

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

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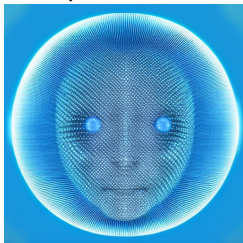
²Duke University and NBER

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Automation on the doorstep?

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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?

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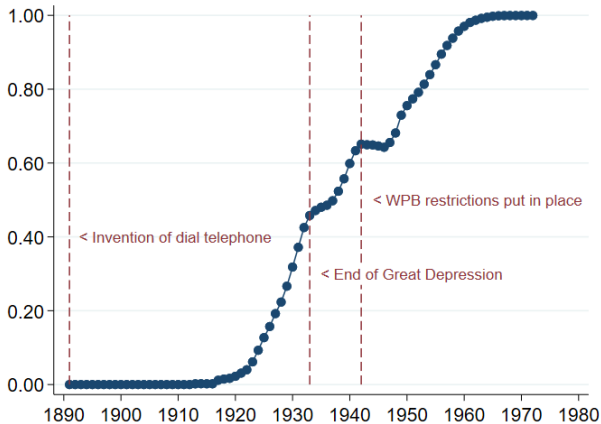
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...manually connecting >60 MM calls per day

But automation took nearly 90 years to complete

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



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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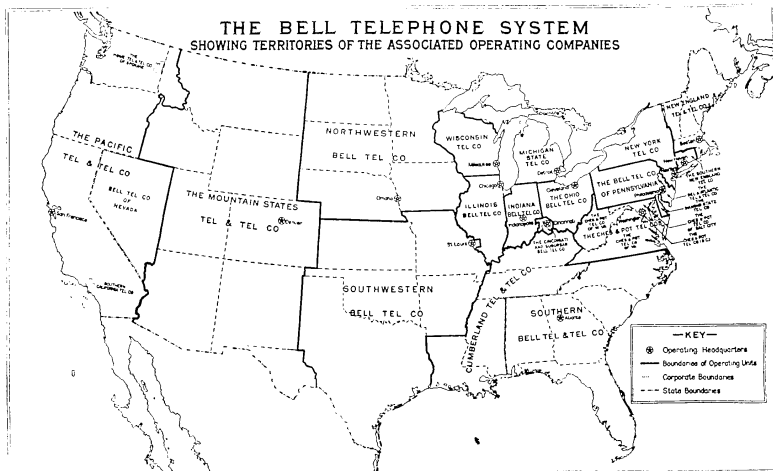
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2 Economies of scale + a long tail of small markets

Prelude:

A little bit of history

Map of Bell operating companies



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At the center of this system: the telephone operator

Telephone operating rooms



Photo: Cassell & Co., Ltd.

Telephone operating rooms



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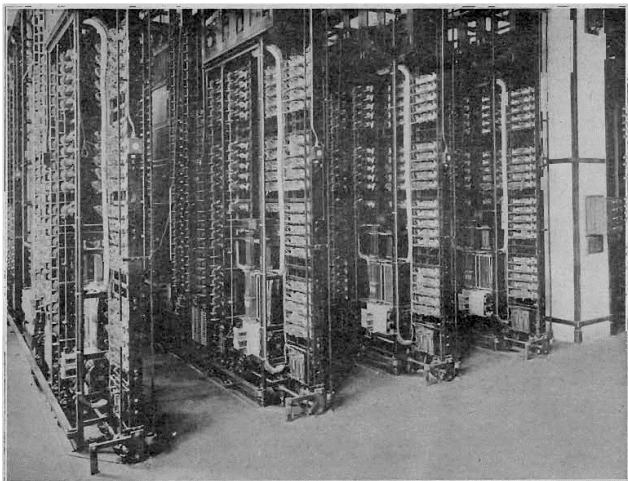
History of dial technology

- First mechanical switching device invented in 1889
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 - "By 1905, the manual system had been developed to a point where it was ... fast, accurate, and dependable"
- 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?

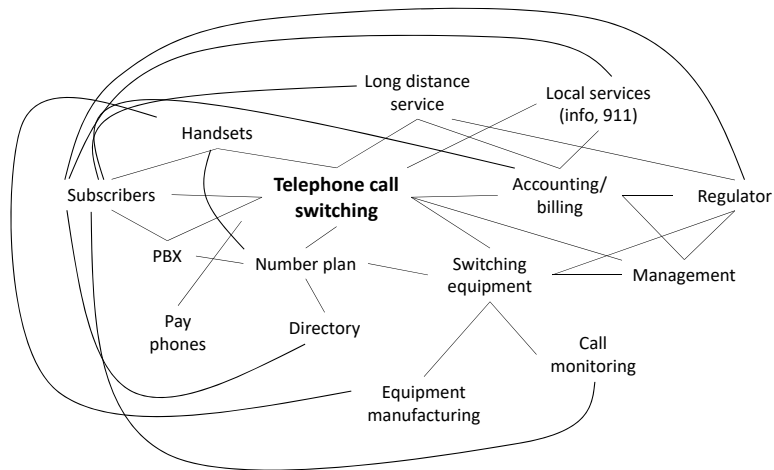
- The idea that organizational changes are necessary for new technologies to have a wide-felt impacts is practically canon
 - In econ (e.g., Milgrom & Roberts 1990, David 1990, Bresnahan et al. 2002)
 - In strategy (e.g., Henderson & Clark 1990, Siggelkow 2001, and more)
- But not all technologies—many 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

Regulators

- Telephone rate changes
- Public concerns

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

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 $i = 1, \dots, n$, each with an associated task i
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- Partial automation challenged by the cost of incongruence, and total automation by cost of changing the full system

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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*

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- 5 Remaining operators are older

The Long Tail

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- In part: integrating automation in new environments
- 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 \implies long lags

Cutovers and city characteristics, 1910

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

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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