
- IT: The Elixir
  - From Asymptotic Stagnation to Increasingly Accelerating Growth
  - If high productivity sectors have price elasticity > -1, then they will shrink as a share of the economy
  - But, if high productivity sectors have price elasticity < -1, then they will grow as a share of economy
  - Prize elasticity of IT has been estimated to be -1.2 (Brynjolfsson, 1996)

- I want to convert labor costs to IT costs to ride the technology curve.
  - Todd Thompson, Citi CFO
- From String Quartets to U2 replicated x 1 million on iTunes
Information Technology Share
of private nonresidential fixed investments

Looking Forward
A) Easy Prediction: Moore’s Law and related trends for storage, communications, etc will continue
   - The power of exponentials
B) IT share of GDP is likely to grow further
   - Common to assume constant share
   - CFOs want to shift costs onto technology curve
C) Points A) and B) imply growing impact of IT on productivity
D) Can IT Reverse the Curse of “Baumol’s Disease”?
   - Depends on the substitutability of IT (and other rapidly improving inputs)
   - IT economy-wide price elasticity has been ~1.2
   - Long-term elasticity may be higher (a la Le Chatelier)

Concerns
- Inequality
- Turbulence
- Innovation Incentives
- Mismeasurement: Beyond Productivity

IT, Labor and Wealth
- The changing demand for labor
  - What types of work will be replaced by machines and which will be in greater demand?
- How will the distribution of wealth be affected by continuing advances in IT?
  - Computer-skill complementarity
    - Growing Inequality
    - The Superstar effect
      - The top 1%; the top 0.1%
Turbulence is Growing


IT as a Strategic Differentiator

Average profit margin IQR by industry category, 1990-2004

Business Process Replication: Achieving Scale Without Mass

Case Study: CVS

New fulfillment process:

- Short-term results: customer satisfaction scores
  - Wait times: 76 → 88
  - Overall pharmacy satisfaction: 80 → 91
- New process embedded in EIT
- 100% compliance
- < 1 year rollout to over 4000 retail pharmacies
Zero Marginal Costs and Efficiency

The Mismeasure of Value
- Value of New Goods, Product Variety and Quality
- Value of "free goods"
  - Wikipedia vs. Britannica
  - The growing gift economy

Product Variety Comparison

<table>
<thead>
<tr>
<th>Product Category</th>
<th>Amazon.com</th>
<th>Typical Large Brick-and-Mortar Store</th>
</tr>
</thead>
<tbody>
<tr>
<td>Books</td>
<td>2,108,000</td>
<td>40,000 – 100,000</td>
</tr>
<tr>
<td>CDs</td>
<td>250,000</td>
<td>5,000 – 15,000</td>
</tr>
<tr>
<td>DVDs</td>
<td>18,000</td>
<td>500 – 1,500</td>
</tr>
<tr>
<td>Digital Cameras</td>
<td>213</td>
<td>36</td>
</tr>
<tr>
<td>Portable MP3 players</td>
<td>128</td>
<td>16</td>
</tr>
<tr>
<td>Flatbed Scanners</td>
<td>171</td>
<td>13</td>
</tr>
</tbody>
</table>

Wal-Mart stocks six times as many SKUs online versus in superstore

Policy Implications
- Beyond (Tangible) Technology
  - Two cheers for Management Consultants and B-Schools!
- Education: A win-win
- Managing Turbulence
  - Protect people, not firms or industries
- Incentives for Innovation
  - Pick prices, not winners
  - New institutions
- Opportunities for Better Measurement
  - Measuring Organizational Capital
  - Product Variety & Consumer Surplus
  - Micro-Micro Data
Beyond Productivity: Consumer Surplus

- Productivity is output/input
- Consumer surplus is difference between what consumer *would* pay vs. what consumer does pay

**Consumer Surplus from Price Drop or from New Good**

\[ P_0 \quad q_0 \quad P_1 \quad q_1 \]

**IT Investment Slowed after 2000**

**Real U.S. Computer Stock**

Source: Bureau of Economic Analysis. Nonresidential assets. Quantity index, Year 2000=100
**Summary**

Computerization → Creation of intangible assets.
- The value of these intangibles can be as much as 20 times as the value of computer assets alone.
- Technology-enabled business process reengineering can lead to significantly higher market value than computers or reengineering alone.
- Finally, the interaction of business process reengineering, computer capital, and a cluster of new work practices and culture is even more valuable.

**Organizational Capital and Intangibles**

- Increasing share of all investment is in business processes, human capital, and other intangibles.

**Computerization > Computers**

- IT Capital (10%)
- Technological Complements (15%)
- Organizational Complements (75%)

*Intangible Assets are more important in the Information Economy*

**Tobin’s q in 2006**

<table>
<thead>
<tr>
<th>Company</th>
<th>Total Market Value</th>
<th>Book Value of Assets</th>
<th>Tobin’s q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walmart</td>
<td>$278.7</td>
<td>$32.4</td>
<td>8.5</td>
</tr>
<tr>
<td>Amazon</td>
<td>$139.9</td>
<td>$5.3</td>
<td>24.7</td>
</tr>
<tr>
<td>Google</td>
<td>$50.6</td>
<td>$6.6</td>
<td>4.4</td>
</tr>
<tr>
<td>Dell</td>
<td>$464.5</td>
<td>$25.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Microsoft</td>
<td>$393.5</td>
<td>$66.0</td>
<td>3.1</td>
</tr>
<tr>
<td>Barnes and Noble</td>
<td>$18.3</td>
<td>$2.1</td>
<td>8.7</td>
</tr>
<tr>
<td>Walmart</td>
<td>$28.4</td>
<td>$1.5</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Source: Google Finance. Cash is subtracted from market value and assets.
Seven Practices of Digital Organizations

1. Move from analog to digital business processes
2. Distribute decision-rights
3. Foster open information access
4. Link incentives to performance
5. Maintain focus and communicate goals
6. Hire the best people
7. Invest in human capital

Scatterplot: Sales Concentration Growth

Below Median IT Intensity
Above Median IT Intensity

Information Overload

Competition in Product Markets

- How does IT affect product markets
- Product variety and the Long Tail
- Winner-take-all markets
Digital information is doubling every 1.1 years

```
PBG/AVG  1000  2000  4000  6000  8000  12000  16000  24000  32000
```

Information Consumes Attention

“The scarce resource is not information, it is the processing capacity to attend to information”

- Herbert Simon

Responses to Information Overload

- **Automate**
  - Offload work from humans to machines
- **Train and hire**
  - Skilled, educated workers
  - Increase the capacity of human processors
- **Reorganize**
  - To distribute decision making
  - Delegate to involve more brains
- **Focus and Filter**
  - Learn to ignore, learn to prioritize, learn to say no
- **Combinations** of the above
  - Creativity needed to boost information metabolism

Emerging topics

- Funding models for digital info
  - Bundling and aggregation, targeted ads, open source, information complements, etc.
- Innovation incentives for digital goods
- Online Communities
  - Cyberbalkanization or Global Village
- Platforms for products and innovation
- Reputation and Recommenders
- Stickiness
Innovation Incentives for Digital Goods

Couponing Mechanism
- Sell the bundle of digital goods to each of \( j \) consumers
- Choose \( m \times n \) random consumers and issue each of them a digital rebate coupon tied to DRM
  - \( n \) price levels
  - \( m \) coupons offered for each price level
  - \( m \times n \ll j \times \sigma \)
  - relatively few consumers face prices for a given good

Example

<table>
<thead>
<tr>
<th>Price</th>
<th>m=3</th>
<th>n=4</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.99</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0.78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0.17</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Simulation

Graph shows decrease in error with more coupons or more samples.
Which Innovation Will Be Pursued?

Targeted Innovation – High Type

Targeted Innovation – Low Type

Targeted Innovation – For Marginal Consumers
Targeted Innovation - For Marginal Consumers

- Social Contribution
- Seller’s gains

Frontier Research Opportunities

1. Using Task-level Data
   - Social Network Analysis
   - Controlled Experiments
2. Consumer Surplus
   - Beyond Productivity
3. Organizational Capital and Intangibles
4. IT, Labor and Wealth
   - Education, skills, and income inequality
   - The economics of superstar
5. Competition in Product Markets
   - The long tail vs. winner take all markets?
6. Business Process Replication
   - Achieving scale without mass
7. Information Overload
   - How much information is produced each year?
   - Technological and organizational responses
8. Innovation Incentives in Information Goods
   - Mechanism design
   - Open-source and the gift economy

Task-level data

- Finer grained data
- Like using a microscope
- Look at communication flows to create social networks
- Designed experiments
A Model of Information Work:

- ESS, Skill & Use
- Communication Network, Size & Structure

Intermediate Output:

- Multitasking
- Duration per Task

Final Output:

- Revenue
- Completion Rate

Revenue From Obscure Titles

- What proportion of sales at Amazon.com are from obscure books?
- Use rank, assume Pareto relationship between rank and sales: \( Q = a \cdot R^b \)

Mapping Communication Networks

Design of the Experiment

- Initial Sample: 20,000
  - Best Customers: 10,000
  - Other Customers: 10,000
  - Random assignment

- Control Group: 5,000
- Test Group: 5,000

- 12 catalogs
- 12+5 catalogs
Fixed Investment and Information Technology Investment Share of GDP