

Organizational Frictions and Increasing Returns to Automation: Lessons from AT&T in the Twentieth Century

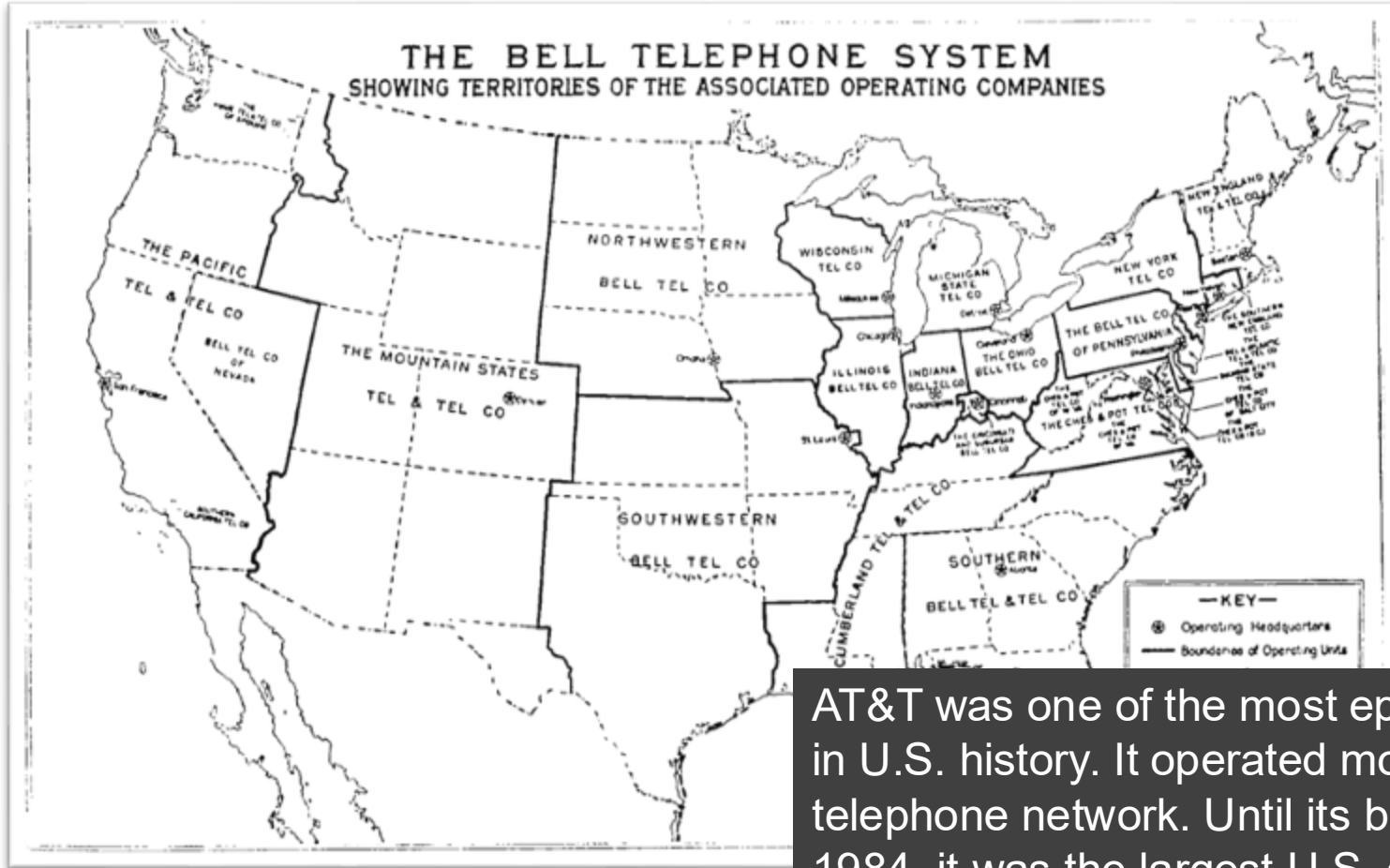
James J. Feigenbaum & Daniel P. Gross

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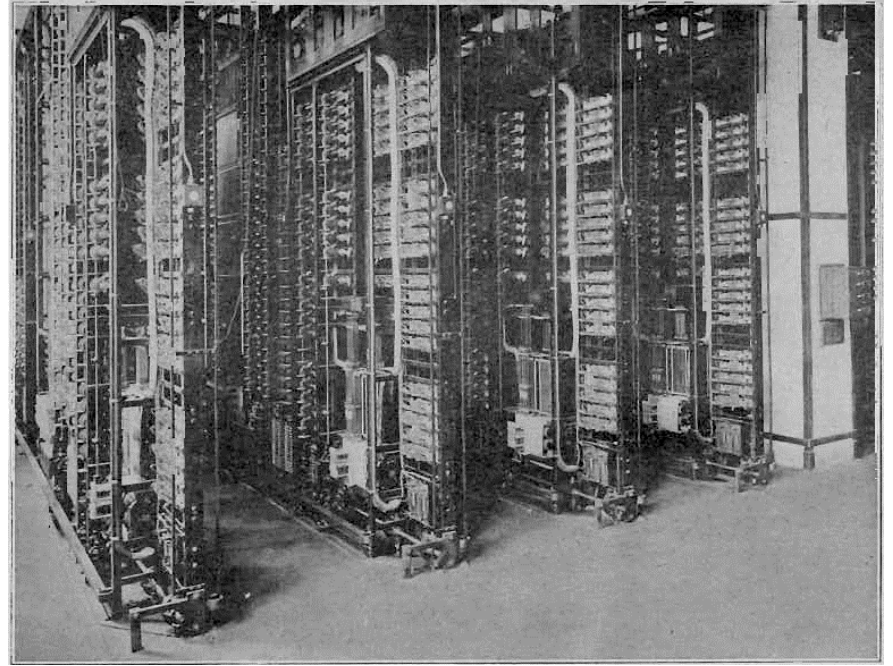
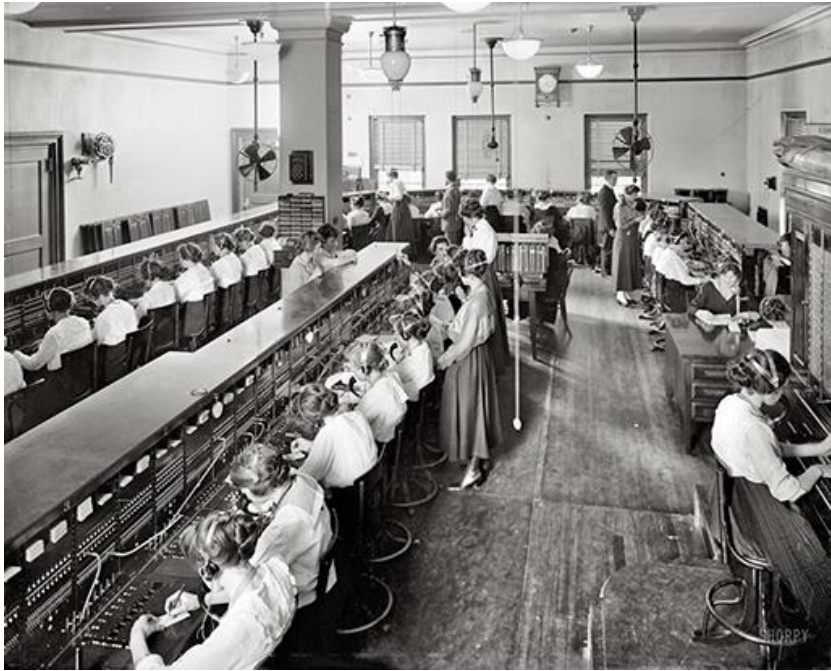
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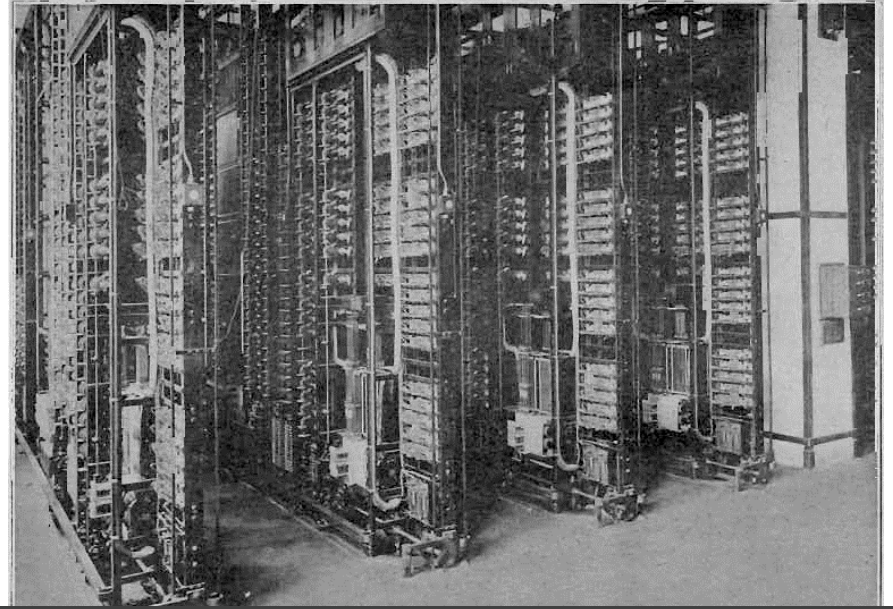
AT&T was the largest U.S. firm for most of the 20th century. Telephone operators once comprised over 50% of its workforce, but in the late 1910s it initiated a decades-long process of automating telephone operation with mechanical call switching—a technology first invented in the 1880s. We study what drove AT&T to do so, and why it took one firm nearly a century to automate this one basic function. Interdependencies between operators and nearly every other part of the business were obstacles: the manual switchboard was the fulcrum of a complex system which had developed around it, and automation only began after the firm and automatic technology were adapted to work together. Even then, automatic switching was only profitable for AT&T in larger markets—hence diffusion expanded as costs declined and service areas grew. We show that automation supported AT&T's continued growth, generating a positive feedback loop between scale and automation that reinforced AT&T's high market share in local markets.



AT&T was one of the most epic mega-firms in U.S. history. It operated most of the U.S. telephone network. Until its breakup in 1984, it was the largest U.S. employer.

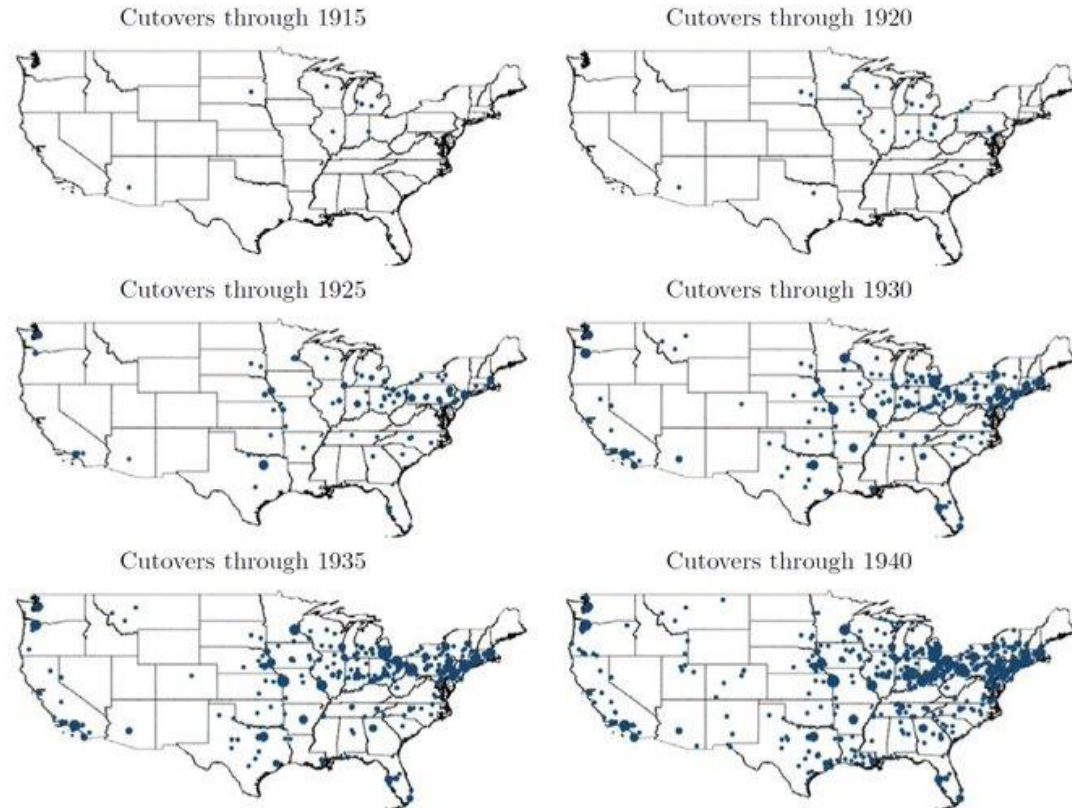


For much of this history, "telephone operator" was also its biggest job: 50% of its employees pre-WW2 were operators! That is, until AT&T decided to begin replacing operators with mechanical switching and dial telephones



The complexity and labor demands of manual operation increased rapidly in large markets with billions of possible connections. Paradoxically, scale was both AT&T's main source of competitive advantage (via network effects), and also its Achilles heel w/ manual operation.

Figure 2: Cities with cutovers in Newspapers data, in 5-year intervals, 1915-1940
bubble sizes proportional to number of cutovers

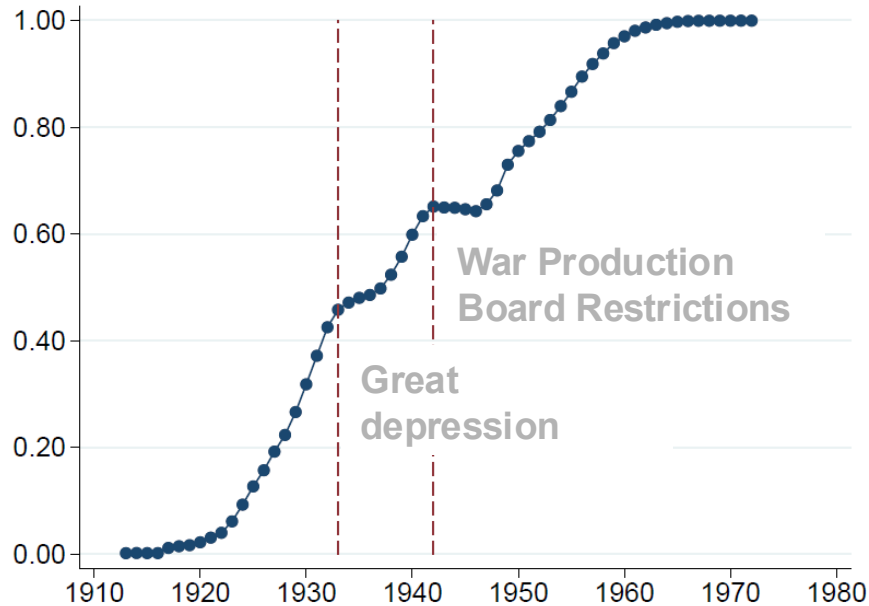


As a result, in the late 1910s, AT&T (and its subsidiaries) decided to begin automating this job, one telephone exchange at a time.

Guess How Long this Transition Took

- A. 1910s – 1930s
- B. 1910s – 1950s
- C. 1910s – 1970s
- D. 1910s – 1990s

Figure 1: Percent of Bell system on dial, 1913-1972



- Mechanical switching technology was invented in the 1880s.
- The first mechanical installation in the Bell system was made in 1919.
- The last was in 1978.

it took one firm, selling essentially one product, with its own vertically-integrated supplier, nearly 100 years to automate its most basic function after the technology is invented, and 60 years after they started automating!

This is a striking adoption lag!
Why why did it take so long?

The Job: More Complex Than It Seemed

The operator job was interdependent with numerous functions and technologies inside the firm

- connected callers
- provided multiple types of service
 - Calls: local vs. long-distance
 - Other services: military, pay, info, emergency...
- tracked billing minutes...

→ System Designed for Manual Switching

- Assets
 - switching equipment, numbering plans, and directories
- Market/Consumer
 - Consumers may not wish to switch to new norms
- Regulation/legal
 - prices were regulated
 - telecoms can be sensitive (military / emergency)

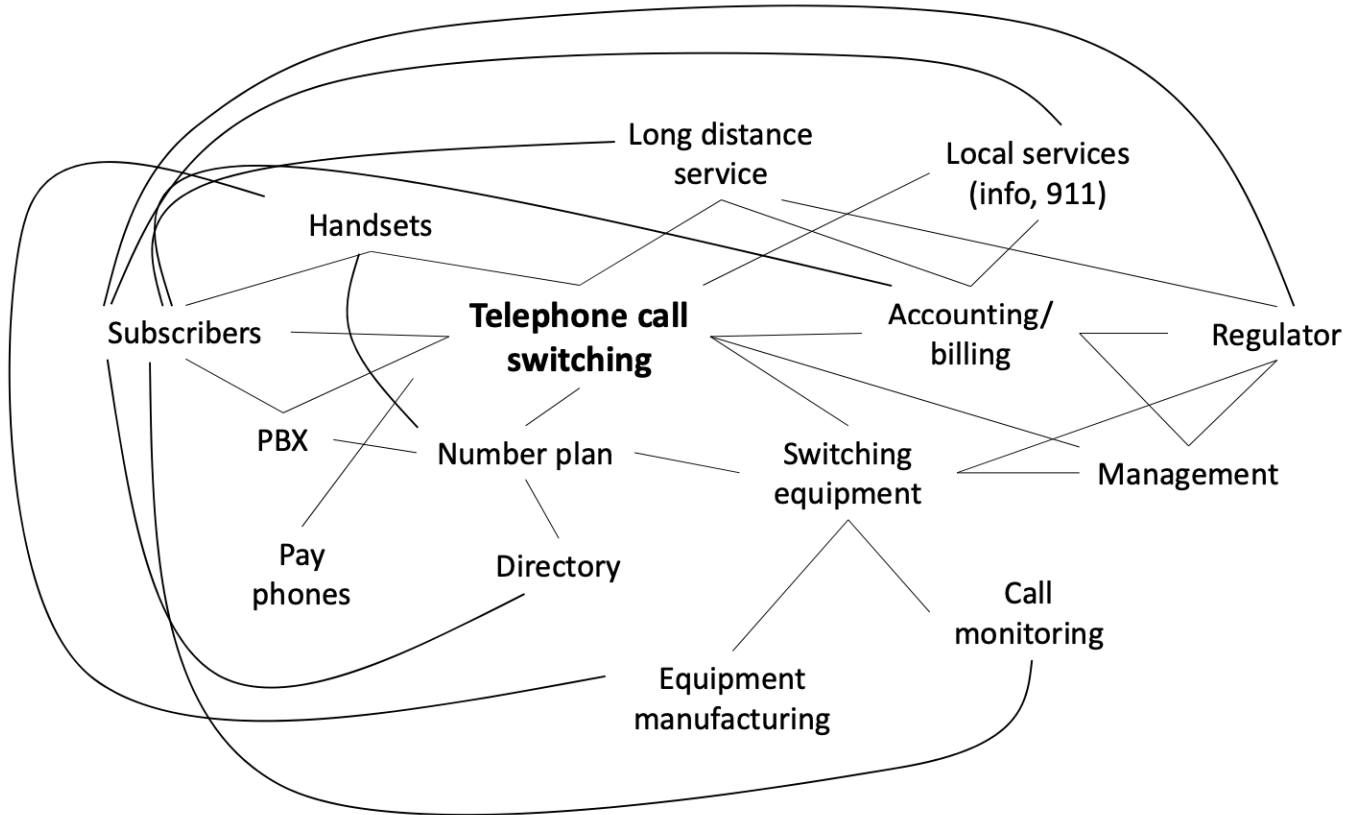
→ Tech Adoption means Lots of Changes

creating new technology +

- developing new manufacturing capabilities
- implementing massive workforce changes (from operators to machine technicians)
- redesigning telephone exchange buildings
- assigning new subscriber numbers
- educating customers
- new pricing and new approaches to cost accounting
- convincing risk-averse regulators...

Figure 3: Integrating automation into the AT&T production system

Panel (A): Example interdependencies in the AT&T system



An example

Telephone subscribers used to have alphanumeric numbers. To reach somebody, you would give the operator the destination exchange name and the subscriber number.

But this system is not compatible with an all-numeric dial!

Took YEARS to conceive a way to map letters in the alphabet to numbers on the dial + get buy-ins from existing partners and regulators.



Technology transitions can require significant complementary investment

But this only explains 10-20 years of lag.

Great Depression and WWII explains another 10-20 years of delay

What about the other ~30 years?

The Economics of Technology Diffusion

How much did AT&T benefit from going mechanical?

Figure 4: Local telephone industry growth before/after dial cutovers (event study)

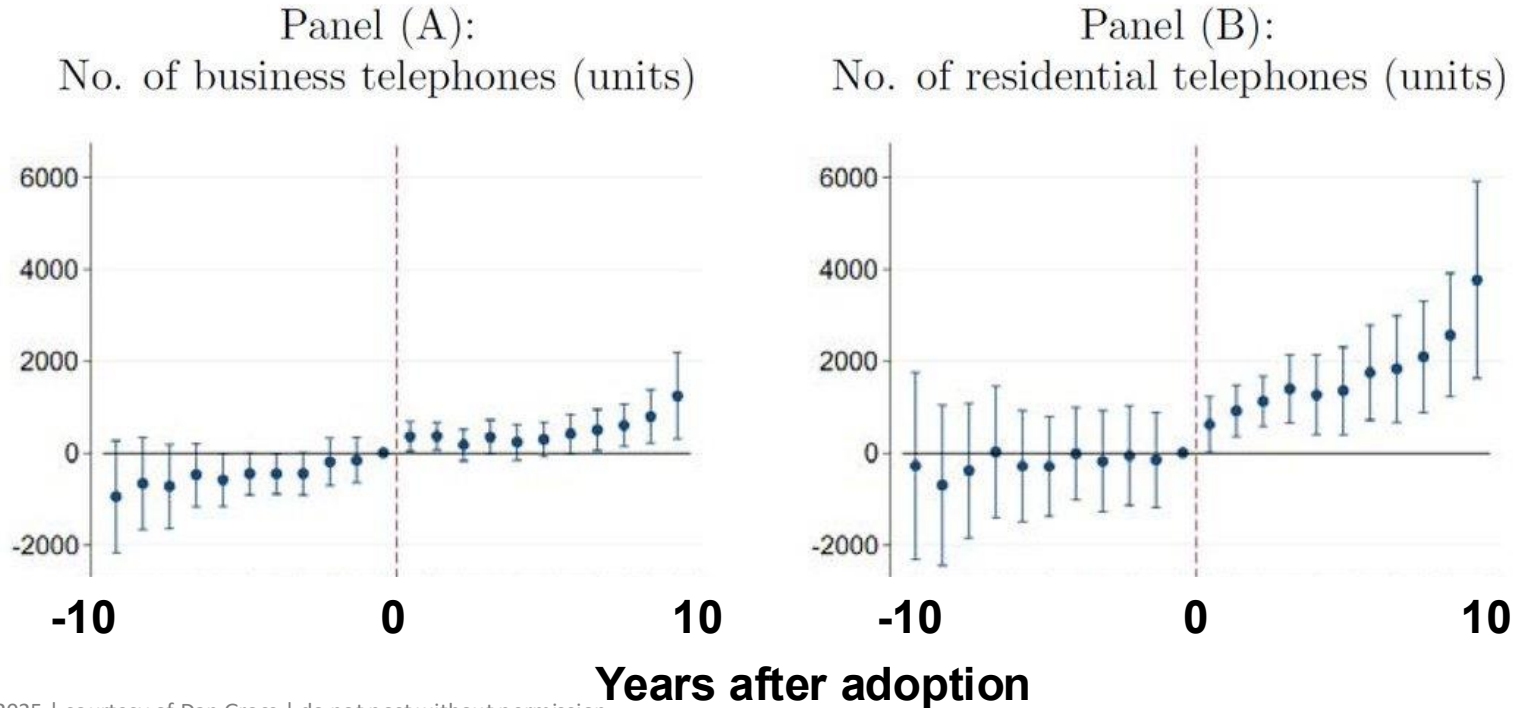


Table 6: City characteristics and the pace of automation

	Any cutover by 1940?		Timing of earliest cutover	
	(1)	(2)	(3)	(4)
Ln(Population 16+)	0.134*** (0.007)	0.132*** (0.007)	-1.744*** (0.198)	-1.852*** (0.213)
F/n/w/y pct. working		0.001 (0.001)		0.043 (0.042)
F/n/w/y pct. operators		-0.004 (0.006)		-0.253 (0.360)
N	2991	2991	324	324
R^2	0.24	0.24	0.28	0.28
Y Mean	0.11	0.11	1929.08	1929.08

Bigger Cities
 Adopted Earlier

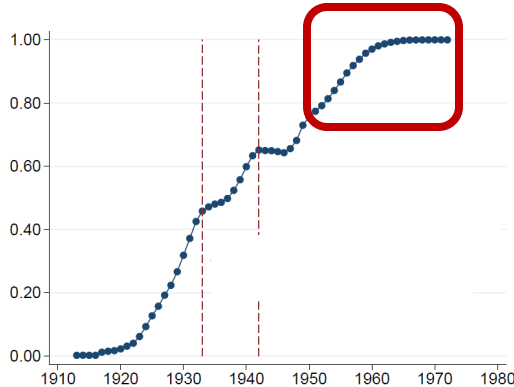
Controlling for
 workforce
 composition and
 number of operators

Notes: Table reports estimates from a regression of an indicator for whether a given city has a cutover in our data by April 1, 1940 (Columns 1 to 2) and the timing of the earliest cutover (Columns 3 to 4) on city characteristics in 1910. The sample for all columns omits cities with a cutover before the 1920 census or ambiguous cutover timing and New York City boroughs. The latter columns are further restricted to cities with a cutover between 1920 and 1940. Population and population percentages reflect the adult (16+) population only, and f/n/w/y is shorthand for female, American-born, white/non-Hispanic, and young (age 16-25). *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. All specifications include state fixed effects. Robust SEs in parentheses.

The Economics of Technology Diffusion

- Smaller regions \rightarrow smaller scale to spread the high adjustment cost necessary
 - Similar to high “fixed cost”
- Some (military bases) required higher adjustment cost

Figure 1: Percent of Bell system on dial, 1913-1972

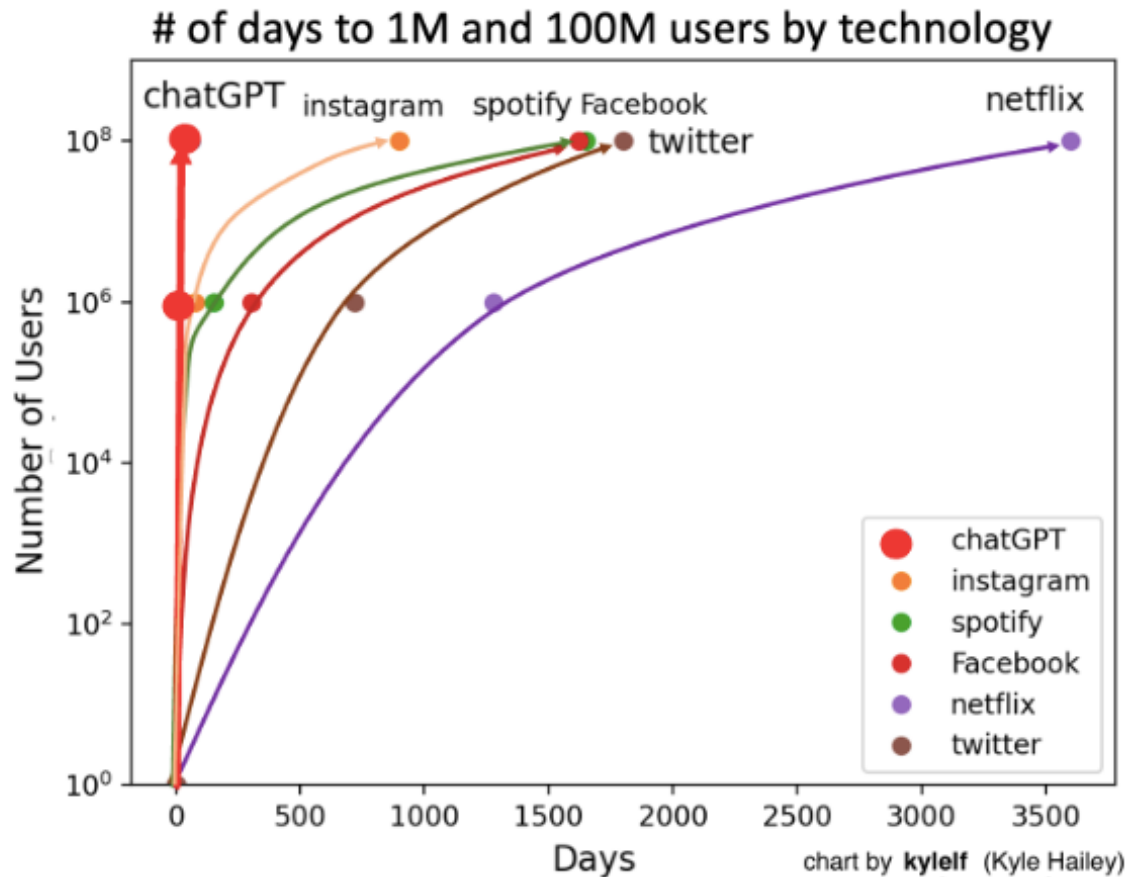


Long (30-year) tail here

Commercializing and adopting technology takes time and depends on...

- Complementary investments
- Market timing / macro events
- Shape of the cost curve

Is AI Different?



Yes and No

Yes: network effects + consumer tech-savvy

Not really though:

- DL/ML was developed in the 80s/90s
- but it took a long time for...
 - ...digitized data to accumulate
 - ...computing power to develop for R&D
 - ...deep-pocketed investors to fund the R&D
 - ...consumers to adopt the internet and personal computing
 - ...(TBD) regulators to understand and manage the risk