Digital Economics and AI: Introduction to the PhD Tutorial

Avi Goldfarb
University of Toronto and NBER

Catherine Tucker
MIT and NBER

September 2023

The Economics of Digitization: An Agenda for NSF

By Shane Greenstein, Josh Lerner, and Scott Stern

Motivation

Our starting point is the gap between research and recent changes brought about by digitization. The increasing creation, support, use, and consumption of digital representation of information touched a wide breadth of economic activities. In less than a generation digitization has transformed social interactions, facilitated entirely new industries and undermined others, and reshaped the ability of people –consumers, job seekers, managers, government officials, and citizens – to access and leverage information.

Key topics

- Understanding changes in market structure and market conduct
- Rethinking the design of copyright
- Redesigning incentives for innovation and creativity
- The economics of the commons
- The economics of privacy
- Measuring digitization with an eye towards open policy issues
- The absence of analysis untied to stakeholders

Authors, please upload your paper here

NATIONAL BUREAU OF ECONOMICS RESEARCH, INC.

Economics of Digitization

Shane Greenstein, Josh Lerner and Scott Stern, Organizers

February 24 and 25, 2011

SIEPR
Stanford University
Stanford, CA

PRELIMINARY PROGRAM

THURSDAY, FEBRUARY 24:

12:00 n	Lunch
1:00 pm	Introduction
1:20 pm	Jonathan Levin, Stanford University and NBER *Learning from Seller Experiments in Online Markets*
2:10 pm	Break
2:40 pm	Avi Goldfarb, University of Toronto *Privacy Regulation and Online Advertising*
3:40 pm	Break
4:00 pm	Panel: The Role of Copyright Preston McAfee, Yahoo! Research Fernando Laguarda, Time Warner Cable Gil Penchina, Wikia Molly Van Houweling, UC Berkeley
5:00 pm	Adjourn
6:30 pm	Group Dinner Il Fornaio Restaurant, 520 Cowper Street (at the Garden Court Hotel), Palo Alto.

FRIDAY, FEBRUARY 25:

8:30 am	Breakfast
9:00 am	Heidi Williams, MIT and NBER *Intellectual Property Rights and Innovation: Evidence from the Human Genome*
9:50 am	Break
10:10 am	Pam Samuelson, UC Berkeley *The Economics of the Digitization of Books As a Rationale for the Google Books Project and Settlement (and the Implications of Google Books for the Future)*
11:00 am	Break
11:15 pm	Panel: The Future of Digitization and its Governance, Ashlee Vance, Bloomberg Businessweek Hal Varian, Google Danny Goroff, Sloan Foundation
12:15 pm	Lunch and Adjourn

Economics of Digitization Spring 2012

DATE February 24, 2012 **LOCATION** SIEPR at Stanford University

ORGANIZERS Shane Greenstein, Josh Lerner and Scott Stern

The Attention Economy: Measuring the Value of Free Goods on the Internet

AUTHOR(S):

Erik Brynjolfsson, Stanford University and NBER
Joo Hee Oh, Massachusetts Institute of Technology

Copyright, Digitization, and Aggregation

AUTHOR(S):

Lesley Chiou, Occidental College
Catherine Tucker, Massachusetts Institute of Technology and NBER

The Effect of Localization on News Consumption

AUTHOR(S):

Susan Athey, Stanford University and NBER
Markus Mobius, University of Michigan and NBER

Ad Revenue and Content Commercialization: Evidence from Blogs

AUTHOR(S):

Monic Sun, Boston University

Piracy Propagation of Information Goods: Demand and Supply-side Dynamics in P2P Networks

AUTHOR(S):

Joo Hee Oh, Massachusetts Institute of Technology
Il-Horn Hann, University of Maryland

Alessandro Acquisti, Carnegie Mellon University

Ajay K. Agrawal, University of Toronto and NBER

Michael Bailey, Facebook

Patrick Bajari, Amazon

Rachel Baker, Stanford University

L. Kamran Bilir, University of Wisconsin at Madison and NBER

Nicholas Bloom, Stanford University and NBER

Timothy F. Bresnahan, Stanford University and NBER

Jennifer Brown, University of Utah

Erik Brynjolfsson, Stanford University and NBER

Helena Buhr, Tagged Inc.

Christopher A. Candelaria, Vanderbilt University

Man Lung Chan, Stanford University

Lesley Chiou, Occidental College

Deven Desai

Michael Dinerstein, University of Chicago and NBER

Liran Einav, Stanford University and NBER

Iiro Pette. Mäkinen, Stanford University

Ryan C. McDevitt, Duke University

Kristina McElheran, University of Toronto

Peter Menell, University of California at Berkeley

Roy Mill

Kevin Montler, Google Inc.

Elizabeth Moody, Google Inc.

John Morgan, University of California at Berkeley

Petra Moser, New York University and NBER

Denis Nekipelov, University of Virginia

Tal Niv, University of California at Berkeley

Chris Nosko, University of Chicago

Joo Hee Oh, Massachusetts Institute of Technology

Bruce Owen, Stanford University

Igor Popov, Apartment List

Jeffrey Prince, Indiana University

Gregory Rosston, Stanford University

Sara Fisher Ellison, Massachusetts Institute of Technology

Chiara Farronato, Harvard University and NBER

Andrey Fradkin, Boston University

Anqi Fu, Stanford University

Michela Giorcelli, University of California, Los Angeles and NBER

Avi Goldfarb, University of Toronto and NBER

Andreea Danie. Gorbatai, University of California, Berkeley

Shane Greenstein, Harvard University and NBER

Daniel Grodzicki, Pennsylvania State University

Jonathan Hall, University of Toronto

Il-Horn Hann, University of Maryland

Heekyung H. Kim, Massachusetts Institute of Technology

Dan Knoepfle, Uber

Jennifer Kuan, University of North Carolina at Chapel Hill

Theresa Kuchler, New York University and NBER

Robin S. Lee, Harvard University and NBER

Phillip Leslie, Amazon

Jonathan D. Levin, Stanford University and NBER

Pam Samuelson, University of California at Berkeley

Ben Shiller, Brandeis University

Rachel Soloveichik, Bureau of Economic Analysis

Luke Stein, Arizona State University

Scott Stern, Massachusetts Institute of Technology and NBER

Koleman Strumpf, Wake Forest University

Neel Sundaresan, eBay Research Labs

Steven Tadelis, University of California, Berkeley and NBER

Mari Tanaka, Hitotsubashi University

Eric S. Taylor, Harvard University

Molly Van Houweling, University of California at Berkeley

Hal R. Varian, Google

Joel Waldfogel, University of Minnesota and NBER

Betsy Williams, Stanford University

Heidi L. Williams, Stanford University and NBER

Rui Xu, Stanford University

Zhichun Jenny Ying, Stanford University

Michael Zhang, Stanford University

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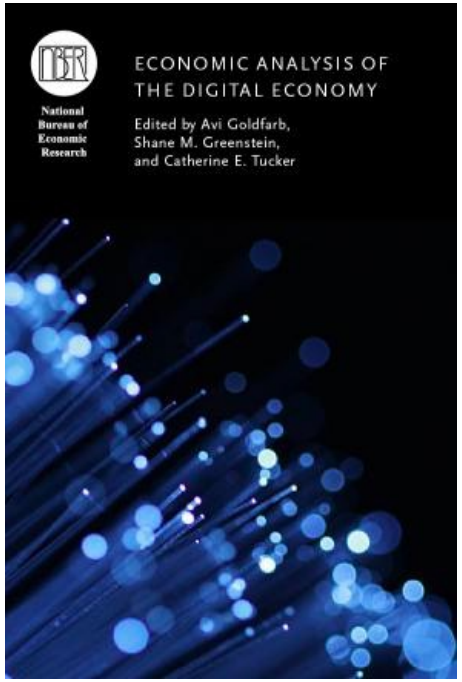


National Bureau of Economic Research, Inc.

To organize and support research on the economics of digitization

7 grants since the beginning

GRANTEE	AMOUNT	CITY	YEAR
National Bureau of Economic Research, Inc.	$724,000	Cambridge, MA	2017

To organize and support innovative research on the economics of digitization

PROGRAM
Research

AMOUNT
$667,316

CITY
Cambridge, MA

INVESTIGATOR
Shane Greenstein

INITIATIVE
Economic Analysis of Science and Technology (EAS

Funds from this grant provide three years of support
National Bureau of Economic Research for expenses
with the continued operation of the Economics of Di
Working Group. Led by Shane Greenstein of Northw
Lerner of Harvard, and Scott Stern of MIT, the Econc
Digitization working group brings together a diverse
economists to examine issues related to the digital r

Digitization changes everything. The rapid decline in marginal costs for information storage, processing, and networking, for example, challenges many basic assumptions of textbook economics. Traditional concepts and analytical tools provide limited help understanding recent phenomena such as on-demand labor markets, zero-cost reproduction of copyrighted material, or exclusively ad-supported consumption goods. This grant provides three years of continued support to the Economics of Digitization Working Group at the National Bureau of Economic Research. Under th leadership of Professors Shane Greenstein and Josh

National Bureau of Economic Research, Inc.	$814,373	Cambridge, MA	2020

To advance research on the economics of digitization including topics like algorithmic fairness and privacy as well as platform competition and regulation

PROGRAM
Research

SUB-PROGRAM
Economic Institutions, Behavior, & Performance

INITIATIVE
Economic Analysis of Science and Technology (EAST)

INVESTIGATOR
Catherine Tucker

This grant provides continued operational and administrative support to the Economics of Digitization working group at the National Bureau of Economic Research. Led by economists Shane Greenstein of Harvard Business School and Catherine Tucker of MIT, the group convenes researchers from a wide variety of economic subdisciplines to develop and nurture a research community focused on the economics of digitization. Research topics explored by the group include the economics of AI, labor market consequences of the rise of the digital economy, the effects of regulatory policies on economic outcomes in the digital marketplace, and the economic effects of digital misinformation. Future research topics under consideration include platform economics, competition and regulation, the economics of privacy, and the potential and consequences of algorithmic bias. Grant funds will support two annual meetings, an annual Digital Economics Tutorial, a conference on the economics of privacy in the digital age, a series of “boot camps” for junior researchers, and a small grants program to stimulate promising research in the area by young scholars.

NATIONAL BUREAU OF ECONOMIC RESEARCH, INC.

Digitization Tutorial

Shane Greenstein, Organizer

March 5, 2015

SIEPR
366 Galvez Street
Room 130
Stanford University
Stanford, CA

SCHEDULE

8:30 am	Continental Breakfast
9:00 am	Introduction
9:10 am	First session (reading list) Erik Brynjolfsson, Massachusetts Institute of Technology and NBER
11:15 am	Second session (reading list) Susan Athey, Stanford University and NBER
12:45 pm	Lunch
1:45 pm	Third session (reading list) Heidi Williams, Massachusetts Institute of Technology and NBER
3:45 pm	Fourth session (reading list) (slides) Shane Greenstein, Northwestern University and NBER
6:00 pm	Group Dinner: MacArthur Park Restaurant 27 University Avenue Palo Alto, Ca 94301

The following is an overview of the activities of the NBER Digitization program

Digitization Tutorial: We hold a "tutorial" every year in conjunction with the Winter Meetings for about 50 PhD students interested in working on digitization-related topics in their research. PhD students come from diverse fields including Economics, Strategy, Marketing, IS and related fields. See below for the program on all of the past tutorials:

- **2015:** http://conference.nber.org/confer/2015/DTs15/DTs15prg.html
- **2016:** http://conference.nber.org/confer/2016/DTs16/DTs16prg.html
- **2017:** http://conference.nber.org/confer/2017/DTs17/DTs17prg.html
- **2018:** http://conference.nber.org/sched/DTs18
- **2019:** http://conference.nber.org/sched/DTs19
- **2020:** http://conference.nber.org/sched/DTs20

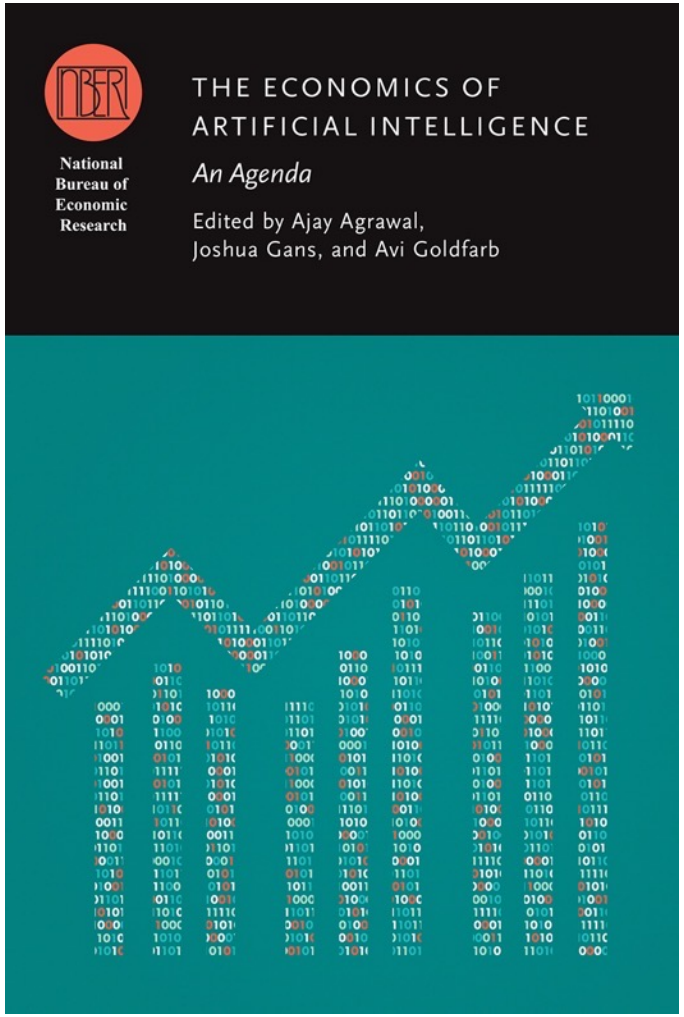
Now also:

https://www.nber.org/conferences/digitization-tutorial-spring-2021
https://www.nber.org/conferences/digitization-tutorial-spring-2022
https://www.nber.org/conferences/digitization-tutorial-spring-2023

Winter Meetings: We meet in the February / March every year at Stanford University to present and discuss latest research in the field in a 1-day conference. About 80-100 people participate every year. See below for programs from the past versions of these meetings.

Summer Meetings: We meet every Summer in conjunction with the NBER Summer Institute in Cambridge, MA to present and discuss latest research in the field in a 2-day conference. About 100-120 people participate every year. See below for programs from the past versions of these meetings.

Separately,
since 2017, NBER Economics of A.I. initiative



Economics of Artificial Intelligence

Ajay K. Agrawal, Joshua S. Gans, and Avi Goldfarb, Organizers
September 13-14, 2017
Willard Room, Second Floor
Intercontinental Hotel
220 Bloor Street West
Toronto, ON Canada M5S 1T8

Tuesday, September 12

6:30pm Dinner at Cibo Wine Bar – Yorkville, 133 Yorkville Ave.

Wednesday, September 13

8:30 am Continental breakfast - Portman Room, Second Floor

9:00 am Introductions

9:10 am Iain M. Cockburn, Boston University and NBER
Rebecca Henderson, Harvard University and NBER
Scott Stern, Massachusetts Institute of Technology and NBER
The Impact of Artificial Intelligence on Innovation
Discussant: Matthew Mitchell, University of Toronto

9:55 am Erik Brynjolfsson, Massachusetts Institute of Technology and NBER
Daniel Rock, Massachusetts Institute of Technology
Chad Syverson, University of Chicago and NBER
Artificial Intelligence and the Modern Productivity Paradox: A Clash of Expectations and Statistics
Discussant: Rebecca Henderson, Harvard University and NBER

10:40 am Break

11:00 am Paul Milgrom, Stanford University
Steven Tadelis, University of California at Berkeley and NBER
Market Design
Discussant: Matt Taddy, Amazon

11:45 am Susan Athey, Stanford University and NBER
Impact on Economics (slides)
Discussant: Mara Lederman, University of Toronto

12:30 pm Lunch - Portman Room, Second Floor
Presentation by Vinod Khosla, Khosla Ventures

1:45 pm Ajay K. Agrawal, University of Toronto and NBER
Joshua Gans, University of Toronto and NBER
Avi Goldfarb, University of Toronto and NBER
Prediction, Judgment and Complexity
Discussant: Andrea Prat, Columbia University

2:30 pm Break

2:45 pm Catherine Tucker, Massachusetts Institute of Technology and NBER
Privacy
Discussant: Ginger Zhe Jin, University of Maryland

3:30 pm Daniel Trefler, University of Toronto and NBER
Avi Goldfarb, University of Toronto and NBER
Trade
Discussant: Dave Donaldson, Massachusetts Institute of Technology and NBER

4:15 pm Break

4:30 pm Panel: *Impact on Policy Making*
Susan Athey, Stanford University and NBER
Austan Goolsbee, University of Chicago and NBER
Lawrence H. Summers, Harvard University and NBER

5:30 pm Adjourn

6:00 pm Dinner, Sassafraz, 100 Cumberland Street
Dinner Panel:
Geoffrey Hinton, University of Toronto and Google
Yann LeCun, New York University and Facebook
Ruslan Salakhutdinov, Carnegie Mellon University and Apple

Thursday, September 14

8:00 am Continental breakfast - Portman Room, Second Floor

8:30 am Colin Camerer, California Institute of Technology
Behavioural Economics (slides)
Discussant: Daniel Kahneman, Princeton University

9:15 am Jeffrey D. Sachs, Columbia University and NBER
Income Distribution
Discussant: Susan Dynarski, University of Michigan and NBER

10:10 am Break

10:30 am Philippe Aghion, College de France
Benjamin Jones, Northwestern University and NBER
Charles I. Jones, Stanford University and NBER
Artificial Intelligence and Economic Growth
Discussant: Patrick Francois, University of British Columbia

11:15 am Joel Mokyr, Northwestern University
Historical Context and the Long Run
Discussant: Manuel Trajtenberg, Tel Aviv University and NBER

12:00 noon Lunch - Portman Room, Second Floor

1:00 pm Carl Shapiro, University of California at Berkeley and NBER
Hal Varian, University of California at Berkeley
Machine Learning, Market Structure and Competition
Discussant: Judith A. Chevalier, Yale University and NBER

1:45 pm Break

2:20 pm Joseph E. Stiglitz, Columbia University and NBER
Anton Korinek, University of Virginia and NBER
Artificial Intelligence, Worker-Replacing Technological Change, and Income Distribution (slides)
Discussant: Tyler Cowen, George Mason University

3:05 pm David Autor, Massachusetts Institute of Technology and NBER
Robocalypse Now: Does Productivity Growth Threaten Employment?
Discussant: Betsey Stevenson, University of Michigan and NBER

3:50 pm Wrap up and closing remarks

4:00 pm Adjourn

Conference volume:
Agrawal, Gans, and Goldfarb eds. *The Economics of Artificial Intelligence: An Agenda.*
University of Chicago Press

National Bureau of Economic Research, Inc.

To develop an active and diverse research community that studies the economics of artificial intelligence

AMOUNT
$914,250

CITY
Cambridge, MA

INVESTIGATOR
Avi Goldfarb

This grant funds efforts by Avi Goldfarb, Joshua Gans, and A
Agrawal, three leading economists from the University of To
and Catherine Tucker, Sloan Distinguished Professor of
Management at MIT, to facilitate rigorous research on the
economics of artificial intelligence (AI). Building on a succe
conference on the economics of AI held in Toronto in 2017,
team plans to hold a series of three more annual conferenc
related topics, commissioning papers for each conference,

GRANTEE	AMOUNT	CITY	YEAR
National Bureau of Economic Research, Inc.	$289,788	Cambridge, MA	2021

To facilitate, promote, and diversify scholarly research about the economics of artificial intelligence

PROGRAM
Research

SUB-PROGRAM
Economics

INITIATIVE
Economic Analysis of Science and Technology (EAST)

INVESTIGATOR
Avi Goldfarb

This grant supports Ajay Agrawal, Avi Goldfarb, Joshua Gans, and Catherine Tucker, who are coordinating a conference on the economics of artificial intelligence at the Rotman School of Management, University of Toronto. Five years since its successful launch in 2017, the fall 2022 instalment of the conference will focus on specific applications of AI—particularly in the realms of national security, infrastructure, and health. The conference will, therefore, seek to connect the community of economics of AI scholars with scholars from these disciplines. AI applications like those in health economics, for example, precipitate questions about privacy, ethics, venture capital, and regulatory issues. In addition to activities relating to the conference, the organizers are also planning to join efforts with the Sloan-supported Working Group on the Economics of Digitization at the National Bureau of Economic Research.

CLOSE

PERMALINK

The Economics of Privacy

Avi Goldfarb & Catherine Tucker

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The Economics of Artificial Intelligence: Health Care Challenges

Ajay Agrawal, Joshua Gans, Avi Goldfarb & Catherine Tucker

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This structure has just changed!

GRANTEE	AMOUNT	CITY	YEAR
National Bureau of Economic Research, Inc.	$974,520	Cambridge, United States	2023

To study the Economics of Digitization and of Artificial Intelligence in a newly unified Working Group that covers both topics

PROGRAM
Research

SUB-PROGRAM
Economics

INVESTIGATOR
Catherine Tucker

When Sloan helped launch an NBER Working Groups on Digitization in 2010 and another on Artificial Intelligence in 2017, there were only scattered researchers studying the economics of these topics. Since then, three developments are especially notable: Both groups have produced blockbuster research. Topics range from the gig economy to the surveillance economy, and from employee selection to employee displacement. While some has been done by distinguished senior faculty, also contributing fresh perspectives are the hundreds of junior faculty who participated in mentoring and training programs run by these two Working Groups for graduate students from departments that did not yet have inhouse expertise. The pace of advances in digital technology and artificial intelligence has only accelerated. So concepts, findings, and models that seemed to explain a great deal just a few years ago now have much more explaining to do. The need for creative and careful research in these areas has, despite significant progress, become even more urgent. Although they started as distinguishable topics, research on Digitization and on AI are converging. The people, problems, and principles associated with one subfield are increasingly the same as those associated with the other. Given that we cannot continue funding both communities indefinitely anyway, a plan was hatched to merge the two working groups going forward. Catherine Tucker of MIT, a leader of the Digitization group, and Avi Goldfarb from the University of Toronto, a leader of the AI Group, will form a unified program dedicated to 'Digital Economics and the Use of AI.' Over the next three years, the combined group will concentrate on (i) the impact of digital technologies on the nature of work, (ii) political economy and digital technology (including surveillance, media, and political protest), and (iii) the relationship between competition and innovation for digital technology. That work will be facilitated by activities that have proven successful to date, including workshops for PhD students, spring and fall meetings in San Francisco and Toronto, respectively, as well as a very popular session at the NBER Summer Institute. The Sloan Economics Program is always looking for ways to help grantees make the whole more than the sum of the parts. In this case, merging two successful Working Groups should result in even greater research on society's most pressing questions about the economics of digital technologies.

Digitization Tutorial, Spring 2023

MARCH 1-2, 2023 - CONFERENCE *Program*

SI 2023 Digital Economics and Artificial Intelligence

JULY 19-21, 2023 - CONFERENCE

NBER Workshop of Digital Economics, Spring 2023

MARCH 3, 2023 - CONFERENCE *Program*

Digital Economics and AI Tutorial, Fall 2023

SEPTEMBER 21, 2023 - CONFERENCE *Program*

Economics of Artificial Intelligence Conference, Fall 2023

SEPTEMBER 22, 2023 - CONFERENCE *Program*

AI and digital economics were increasingly covering the same topics

- Platforms
- Privacy
- Discrimination and bias
- Jobs and inequality
- Copyright and intellectual property
- Surveillance
- Etc.

Journal of Economic Literature 2019, 57(1), 3–43
https://doi.org/10.1257/jel.20171452

Digital Economics†

Avi Goldfarb and Catherine Tucker*

Digital technology is the representation of information in bits. This technology has reduced the cost of storage, computation, and transmission of data. Research on digital economics examines whether and how digital technology changes economic activity. In this review, we emphasize the reduction in five distinct economic costs associated with digital economic activity: search costs, replication costs, transportation costs, tracking costs, and verification costs. (JEL D24, D83, L86, O33, R41*)*

1. *What Is Digital Economics?*

Digital technology is the representation of information in bits. This reduces the cost of storage, computation, and transmission of data. Research on digital economics examines whether and how digital technology changes economic activity.

Understanding the effects of digital technology does not require fundamentally new economic theory. However, it requires a different emphasis. Studying digital economics starts with the question of "what is different?" What is easier to do when information is represented by bits rather than atoms? economic models change as certain costs fall substantially and perhaps approach zero. We emphasize how this shift in costs can be divided into five types:

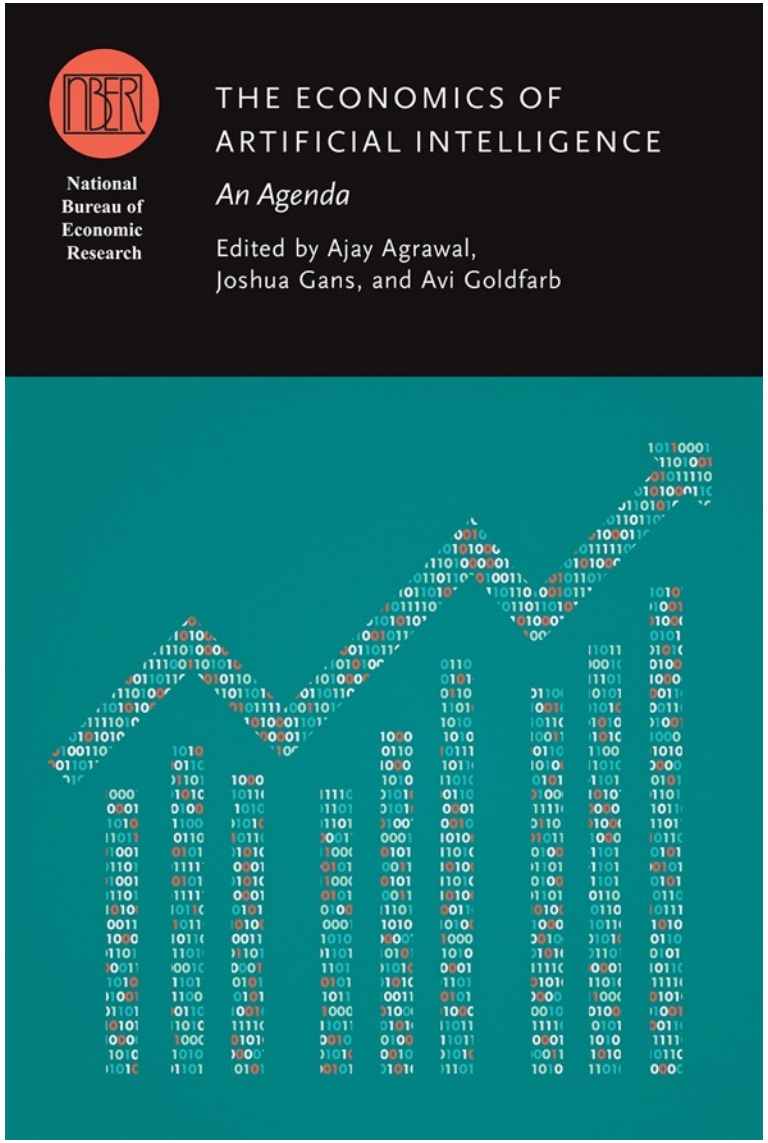
(i) Lower search costs

(ii) Lower replication costs

(iii) Lower transportation costs

(iv) Lower tracking costs

(v) Lower verification costs



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Definitions

- ***Digital technology*** is the representation of information in bits.

- This has reduced the cost of storage, computation, and transmission of data.

- ***Digital economics*** examines whether and how digital technology changes markets.

Organizing the literature

Journal of Economic Literature 2019, 57(1), 3–43
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Digital Economics†

Avi Goldfarb and Catherine Tucker*

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Bar-Isaac, Hesk Cuñat. 2012. ture." *Americ*
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Bechtold, Stefan marks, Trigge *Empirical Leg*
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Brown, Jeffrey R., and Austan the Internet Make Markets M dence from the Life Insuran *Political Economy* 110 (3): 48
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Brynjolfsson, Erik, and Lorin M ing Productivity: Firm-Level *Economics and Statistics* 85 (
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Five distinct changes

The literature has emphasized five distinct changes:

1. Low search costs for information.
2. Zero marginal costs of production of information.
3. Low cost of transportation of information.
4. Low cost of tracking behavior.
5. Low cost of verification of information.

1. Low cost of search

If the internet lowered search costs…

- Internet technology should reduce prices
  - Life insurance: Brown and Goolsbee (2002)
  - Books and CDs: Brynjolfsson and Smith (2000)
- Internet technology should lower price dispersion
  - It might have: Brynjolfsson and Smith (2000)
  - It is still substantial: Baye, Morgan, and Scholten (2004)
- Internet technology should reduce unemployment and vacancies
  - Mixed evidence: Autor (2001), Kuhn and Skuterud (2004), Stevenson (2008), Kuhn and Mansoor (2014)
- The types of products offered should change
  - Theory: Bar Isaac, Caruana, and Cunat (2012)
  - Long tail: Brynjolfsson, Hu, and Simester (2009), Fleder and Hosanagar (2009)
- The search algorithm should matter
  - Easy quality search reduces price sensitivity: Lynch and Ariely (2000)
  - Manipulation of the search process to raise margins: Ellison and Ellison (2009), Hossain and Morgan (2006).
  - The search algorithm affects matching: Hitsch, Hortacsu, and Ariely (2010)

2. Zero MC of production

Economics with zero MC

- **Old ideas became interesting again!**

- Copyright (and piracy)
  - Media revenues fall (Waldfogel, Smith/Telang, Zentner).
  - In the static model, piracy is good for welfare (Waldfogel).
  - Production costs fall so media quality and variety may be rising (Waldfogel).
- Public goods
  - Open source and Wikipedia. Why contribute? Biases in open platforms? (Greenstein/Zhu, Lerner/Tirole, Nagaraj)
- Inequality
  - Scalability of innovation without need for many employees.
- Bundling
  - Bundling models got interesting again! (Bakos & Brynjolfsson)

3. Low cost of transportation

The death of distance?

- Offline options matter
  - Balasubramanian (1998), Brynjolfsson, Hu, and Rahman (2009), Forman, Ghose, and Goldfarb (2009), Choi and Bell (2011), Lieber and Syversson (2012), Gentzkow and Shapiro (2011), Sinai and Waldfogel (2004)
- Government policy
  - Taxes: Goolsbee (2000), Ellison and Ellison (2009), Anderson et al (2011), Einav et al (2014)
  - Copyright policy: Gomez Herrera and Martens (2014)
  - Privacy policy, cultural policy (play and download limits), etc.
- Trust is easier locally
  - Jin and Kato (2007), Douglas, Hortacsu, and Martinez-Jerez (2009)
- Spatial correlation in tastes (local culture)
  - Blum and Goldfarb (2006), Sinai and Waldfogel (2004), Gandal (2006), Gentzkow and Shapiro (2011)
- Social networks are disproportionately local
  - Gaspar and Glaeser (1998), Hampton and Wellman (2002), Forman, Ghose, and Weisenfeld (2008), Agrawal and Goldfarb (2008), Agrawal, Catalini, and Goldfarb (2015)

4. Low cost of tracking

Low tracking costs

- Price discrimination
  - Behavioral price discrimination (Fudenberg/Villas Boas, Shin/Sudhir, Acquisti/Varian)
  - Versioning (Bhargava/Choudhary, Fay/Xie, Rao, Lambrecht/Misra, etc.)
  - Too little (Shiller/Waldfogel)
  - First degree (Dube/Misra)
- Personalized advertising
  - Two-sided markets (Baye/Morgan, Athey/Calvano/Gans, etc.)
  - Targeting opportunities (Goldfarb/Tucker, Bergemann/Bonatti, Iyer/Soberman/Villas Boas)
  - Ad measurement (Lewis/Rao/Reiley, Blake/Nosko/Tadelis, Gordon/Zettelmeyer)
  - Pricing by auction (Varian, Edelman/Ostrovsky/Schwarz)
  - Perhaps not as effective as expected (Neumann/TuckerWhitfield, Lambrecht/Tucker)
- Privacy
  - Price discrimination (Taylor, Acquisti/Varian)
  - Regulation (Goldfarb/Tucker, Johnson, Miller/Tucker, Kim/Wagman)

5. Low cost of verification

Low verification costs

- Historically, branding (Tadelis, Waldfogel/Chen)

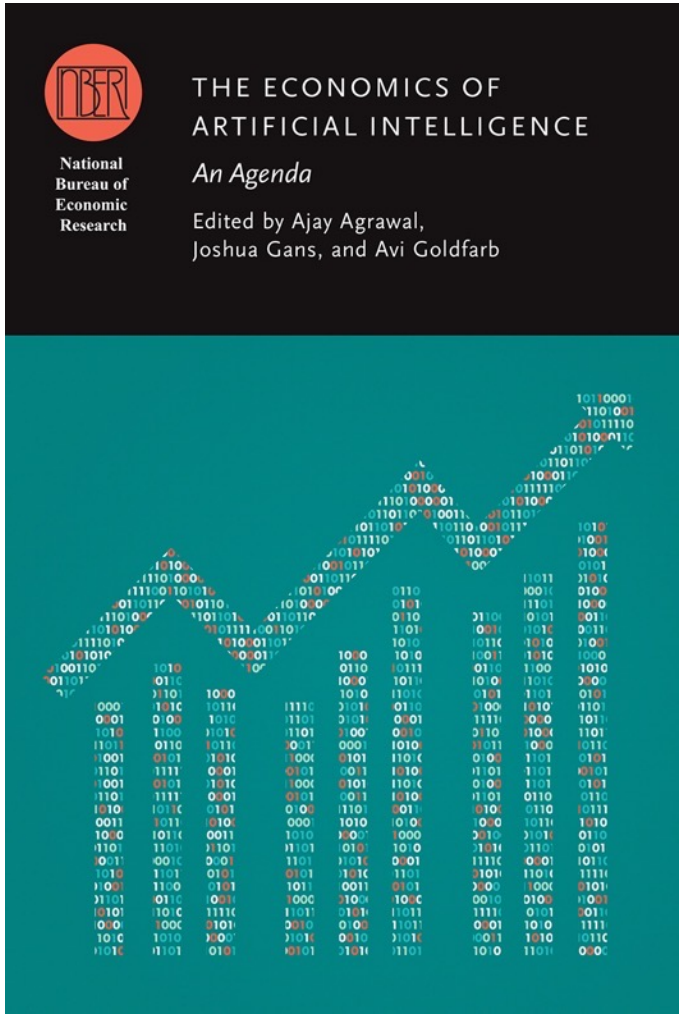
- Move to reputation systems
  - Ebay (Resnick/Zeckhauser, Cabral/Hortacsu)
  - Theory of feedback (Dellarocas 2003)
  - Intermediaries (Stanton/Thomas, Jin/Kato)
  - Reviews and user generated content (Mayzlin/Chevalier, Godes/Mayzlin, Fradkin)
  - Online reputation systems for offline products (Luca, Hollenbeck)
  - Manipulation of reputation systems (Mayzlin/Dover/Chevalier, Luca/Zervas)

- Secure payments
  - In developing markets (Economides/Jeziorski)
  - Through blockchain (Catalini/Gans)

- Discrimination
  - Reduced: Scott Morton/Zettelmeyer
  - Enabled by accident: Lambrecht/Tucker
  - Enabled on purpose: Edelman/Luca

These changes are key to the economics of AI

1. Low search costs for information—matching
2. Zero marginal costs of production of information—copyright and open source
3. Low cost of transportation of information—AI and trade
4. Low cost of tracking behavior—privacy and surveillance
5. Low cost of verification of information—bias, information security, reputation systems



Economics of Artificial Intelligence

Ajay K. Agrawal, Joshua S. Gans, and Avi Goldfarb, Organizers
September 13-14, 2017
Willard Room, Second Floor
Intercontinental Hotel
220 Bloor Street West
Toronto, ON Canada M5S 1T8

Tuesday, September 12

6:30pm Dinner at Cibo Wine Bar – Yorkville, 133 Yorkville Ave.

Wednesday, September 13

8:30 am Continental breakfast - Portman Room, Second Floor

9:00 am Introductions

9:10 am Iain M. Cockburn, Boston University and NBER
Rebecca Henderson, Harvard University and NBER
Scott Stern, Massachusetts Institute of Technology and NBER
The Impact of Artificial Intelligence on Innovation
Discussant: Matthew Mitchell, University of Toronto

9:55 am Erik Brynjolfsson, Massachusetts Institute of Technology and NBER
Daniel Rock, Massachusetts Institute of Technology
Chad Syverson, University of Chicago and NBER
Artificial Intelligence and the Modern Productivity Paradox: A Clash of Expectations and Statistics
Discussant: Rebecca Henderson, Harvard University and NBER

10:40 am Break

11:00 am Paul Milgrom, Stanford University
Steven Tadelis, University of California at Berkeley and NBER
Market Design
Discussant: Matt Taddy, Amazon

11:45 am Susan Athey, Stanford University and NBER
Impact on Economics (slides)
Discussant: Mara Lederman, University of Toronto

12:30 pm Lunch - Portman Room, Second Floor
Presentation by Vinod Khosla, Khosla Ventures

1:45 pm Ajay K. Agrawal, University of Toronto and NBER
Joshua Gans, University of Toronto and NBER
Avi Goldfarb, University of Toronto and NBER
Prediction, Judgment and Complexity
Discussant: Andrea Prat, Columbia University

2:30 pm Break

2:45 pm Catherine Tucker, Massachusetts Institute of Technology and NBER
Privacy
Discussant: Ginger Zhe Jin, University of Maryland

3:30 pm Daniel Trefler, University of Toronto and NBER
Avi Goldfarb, University of Toronto and NBER
Trade
Discussant: Dave Donaldson, Massachusetts Institute of Technology and NBER

4:15 pm Break

4:30 pm Panel: *Impact on Policy Making*
Susan Athey, Stanford University and NBER
Austan Goolsbee, University of Chicago and NBER
Lawrence H. Summers, Harvard University and NBER

5:30 pm Adjourn

6:00 pm Dinner, Sassafraz, 100 Cumberland Street
Dinner Panel:
Geoffrey Hinton, University of Toronto and Google
Yann LeCun, New York University and Facebook
Ruslan Salakhutdinov, Carnegie Mellon University and Apple

Thursday, September 14

8:00 am Continental breakfast - Portman Room, Second Floor

8:30 am Colin Camerer, California Institute of Technology
Behavioural Economics (slides)
Discussant: Daniel Kahneman, Princeton University

9:15 am Jeffrey D. Sachs, Columbia University and NBER
Income Distribution
Discussant: Susan Dynarski, University of Michigan and NBER

10:10 am Break

10:30 am Philippe Aghion, College de France
Benjamin Jones, Northwestern University and NBER
Charles I. Jones, Stanford University and NBER
Artificial Intelligence and Economic Growth
Discussant: Patrick Francois, University of British Columbia

11:15 am Joel Mokyr, Northwestern University
Historical Context and the Long Run
Discussant: Manuel Trajtenberg, Tel Aviv University and NBER

12:00 noon Lunch - Portman Room, Second Floor

1:00 pm Carl Shapiro, University of California at Berkeley and NBER
Hal Varian, University of California at Berkeley
Machine Learning, Market Structure and Competition
Discussant: Judith A. Chevalier, Yale University and NBER

1:45 pm Break

2:20 pm Joseph E. Stiglitz, Columbia University and NBER
Anton Korinek, University of Virginia and NBER
Artificial Intelligence, Worker-Replacing Technological Change, and Income Distribution (slides)
Discussant: Tyler Cowen, George Mason University

3:05 pm David Autor, Massachusetts Institute of Technology and NBER
Robocalypse Now: Does Productivity Growth Threaten Employment?
Discussant: Betsey Stevenson, University of Michigan and NBER

3:50 pm Wrap up and closing remarks

4:00 pm Adjourn

Conference volume:
Agrawal, Gans, and Goldfarb eds. *The Economics of Artificial Intelligence: An Agenda.*
University of Chicago Press

ML or AI?

Themes

- A.I. as a General Purpose Technology
- Growth, jobs, and inequality
- Regulation

Potential for a Productivity Boom?

9

Artificial Intelligence and Economic Growth

Philippe Aghion, Benjamin F. Jones, and Charles I. Jones

9.1 Introduction

This chapter considers the implications of artificial intelligence for economic growth. Artificial intelligence (AI) can be defined as "the capability of a machine to imitate intelligent human behavior" or "an agent's ability to

RESEARCH - REPORT

Machines of mind: The case for an AI-powered productivity boom

Martin Neil Baily, Erik Brynjolfsson, and Anton Korinek · Wednesday, May 10, 2023

There is an emerging literature that estimates the productivity effects of AI on specific occupations or tasks. Kalliamvakou (2022) finds that software engineers can code up to twice as fast using a tool called Codex, based on the previous version of the large language model GPT-3. That's a transformative effect. Noy and Zhang (2023) find that many writing tasks can also be completed twice as fast and Korinek (2023) estimates, based on 25 use cases for language models, that economists can be 10-20% more productive using large language models.

future of life INSTITUTE

Pause Giant AI Experiments: An Open Letter

We call on all AI labs to immediately pause for at least 6 months the training of AI systems more powerful than GPT-4.

View this open letter online.

Published	PDF created	Signatures
March 22, 2023	May 5, 2023	27565

AI systems with human-competitive intelligence can pose profound risks to society and humanity, as shown by extensive research[1] and acknowledged by top AI labs.[2] As stated in the widely-endorsed Asilomar AI Principles, *Advanced AI could represent a profound change in the history of life on Earth, and should be planned for and managed with commensurate care and resources.* Unfortunately, this level of planning and management is not happening, even though recent months have seen AI labs locked in an out-of-control race to develop and deploy ever more powerful digital minds that no one – not even their creators – can understand, predict, or reliably control.

"Should we risk loss of control of our civilization?"

"Should we develop nonhuman minds that might eventually outnumber, outsmart, obsolete and replace us?"

"Should we let machines flood our information channels with propaganc and untruth?"

"Should we automate away all the jobs, including the fulfilling ones?"

A.I. as a General Purpose Technology

8:50 am — Keynote:
Governor Lisa D. Cook, Board of Governors of the Federal Reserve System

9:15 am — **The A.I. Dilemma: Growth versus Existential Risk**
Charles I. Jones, Stanford University and NBER

Discussant:
Joshua S. Gans, University of Toronto and NBER

10:00 am — Break

10:30 am — **Machine Learning as a Tool for Hypothesis Generation**
Jens Ludwig, University of Chicago and NBER
Sendhil Mullainathan, University of Chicago and NBER

Discussant:
John McHale, University of Galway

11:15 am — **GPTs are GPTs: An Early Look at the Labor Market Impact Potential of Large Language Models**
Tyna Eloundou, OpenAI
Sam J. Manning, OpenResearch
Pamela Mishkin, OpenAI
Daniel Rock, University of Pennsylvania

Discussant:
Timothy F. Bresnahan, Stanford University

Growth, Jobs, and Inequality

8:50 am

Keynote:
Governor Lisa D. Cook, Board of Governors of the Federal Reserve System

9:15 am

The A.I. Dilemma: Growth versus Existential Risk

Charles I. Jones, Stanford University and NBER

Discussant:
Joshua S. Gans, University of Toronto and NBER

11:15 am

GPTs are GPTs: An Early Look at the Labor Market Impact Potential of Large Language Models

Tyna Eloundou, OpenAI
Sam J. Manning, OpenResearch
Pamela Mishkin, OpenAI
Daniel Rock, University of Pennsylvania

Discussant:
Timothy F. Bresnahan, Stanford University

Regulation

1:00 pm **Does Human-Algorithm Feedback Loop Lead to Error Propagation? Evidence from Zillow's Zestimate**

Runshan Fu, New York University
Ginger Zhe Jin, University of Maryland and NBER
Meng Liu, Washington University in St. Louis

Discussant:
Emilio Calvano, LUISS University

1:45 pm **Automation and the Rise of Superstar Firms**

Hamid Firooz, University of Rochester
Zheng Liu, Federal Reserve Bank of San Francisco
Yajie Wang, University of Missouri

Discussant:
Maryam Farboodi, Massachusetts Institute of Technology and NBER

2:30 pm Break

3:00 pm **Privacy Preserving Signals**

Kai Hao Yang, Yale University
Philipp Strack, Yale University

Discussant:
Shota Ichihashi, Queen's University

3:45 pm **The Value of External Data for Digital Platforms: Evidence from a Field Experiment on Search Suggestions**

Xiaoxia Lei, Shanghai Jiao Tong University
Yixing Chen, Notre Dame University
Ananya Sen, Carnegie Mellon University

Discussant:
Abhishek Nagaraj, University of California, Berkeley and NBER

The Economics of Privacy

Avi Goldfarb & Catherine Tucker

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The Economics of Artificial Intelligence: Health Care Challenges

Ajay Agrawal, Joshua Gans, Avi Goldfarb & Catherine Tucker

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What Questions Did We Ask in our Next Grant?

Platform regulation

There have been growing concerns in regulatory circles about the role of large digital platforms that have expanded rapidly and are able to use data to track and match users with either appropriate personalized advertising, products, or other users of the platform.

Economic growth and productivity:

Without innovation, there is no per capita economic growth in the long run. Much innovation over the past few decades has been in digital technologies. Despite this innovation, productivity growth has slowed. There are a number of open questions related to the nature of digital technologies, data, AI, and automation with respect to their distinctive impact on growth and productivity compared to other technologies.

Work and workers:

Earlier waves of information technology were skill-biased and capital intensive, thereby increasing inequality. It is an open question whether more recent digital technologies and AI will increase or decrease inequality. There are also open question related to the nature of work and the role of digital technology in enabling work-from-home.

Political economy:

Technological changes can impact politics, both through changes in the nature of media and through the creation of winners and losers from the technological change. The NBER Digital Economics and AI project will look at these questions through an economic lens, informed by research in other disciplines.

Wrap-Up

The opportunity

- There has never been a better time to be in this field.
- Indeed I find the number of questions that need to be answered to be overwhelming
- That means as a field we are in an unusual position of asking new questions rather than providing better answers to existing questions
- Be super ambitious

We look forward to hearing your ideas over the next two days!

QUESTIONS?