Organizational and Economic Obstacles to Automation: A Cautionary Tale from AT&T

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Automation on the doorstep?

- Fears of an imminent, sweeping wave of automation are again riding high (Brynjolfsson & McAfee 2014, Autor 2015)

Latest culprit: Generative AI
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- In a recent paper we studied the impacts of one of the largest automation events in modern history—AT&T’s mechanization of telephone operation—on workers and labor markets

- Today we’ll peer inside the firm, and ask:

  Why did it take a century?
Who remembers Ma Bell?
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- Horizontally integrated: owned regional operating companies and long-distance lines that connected them
- Vertically integrated: Western Electric, Bell Labs
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By 1920s, America’s largest employer... and >50% operators
...manually connecting >60 MM calls per day
But automation took nearly 90 years to complete

Percent of AT&T system on dial, 1890-1972

- Invention of dial telephone
- WPB restrictions put in place
- End of Great Depression
Why did it take 90 years to automate one job?
Classic challenges to adoption are unlikely

- Large, wide-ranging literature on technology adoption
  - Hold-ups include fixed costs and indivisibility, uncertainty, organizational and information frictions

- AT&T seems like it would clear the common hurdles
  - Enormous scale
  - Powerful management
  - Full information
  - Access to capital
  - Vertically integrated
We argue two points in this paper

1. **Interdependencies & organizational challenges**

   - Call switching interacted with essentially every other part of AT&T’s business: automating it risks incongruence.
   - Example highlights that when a task interacts with many others, automating that task can be a hard problem.
   - Merges principles of Milgrom-Roberts, Bresnahan & Bryn, Rivkin-Siggelkow, etc. into task-based production models.
   - We give this a label (+ model): the “integral task”
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2. **Economies of scale + a long tail of small markets**
Prelude:

A little bit of history
Map of Bell operating companies
Telephone exchanges ("Central Offices")

- Telephone exchanges were the functional units of the network
  - Connected to subscribers and each other
  - Day-to-day work of administering telephone service
  - Thousands around the country
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- Four departments (Traffic, Plant, Commercial, Accounting)
- Multiple service types (business, residential, PBX, long-distance, pay, collect)
- Many types of operators ("A", "B", tandem, long-distance, info, 911)
- Complementary tech (switching, handsets, tel. numbering, directories)
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At the center of this system: the telephone operator
Telephone operating rooms
Telephone operating rooms
Telephone operating rooms
History of dial technology

- First mechanical switching device invented in 1889
  - AT&T’s early cost studies unfavorable
  - Continued focus on manual operation
  - “By 1905, the manual system had been developed to a point where it was ... fast, accurate, and dependable”
History of dial technology

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- New pressures on the business in 1910s:
  - Network growth straining equipment and operators
  - Deeper issue: massive diseconomies of scale
    - MC of manual tech ↑↑ as network grows
  - In 1917, AT&T began advising automation for large cities
Telephone operators after cutover to dial
Why is this a hard problem?

- The idea that organizational changes are necessary for new technologies to have a wide-felt impacts is practically canon
  - In econ (e.g., Milgrom & Roberts 1990, David 1990, Bresnahan et al. 2002)
  - In strategy (e.g., Henderson & Clark 1990, Siggelkow 2001, and more)

- But not all technologies—many important technologies did not
  - E.g. hybrid seed corn, vaccines and antibiotics, many more
  - Even automation: e.g. clothes washers/dryers vs. laundering
What’s special about AT&T’s problem?
Our emphasis: the “integral task”

- The task being automated interacts activities across the firm
  - *Service offerings, plant and equipment, technology, operations, workforce composition, job structures, pricing, accounting, billing, customer relations, ...*

- Shared intuition with prior work, but with a refinement
  - Not about the system, but rather the task’s centrality in it (this builds on ideas from the org. design literature)
Example interdependencies in the AT&T system
Major activities and changes required to adapt this system to mechanical switching

**AT&T Corporate**
- Develop + test equipment
- Equipment mfg. at scale
- Educate operating company managers on the tech
- Make data-driven recommendations for adoption
- Integrate w/ AT&T Long Lines, other markets

**Central Offices**
- Install equipment
- Re-wire exchange
- Integrate with manual
  - Auto-manual boards
- Traditional operator (contingent labor)
- New approaches to:
  - Information services
  - Emergency services
  - Call monitoring
  - Caller assistance
- Personnel challenges:
  - Labor management
  - Transitional labor
  - New maintenance staff, training, processes
- New building design
- New cost accounting

**User Behavior**
- User acceptance of dial
- User training on dial
  - On-site training
  - Media campaigns
- Changes in organization (e.g., secretaries)
  - Integration w/ PBX

**Regulators**
- Telephone rate changes
- Public concerns

**User Technology**
- New handsets, w/ dial
- New numbering plans
- New telephone directory
- Method for mapping alphanumeric IDs to a fully-numeric dial
We give this structure with a simple model

- Monopolist firm engaged in task-based production

- Each unit of output requires performing a set of $n$ activities $i = 1, \ldots, n$, each with an associated task $i$

- There is a distinct task, $i = 0$, which enters all activities
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- Partial automation challenged by the cost of incongruence, and total automation by cost of changing the full system
You may be thinking: Show me the data

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- What we can do: look for evidence of workforce changes
  - We treat as a sufficient statistic for wider changes
To do this, we need data. From where?

- Telephone industry (equiv. AT&T) workforce
  - *Complete count census data, 1910-1940*

- The local adoption of mechanical switching (RHS)
  - *Records from AT&T corporate archives*
  - *Newspaper reports of local cutovers to dial*
What we find (in one slide):

1. Large decline (≈ 50%) in operators
2. Clerks and bookkeepers ↑ (residual tasks)
3. Electrical engineers ↑
4. Managers ↑, avg. span of control ↓
5. Remaining operators are older
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- But also: The unit economics of the problem
  - Automation naturally adopted first by large units (scale)
  - In this case, the goal wasn’t shifting VC down, but rather limiting rate at which MC grew, by reducing complexity
  - Benefits of technology decayed quickly in smaller markets
  - This, plus long rural tail → long lags
## Cutovers and city characteristics, 1910

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>pre-1920</th>
<th>1921-1925</th>
<th>1926-1930</th>
<th>1931-1935</th>
<th>1936-1940</th>
<th>post-1940</th>
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<tbody>
<tr>
<td>Population 16+ (1000s)</td>
<td>38.92</td>
<td>116.82</td>
<td>43.87</td>
<td>18.41</td>
<td>9.14</td>
<td>4.06</td>
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<td></td>
<td>(55.49)</td>
<td>(248.98)</td>
<td>(80.23)</td>
<td>(27.30)</td>
<td>(13.33)</td>
<td>(6.68)</td>
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<td>Percent working</td>
<td>60.54</td>
<td>60.35</td>
<td>60.81</td>
<td>59.60</td>
<td>58.96</td>
<td>57.55</td>
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<tr>
<td></td>
<td>(5.27)</td>
<td>(5.05)</td>
<td>(5.69)</td>
<td>(5.64)</td>
<td>(5.83)</td>
<td>(7.28)</td>
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<tr>
<td>Percent operators</td>
<td>0.19</td>
<td>0.21</td>
<td>0.19</td>
<td>0.17</td>
<td>0.19</td>
<td>0.21</td>
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<tr>
<td></td>
<td>(0.10)</td>
<td>(0.12)</td>
<td>(0.14)</td>
<td>(0.11)</td>
<td>(0.11)</td>
<td>(0.15)</td>
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<tr>
<td>F/n/w/y percent working</td>
<td>41.17</td>
<td>40.68</td>
<td>40.23</td>
<td>44.01</td>
<td>36.71</td>
<td>35.09</td>
</tr>
<tr>
<td></td>
<td>(7.79)</td>
<td>(12.09)</td>
<td>(10.32)</td>
<td>(11.86)</td>
<td>(12.31)</td>
<td>(12.12)</td>
</tr>
<tr>
<td>F/n/w/y percent operators</td>
<td>1.16</td>
<td>1.36</td>
<td>1.19</td>
<td>1.02</td>
<td>1.12</td>
<td>1.21</td>
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<tr>
<td></td>
<td>(0.65)</td>
<td>(1.09)</td>
<td>(0.87)</td>
<td>(0.67)</td>
<td>(0.79)</td>
<td>(0.97)</td>
</tr>
<tr>
<td>Observations</td>
<td>29</td>
<td>62</td>
<td>114</td>
<td>67</td>
<td>60</td>
<td>2660</td>
</tr>
</tbody>
</table>

Notes: Observations are cities. “f/n/w/y” is shorthand for female, native-born, white/non-Hispanic, and young (age 16-25). Standard deviations in parentheses.
Concluding Remarks
How generalizable is AT&T’s example?

- AT&T was distinctive: regulated monopoly

- Could either of these features have slowed innovation?
  - Rate of return regulation incentivized capital investment (which AT&T could use to justify rate increases)
  - If margins were fixed, the only way to grow profit is volume
    - Universal service was AT&T’s explicit objective (and motto)
    - Controlling MC (via mechanization) better for keeping volume high than raising prices to match growing costs
  - Monopoly conferred greater scale (Macher et al. 2021)

- Abroad: mechanization in UK, AU took just as long
Modern insights

- Where else might this intuition apply?
  - Many applications of AI (Bresnahan 2021, Agrawal et al. 2022)

- Another example: the computerization of the IRS
  - Probably the biggest digitization event in history
  - Required a “total systems approach” with “extensive changes in work flow, services to taxpayers, and location of jobs ... [and] a review of the total organization of [the IRS]” (IRS 1964)

- Happy to discuss more at the break
Thank you!

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