The Impact of Cloud Computing and Machine Learning on Entrepreneurship and Firm Performance

Proposal for the NBER Productivity, Innovation and Entrepreneurship (PIE) Research Grant

Submitted by Kristina McElheran, Assistant Professor, University of Toronto

Summary

Using new data on cloud computing and machine learning collected by the U.S. Census Bureau, this project will generate new insights into the prevalence of cloud computing and machine learning in small firms and will analyze the implications of these new technologies for young firm performance, innovation, and new-firm founding in the United States.

Motivation & Contribution

Recent studies have provided early insights into how new technologies are transforming the nature of entrepreneurship in the United States. For instance, we have learned that dramatic reductions in the costs of starting a new venture due to cloud computing have changed the financing strategies of venture capitalists (Ewens, et al, *forthcoming*). A study I presented at the National Bureau of Economic Research summer institute in 2017 shows that cloud computing is promoting the survival and productivity of young firms in the manufacturing sector (Jin and McElheran 2018). However, while anecdotal evidence abounds concerning the impact of cloud-enabled technologies, systematic data on their diffusion and economic implications have been difficult to come by.

Even less is known about the prevalence and impact of machine learning technologies – many of which are leveraging cloud infrastructure to advance and scale. As a Lab Economist at the Creative Destruction Lab in Toronto, I have seen an enormous surge in machine learning-focused ventures. Whether this is representative of startup activity in the U.S., however, remains an open question – as well as a topic of very active speculation.

To fill these knowledge gaps, I worked with the U.S. Census Bureau in 2017 to design new questions for the Annual Business Survey (the follow-on to the Annual Survey of Entrepreneurs). These questions specifically ask about cloud computing and machine learning. This survey, which will go to 850,000 business owners – specifically including owners of small businesses (1-9 employees) – this summer and fall, contains questions on **how much the firm spends on cloud services, distinguishing among different cloud applications** (security, storage, data analysis, customer relationship management, etc.). It also contains questions on **the use of advanced business technologies, including machine learning, machine vision, and natural language processing.** Once complete, this will represent the largest independently-collected data set directly addressing these frontier technologies. As a member of the survey development team, I will have preferential access to the new data.

This data will shed light on the prevalence of these technologies in the U.S. economy. The survey is planned to run through 2021 (300,000 firms per year) which will generate a useful panel of observations over time. The two questions together will make it possible to start to unpack how interdependent they are in practice – and, critically, in what types of business settings. The rich data collected elsewhere in the survey (e.g., founder intentions, different complementary investments, strategic positioning, and financing) will make it possible to better understand what drives the adoption of these technologies and what elements of the firm context make these technologies easier (or more difficult) to adopt and leverage. Details of the survey

will help disentangle the difference between "lifestyle" entrepreneurship and high-growth entrepreneurship, which has recently proven to be an important distinction (e.g., Guzman and Stern 2015). Other questions on business strategy will also help clarify the extent to which firms are using these technologies to cut costs versus experiment and innovate, a difference that matters for both firm strategy and economic outcomes (Jin and McElheran 2018).

In addition to technology diffusion, this proposed research will focus on key performance implications. In addition to sales and sales per employee, innovation productivity is an important performance metric that can be explored. Improving on prior data collection efforts, this detailed survey includes information on both inputs to innovation (e.g., R&D expenditure, equipment purchases, additional training, etc.) and innovative outputs (e.g. process or product innovation, revenues from new products, etc.) along many different dimensions.

Finally, matching this data set to other Census micro data will make it possible to more deeply understand the performance implications of these technologies for outcomes such as revenue growth, employment growth, survival, and productivity. Matching to other sector-specific surveys will provide information on expenditure levels to help gauge technical productivity and observe important investments in IT infrastructure in certain sectors (e.g., high tech manufacturing). Population level data (e.g., such as that provided by the Longitudinal Business Database) will make it possible to delve into how rates of firm founding vary by the use of these technologies. For instance, I have early evidence of local spillovers in the use of cloud computing in manufacturing, as well as industry variation, both of which may drive important patterns in firm founding. Studying this in the broader economy would be a significant advance and would leverage my experience both with the phenomenon and with the Census data.

Insights from this project are important to practitioners, academics, and policy makers alike. Better insights into how successful firms are leveraging these technologies can provide guidance on early investment and growth strategies for founders and heads of small firms. Academics trying to understand the forces influencing entrepreneurship will benefit from a better understanding of how important technology is in these processes and can focus attention on where this matters most. Finally, policy makers will learn about how technological change might be shifting the impact of policies geared to promoting small businesses.

Research Plan

This project will use confidential micro-data from the U.S. Census Bureau that includes detailed firm background information as well as the new questions from the Annual Business Survey. The first stage of the study will involve careful validation and verification of the quality of the data. The second stage will focus on understanding patterns of diffusion. The third stage will focus on matching to other Census data sets to explore performance outcomes such as revenue and employment growth, survival, innovation, and productivity, as well as changes in population-level rates of founding.

Budget

Access to the data requires being physically present in a Census Bureau Research Data Center (RDC). Thus, the grant funds will be used entirely to support frequent travel to the Boston RDC for data analysis ($5,000) as well as a part-time research assistant ($10,000).

References

Ewens, Michael, Ramana Nanda and Matthew Rhodes-Kropf, forthcoming. "Cost of Experimentation and the Evolution of Venture Capital." *Journal of Financial Economics*.

Jin, Wang and Kristina McElheran, 2018. "Economies before Scale: Learning, Survival, and Performance of Young Firms in the Age of Cloud Computing." SSRN working paper.

Guzman, Jorge and Scott Stern. 2015. "Nowcasting and Placecasting: Entrepreneurial Quality and Performance," *Measuring Entrepreneurial Businesses: Current Knowledge and Challenges.* University of Chicago Press.

Kristina Steffenson McElheran

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Toronto, ON M5S 3E6

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kmcel@mit.edu

ACADEMIC POSITIONS

2014-present **University of Toronto**
Assistant Professor, Strategic Management
U of T Scarborough Campus & Rotman School of Management

2013-present **Massachusetts Institute of Technology**
Visiting Scholar & Digital Fellow, Initiative on the Digital Economy
Sloan School of Management

2008 – 2013 **Harvard Business School**
Assistant Professor, Technology and Operations Management Unit
Lumry Family Assistant Professor of Business Administration 2009-2013
(Parental leave 2009-2010 and 2011-2012)

EDUCATION

2009 **Kellogg School of Management,** Northwestern University
Ph.D. in Managerial Economics and Strategy
Dissertation: *Market Position and Organizational Structure in Information Technology Investment*
Committee: Shane Greenstein, Scott Stern, Ranjay Gulati, Leemore Dafny

1999 **London School of Economics**
Diploma in Economics, *with credit*

Stanford University
1994 A.M. in International Development Policy
1993 A.B. in Political Science, *with distinction*

1988-1991 **Albion College**
Undergraduate studies in political philosophy and French
B.A. in French (awarded 1993), *summa cum laude*

RESEARCH INTERESTS

Innovation and technological change, information technology, corporate strategy, organizational economics, managerial decision making, industrial organization

MAIN PUBLICATIONS

"The Rapid Rise of Data-Driven Decision Making" (with Erik Brynjolfsson) *American Economic Review Papers and Proceedings 2016*, **106**(5), pp. 133-139.

"Do Market Leaders Lead in Business Process Innovation? The Case(s) of E-Business Adoption," *Management Science*, **61**(6), June 2015, pp. 1197-1216. ***Lead article***

"Delegation in Multi-Establishment Firms: Adaptation vs. Coordination in I.T. Purchasing Authority," *Journal of Economics and Management Strategy*, **23**(2), summer 2014, pp. 225-257. ***Lead article.***

BOOK CHAPTERS

"Pitfalls of Data-Driven Decisions: Cognitive Biases and Data-Driven Decision Making" (with Megan MacGarvie), November 15, 2016. *The HBR Guide to Data Analytics Basics for Managers* (e-book). Harvard Business Publishing, Cambridge, MA.

SUBMITTED/CIRCULATING WORKING PAPERS

"Firm Organization in the Digital Age: IT Use and Vertical Transactions in U.S. Manufacturing," (with Chris Forman). *R&R at Management Science.*

"Economies before Scale: Survival and Performance of Young Plants in the Age of Cloud Computing" (with Wang Jin). *Nominated for best paper, Strategic Manage Society Special Conference, Oslo.* SSRN working paper series: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3112901

"Data in Action: Data-Driven Decision Making in U.S. Manufacturing" (with Erik Brynjolfsson). *Center for Economic Studies Discussion Papers #CES 16-06, U.S. Census Bureau.* (2015 results pending Census Bureau disclosure avoidance review.)

"Information Technology Investment and Working Capital in Supply Chains" (with John Bai, Wang Jin, and Ryan Williams).

WORK IN-PROGRESS

"Moral Hazard in Management Practices: Adoption and De-Adoption of Data-Driven Decision Making" (with Erik Brynjolfsson, Wang Jin, Scott Ohlmacher, and Mu-Jeung Yang). Pending US Census Bureau disclosure avoidance review.

"How Do You Catch a Cloud and Pin it Down? Complements to Cloud Computing and Barriers to IT Productivity in Incumbent Firms" (with Wang Jin).

"A Contingency View of Structured Management in Manufacturing" (with Mu-Jeung Yang).

"Managerial Practices, Productivity, and Employment Growth of Young Manufacturing Firms," (with Wang Jin and Kathryn Shaw).

OTHER PUBLICATIONS

"Taking a Value-Chain Perspective on Innovation," *Sloan Management Review,* online October 25, 2016. http://sloanreview.mit.edu/article/taking-a-value-chain-perspective-on-innovation/

"Data-Driven Decision Making: Closing the Skills Gap," Interview by Karen Christensen in *Rotman Management*, fall 2016, pp. 107-110.

"The Rise of Data-Driven Decision Making is Real but Uneven," (with Erik Brynjolfsson) *Harvard Business Review,* online February 3, 2016. https://hbr.org/2016/02/the-rise-of-data-driven-decision-making-is-real-but-uneven

"Decentralization vs. Centralization in IT Governance: It's Not as Simple as You Might Think," *Communications of the ACM*, no. 11, November 2012, pp. 28-30

"The Short Life of Online Sales Leads," (with James B. Oldroyd and David Elkington) *Harvard Business Review* **89** (3), March 2011, p. 28

"Productivity Leadership and Strategic Investments in Innovation: The Adoption of E-Business Capabilities," *Academy of Management Best Paper Proceedings,* George T. Solomon (Ed.), 2008

MEDIA COVERAGE

Quoted in "Analytics as a Source of Business Innovation," by Sam Ransbotham and David Kiron, *Sloan Management Review*, February 28, 2017. http://sloanreview.mit.edu/projects/analytics-as-a-source-of-business-innovation/.

AWARDS, HONORS & FELLOWSHIPS

2018	Best paper nominee, Strategic Management Society Conference, Oslo, Norway
2017	SSHRC Insight Development Grant
2017	SSHRC Insight Grant
2016	NBER Entrepreneurship Working Group Research Grant
2016	SSHRC Institutional Grant, University of Toronto
2015	Connaught New Researcher Award, University of Toronto
2015	Finalist, Best Paper Award, Workshop on Information Systems and Economics (WISE)
2014	Finalist, Oliver E. Williamson Best Conference Paper Award, ISNIE 2014 Annual Conference
2013	U.S. – Israel Binational Science Foundation Grant, joint with Naomi Hausman
2010	Finalist, Best Dissertation Award, Technology & Innovation Management (TIM) Division, Academy of Management
2008	Best Paper Proceedings, Academy of Management
2008	Finalist, Best Student Paper - TIM Division, Academy of Management
2007-2008	U.S. Census Bureau Dissertation Fellowship
2007	State Farm Companies Foundation Doctoral Dissertation Award
2007	Kellogg Nominee, BPS Dissertation Consortium, Academy of Management
2007	Kellogg Nominee, CCC Doctoral Student Colloquium
2006	Kellogg Nominee, TIM Doctoral Student Consortium, Academy of Management
2002-2007	Kellogg School of Management Doctoral Fellowship
1993	Phi Beta Kappa, Stanford University

PROFESSIONAL ACTIVITIES

Academic Presentations

2018
Stanford University, SIEPR (pending)
Duke Fuqua School of Business (pending)
Center for Economic Studies, U.S. Census Bureau (pending)
Society for Institutional and Organizational Economics (SIOE) annual conference, Montreal (pending)
Strategic Management Society Special Conference, Oslo (pending) – **best paper nominee**
University of Maryland Smith School of Business
Rotman Innovation Roundtable, Toronto, ON

2017
Roundtable for Engineering Entrepreneurship Research (REER), Georgia Tech
NBER Summer Institute, Economics of Digitization, Cambridge, MA
Economics of Entrepreneurship Conference, Queens University
SMS Special Conference on "Transforming Entrepreneurial Thinking into Dynamic Capabilities," Banff, AB
NBER Productivity Lunch, Cambridge, MA
American Economic Association Annual Meeting, Chicago

2016
Bocconi University, Milan, Italy
Academy of Management annual meeting, Anaheim, CA
Cornell University Applied Microeconomics Seminar
American Economic Association Annual Meeting, San Francisco
webcast on January 4, 2016: https://www.aeaweb.org/webcasts/2016/index.php
in "Digitization and Innovation" session

2015
Workshop on Information Systems and Economics (WISE), Dallas **– best paper finalist**
Empirical Management Conference, Stanford University
MIT Organizational Economics Lunch
Academy of Management annual meeting, Vancouver- *All-Academy PDW on "Big Data Management and Strategy: Emerging Research Directions"* – virtual participation
Initiative on the Digital Economy Annual Meeting, MIT Sloan School of Management
The Wharton School, University of Pennsylvania
Fox School of Business, Temple University
NBER Winter Digitization Meetings, Stanford University

2014
Carey Business School, Johns Hopkins University
NBER Productivity Lunch, Cambridge, MA
ISNIE Annual Conference, Duke University – **best paper finalist**

2013
Roundtable for Engineering Entrepreneurship Research (REER), Georgia Tech
3rd ICT Conference Munich, Germancy

12th Conference on the Comparative Analysis of Enterprise Data (CAED), Atlanta Fed
Academy of Management annual meeting, Orlando
NBER Summer Institute: Economics of IT and Digitization, Cambridge, MA
DRUID, Barcelona
Atlanta Competitive Advantage Conference, Georgia Tech
Smith Entrepreneurship and Innovation Research Conference, University of Maryland
Center for Economic Studies, U.S. Census Bureau, Washington D.C.
Brandeis University International Business School
Fuqua School of Business, Duke University
Weatherhead School of Management, Case Western Reserve University
Rotman School of Management, University of Toronto
Scheller College of Business, Georgia Tech
American Economic Association annual meeting, San Diego

2012 Harvard Business School Digital Business Seminar
Workshop on Information Systems and Economics (WISE), Orlando
Toulouse Network for Information Technology, Washington D.C.
Academy of Management annual meeting, Boston
NYU Economics of Strategy Workshop
Statistical Challenges in e-Commerce Research (SCECR), Montreal
DRUID, Copenhagen – **semi-plenary session**
MIT Organizational Economics Lunch
NBER Productivity Lunch, Cambrdige, MA

2011 Census Research Data Center Annual Conference, Minneapolis
NBER Summer Institute: Personnel Economics, Cambridge, MA

2010 International Industrial Organization Conference (IIOC), Vancouver
Sloan Industry Studies Association conference, Chicago
American Economic Association annual meeting, Atlanta

2009 Harvard/MIT Organizational Economics Seminar, Harvard University
Academy of Management annual conference, Chicago
International Industrial Organization Conference (IIOC), Boston

2008 NBER Productivity Lunch, Cambridge, MA
MIT Innovation and Entrepreneurship Seminar, Sloan School of Management
Technology and Operations Management Seminar, Harvard Business School
Workshop on Information Systems and Economics (WISE), Paris
North American Productivity Workshop (NAPW), New York

2007 Federal Reserve Bank of Chicago
Workshop on Information Systems and Economics (WISE), Montreal
NBER Productivity Lunch, Cambrdige, MA
Management and Strategy Seminar, Kellogg School of Management

Research Data Centers Annual Research Conference, U.S. Census Bureau, Washington DC
Center for Economic Studies, U.S. Census Bureau, Washington D.C.
CCC Doctoral Student Consortium, Georgia Tech

2007 Job Market Talks: Harvard Business School; Goizueta Business School; Fuqua School of Business; Wharton School of Management; University of Illinois at Urbana-Champaign College of Business; Robert H. Smith School of Business; Columbia University Graduate School of Business; HEC Montréal École de Gestion; Center for Economic Studies, U.S. Census Bureau

Non-Academic Presentations

2017 Conference on Digitalization and the Economy, Bank of Canada

Evidence-Based Leadership Conference, Edwards School of Management, University of Saskatoon, SK – **Keynote speaker**

2016 "Rotman Reunite" Alumni event, Rotman School of Management, Toronto, ON
UTSC Alumni Association, Telus Center, Toronto, ON – **Keynote speaker**

Discussant

2015 NBER Summer Institute: Economics of IT and Digitization Workshop
2013 DRUID, Barcelona
2011 NBER Summer Institute: Economics of IT and Digitization Workshop
2010 Workshop on Information Systems and Economics (WISE), Phoenix
International Industrial Organization Conference (IIOC), Vancouver
2009 Workshop on Information Systems and Economics (WISE)
International Industrial Organization Conference (IIOC), Boston
2008 Workshop on Information Systems and Economics (WISE)

Participant

2009-present NBER Summer Institute and winter meetings for Economics of IT and Digitization; Entrepreneurship; Innovation; Organizational Economics; Personnel Economics; and Productivity, Innovation, & Entrepreneurship
2010 BPS Division New Faculty Consortium, Academy of Management
2009 TIM Division New Faculty Consortium, Academy of Management
2005 Center for Digital Economy Research Summer Workshop on the Economics of Information Technology, Stern School of Business, New York, NY
2004 European Science Days Summer School on Economics of Organizations in Steyr, Austria

Ad-Hoc Referee

American Economic Review; DRUID annual meeting; Information Economics and Policy; Information Systems Research; Journal of Business and Economic Statistics; Journal of Economic Behavior and Organizations; Journal of Economics and Management Strategy; Journal of Financial Economics; Journal of Law, Economics, and Organization; Journal of

Industrial Economics; Journal of Management Information Systems; Journal of Productivity Analysis; Management Science; Organization Science; Production and Operations Management Journal; Review of Industrial Organization, Strategic Management Journal; Social Sciences and Humanities Research Council of Canada (SSHRC)

Primary Investigator

2014 - present "Organizations in the Digital Economy: Information Technology Use, Complementary Investments, and their Impacts on Firm Outcomes," U.S. Census Research Data Center Project, joint with Chris Forman

2007-2012 "Productivity, Supply Chain Structure, and Information Technology Investment," Census Research Data Center Project

Co-Investigator

2015 – present "Management and Organizational Practices," U.S. Census Bureau Internal Project. Principals: Nick Bloom, Erik Brynjolfsson, Lucia Foster, & John Van Reenan

2018 – present "Does Organizational Innovation Complement Technology Adoption?" U.S. Census Research Data Center Project. Principal: Adam Saunders

Post-Doctoral Advising

2014-2017 Wang Jin (promoted to Research Fellow at Sloan)
2015-2017 Erina Ytsma (Carnegie Mellon)

Doctoral Advising & Committees

Patrick Rooney (current student, Rotman School of Management)
Frank Nagle (2015, University of Southern California)
Venkat Kuppuswamy (2011, University of North Carolina)

Service

2016 - present Lab Economist, Creative Destruction Lab, Rotman School of Management
2017- present Research Advisory Group for the Internet Association, Washington DC https://internetassociation.org
2017-2018 Rotman Strategic Management Seminar Co-Organizer
2013 - 2015 CCC Doctoral Student Consortium (faculty participant)
2012-2014 Industry Studies Association Early Career Development Committee

Member

Academy of Management
American Economic Association
DRUID
INFORMS
Society for Institutional and Organizational Economics (SIOE)
Strategic Management Society

NON-ACADEMIC EMPLOYMENT

2000-2002 **Exemplary Software** **Cupertino, CA**
Marketing Manager, Sr. Product Marketing Analyst, and Quality Assurance Lead
Early-stage startup focused on web-based supply chain management software solutions. Assisted in business plan development, pitching to investors, development of initial marketing collateral, and early product strategy. Built the first QA team and testing protocols.

1994-1998 **Risk Management Solutions, Inc.** **Menlo Park, CA**
Senior Analyst, Analyst, and Quality Assurance Engineer
Now a leading provider of software and services for managing insurance portfolio risk from natural disasters. Joined when the firm was an early-stage startup. Used early versions of the product on behalf of insurance and re-insurance clients to analyze large portfolios, helped in specification development, tested later versions of the software.

PERSONAL

Citizenship: United States
Permanent Residency: Canada
Married; 2 children

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