Diffusion

NBER Innovation Boot Camp 2025

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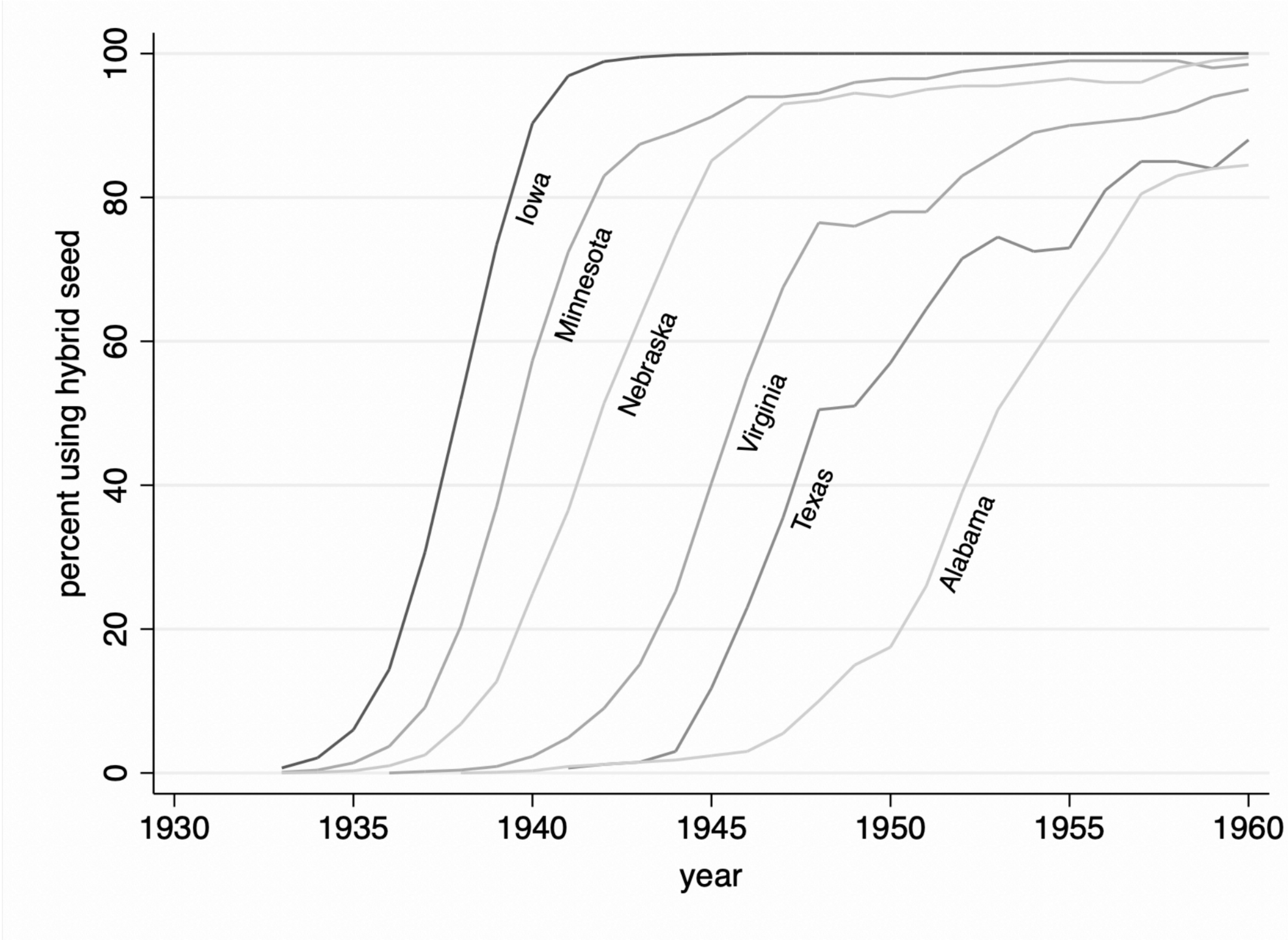
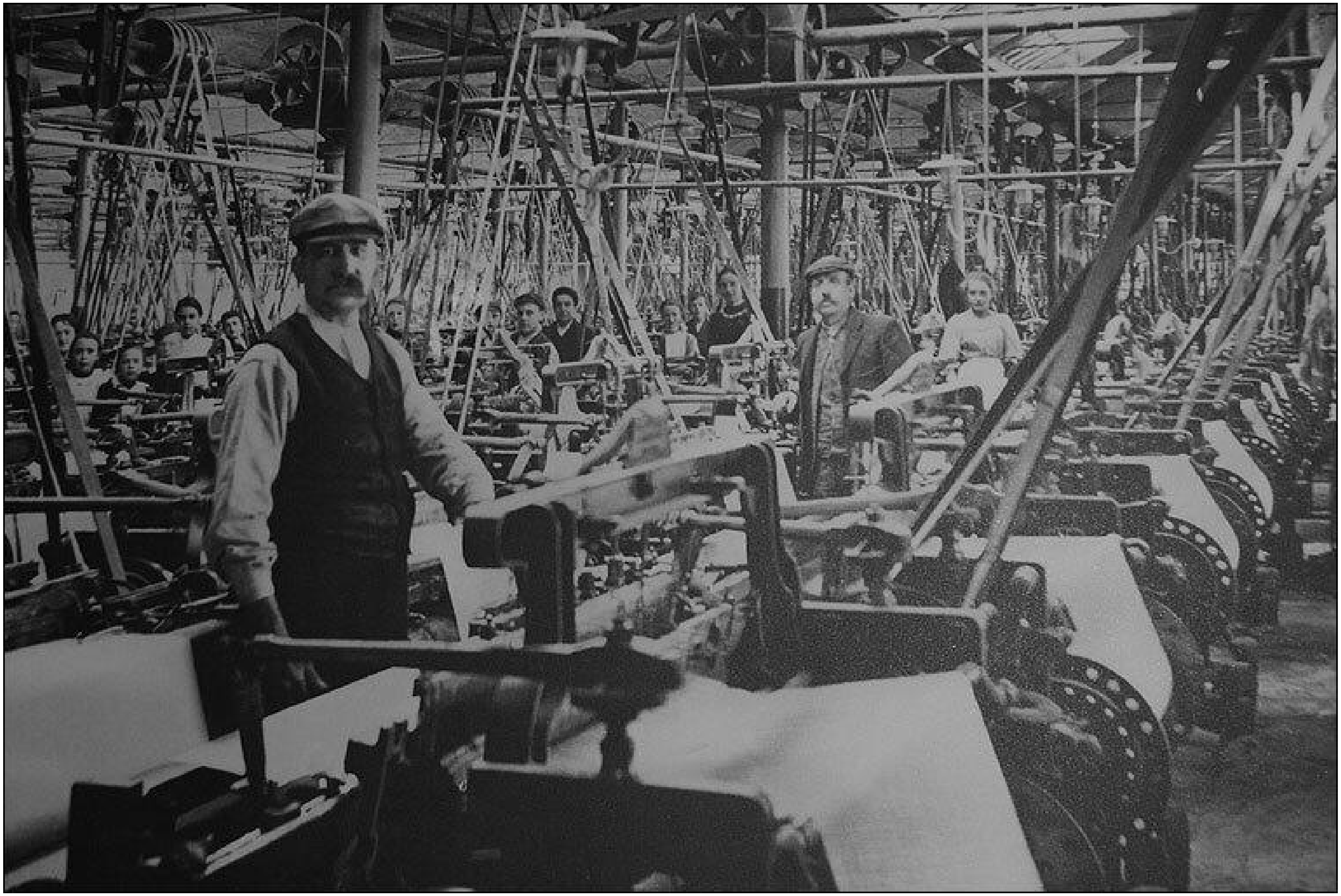
The simplest empirical problem



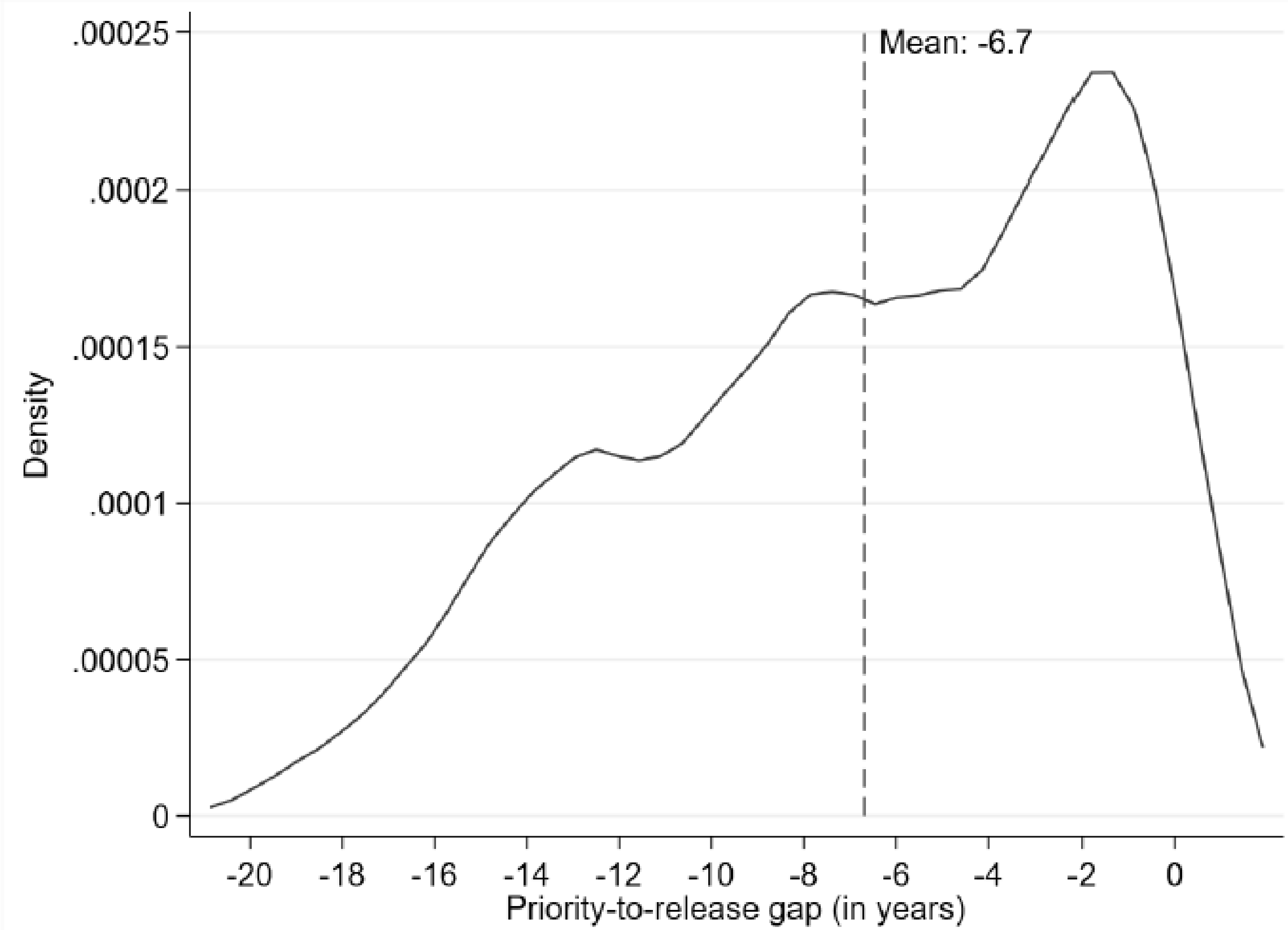
Note: The y-axis measures the percent of total corn acreage planted with hybrid seed by state, and also nationally. The graph shows the staggered implementation of hybrid corn across the corn belt in the US between 1930 and 1960. Source: Sutch, Libecap, and Steckel (2011), updating data from Griliches (1957)

The simplest empirical problem



Line shafts in a late 1800s factory; see David, Computer and the Dynamo

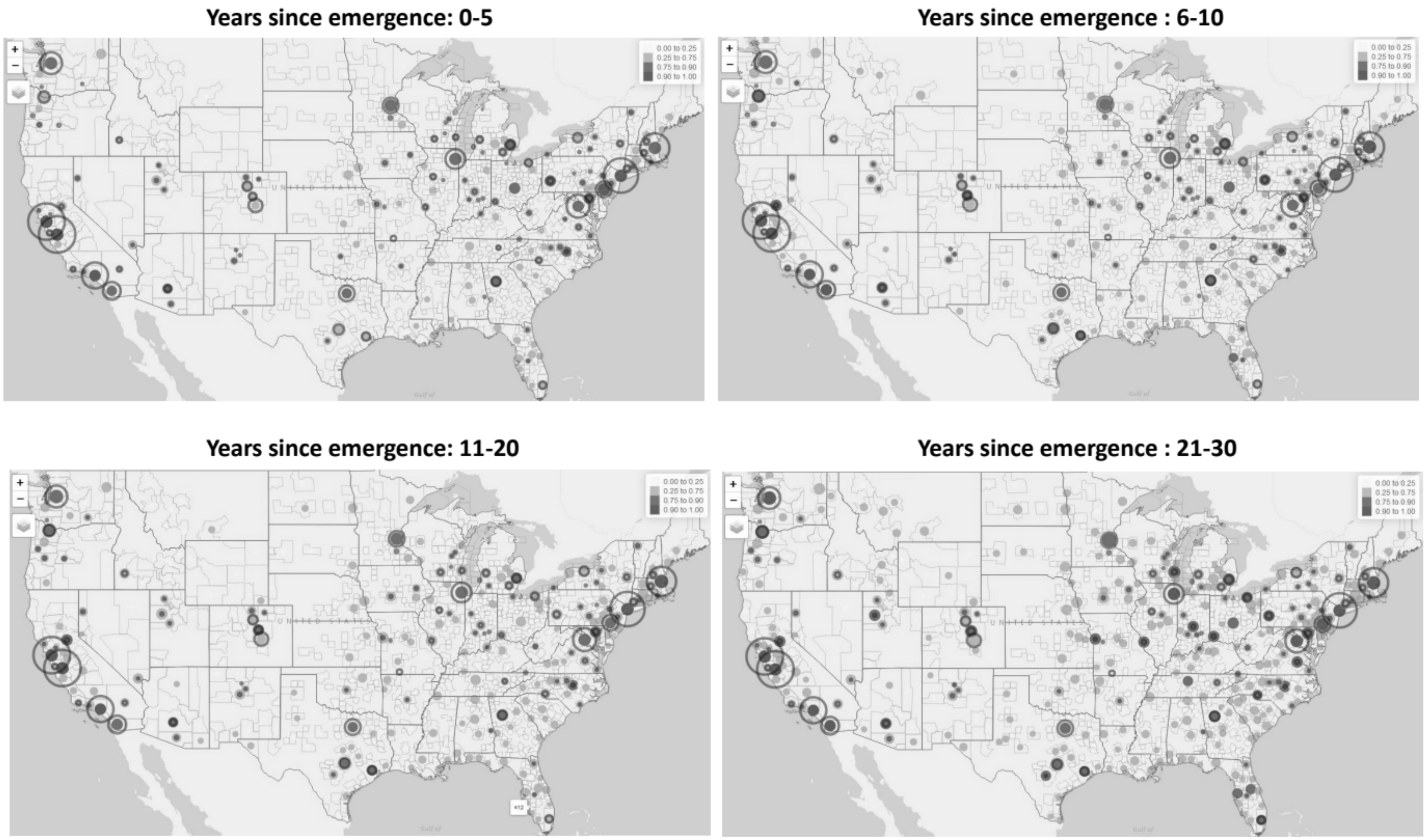
The simplest empirical problem



From de Rassenfosse et al (WP) linked dataset of product introductions and patents

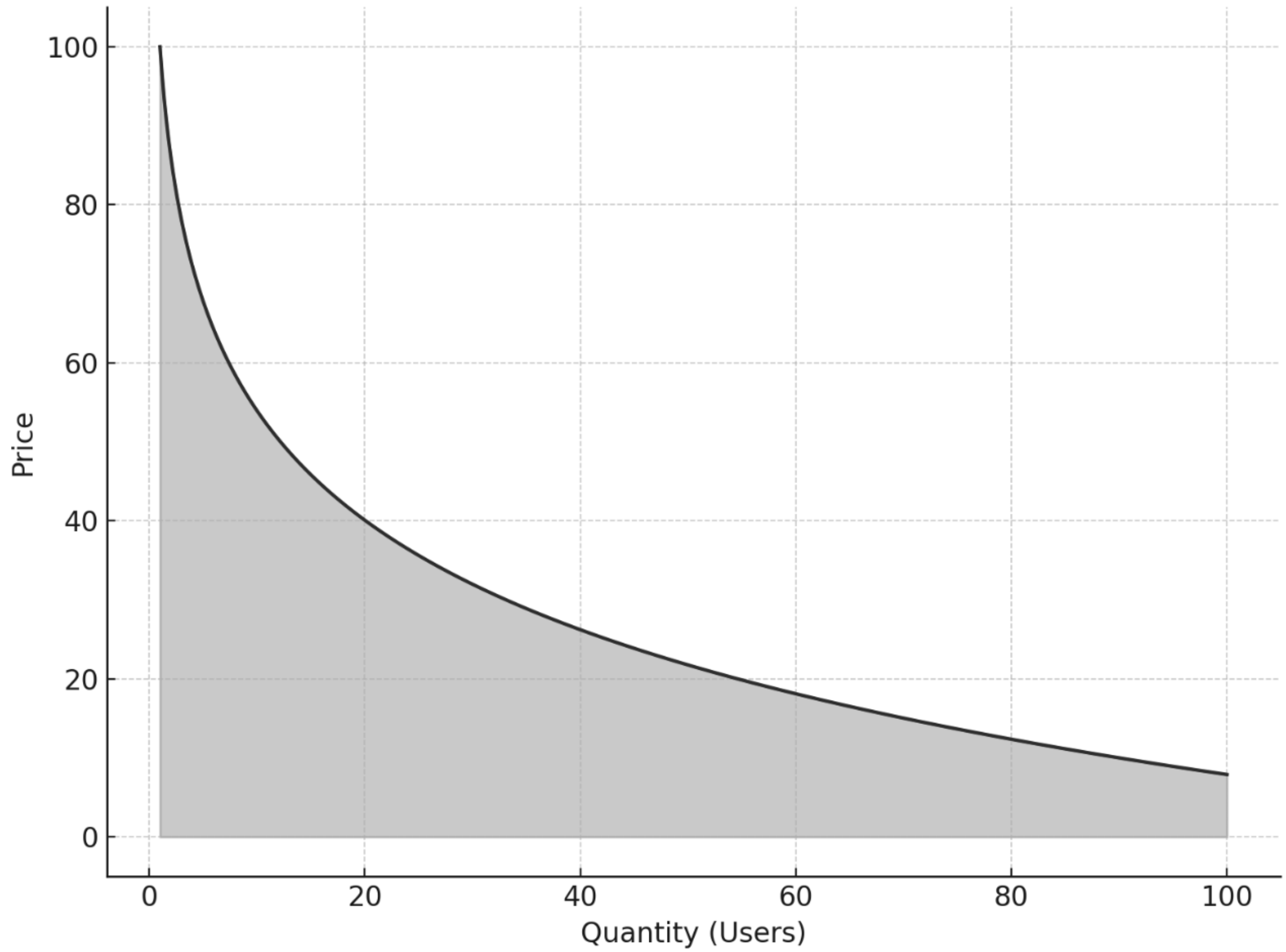
The simplest empirical problem

Figure 5 – Geographic diffusion of technology job postings, by year since emergence



From Kalyani et al (2025), new technology n-grams mentioned in at least 100 earnings calls,

The simplest empirical problem



The social value of an invention

Defining diffusion

The social value of an innovation does not stop with an initial invention, but rather depends also on its diffusion

Diffusion: *the change over time in who produces and uses the invention, and where it is used and produced*

We will discuss two types of diffusion

- Technology diffusion: the adoption of a good by new users and in new places
- Knowledge diffusion: where ideas spread from one agent to another

Importance of diffusion

Social value of an innovation derives from the invention diffusing to new firms or plants, or to more varied final users

- Particularly relevant as global R&D is highly concentrated in a very small number of countries, and most firms do little R&D themselves
  - Diffusion of technology from those countries and firms is the main source of productivity improvement
- Critical inventions like electricity and the computer took decades to become commonplace in industries where both technologies are now fundamental [David 1990]

Historical ideas on diffusion

The fact that good ideas do not immediately spread has been studied by sociologists and anthropologists as far back as the late 19th century

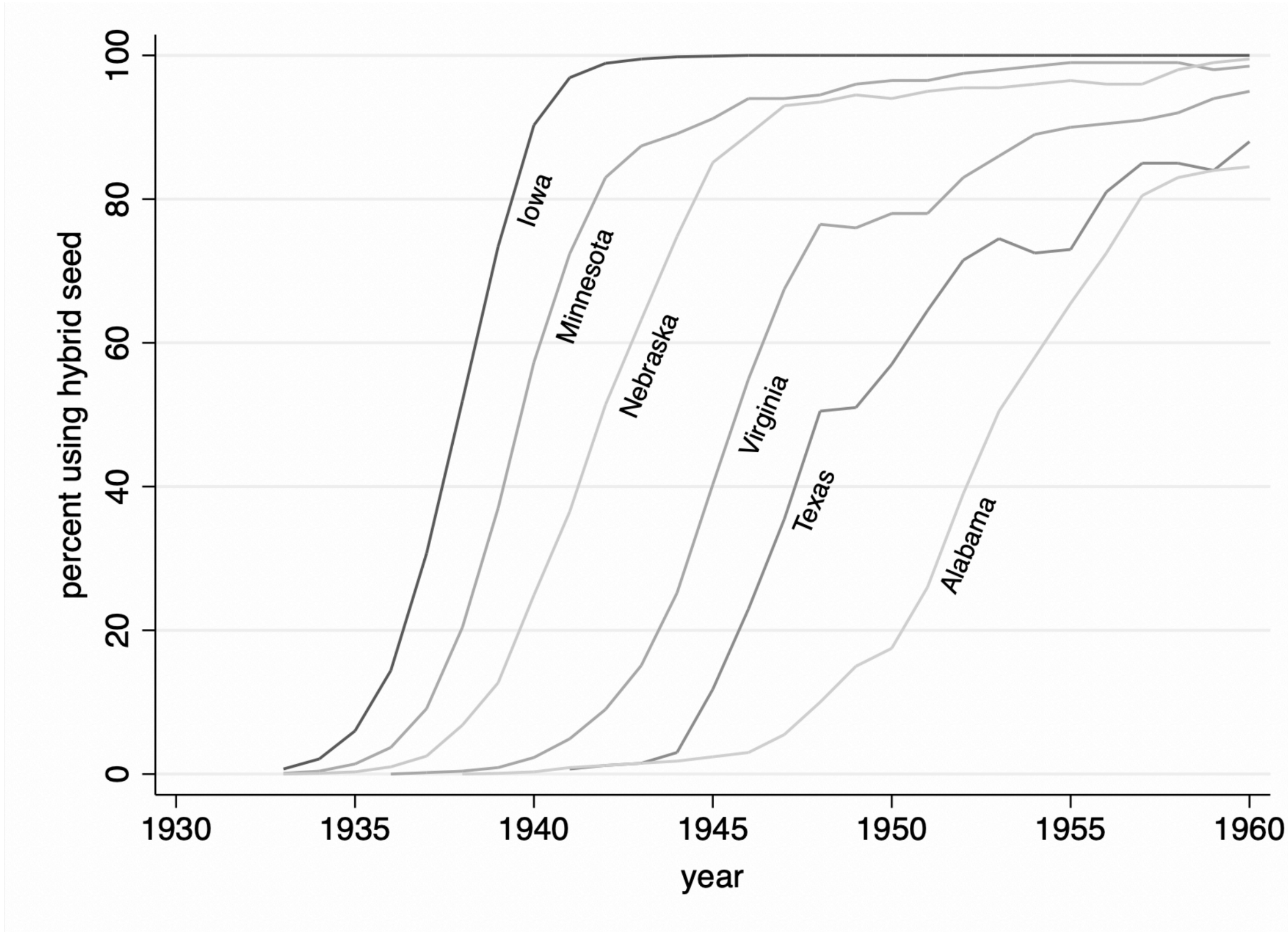
- Tarde (1890): Societal change depends on the diffusion of new inventions, which flow to new regions based on the amount of social contact and "logical laws"
- Chapin (1928) mapped the cumulative distribution function of a number of social innovations over time, finding an S-curve
  - Generally, innovations have slow initial adoption, then rapid uptake, then a slowdown as a market reaches saturation

Early empirical studies

Three canonical studies highlight mid-20th century work in this area

- Ryan and Gross (1943): Hybrid seen corn was known to many Iowa farmers in the early 1930s, but it was not commonly planted until the end of the decade
  - Authors argue adoption was driven by neighbors attesting to its benefit
- Coleman et al. (1957): The antibiotic “gammanym” diffused across Chicagoland doctors through social ties, especially early on, and particularly amongst professionally-oriented (rather than patient-oriented) doctors
- Griliches (1957): Hybrid corn is adopted slowly and diffuses following S-shaped adoption curves
  - Griliches divides the curve into three parts - “origin”, “slope”, and “ceiling” - and looks at how economic factors affect them

Percentage of total corn acreage planted with hybrid seed



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Consequences of diffusion

The time lag in adoption due to diffusion frictions is consequential on micro- and macro-grounds

Microeconomically:

- For example, Skinner and Staiger (2015) finds US heart attack patients have higher one-year survival rates at hospitals that adopt effective treatments (e.g. beta blockers, aspirin) quickly

Macroeconomically:

- Diffusion is critical to growth because cross-country differences in per capita output are too large to be explained by differences in factor inputs
- Eaton and Kortum (1999) gives a tractable structural model of innovation diffusion across regions
  - Domestic TFP increases when foreign inventions are used as inputs to final goods in the destination country, and when ideas in foreign inventions are used as the source of sequential inventions

Importance of Diffusion

Ideas may be nonrival, but they do *not* transmit for free!

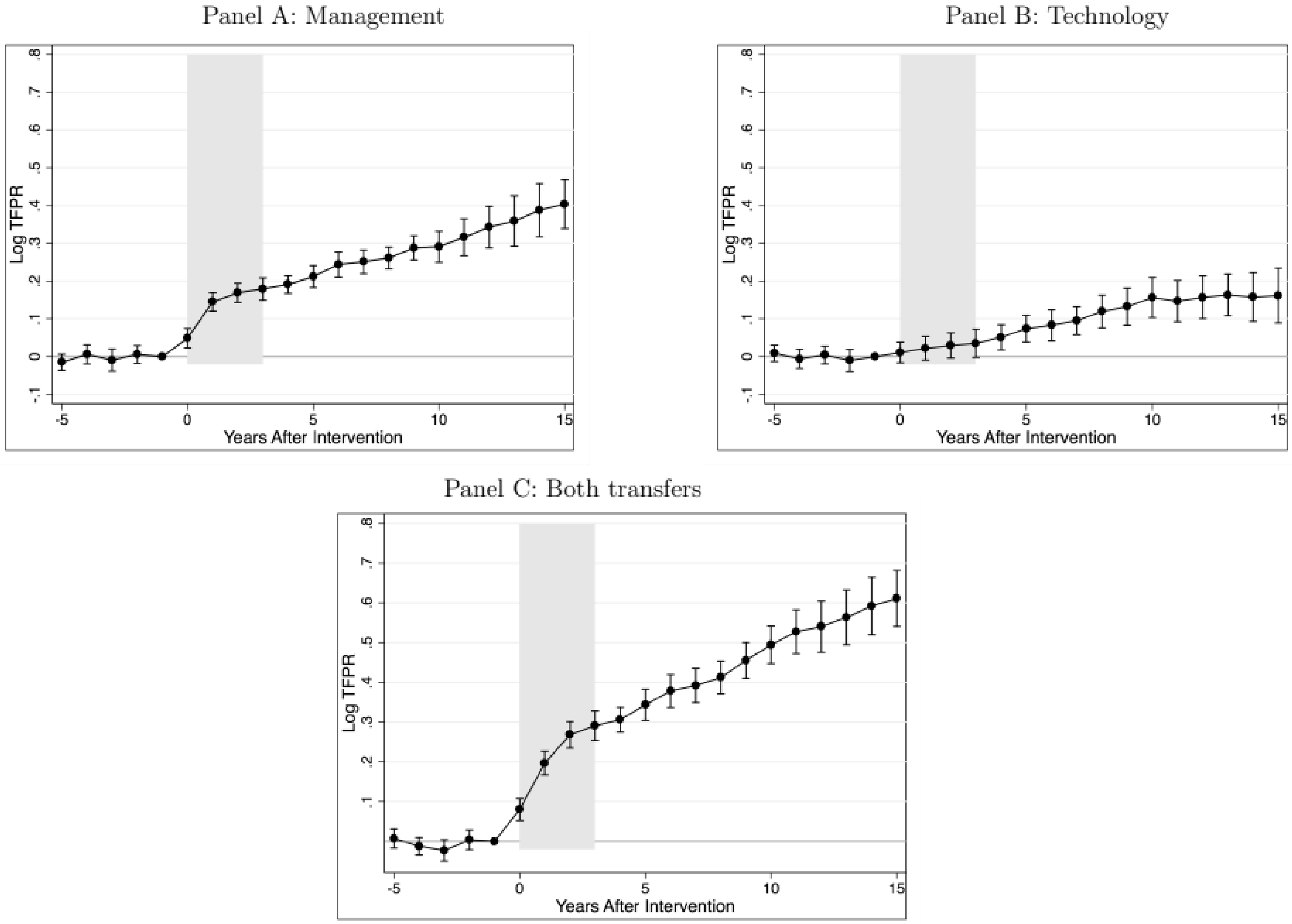
Just as human capital must be invested in, so must diffusion require active choices

Some Open Questions

- Is it more cost-effective to speed the diffusion of existing invention or to create new ones? What policies do this best (e.g., embedded technology, standardization, etc.)?
- Should countries limit or encourage tech transfer agreements or other training regimes?
- Do some types of knowledge require in-person transfer? Does WFH/hybrid work have costs over time from slower diffusion?
- How can we get organizations to adopt best practices/new technologies?
- Do existing innovation policies properly incentivize diffusion (see Schumpeter!)
- Is diffusion "speeding up"?

Importance of Diffusion

Figure 4: The Effects of Productivity Program on Firm TFPR



An Example of Diffusion: Stylized Facts (Akcigit and Ates)

1. Market concentration has risen.
2. Average markups have increased.
3. The profit share of GDP has increased.
4. The labor share of output has gone down.
5. The rise in market concentration and the fall in the labor share are positively associated.
6. The productivity dispersion of firms has risen; similarly, the labor productivity gap between frontier and laggard firms has widened.
7. The firm entry rate has declined.
8. The share of young firms in economic activity has declined.
9. Job reallocation has slowed.
10. The dispersion of firm growth has decreased.

An Example of Diffusion: Stylized Facts (Akcigit and Ates)

- Extended Aghion-Howitt “inverted U” model with more flexibility
- Calibrate to 1980 US data
- Shock balanced growth path with multiple policies and see how well they explain
- One is diffusion: probability laggard firms exogenously catch up with leaders in productivity
- Note this may be bad! Bessen, among others, has argued that firms taking market share in recent US data are high productivity, not low, and also high innovation. That is, sometimes high profits for market leaders are quasi-rents!

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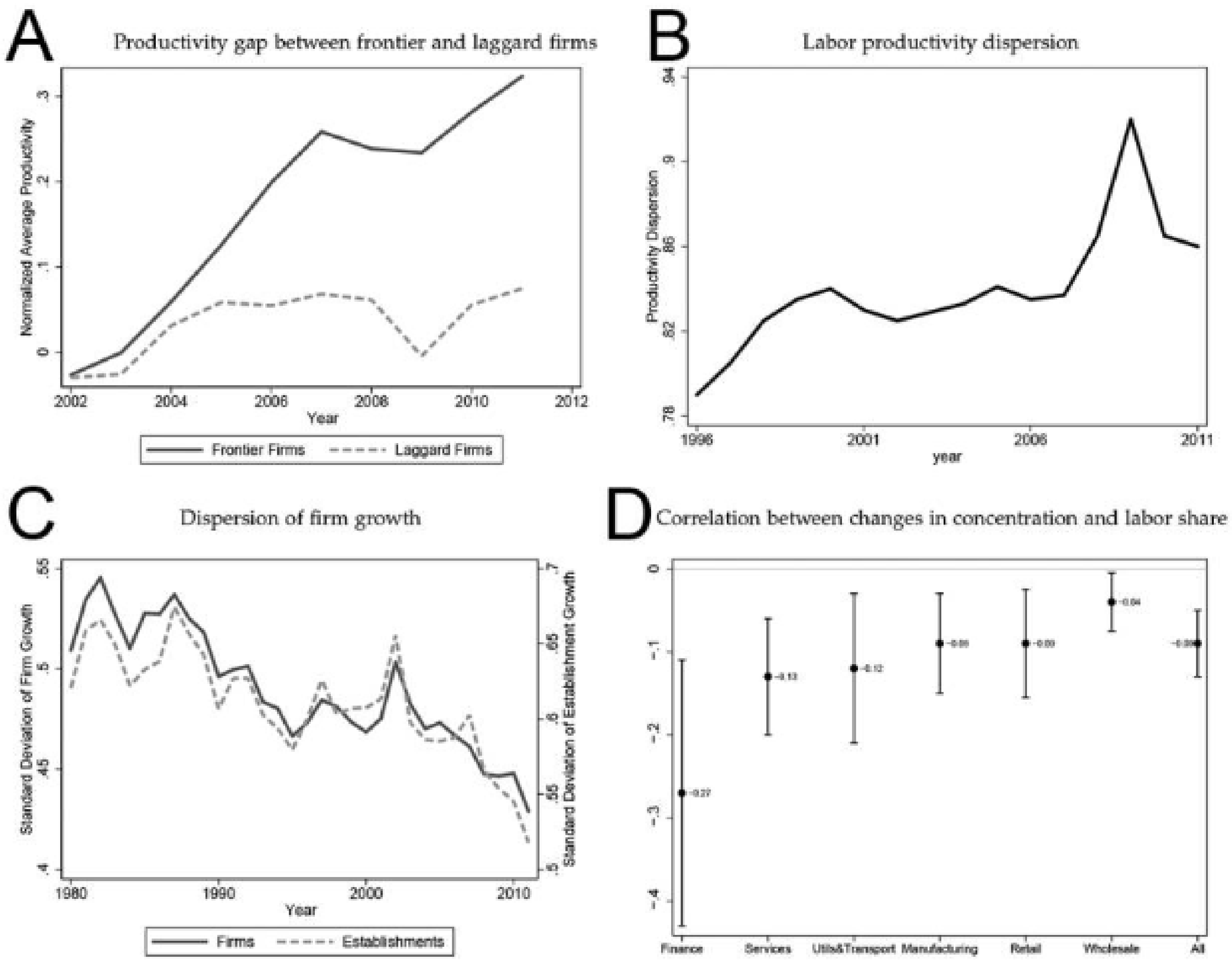

FIG. 1.—Empirical trends that inform the theory. *A* is taken from Andrews, Criscuolo, and Gal (2016), *B* from Decker et al. (2020), *C* from Decker et al. (2016), and *D* from Autor et al. (2017b).

From Akcigit and Ates (2023)

An Example of Diffusion: Stylized Facts (Akcigit and Ates)

TABLE 6
QUANTITATIVE EXPERIMENT RESULTS (Contributions as in Eq. [29])

Channel i	Lower Corporate Tax (%)	Higher R&D Subsidies (%)	Higher Entry Cost (%)	Lower Knowledge Diffusion (%)
Entry	−10.7	−1.0	78.1	24.5
Labor	−7.1	−9.9	2.4	109.8
Markup	6.1	6.3	1.6	91.4
Profit	−7.1	−9.9	2.4	109.8
Concentration	3.8	4.2	1.1	87.4
Young firms	−2.5	1.0	23.4	60.7
Productivity gap	5.3	5.6	1.5	90.1
Reallocation	−14.0	−2.5	17.7	66.3
Dispersion	−13.4	−.7	27.7	60.7

NOTE.—Percentage values measure the share of the contribution from the specific channel to the total model-generated deviation between 1980 and 2015. Negative values mean that adding the specific channel moves the model-generated variable in the opposite direction of the empirical counterpart. A value larger than 100% means that the difference between the hypothetical and empirical paths is larger than the observed variation.

From Akcigit and Ates (2023)

An Example of Diffusion: Stylized Facts (Akcigit and Ates)

Why diffusion may be falling? At micro level, top firms hold larger share of patents, larger share of high-quality labor than in past. Model fully rectifying heterogeneity in pay may be worth considering over life-cycle - I am not aware of high-quality evidence on this point.

Importance of Diffusion

A question for you: Why? Why doesn't knowledge transmit quickly? Why aren't new innovations adopted immediately?

Factors affecting diffusion

Many factors are thought to impact diffusion

Early literature:

- Information asymmetries mean that social networks smooth diffusion
- Adoption is costly in both a real sense and in terms of the option value of waiting to learn more

Recent Literature:

- Heterogeneity in adoption costs/benefits (incl. complements!)
- "Goldbricking" incentives among labor to prevent adoption

Information asymmetries

Asymmetric information, and hence the role for social contracts, as an explanation for slow diffusion goes back to sociological studies of ideas spread in the nineteenth century.

Firms introducing new products often make them similar to existing products in the same category to smooth this learning

- For example, Edison deliberately made the electric light as similar to existing gas technology as possible [Hargadon and Douglas 2001]

When the benefits of new technology are hard to observe, social learning can drive adoption.

Social learning

Empirically documenting evidence of social learning is a challenge given that social contacts likely share covariates

- Conley and Udry (2010) leverages the lengthy period between planting and the revelation of information about crop output to identify social learning as a driver of the diffusion of fertilizer-heavy pineapple crops in Ghana
- Adhvaryu (2014) studies a new malaria medicine in Tanzania which was rolled out quasi-randomly, finding that misdiagnosis of malaria and fever slows social learning and lowers future adoption
- Garcia-Jimeno et al (2022) look at spread of anti-alcohol protests using rail accidents as "shock" to network (reflection problem very serious!)
- Subsidies for tools that help social learning may be valuable

Information asymmetries can also be solved with non-social information, such as access to reference databases [Arrow et al. 2020]

Defining social learning

One must be careful to distinguish contagion, social influence, and social learning models of diffusion when comparing diffusion studies across disciplines

- Contagion model: implicitly assumes that diffusion requires social contact, often used in sociology and marketing ("Bass model": in population of m people, with $N(t)$ having adoped by t, a fraction of non-adopters $(p + \frac{q}{m}N(t))$ adopt today. This generates an S curve)
- Social influence model: based on wanting to conform to the choices of neighbors (status, etc., matter)
- Social learning model: involves rational updating of beliefs about a technology on the basis of observing the choices and outcomes of friends

Costs of adoption

Many inventions must be explained in order to be used by others

Examples:

- Teece (1977): Costs of transferring knowledge about production made up 20% of the costs of moving production to a new plant in a multinational firm
- Glitz and Meyersson (2020): Active corporate espionage was required to keep East Germany from falling further behind the productivity frontier in the West
- Dudley (2017): Regions with a common language have historically produced disproportionate numbers of important inventions, particularly those which require cooperation among many inventors

Factors that reduce adoption or information costs, smoothing technology adoption across firms, consumers, or regions, are understudied

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What other cost might matter for adoption?

Option value

The decision to adopt a technology *today* must be weighed not just against nonadoption, but against adopting tomorrow

- When adoption incurs a fixed cost and information about the benefit of adoption is revealed over time, there's value in waiting
  - The decision to wait under social learning also imposes an externality to future adopters in one's social network
- Farzin et al. (1998): Theoretically, diffusion is slower than optimum for many sources of uncertainty about a new technology
- The option value of potentially free-riding on external innovation in the future distorts the rate of invention today [Benhabib et al. 2014]

To what extent do irreversible adoption decisions and the option value of waiting cause inefficient technological direction?

Option value and social learning in development

The combination of option value to adopting and social learning has been studied by development economists investigating why some highly productive inventions don't diffuse widely in developing regions

- Foster and Rosenzweig (1995): high-yield seeds in India are underused because farmers must experiment to learn of seeds' effectiveness; they can learn from others in their village, and they underexperiment due to this positive spillover
- Bandiera and Rasul (2006): Adoption of sunflower seeds amongst members of the same religion, or by friends and family, improves adoption probability

One potential lesson - the effect of ethnic or religious cleavages on information transfer, or the benefit of technology solving this information problem, are questions relevant to addressing global poverty

Not always inefficient to wait!

- The spinning jenny - a labor-saving invention in textiles which played a fundamental role in the Industrial Revolution in England - did not diffuse widely in France or India in the late 18th century
- Allen (2009) estimates that wages were not high enough in France or India for the spinning jenny to be cost effective until the relative price of the device compared to wages fell
- Prices of new inventions often fall due to scale economies or learning-by-doing [Arrow 1962]
- Diffusion lags may simply result from the fact that early adopters have higher value for the invention. Important to understand the externality!

Diffusion costs reduced by knowledge spillovers

Adoption costs for new innovations differ due to the local nature of knowledge spillovers

- Audretsch and Feldman (1996): Particularly in knowledge-intensive industries like computers or pharmaceuticals, innovation production is more geographically specialized than final goods production
- The same importance of local spillovers is evident in the geography of citations between patents and the concentrated location of high-growth new firms [Jaffe et al. 1993, Guzman and Stern 2020]
- Local technology diffuses more quickly due to lower adoption and search costs. Matters for growth [e.g., Berkes, Gaetani, Mestieri 2025]

These externalities have important policy implications (e.g. local tax incentives could pull firms away from highly productive agglomerations) [Slattery 2020]

Diffusion costs reduced by knowledge spillovers

Question: I want to know whether work from home slows the diffusion of learning in firms, or across firms in the same geography or industry. How would you study this? What theoretical factors might you want to investigate?

Standard-setting organizations

Standard-setting organizations (SSO) attempt to solve option value-related inefficiencies by creating standards to avoid wasteful innovation and marketing

- Simcoe (2012) develops a theoretical model of voluntary SSOs
- The internal organization and development of voluntary SSOs are important for efficiency
  - How to prevent "standard-essential" patent holders from demanding high license fees once the standard is established? [Lerner and Tirole 2015]
  - Implication of "forum-shopping" among different SSOs? [e.g., Lerner and Tirole 2006]

SSOs involve reciprocal patent licenses, so they might face efficiency concerns arising from patent pools [Hagiu and Yoffie 2013]

One important option value: complementary tech

Potential adopters have heterogeneous preferences or benefits of the technologies

- Fertilizer and hybrid seeds are not adopted by 40% of small-scale farmers in Kenya, because they lack the complementary technologies [Duflo et al. 2008, Bresnahan and Trajtenberg 1995]
- Gross (2018) finds that fixed-tread tractors did not spread to Midwestern farms until complemented by general-purpose tractors and cotton and corn farming technologies
- The role of complementary technology is particularly important when multiple agents must adopt simultaneously for a technology to be valuable
  - e.g. Basker and Simcoe (2021) finds manufacturers are more likely to adopt UPC codes when other manufacturers with the same retail partner have adopted them

Goldbricking

Diffusion may be limited because some agents benefit from preventing use of new technology

Goldbricking: Concealing the effectiveness of new technology, particularly labor-saving technology

- Lazonick (1979): Workers during the Industrial Revolution resisted the adoption of the self-acting mule, which was thought to reduce labor demand
- Atkin et al. (2017): Soccer ball producers in Pakistan do not adopt a highly efficient new method of preparing soccer balls because piece rate workers are not compensated for avoiding waste in production, but do lose wages when production slows as they learn the method
- When organizational practices are sticky, useful technologies may not diffuse rapidly [e.g. Gibbons and Henderson 2011]

Goldbricking

Diffusion may be limited because some agents benefit from preventing use of new technology

Goldbricking by management: Consider Henderson's "architectural innovation"

A quick pause

Let's see how we should study this.

Take large language models/transformers. How long will these take to "show up in the producivity statistics", as Solow said?

What are the major diffusion barriers? How would you show this?

Diffusion in health econ

- Agha and Molitor (2018): When cancer treatment clinical trials are led by a local scientist, patients in the region are 36% more likely to be given the drug in the two years after FDA approval
- Allen et al. (2019): Doctors learn over time as a function of geographic and medical school cohort similarity with doctors who learn about more effective treatments early
  - To diffuse accurate information, strengthening information flow over time in highly-connected parts of the network is more effective than targeting the initial beliefs of doctors
- At the country level, Kyle (2006) shows many drugs are introduced to some countries with substantial delay, or never launched at all, depending on whether inventing firms have experience in that or geographically/culturally similar countries: only 1/3 of drugs launched in a G7 are sold in all seven!

Diffusion in trade

In standard trade models, the gains from free trade are often thought to be counterintuitively low

Models that capture dynamic gains from trade (e.g. the effects of openness on firm productivity distribution) could resolve this concern

- Buera and Oberfield (2020) creates a model of diffusion where the crucial parameter is how important global ideas are to local productivity
    - Benefits of trade to growth are highest when this parameter is in an intermediate range: foreign ideas are important to productivity, but you can't learn everything that is useful just by importing a small variety of foreign products

Thus, the nature of frictions to diffusion is critical for welfare analysis of trade policy

Diffusion policies: Technology transfer requirements

Technology transfer requirements can help speed up diffusion

- Policies that increase technology transfer:
  - IP rules that incentivize transfers
  - Direct technology transfer requirements for producers
  - Subsidies and government programs, like agricultural extension services and deliberate transfer of productivity advice
- Reciprocity in treatment of foreigners in IP protection improves welfare by solving the free-riding problem of low innovation countries [Scotchmer 2004]
- Forced technology transfer also acts as a tax on initial innovators by shrinking the gap in productivity between innovators and beneficiaries
- Analysis of a Marshall Plan program in Italy found the transfer of management knowledge led to increased productivity and a higher probability of exporting even fifteen years after the program ended. [Giorcelli 2019]

Diffusion policies: Taxing foreign technology

Some countries tax foreign technology to promote domestic innovation and ensure that innovation is more “appropriate” for the domestic labor force

- de Souza (2024) studies effects of a 2001 law taxing foreign technology and subsidizing domestic innovation
- Firms that previously used technology from abroad to increase patenting: hire lower skilled workers, and decrease production
- But trade can also lower tech transfer: firms abroad just sell the good instead of transferring tech to local partner via license [de Souza, Gaetani, Mestieri 2025]

Broadly, the global level of technology is sufficiently high quality that skill mismatch alone does not mitigate against its use

Diffusion policies: Absorptive capacity

Absorptive capacity: Across and within firms, the ability to absorb invention from the outside depends on what the recipient knows

- Bilir and Morales (2020): 20% of the productivity benefits of innovation in the US by the median multinational firm accrues to foreign affiliates
  - Additionally, there is strong complementarity between those affiliates' R&D and this productivity gain
- Coe et al. (2009) finds that foreign R&D stocks benefit domestic TFP especially when the recipient nation is highly educated and has strong IP protection

The need for absorptive capacity may partially counteract the harms to R&D incentives caused by technology transfer requirements

Diffusion policies: Competition and diffusion

If diffusion is slow, productivity differences between firms can remain even in the absence of anti-competitive behavior

- Syverson (2004): 90th percentile firm in a given industry is almost twice as productive as the 10th percentile firm
- If technology diffusion requires active effort, policies which increase competition may change the incentive of incumbents to adopt frontier technology, or force low-productivity firms out of business if they don't adopt
  - Schmitz (2005): Competition with Brazilian mines forced American and Canadian iron ore mines to adopt organizational practices and labor contracts, doubling productivity
  - Bloom et al. (2016): Lower tariffs for Chinese producers forced European manufacturers to either adopt productivity-enhancing technology or exit the industry

Data limitations

- Dating back to Ryan and Gross (1943), most diffusion studies rely on hand-collected data about specific technologies
- Government and private sector datasets tend to have very limited data on diffusion of particular technologies, and tracing the source of diffusion is even harder
- Five classes of nonproprietary data which have proved useful:
  - CHAT
  - Scanner data
  - Census data
  - Patent data
  - New corpuses extracted using ML?

CHAT

For data on technology adoption over time and space, including the intensive margin of adoption in each location, the Cross-Country Historical Adoption of Technology (CHAT) dataset from Comin and Hobijn (2010) is the most extensive

- The dataset traces the intensity of adoption of over 100 technologies in 161 countries since 1800
- Importance of *intensity* data: the airplane was available in both China and US in 1960, but the number of flights was orders of magnitude higher in the US
- Comin and Mestieri (2018) argues that the intensive margin of diffusion, rather than the extensive margin, explains why incomes diverged between countries even as technology "arrived everywhere"

Scanner data

Scanner datasets contain panel information on precisely which products are available for sale when and where

- Some datasets are limited to specific industries (e.g. IRI Academic Dataset on foodstuffs)
- The standard cross-industry reference is the Nielsen Retail Scanner Dataset
  - Weekly data for millions of consumer-oriented UPCs from tens of thousands of stores since 2006
- Linking the diffusion data from Nielsen UPCs to other covariates in patent or hand-collected data has tremendous potential (see NBER-backed IPRoduct dataset)

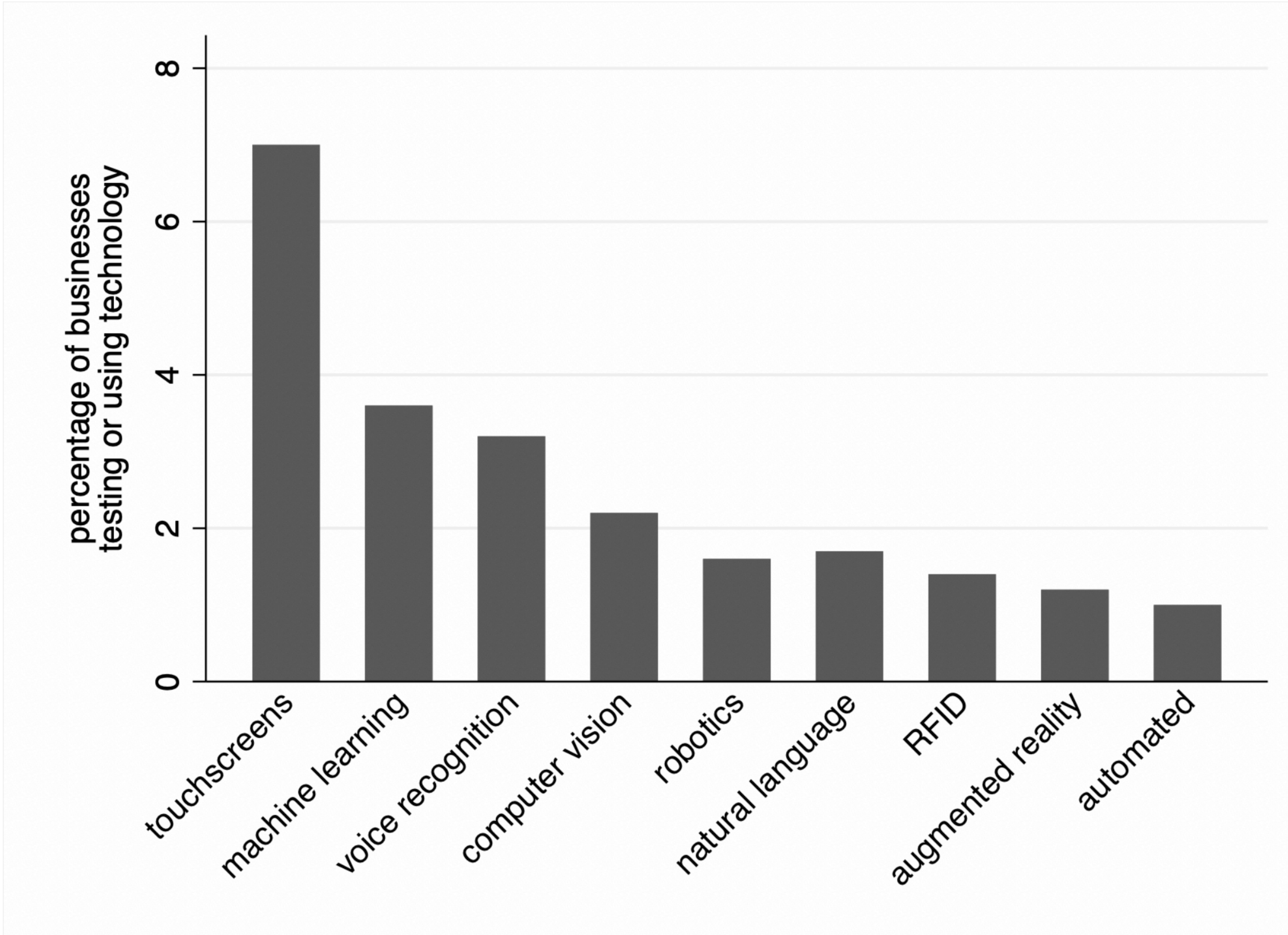
Census data

Standard population surveys in many countries have long tracked certain classes of consumer goods

Two surveys appear particularly promising for studying diffusion to firms:

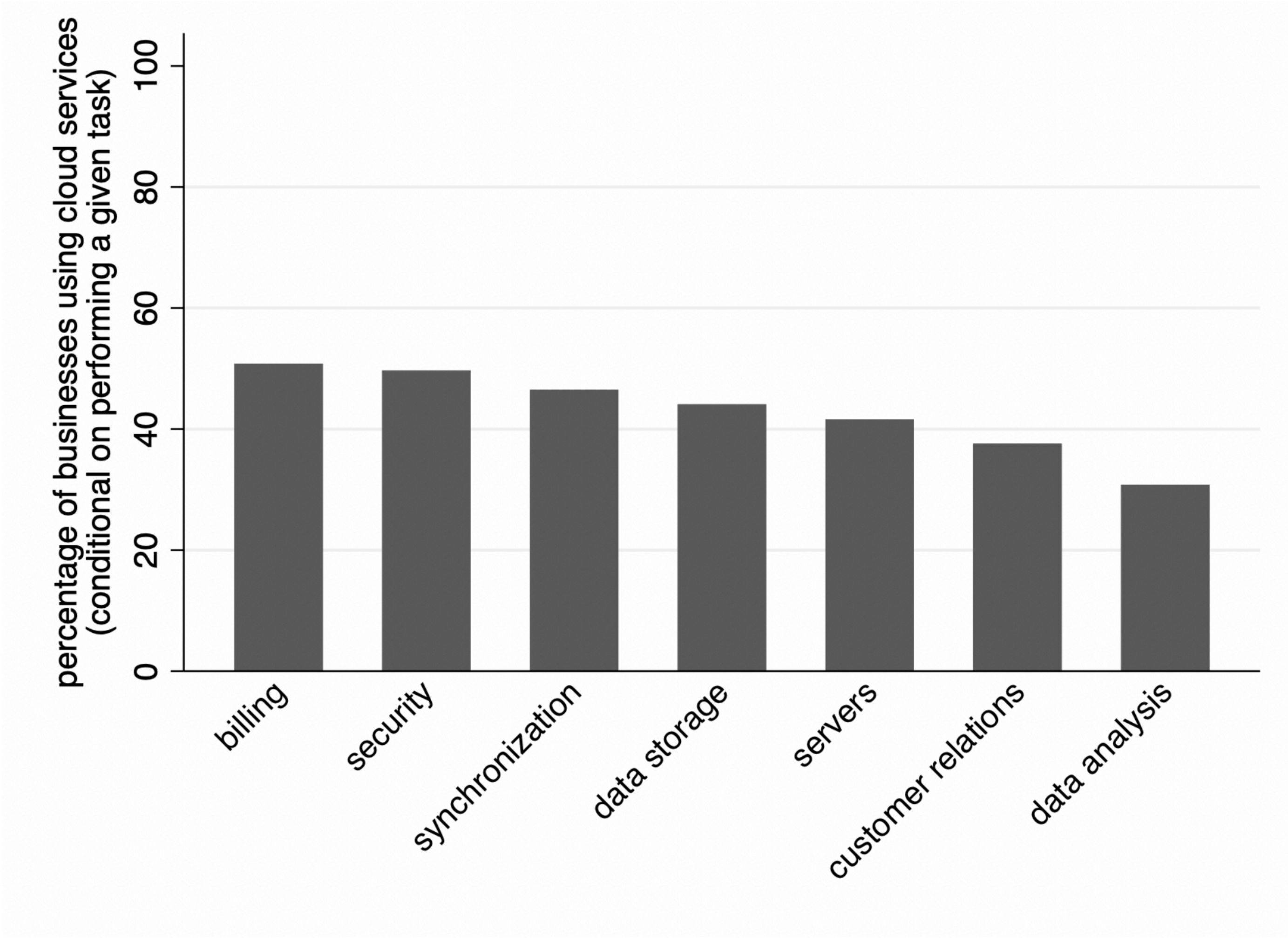
- US Census Annual Business Survey
  - First wave in 2018, it surveys 850,000 nationally representative businesses about their adoption of technologies
- World Management Survey
  - Deriving from Bloom and Van Reenen (2007), this survey asks managers in a growing number of countries about their adoption of process technologies

Adoption or trial of advanced technologies



Note: Data comes from the 2018 Annual Business Survey. The data are weighted to match all US firms on the basis of responses from over 570,000 businesses. Source: McElheran et al. (2020)

Adoption of cloud services



Note: Data comes from the 2018 Annual Business Survey. The data are weighted to match all US firms on the basis of responses from over 570,000 businesses. Source: McElheran et al. (2020)

Patent data

As with other questions in innovation, the “paper trail of knowledge” in patents has been a useful dataset for studying diffusion

- Jaffe et al. (1993) canonically shows that patents are 2-6x as likely to be cited by a future inventor in the same metropolitan area
  - Localization effect suggests that the ideas in a patent diffuse over space only with time
- Thompson and Fox-Kean (2005) reaches a similar result after comparing inventor patent citations and examiner-added citations
- Arora et al. (2018) cautions that “citation reversals” could result in imprecise data, but the citation reversals have nearly the same geographic decay as non-reversal citations
- Patent-patent and patent-paper links now standardized (Matt Marx’s “Reliance on Science” is most up to date)

Text-based approaches

Researchers could look at the text of patents with machine learning to measure diffusion

- Myers and Lanahan (2022) investigates spillovers from SBIR grants targeted at particular technical problems
- The authors look at the cosine similarity between text in SBIR call for proposals and the full corpus of US patents in order to infer which technology classes the grant was targeting
- Findings:
  - Up to four patents overall are generated for each patent induced by the grant recipient
  - The citation network misses up to half of these spillovers
  - Spillovers are more likely to be geographically proximate

Text-based approaches plus patents

- Combining patent data with information about invention and external data on adoption by end users or non-patenting intermediate users is a promising future path
- The text of patents themselves often contains information written by inventors about the precursors of their invention, as leveraged in Bryan et al. (2020) and Marx and Fuegi (2020)

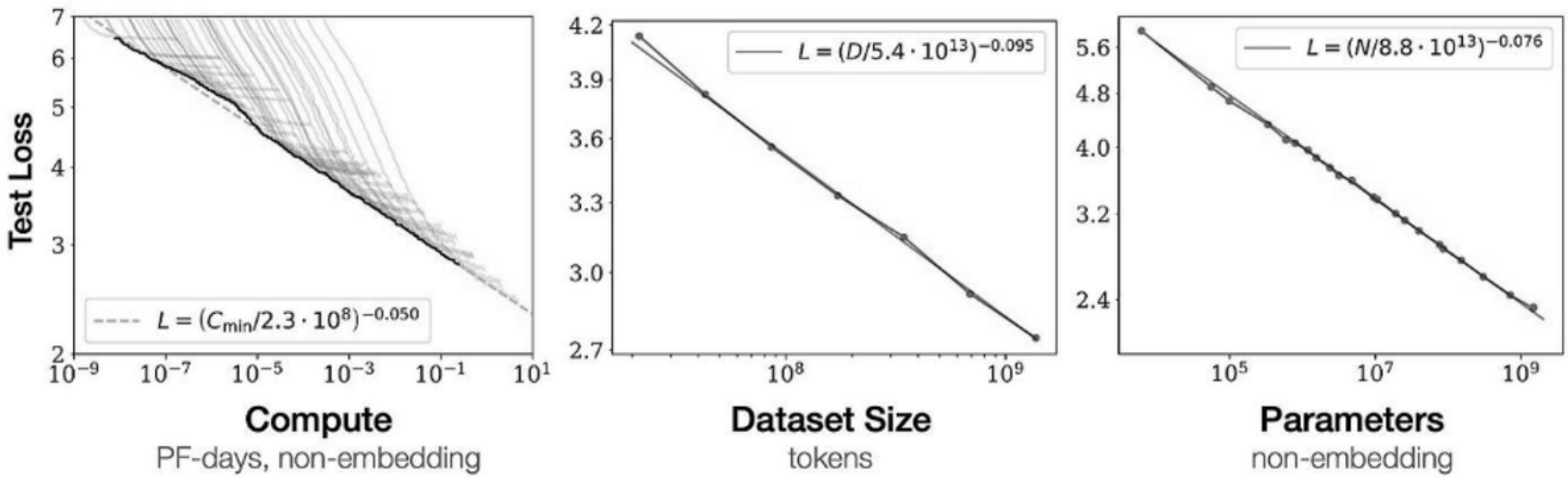
Non-patent datasets

- The arrival and expansion of new technology is clearly evident in non-patent data, and helps capture broader "technology spread"
- E.g., at what rate does air-based cropdusting arrive? Local newspapers highly likely to report on use of a new technology of this type. Melissa Dell and coauthors have an ongoing project to digitize all late 19th and early 20th century US newspapers in a high-quality OCR format. Topic modeling can identify air-based pest control without need for individual keyword search.
- Alternative large text- or image-based sources that could be searched? AI is **really** good at OCRing documents (esp. Gemini)

Need for further research

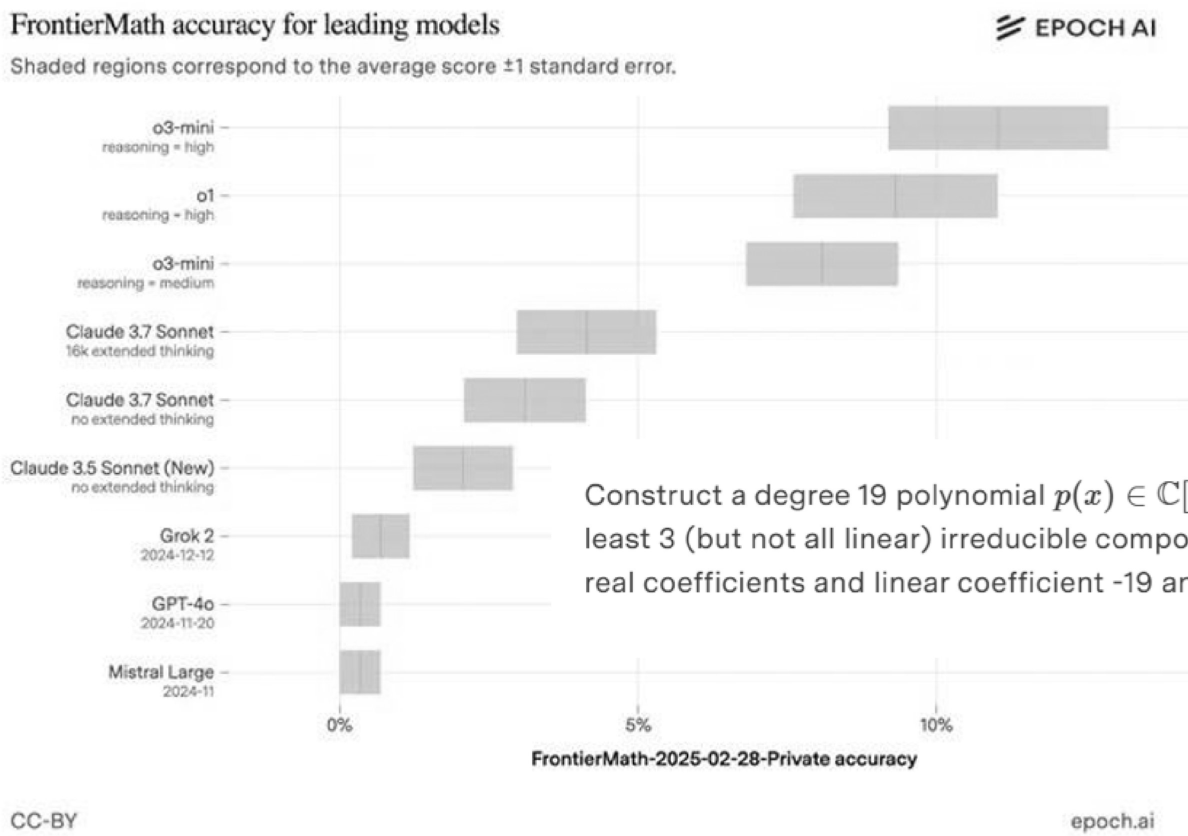
- Despite the enormous social returns of specific inventions, once adopted there are very few credible estimates of the social return to policies which speed diffusion in the aggregate
- We need more research to understand where equilibrium investment in marketing and diffusing new products is inefficient, and which public policies can ameliorate these inefficiencies. Even the theoretical externalities are not totally clear.

Let's return to AI



The famous "scaling law" paper

Let's return to AI



Construct a degree 19 polynomial $p(x) \in \mathbb{C}[x]$ such that $X := \{p(x) = p(y)\} \subset \mathbb{P}^1 \times \mathbb{P}^1$ has at least 3 (but not all linear) irreducible components over $\mathbb{C}$. Choose $p(x)$ to be odd, monic, have real coefficients and linear coefficient -19 and calculate $p(19)$.

Performance on frontier math: top is now 19.31%!

Let's return to AI

Anthropic CEO Dario Amodei warns: AI will match 'country of geniuses' by 2026

Sam Altman predicts AI progress in the next 2 years will be extraordinary

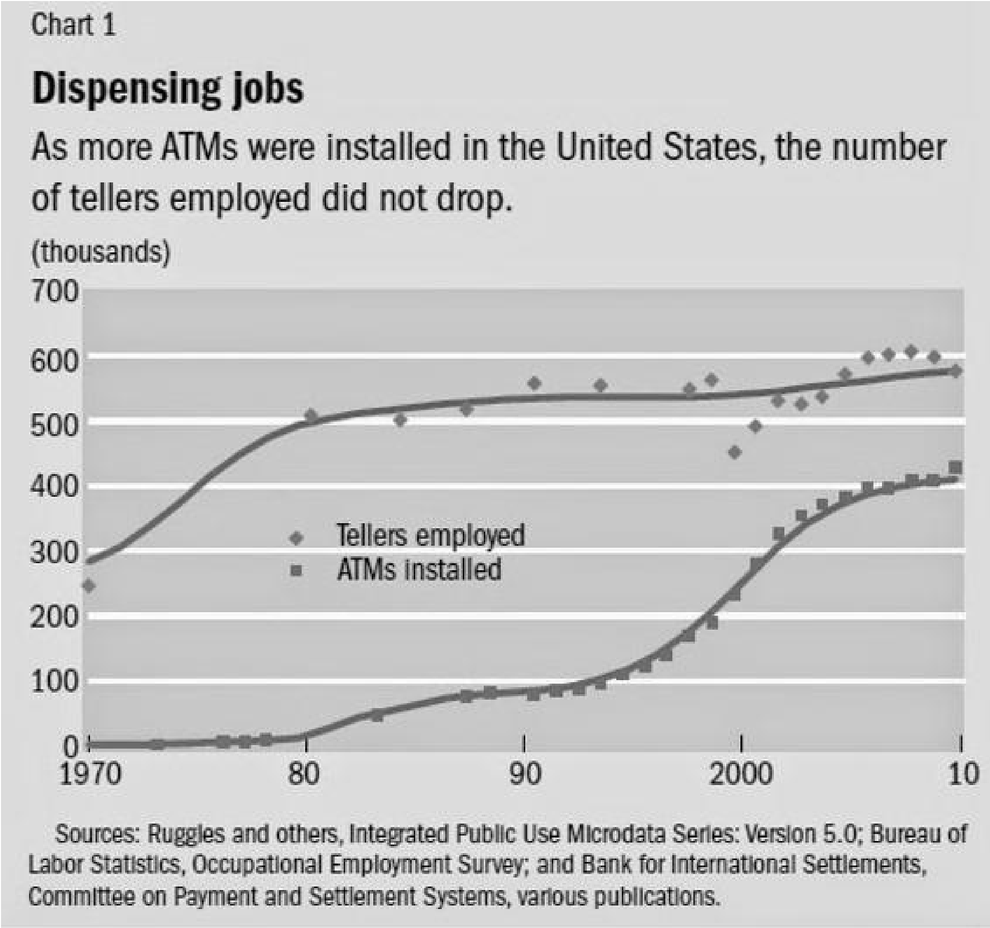
he said,

- we know how to improve these models so much, and there's no roadblock in front of us

- the progress from February 2025 to 2027 will be more impressive than from 2023 to 2025

But effects of this technology are not so obvious...

Let's return to AI



But effects of this technology are not so obvious...

Let's return to AI

Why will AI spread quickly or not? How big do you expect benefit to productivity to be *taking seriously the technology projections given by the AI labs*. Who will "win"?

Summing up

- The social value of an invention derives from the innovation diffusing to new firms and regions
- Diffusion is frequently impacted by information asymmetries and high costs of adoption
- Diffusion is often limited to local spillovers, with real impacts on trade, agricultural production, medicine, and other areas
- Social learning, standard-setting organizations, technology transfer requirements, and competition are among the potential tools to encourage diffusion of frontier technology
- More research is needed to shape policy that optimizes the social value of innovation via diffusion.

The following is a near-complete list of new diffusion papers from Jan 2022 to July 2025, focused on published work and that which is published in top economics journals. Take a look for an idea of where the field stands currently.

Lind and Ramondo, AER Insights, 2023

Title: Global Innovation and Knowledge Diffusion
Summary: Builds on previous growth theoretic models of diffusion balancing adoption against innovation. Develops a technical apparatus to estimate the extent of diffusion in a general way. Non-CES expenditure shares across countries in international trade are indicators of diffusion frictions.

de Souza, Chicago Fed Working Paper, 2024

Title: The Labor Market Consequences of Appropriate Technology
Summary: Brazil tax data lets you observe international technology licensing. Higher taxes were meant to incentivize "appropriate" domestic innovation. Result: worse innovation, lower wages, lower GDP. Not all tech from abroad is inappropriate and there are limits to how much you can produce domestically anyway!

Nagler et al, J Ind E, 2022

Title: Fostering the Diffusion of General Purpose Technologies
Summary: Empirically shows that transistor use increased in frequency and across more fields following open licensing and educational symposia by AT&T in 1952. Changes in royalty rates had a much smaller effect on diffusion.

Cai et al, AEJ Macro, 2022

Title: Knowledge Diffusion, Trade, and Innovation across Countries and Sectors
Summary: Models and estimates welfare effects of trade when innovations can diffuse. Theoretically, if poor innovators are good adopters, trade may lower growth. Empirically, good innovators are better at adopting outside technology, countering the theoretical prediction.

Ayerst et al, JME, 2023

Title: Trade and diffusion of embodied technology: an empirical analysis

Summary: Input-Output tables for knowledge inputs based on patent data are less stable, less geographically clustered, and uncorrelated with production input-output tables. Importing goods increases patenting in downstream activities significantly.

Berkes et al, Chicago Working Paper, 2022

Title: Global innovation spillovers and productivity: evidence from 100 years of world patent data
Summary: Observes large increase in patent citations in recent decades. Using shift-share technique, finds that international spillovers increase domestic patenting, which in turn boosts sectoral growth, TFP, and long-run income substantially.

McElheran et al, JEMS, 2024

Title: AI Adoption in America
Summary: Using 2018 Annual Business Survey, finds AI adoption still rare (6% of firms, 18% of employment-weighted firms). Higher adoption rates among firms with more-educated, younger, more-experienced owners. Adoption shows significant geographic heterogeneity, with a few superstar cities leading.

Moscona and Sastry, Working Paper, 2022

Title: Inappropriate Technology: Evidence from Global Agriculture
Summary: Crop technology diffuses across countries with similar pest conditions. R&D focus on rich world issues limits diffusion to different pest environments. Reallocating R&D to global first-best could increase global agricultural productivity by 58%.

Cheng et al, ASR, 2023

Title: How New Ideas Diffuse in Science
Summary: Analysis of 60,000 ideas in Web of Science over 25 years. Adoption increases with idea age if it reaches a broader user set, is used consistently, associates with other growing ideas, and aligns with dominant scientific ideas.

Arque-Castells and Spulber, JPE, 2022

Title: Measuring the Private and Social Returns to R&D: Unintended Spillovers versus Technology Markets
Summary: [No summary provided in the original text]

Bai et al, JEG, 2022

Title: Surname distance and technology diffusion: the case of the adoption of maize in late imperial China
Summary: Maize adoption and IR technologies diffuse more slowly, especially when new to China, when surname similarity across neighboring prefectures is larger.

Bai et al, NBER, 2024

Title: Optimal Trade Policy with International Technology Diffusion

Summary: What tariffs and export taxes should be set when imports and exports cause technology and not just products to be traded? You want to subsidize imports that bring in useful technology, and tax exports that cause competition strong enough to overwhelm the more efficient foreign producers making lower cost goods for you to buy. Unilaterally, the US imposes import tariffs, ensuring that US technology which diffuses given high US wages do not compete the US down.

Ploeckl, JEH, 2023

Title: Market Access and Information Technology Adoption: Historical Evidence from the Telephone in Bavaria

Summary: Around the turn of the century, state telephone monopoly granted access at town level. Large towns with intra-city calling were first, followed by smaller towns with significant trade linkages to larger ones.

Cinnirella et al, EJ, 2023

Title: Flow of Ideas: Economic Societies and the Rise of Useful Knowledge
Summary: Late 18th century "economic societies" in Europe led to earlier vocational school formation, higher manufacturing productivity a century later, and quicker diffusion of ideas (cities with members in common became more similar in their patenting and industrial production).

Prato, QJE, 2025

Title: The Global Race for Talent: Brain Drain, Knowledge Transfer, and Growth
Summary: Preventing brain drain helps a country in the short run, but since knowledge spills over and locations differ in their effect on inventor productivity, increased, for example, EU migration of inventors to the US improves long-run growth in both countries. Model is two-country endogenous growth with spillovers.

Roche et al, NBER, 2022

Title: (Co-)Working in Close Proximity: Knowledge Spillovers and Social Interactions
Summary: Startups in an incubator adopt similar upstream tech causally from being at the incubator only if initially dissimilar, socially interacting, and located very close to each other (e.g., not on different floors).

Chandrasekhar et al, NBER, 2022

Title: Blue Spoons: Sparking Communication About Appropriate Technology Use
Summary: [No summary provided in the original text]

Fry and MacGarvie, NBER, 2023

Title: Author Country of Origin and Attention on Open Science Platforms: Evidence from COVID-19 Preprints
Summary: Controlling for paper quality, topic, and eventual publication output, especially on poorly understood topics, Chinese Covid preprints received less attention than rest-of-world ones, which received less than US ones.

Flynn et al, NBER, 2024

Title: Building a Wall Around Science: The Effect of U.S.-China Tensions on International Scientific Research

Summary: From 2016 to 2019, 16% drop in Chinese grad student attendance of STEM degrees in US, drop in Chinese citation of US citation (no change in reverse), showing political conditions may harm diffusion of knowledge.

Duflo et al, NBER, 2023

Title: Chat Over Coffee? Diffusion of Agronomic Practices and Market Spillovers in Rwanda

Summary: Rwandan coffee farmers given random agronomy training increased fertilizer use, raising yields by 6.7%. No evidence of knowledge diffusion; control farmers harmed by higher fertilizer prices in imperfect competition setting.

Eaton and Kortum, NBER, 2024

Title: Technology and the Global Economy
Summary: Review article, where Section 6 presents a simple trade model with heterogeneous technology by location and a basic model of diffusion lags.

Goldberg et al, NBER, 2024

Title: Industrial Policy in the Global Semiconductor Sector
Summary: [No summary provided in the original text]

Boustan et al, NBER, 2022

Title: Computerized Machine Tools and the Transformation of US Manufacturing
Summary: CNC tooling in the late 20th century led to large increases in labor productivity and reduced employment, with predictable early diffusion patterns.

Bernstein et al, NBER, 2022

Title: The Contribution of High-Skilled Immigrants to Innovation in the United States
Summary: Immigrants produce 16% of all US inventions and 23% of US patent value. They are more likely to cite foreign tech, patent with foreign inventors, and be cited by foreign patents, demonstrating the "human" role in innovation diffusion.

Hegde et al, JPE, 2023

Title: Patent Publication and Innovation
Summary: 1999 AIPA causes (most) US patent applications to be disclosed before grant. Compared to twin EU patents get more and faster citations, more "distant" citation in the technology sense, and less "very similar" citation. R&D rises for firms in most affected tech classes (those with big lags between application and grant). This all occurs even though the identification comes from EU-US patent pairs which were already public 18 months after application in the EU databases prior to 1999, but is in line with Furman et al 2021 AEJ: Policy on patent libraries.

Eli et al, NBER, 2023

Title: The Model T
Summary: Explores why the US adopted the car as a mass market good so early. The Model T had enormous economies of scale, especially when made in Detroit, and trade costs/tariffs/smaller markets made this hard to replicate elsewhere.

Hornbeck et al, NBER, 2024

Title: Gaining Steam: Incumbent Lock-in and Entrant Leapfrogging
Summary: A structural model of leapfrogging. Firms start with water power; switching costs exist. As steam price falls, older incumbents don't adopt and fall behind. New entrants in water-heavy areas start with water (lower fixed cost) but may get locked in if they grow due to good productivity draws.

Sampson, AEJ Micro, 2024

Title: Technology Transfer in Global Value Chains
Summary: Theoretical model of how diffusion along a value chain affects incentives. In some cases, the focal firm benefits from others imitating its supplier's technology; in others, it's harmed. A taxonomy of these cases is provided. Supply chain globalization into relational contract environments depends on this factor.

Akcigit and Ates, JPE, 2023

Title: What Happened to US Business Dynamism?
Summary: In a micro-founded GE model, the fall in dynamism appears to be driven by a declining diffusion of knowledge from frontier firms to laggard ones.

Li et al, JPAM, 2022

Title: The Role of Government in the Market for Electric Vehicles: Evidence from China
Summary: Analyzes Chinese EV adoption between 2015 and 2018. Consumer subsidies drove half of EV sales, but infrastructure investments were much more cost-effective.

Blasutto and de la Croix, Econ J, 2023

Title: Catholic Censorship and the Demise of Knowledge Production in Early Modern Italy

Summary: Censorship limits the market for ideas, slowing diffusion and shifting incentives for idea generators. Early Italian censorship caused a large drop in publications, initially raising the quality of work on censored topics, but later driving researchers to different fields.

Spolaore and Wacziarg, Econ J, 2022

Title: Fertility and Modernity
Summary: France experiences its demographic transition first. Even controlling for many demographic factors, places with cultural similarity to France see fertility drop earlier than otherwise-similar parts of Europe.

Akcigit and Ates, JPE, 2023

Title: What Happened to U.S. Business Dynamism?
Summary: See discussion above in these slides.

Arque-Castells and Spulber, JPE, 2022

Title: Measuring the Private and Social Returns to R&D: Unintended Spillovers versus Technology Markets

Summary: How large are markets for technology? When firm A does R&D, there is a direct return, licensing revenue from other firms, and a spillover for which firm A is not compensated. The largest inventors are also highly correlated with the largest licensors. Back-of-the-envelope calculations still suggest a large private-social wedge, but a smaller role for "spillovers" in diffusion than traditional estimates.

Chandrasekhar et al, NBER, 2022

Title: Blue Spoons: Sparking Communication About Appropriate Technology Use

Summary: Following the Duflo et al papers on the difficulty of diffusing information about useful fertilizer in Kenya, a simple technology that inspires local conversations (a "blue spoon" sized for fertilizer) is much more effective at diffusing the fertilizer use that decreases in price via coupons or induced general agricultural communication following the seeding of fertilizer among test farmers.

Garcia-Jimeno et al, AER, 2022

Title: Information Networks and Collective Action: Evidence from the Women's Temperance Crusade
Summary: Personal interaction, mediated through local newspaper coverage, was an important driver of temperance protests in 1873 and 1874. When rail links were cut by accidents and rallies didn't happen, neighboring towns were much less likely to see temperance activity. This study examines exogenous "shutting down" of network links, avoiding the reflection problem.