Curriculum Vitae
Erica R.H. Fuchs

1. Research Statement

My research studies the institutions[1] that influence global technology trajectories, through three inter-related questions: (1) are global shifts in manufacturing influencing the technological frontier, (2) what is the appropriate role of government in influencing the technological frontier, and (3) can we quantify the viability of emerging technologies at the technological frontier. I combine traditional social science methods (interviews, participant observation, surveys, econometrics) with engineering models that quantify the techno-economic landscape, and machine learning. Throughout this research both the questions I ask and the theory I develop emerge bottom-up from my time collecting data in the field.

Are Global Shifts in Manufacturing Influencing the Technological Frontier? Manufacturing has shifted from developed to developing nations, driven in part by rising demand and production in China. Classical economics suggests global productivity gains from such shifts will outweigh the losses. These models assume offshore firms will adjust factor inputs (more labor, less capital in developing nations) to make the same product at lower cost. My research demonstrates that shifts in the global locus of manufacturing can affect not just choice of factor inputs, but the nature and pace of technological change.

My earliest research studied two industries: automobiles and optoelectronics. In automobiles, we studied advanced composites for light-weighting automobiles, yielding better fuel economy (Fuchs et al 2008, Fuchs et al 2011). In optoelectronics, we studied the monolithic integration of multiple photonic functions on a single chip (Fuchs et al 2006, Fuchs and Kirchain 2010). In the short term such integration is relevant to telecommunications; in the long term, to computing (and Moore's Law), sensor, energy, biomedical and military applications. In both cases, when firms shift production from the U.S. to developing East Asia, the most advanced technologies developed in the U.S. were no longer profitable. Production characteristics abroad differ, and older technologies can be more cost-effective in developing country production environments. These economics leave production of the most advanced technologies abandoned, and, in the case of optoelectronics, create a barrier to pursuing R&D in these technologies back in the U.S. (Fuchs et al 2006, Fuchs et al 2008, Fuchs and Kirchain 2010, Fuchs et al 2011.)

Optoelectronics represents an extremely constrained context: firms face a homogenous global market, are unable to separate manufacturing from R&D, and have minimum-efficient plants the same size as the global market. The latter two constraints force the firms to choose one manufacturing location and a technology path associated with that location. Indeed, we find that U.S. optoelectronic component manufacturers for telecommunications that offshore decrease emerging technology innovation (Yang et al 2015). The majority of emerging technology inventors at those firms leave and stop work in the emerging technology (Yang et al 2015). The only firms that stay on-shore and continue emerging technology innovation are private and venture or government backed (Yang et al 2015). These dynamics may generalize to small firms with early-stage technologies where product and process innovation are linked.

National differences need not impair innovation. In the case of automobile bodies, firms face heterogeneous markets globally and a minimum-efficient plant the size of regional markets. They can leverage national differences to diversify their innovation portfolio by manufacturing locally for local regions (Fuchs et al 2011). In the case of electric vehicles, consumer preferences are such that there may be greater opportunities for the introduction of electric vehicles in China than in the U.S. (Helveston et al 2015). In developing East Asia, firms may be leveraging innovative organizational and technological routines to achieve high variety in assembled products (Engelman et al 2015, Treado and Fuchs WP).

[1] "Institutions" refer to the rules of the game in society that constrain human interaction. North, D., *Institutions, Institutional Change and Economic Performance*. 1990, New York: Cambridge University Press.

It is critical to avoid "one–size-fits all" policy: the same policies that enhance innovation in one sector can undermine innovation in another. I define three constraints that shape how manufacturing location interacts with global technology development: (i) the number of economically sustainable manufacturing facilities (determined by the ratio of minimum efficient plant to market size and costs of transportation); (ii) the location of design expertise and whether designers must be located with production (common in early-stage technologies where product and process are linked, such as chemicals, pharmaceuticals, and semiconductors); and (iii) the importance and enforcement of intellectual property. (Fuchs 2014)

What Role Can Government Play in Influencing the Technological Frontier? What political, institutional, and regulatory arrangements hold promise to accomplish this customization of policy to technological and industrial specificity? My work on DARPA suggests that government need not be limited to the market or top-down selection of technological winners. Embedded network agents (technical experts from academia and industry temporarily in program manager positions) can orchestrate the technological frontier, influencing networks of scientists to achieve organizational goals (Fuchs 2010). In Khan et al (2018, also R&R *Research Policy*), we explore the potential for institutional failure at the end of a technology paradigm, and how different institutional structures may match to different innovation needs. In Helveston et al (2019) we explore institutional complementarities, including, how the interaction between policies can lead to opposite outcomes of either policy alone. In Bonnin-Roca et al we raise the challenges regulating an emerging technology still more of an art than a science (2017), how failure for that regulation to be adaptive may "kill the golden goose" (2016), and how the stage of technology maturity can affect its resilience to institutional instability, i.e. it's "technology foregiveness."

In my pursuit of the science of innovation, I have contributed to improving innovation metrics. Despite increasing use of patent applications as measures of research effort, in the case of emerging optoelectronics technologies, there are more granted patents than patent applications (due to the option not to disclose applications), and no correlation between the two measures (Yang et al 2015). We also show that widely-used USPTO disambiguation approaches have 10-22% error rates on our closest sample to the full USPTO. These errors misidentify mobile inventors as multiple individuals (mobility is a prime area for which this data is used), and suggest differences across institutional and contexts that are creations of the algorithm rather than a reality in the original data (Ventura et al 2015).

Going forward, I seek to expand my work on the role of government at the technological frontier, and institutions to support the State in responding to technological and industrial specificity. I also have undertaken a new stream of research, leveraging engineering modeling and extensive firm-level data to measure and disentangle the implications of simultaneous technology change on labor demand. Our initial work focuses on automation versus monolithic production (parts consolidation removing assembly), and shows that while automation leads to skill polarization, consolidation leads to skill convergence, at least in shop-floor operators (Combemale et al working paper). Through our empirical analyses, we seek to propose a taxonomy for the differential impacts of emerging technologies on labor outcomes, and incorporate both the rich insights from our engineering process models as well as this taxonomy into state of the art production functions so as to be able to predict the labor implications of emerging technologies at a level meaningful for policy (Ales, Fuchs, Kovak, Whitefoot multiple grant submissions).

Can we quantify the Viability of Emerging Technologies at the Technological Frontier? Decisions affecting which technologies to pursue and where to direct investment are guided by current perception of the viability of those technologies. My work has improved models to understand this viability (e.g. Fuchs et al 2011, Satki et al 2014, Helveston et al 2015), including the implications of high product variety, local institutional environments (Fuchs and Kirchain 2010, Fuchs et al 2011), and policy (Helveston et al 2015). I have become increasingly interested in how cognitive bias affects popular consensus on the viability of emerging technologies. It has been theorized that humans are poor at additive and systemic estimates. In Satki et al (2015), we find that 55% of our leading industry experts estimate battery component costs incompatible with their total battery cost estimates, and 55% provide battery design and

process parameters inconsistent with their estimates of total battery costs. To help future entrepreneurs and scientists create better estimates of the viability of emerging technologies, we have developed a course, *Quantitative Entrepreneurship: Analysis for New Technology Commercialization* (with J. Michalek), in which student teams work on real-world projects to quantify technical pathways (changes in design geometry, material, or process) for an emerging technology to become economically viable against existing technologies on the market. Michalek and I have begun writing a textbook to disseminate these methods, their limitations, and what cannot be quantified across academia, industry and government.

Most recently, I have also developed a new stream of research leveraging machine learning, decision sciences, and engineering to accelerate the commercialization of emerging materials and process technologies. In this work, our focus is how to capture and scale an expert decision-processes when there are few experts, expert decision-making is an art, and there are many candidate components for the new technology's introduction (Davis, Fuchs, Vaishnav multiple grants). Our initial context is metal additive manufacturing in aviation (Funk et al 2020).

Policy Impact: I have testified before Congress's Ways and Means subcommittee on trade, and given invited talks to the Council on Foreign Relations, the NSF Engineering Directorate, and Bloomberg Headquarters. My research has been covered on NPR and in the *New York Times*. I was the only policy academic invited to a closed-door PCAST meeting on the future of advanced manufacturing, and led faculty across multiple universities and industry in writing the commercialization and supply chain section in the winning $70M proposal for the first National Manufacturing Innovation Institute (NAMII, now America Makes). My work on inventor disambiguation in the United States Patent and Trademark Office database led to a publicly available labeled inventor dataset and disambiguation algorithm, both of which were used in the USPTO Patents View disambiguation competition, for which I served on the judges panel. I recently co-chaired with Eric Lander the NASEM committee on U.S. Science and Technology Leadership for the 21st Century: Challenges and Prospects, which is on hold. I served on the NRC committees on the future of optical science (out of which emerged the AIM Photonics National Manufacturing Innovation Institute) and the Evaluation of ARPA-E.

Community: The interdisciplinary intellectual environment in EPP and at CMU have come to define me as a scholar. I have benefitted from research collaborations across campus. I enjoy launching new initiatives with colleagues: founding the university-wide STEM junior women lunch series; serving on our EPP Department Head Search; chairing the EPP innovation faculty search committee; bringing NAMII (now America Makes) to the region, and being the founding faculty director of the Manufacturing Futures Initiative – an initiative to accelerate the commercialization of advanced manufactured products spanning five schools at Carnegie Mellon. I currently serve on the Advisory Editorial Board for *Research Policy*, the M.I.T. Corporation's Visiting Committee for the Institute for Data, Systems, and Society (IDSS), including the Technology Policy Program, and the Academic Advisory Board for M.I.T.'s IDSS Program, including the Technology Policy Program. Among other professional activities, I have previously served on the National Academies' National Materials and Manufacturing Board, and the World Economic Forum's Future of Production Global Agenda Council.

2. Biographical Data

2.A Name

Erica R.H. Fuchs

2.B Place and Date of Birth

Reading, PA; November 23, 1977

2.C Education

Degree	Discipline	University	Date
Ph.D.	Engineering Systems	M.I.T.	2006
S.M.	Technology Policy	M.I.T.	2003
S.B.	Materials Science & Engineering	M.I.T.	1999

2.D Positions

July 2016-Present
Professor, Department of Engineering and Public Policy
Carnegie Mellon University, Pittsburgh, PA

May 2019-Present
Research Associate, National Bureau of Economic Research

January 2017-August 2017
Faculty Director, Manufacturing Future Initiative
Carnegie Mellon University, Pittsburgh, PA

2012-July 2016
Associate Professor, Department of Engineering and Public Policy
Carnegie Mellon University, Pittsburgh, PA

2006-2007
Postdoctoral Fellow, Microphotonics Center and Industrial Performance Center
Massachusetts Institute of Technology, Cambridge, MA

Advised Technology Policy masters student Shan Liu on research on the economic viability of silicon photonics, developed the technical and economic framework for the 2006 Industry Roadmap, brought in $25,000 funding from Kotura Corporation

2007-2012
Assistant Professor, Department of Engineering and Public Policy
Carnegie Mellon University, Pittsburgh, PA

June-August 2001
Internal Consultant to the Executive Team, Intern
Nanogram Corporation, Fremont, CA

Modeled the economic viability of the start-up's new, photonic deposition technology against the prevailing alternatives on the market.

1999-2000
Research Fellow
United Nations Industrial Development Organization, Beijing, China
Initiated and led field research on institutional barriers to innovation in state-owned industrial boiler manufacturers.

June-August 1998
Technical Failure Analysis Engineer, Intern
Bayer Corporation, Cologne, Germany
Assessed the cause of microbial corrosion in Bayer's steel coolant piping system. Research results published as part of my undergraduate M.I.T. thesis.

June-August 1997
Researcher, Intern
OVAKO Steel / Royal Institute of Stockholm, Hofors / Stockholm, Sweden
Analyzed inclusion characteristics in high-performance ball bearing steel using optical and SEM microscopy. Presented at 1998 Society for Mining, Metallurgy, and Exploration Annual Meeting. Published in *High Temperature Materials and Processes*.

2.E Consulting Assignments

October 2016
Executive Educator
Covestro Corporation

July 8, 2015 – July 9, 2015
Executive Educator
Fulbright Senior Managers and Executives

March, 2011 – September 2011
Speaker, Expert

Invited speaker and expert for day-long discussion and subsequent formulation of policy white papers by West-Coast industry and regional economic leaders on "Innovation and Production: Reviving U.S. Prosperity," CONNECT Innovation Institute.

November 5, 2010
Executive Educator
Led half-day workshop on "The Automotive Setting in 2025." Advanced Development. Product Design and Development. Alcoa Technology Center. Alcoa, Inc.

September 19, 2008
Executive Educator
Chris Kubasik, Sr. VP, Electronic Systems Business Area, Lockheed Martin Corporation, Senior Executive Engineering Program, Carnegie Mellon University

3. Teaching and Education

3.A Courses Taught at CMU

	Course Title	Units	Class	Offered	Num of Students	Num Resp	FCE Crse*	FCE Instr*
19-452 88-452	EPP Project	12	Ugrad	Fall 20				
19-670, 24-680	Quantitative Entrepreneurship	12	Sr/Gr	Fall 19				
19-411 19-711 88-415	Global Competitiveness	12	Sr/Gr	Spring 19	15			
19-452 88-452	EPP Project	12	Ugrad	Fall 18	15	7	3.4	3.4
19-670, 24-680	Quantitative Entrepreneurship	12	Sr/Gr	Spring 15	40	34	4.3	4.4
19-411, 19-711	Global Competitiveness	12	Sr/Gr	Fall 14	17	12	4.6	4.5
19-411, 19-711	Global Competitiveness	12	Sr/Gr	Fall 13	11	10	4.9	5.0
19-484, 19-784, 24-484,	Decision Tools for Engineering Design and	12	Sr/Gr	Spring 13	49	41	3.8	3.4

24-784	Entrepreneurship (a)							
19-741	Global Entrepreneurship (b)	12	Sr, Gr	Spring 12	24	22	4.0	3.9
19-411, 19-711, 88-415	Global Competitiveness	12	Sr, Gr	Fall 11	20	20	4.9	4.9
19-741	Global Entrepreneurship (b)	12	Sr, Gr	Spring 11	17	15	4.4	4.4
19-611, 84-415, 94-809	Global Competitiveness	12	Sr, Gr	Fall 10	9	8	5.0	5.0
19-484, 19-784, 24-484, 24-784	Decision Tools for Engineering Design and Entrepreneurship (a)	12	Sr/Gr	Spring 10	40	37	3.9	3.8
19-684 84-415 94-809	Global Competitiveness	12	Sr, Gr	Fall 09	19	15	4.5	4.8
19-484, 19-784, 24-484, 24-784	Decision Tools for Engineering Design and Entrepreneurship (a)	12	Sr/Gr	Spring 09	37	31	4.4	4.1
19-611 84-415	Global Competitiveness (b)	12	Sr, Gr	Fall 09	9	4	4.5	4.2
19-484, 19-784, 24-484, 24-784	Decision Tools for Engineering Design and Entrepreneurship (a, b)	12	Sr/Gr	Spring 08	18	16	4.2	3.6

(a) Team taught with Professor Jeremy Michalek, (b) New course
* Faculty Course Evaluations (FCEs) are scored by students on a scale of 1 (worst) to 5 (best).

3.B Student Research Projects

(a) Undergraduate Projects

1. Xiyu Yang, "Coding of optoelectronic inventor assignee changes from CV data." 5/4/15-1/23/17.

2. Alexander Lucci, “Accuracy of Hand-matching of patent data using inventor CVs.” May 15, 2013 – October 2013.
3. Angela Ng. “Careers of optoelectronic inventors post-bubble,” Feb 2012-Aug 2013.
4. Carl Glazer, “Born Global? Start-up location decision-making and the future of advanced manufacturing.” January 2012-March 2013. (EPP Tom Johnson and CMU Summer Undergraduate Research Fellowship recipient for Summer 2012.); “Careers of optoelectronic inventors post-bubble,” April 2011-December 2012.
5. Neha Nandakumar, “The quality of inventor disambiguation of patenting algorithms.” June 2011-February 2013.
6. Willis Chang, “Process-Based Cost Modeling of the Economic Viability of Gas Turbine Blades for the Aerospace Industry.” Fall 2012. “Careers of optoelectronic inventors post-bubble,” Fall 2010 - Spring 2011
7. Sabrina Larkin. “Careers of optoelectronic inventors post-bubble,” May 2012-August 2012.
8. Stephanie Hsuan Kao. “Predicting career states of optoelectronic inventors in telecommunications firms post-offshoring.” September 2011-May 2012.
9. Jane Sun, “Technology directions in monolithic versus hybrid integration photonic patenting,” Fall 2010-Spring 2011. January 2012.
10. Derek Lessard, “Careers of optoelectronic inventors post-bubble,” Sept-Nov 2011.
11. Farjad Zaim, “Careers of optoelectronic inventors post-bubble,” April-August 2011
12. Dan Murby, “Careers of optoelectronic inventors post-bubble,” April-May 2011
13. Sandeep Patel, “The Resiliency of the Innovation Ecosystem,” Fall 2009-Spring 2010 (became a MISM masters student in Fall 2010.)
14. Jack Wang, “The Relationship between Manufacturing and Jobs,” Spring 2010
15. Alex Chrichton, EPP-CMU Patent Inventor Matching System, Spring 2010
16. Peter Pong, “The Resiliency of the Innovation Ecosystem,” Fall 2008-Spring 2009
17. Jason Mirra, ‘Learning in Geographically Distributed Organizations,” Fall 2008
18. Tubtim Eawchoowongse, “Learning in Geographically Distributed Organizations,” Fall 2008
19. Luke Kryznowski, “The Role of DARPA in Seeding and Encouraging New Technology Trajectories,” Summer 2008

(b) Master’s Students

20. Michael Jiang, “Process-Based Cost Modeling of the Economic Viability of Gas Turbine Blades for the Aerospace Industry: Adding Arcam and Stellite” Fall 2013
21. Sangyoung Cho, “Process-Based Cost Modeling of the Economic Viability of Gas Turbine Blades for the Aerospace Industry: Adding Arcam and Stellite” Fall 2013
22. Ria Laureijs, “Process-Based Cost Modeling of the Economic Viability of Gas Turbine Blades for the Aerospace Industry.” Fall 2012
23. Jessica Chuang, “Process-Based Cost Modeling of the Economic Viability of Gas Turbine Blades for the Aerospace Industry.” Fall 2012
24. Sreeram Kurup Unnikrishna Kurup, “Process-Based Cost Modeling of the Economic Viability of Gas Turbine Blades for the Aerospace Industry.” Fall 2012
25. Christina Onarato, “Location Decision Factors in U.S. Solar Manufacturing Firms,” Fall 2011.

26. Jonathan Bates, "Process-Based Cost Modeling of CdTe Thin Film Solar Technologies," Fall 2011.
27. Sandeep Patel, "The Resiliency of the Innovation Ecosystem," Fall 2010
28. Edward Lynch-Bell, "Process-Based Cost Modeling of Stationary Battery Production," Summer 2009 (co-advised with Jay Whitacre).

(c) Ph.D. Students

29. Ashley Orr, "The labor implications of technology change in manufacturing" (Lead advisor, transferring to Heinz at the end of first year) Septmber 2018-May 2019.
30. Patrick Funk, "Expert Heuristics for Identifying Part Opportunities in Metal Additive Manufacturing" (50-50 co-advised with Alex Davis, Department of Engineering and Public Policy.) September 2016-Present.
31. Christophe Combemale, "The labor implications of technology change in manufacturing." (50-50 co-advised with Katie Whitefoot, Departments of Mechanical Engineering and Engineering and Public Policy.) September 2016-Present.
32. Kate McMahnon, "Institutional and Technological Conditions for New Technology Commercialization: Quantum Dots and Carbon Nanotubes" (Co-advisor with Daniel Armanios, Department of Engineering and Public Policy.) Currently on leave as a ORISE Science and Technology Scholar, Vehicle Technologies Office, Department of Energy.
33. Ria Laureijs, "The Cost of Complexity and the Value of Simplification." January 2016-present. (50-50 co-advised with Katie Whitefoot, Departments of Mechanical Engineering and Engineering and Public Policy.) January 2016-Present. Employment starting July 2020: Bain & Co.
34. Jaime Bonnin Roca. "Additive Manufacturing in Aerospace Applications." September 2014-Present. (Co-advisor with Granger Morgan, Department of Engineering and Public Policy and Manuel Heitor, Instituto Superior Tecnico, Technical University of Lisbon) Employment: Post-doctoral Fellow, Institute for Manufacturing (IfM), Department of Engineering, University of Cambridge (Jan 2018-Dec 2018); Assistant Professor, Department of Industrial Engineering and Innovation Sciences, Eindhoven University of Technology (January 2019 – present)
35. Jeff Anderson. "Man or Machine? A Strategic Toolset to Quantify and Accelerate the Economic Viability of Emerging U.S. Science & Technology Adaptive Make Capabilities" August 2012-August 2013. (Lead Advisor.)
36. Hassan Khan. "Beyond Sematech as the model for public-private partnerships: Insights from the Semiconductor Research Corporation for the administration of the NIST Advanced Manufacturing Technology Consortia Program." (Lead Advisor. Co-advised with David Hounshell; Social and Decision Science Department.) (August 2012-December 2017) Employment: Operations Strategist, KeepTrukin (Dec 2017-July 2018); Associate, McKinsey Corporation (August 2018-Present)
37. John Helveston, "Think Globally, Act Locally: China and the Future of Energy Savings Vehicle Technologies" (50-50 co-advised with Jeremy Michalek) September 2011-August 2016. Employment: Post-doctoral fellow, Institute for Sustainability, Boston University (September 2016-August 2018); Assistant Professor, Department of Engineering Management & Systems Engineering, School of Engineering & Applied Sciences, George Washington University (September 2018-Present).

38. Apurba Sakti, "Quantification of Li-Ion Electric Vehicle Battery Performance and Cost Trajectories." March 2011-December 2013. (Co-advisor. Lead advisors: Jeremy Michalek, Departments of Mechanical Engineering and Engineering and Public Policy; Jay Whitacre, Departments of Materials Science and Engineering and Engineering and Public Policy.) Employment: Post-doctoral associate, M.I.T.
39. Samuel Ventura, "Methods Matter: Revamping Inventor Disambiguation Algorithms with Classification Models and Labeled Inventor Records." June 2010-July 2014. (Co-advisor. Lead advisor: Rebecca Nugent, Dept. of Statistics) Employment: Visiting Professor, Carnegie Mellon University; Director of Hockey Research for the Pittsburgh Penguins of the National Hockey League and Affiliate Faculty, Carnegie Mellon University.
40. Eyiwunmi Akinsanmi, "The Resiliency of the Innovation Ecosystem: Technology Directions and Productivity During Economic Downturn," August 2009-June 2014. (Lead advisor. Co-advised with Ray Reagans, M.I.T. Sloan School of Management) Employment: Associate, McKinsey & Company
41. Chia-Hsuan Yang "Gains from Others' Losses: Technology Trajectories and the Global Division of Firms," July 2009-June 2014 (Lead advisor. Co-advised with Rebecca Nugent, Dept. Statistics) Employment: Consultant to RHM International, 2015; Research Scientist, New York University, 2016.
42. Carolyn Denomme, "The Benefits of Bounded Diversity: Organizational Learning in a Multi-Product Manufacturing Environment," August 2007-December 2013 (Lead advisor. Co-advised with Linda Argote and Dennis Epple, Tepper School of Business) Employment: Medallia
43. Timothee Doutriaux, "The Resiliency of the Innovation Ecosystem: The Impact of Offshoring on Firm vs. Individual Technology Trajectories," August 2007-May 2009 (Lead advisor. Co-advised Sept 2008 – Jan 2009 with Francisco Veloso) Employment: McDermott Will & Emery LLP
44. Matthew Hamilton. "The Cooperative Role of Formal and Informal Institutions in Regional Innovation Systems." August 2007-August 2008 (Dissertation Committee) Employment: Wellspring Worldwide

(d) Post-Doctoral Students

45. Parth Vaishnav, "Additive Manufacturing Policy" (Co-advised with Granger Morgan)
46. Chia-Hsuan Yang "Gains from Others' Losses: Technology Trajectories and the Global Division of Firms," June 2014-Present. (Lead Advisor)
47. Eyiwunmi Akinsanmi, "The Resiliency of the Innovation Ecosystem: Technology Directions and Productivity During Economic Downturn," June 2014 (Lead advisor)
48. Carolyn Denomme, "The Benefits of Bounded Diversity: Organizational Learning in a Multi-Product Manufacturing Environment," January 2013-present (Lead advisor. Co-advised with Linda Argote and Dennis Epple, Tepper School of Business)

3.C Educational Contributions

Since arriving at CMU, I have developed three new classes. The first – Quantitative Entrepreneurship (previously Decision Tools for Engineering Design and Entrepreneurship), co-taught with Jeremy Michalek (Dept. Mechanical Engineering & EPP) and recently also taught by Katie Whitefoot (Dept. Mechanical Engineering & EPP) – teaches students a computational

modeling toolset with which to assess the economic viability of a new technology prior to large-scale investment. For Spring 2008, we received $5000 in course sponsorship and approximately $10,000 in student travel funds from RHM International, a company commercializing technology originating in the Chinese Academy of Sciences. The three students on the RHM team spent spring break collecting data for their project at the company's manufacturing facility in China. At the end of the term, the company offered jobs to all three students, two of whom are now in permanent positions at the company's headquarters in China. In Spring 2009, we received $25,000 from the R.K. Mellon Foundation to bring into our course emerging technology projects from Carnegie Mellon's Center for Technology Transfer. At the end of this second year, two students received job offers as a direct consequence of the course, and four CMU-based start-ups are now using the students' models and technology assessments in their business plans. These four start-ups are nanoGriptech™ (founded by Professor Metin Sitti), 44Tech™ (founded by Professor Jay Whitacre), a company seeking to commercialize nanofiber air filters for respirator systems (led by CMU post doctoral student Amrinder Nain), and a company seeking to create new home energy monitoring solutions (led by CMU undergraduate student Ethan Goldman). In Spring 2010, we continued to work closely with the CMU Center for Technology Transfer. In this year, company involvement continued to expand such that all eight of the projects were supported by real-world start-ups, with seven of the eight projects involving technologies developed at CMU. In spring 2013 the course completed its fourth year. In this fourth year, DTEDE had nine sponsored real-world technology commercialization projects and just shy of fifty students. In its fifth year we renamed the course, Quantitative Entrepreneurship: Analysis for New Technology Commercialization. In this year we had forty students and seven sponsored real-world technology commercialization projects, all of which were start-ups out of CMU. My colleague, Jeremy Michalek, and I have been working on a textbook / practitioner's book by the same title (Quantitative Entrepreneurship.) Completing it's institutionalization at CMU, the course was taught independently of me, jointly by Katie Whitefoot and Jeremy Michalek in Fall 2016 , by Katie Whitefoot solo in Fall 2017, jointly by Katie Whitefoot and Jeremy Michalek in Fall 2018, and by Katie Whitefoot solo in Fall 2019.

My second new course – Science and Innovation Leadership for the 21st Century (previously Global Competitiveness: Firms, Nations, and Technological Change) – introduces students to the historical and contemporary intellectual foundations from economics, sociology, and political science of our current understandings of national innovation systems and technological change. It is now an approved elective in many programs across the university, including CIT's masters program in E&TIM and H&SS's new undergraduate minors in Innovation, Entrepreneurship, and Economic Development (IEE), and also accepted toward one of the school of engineering's elective GenEd requirements. Fall 2020 represented its eight year.

My third new course – Global Entrepreneurship and the Future of Advanced Manufacturing – had its inaugural term in Spring 2011, and is my solo-teaching version of Quantitative Entrepreneurship / Decision Tools for Engineering Design and Entrepreneurship. This project course was executed in collaboration with the Science and Technology Policy Institute (STPI) of the Institute of Defense Analysis. Working with real-world start-ups, students developed computational production models to quantify the technical developments necessary for four "green" technologies – one each in fuel cells, stationary grid batteries, solar cells, and environmental sensors – to become economically viable in today's marketplace. They then interviewed firms industry-wide in the same technical space and compared the economic viability of manufacturing their team's "green" technology in the United States according to their

computational models, with the companies' stated reasons for their manufacturing location. They conclude their final reports with an analysis of the economics versus other forces influencing manufacturing location decisions. Outcomes from the class may be used by STPI to inform future manufacturing policy in the United States. In it's second year, 2012, Global Entrepreneurship consisted of five projects, three of which were CMU-related start-ups – Aquion Energy, nanoGriptech, and RE-Squared – and two of which were outside corporate sponsors – Ciena Corporation and Kennametal, Inc. Together the corporate sponsors contributed $40,000 in gift funding to run a real-world project in the course. All three of the CMU start-ups are using the modeling to support U.S.-based manufacturing scale-up decisions. Both outside companies plan to make manufacturing and/or acquisition decisions based on the students' analyses.

Finally, in Spring 2009 I taught and participated in the weekend course *China Today*, held jointly by the University of Pittsburgh and CMU. This course was attended by students, faculty, and staff from both CMU and University of Pittsburgh, as well as by K-12 teachers receiving credit for continuing education.

4. Publications

4.A Books

1. (Committee Member.) 2017. *An Assessment of ARPA-E.* Science Technology and Economic Policy (STEP) Board. National Academy of Sciences.

2. (Committee Member.) 2013. *Optics and Photonics: Essential Technologies for Our Nation*. Board of Manufacturing and Engineering Design, National Materials Advisory Board, National Academy of Sciences.

4. B Archival Papers Critically Reviewed Before Publication

3. Combemale, C., Whitefoot, K., **Fuchs, E.** 2021. Not all Technologies are Equal: Disentangling Labor Demand Effects of Automation and Parts Consolidation. *Industrial and Corporate Change*. Accepted. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3291686. **Industry Studies Best Paper Award.**

4. Bonnin-Roca, J., Vaishnav, P., Mendoca, J., Morgan, G., **Fuchs, E.** 2017. Technology Forgiveness: Why emerging Technologies differ in their resilience to institutional stability. *Technology Forecasting and Social Change*. Accepted. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3077276#

5. Funk, P., Vaishnav, P., White, B., Davis, A., **Fuchs, E.** 2020. Individual inconsistency and aggregate rationality: Overcoming inconsistencies in expert judgment at the technical frontier. *Technology Forecasting and Social Change*. 155: 119984 https://doi.org/10.1016/j.techfore.2020.119984

6. Bonnin-Roca, J., Vaishnav, P., Mendoca, J., **Fuchs, E.** 2019. Technology cost drivers for a potential transition to decentralized manufacturing. *Additive Manufacturing*. 28: p136-151 https://doi.org/10.1016/j.addma.2019.04.010

7. Laureijs, R., **Fuchs, E.** Whitefoot, K. 2019. Is More Less: Benefits and Costs of High Variety Production in Non-Assembled Production Environments. *ASME Journal of Mechanical Design.* doi:10.111.5/1.4041943

8. Helveston, J., Karplus, V., Wang, Y., and **Fuchs, E**. 2019. Institutional Complementarities: The (Unlikely) Origins of Experimentation in China's Plus-In Electric Vehicle Industry. *Research Policy*. Vol 48. Issue 1. February 2019, 206-222 **Industry Studies Association Best Paper Award**. http://dx.doi.org/10.2139/ssrn.2817052

9. Khan, H., Hounshell, D. and **Fuchs, E.** 2018. Science Policy for the End of Moore's Law. *Nature Electronics*. Vol. 1. January 2018, 14-21. (Accepted Nov 15, 2017)

10. Bonnin-Roca, J., Vaishnav, P., Mendoca, J., Morgan, G., **Fuchs, E.** 2017. When Risks Cannot be Seen: Fostering the (safe) introduction of Metal Additive Manufacturing in Commercial Aviation. *Research Policy*. vol. 46, issue 7, 1215-1233 https://doi.org/10.1016/j.respol.2017.05.010

11. Fuchs, P., Xue, L., Zheng, P., Gallagher, K., Cowhey, P., Fuchs, E. 2017. Why China Needs Data Sharing to Address It's Air Quality Challenge. *National Science Review*. nwx059, https://doi.org/10.1093/nsr/nwx059

12. Sakti, A., Azevedo, I., **Fuchs, E.**, Michalek, J., Gallagher, K., and Whitacre, J. 2017. Consistency and robustness of forecasting for emerging technologies: The case of Li-ion batteries for electric vehicles. *Energy Policy.* Vol 106, July 2017, p. 415-426. https://doi.org/10.1016/j.enpol.2017.03.063

13. Laureijs, R., Bonnin-Roca, J., Prabha Narra, S., Montgomery, C., Beuth, J., **Fuchs, E.** 2017. Metal Additive Manufacturing: Cost Competitive Beyond Low Volumes. ASME *Journal of Manufacturing Science and Engineering.* 139(8), 081010 (May 10, 2017) (9 pages) doi: 10.1115/1.4035420

14. Bonnin-Roca, J., Vaishnav, P., Fuchs, E., and Morgan, G. 2016. Additive Manufacturing: Policy Needed. *Nature Materials*. **15**, 815–818. doi:10.1038/nmat4658

15. Engelman, C., Epple, D., Argote, L., and **Fuchs, E.** 2016. Learning by Doing in a Multi-Product Manufacturing Environment: Product Variety, Customizations, and Overlapping Product Generations. NBER Working paper No 19674. http://www.nber.org/papers/w19674 *Management Science.* 63(2):405-423. http:// dx.doi.org/10.1287/mnsc.2015.2352

16. Yang, C., Nugent, R., and **Fuchs, E.** 2016. Gains from Other's Losses: Technology Trajectories and the Global Division of Firms. *Research Policy.* 54(3): 724-745. https://doi.org/10.1016/j.respol.2015.12.005

    Notable Paper: This paper offers new insights into the role of firms versus individuals in driving technology directions, and the extent to which human capital may be lost during industrial shifts. We find that, in the case of U.S. optoelectronic component manufacturers for telecommunications, offshoring is not only associated with firms stopping production of the emerging technology (per Fuchs and Kirchain 2010), but also associated with a decrease in innovation in the emerging technology. We also find that in contrast to what would be suggested by literature on the persistence of inventors in their área of expertise, the majority of inventors in the emerging technology previously at those firms depart to firms outside the industry and stop work in the emerging technology.

17. Ventura, S., Nugent, R., and **Fuchs, E.** 2015. Seeing the Non-Stars: (Some) Sources of Bias in Past Disambiguation Approaches and a New Public Tools Leveraging Labeled Records. *Research Policy*. **Special Issue on Data.** 44(9): 1672-1701. http://dx.doi.org/10.1016/j.respol.2014.12.010

    Notable Paper: First extensive evaluation of existing approaches to USPTO inventor disambiguation. Develops and one of the largest publically available labeled datasets. Shows prior approaches have 10-22% error rates on our closest sample to the full USPTO. These errors are such that they are particularly problimatic when inventors are mobile (one of the prime research áreas for which this data hás been used), and have performance that varies with the features of the dataset to be disambiguated. (An algorithm that performs inconsistently across contexts will provide results that suggest differences across, for example, institutional or industrial contexts, that are created by the algorithm rather than being a reality in the original data.) We develop the first learning algorithm using labeled records for USPTO disabiguation. Our algorithm consistently maintains error rates below 3% across varying contexts for all available samples.

18. Helveston, J., Liu, Y., Feit, E., **Fuchs, E.,** Klampfl, E., and Michalek, J. 2015. Will subsidies drive electric vehicle adoption in China and the U.S.? *Transportation Research Part A: Policy and Practice.* 73: March 2015 pp. 96-112.

19. Sakti, A., Michalek, J., **Fuchs, E.**, and Whitacre, J. 2014. A techno-economic analysis and optimization of Li-ion batteries for personal vehicle electrification. *Journal of Power Sources*. 273: January 2015 pp. 966-980. 10.1016/j.jpowsour.2016.09.072

20. **Fuchs, E.** 2014. Global Manufacturing and the Future of Technology. *Science.* 345(6196): 519-520.

Research Framing / Notable Paper: Classical economics suggests that global productivity gains achieved by shifting the location of manufacturing will outweigh the losses. And yet, our research shows empirically that shifts in the global locus of manufacturing can affect not just production costs, but the nature and pace of technological change. Drawing from across my research, the paper goes on to spell out why not all technologies can be treated equally. It defines three constraints that shape the impact of manufacturing location on global technology development: (i) the largest number of manufacturing facilities economically sustainable for a firm; (ii) the location of design expertise and whether the designers need to experiment regularly on and be physically present at the production line; and (iii) the importance, security, and enforcement of intellectual property rights. The paper concludes that it is critical to avoid a "one–size-fits all" policy approach, both across technologies and across nations: policies that enhance one sector can undermine another.

21. Woolley, A. and **Fuchs, E.** 2011. Collective Intelligence in the Organization of Science, Invited Paper. Special Issue on New Directions in Organization Science. *Organization Science.* 22(5): 1359-1367.

22. **Fuchs, E.**, Kirchain, R., and Liu, S. 2011. The Future of Silicon Photonics – Not So Fast?: Insights from 100G Ethernet LAN Transceivers. *Journal of Lightwave Technology.* 29(15): 2319-2326.

23. **Fuchs, E.**, Field, F., Roth, R., and Kirchain, R. 2011. Plastic Cars in China? The Signifiance of Production Location over Markets for Technology Competitiveness in the United States versus the People's Repulic of China. *International Journal of Production Economics*. 132(2011): 79-92.

24. **Fuchs, E.**, and Kirchain, R. 2010. Design for Location?: The Impact of Manufacturing Off-Shore on Technology Competitiveness in the Optoelectronics Industry. *Management Science,* 56(12): 2323-2349.

    Notable Paper: Leveraging detailed production-level data from over 23 firms in the optoelectronics industry, demonstrates that production characteristics (wages, yields, downtimes, materials, and organization of production) are so different between nations (and in particular between developed and developing ones) as to change with product developments it is profitable for the firms to pursue globally. Specifically, when firms shifted production to developing East Asia, products produced in the U.S. were no longer immediately profitable. Firms follow these economics and produce the prevailing design overseas. The paper concludes by suggesting that the optoelectronics case may be representative, more broadly, of small entrepreneurial start-ups with immature process technologies. If offshoring discourages technology development by increasing the cost-advantage of the prevailing technology, these small start-ups with immature technologies may need government support to keep manufacturing in the U.S. long enough to meet longer-term technology development goals.

25. **Fuchs, E.** 2010. Rethinking the Role of the State in Technology Development: DARPA and the Case for Embedded Network Governance, **Lead article.** *Research Policy,* 39(2010): 1133-1147.

    Notable Paper: Debates on the appropriate role for government in technology policy often fall into two camps—proponents of free markets and proponents of a top-down bureaucratic government choosing technology winners. Leveraging rare access to empirical insights from inside DARPA, our results suggest a third alternative (which in the case of DARPA has functioned in the U.S. for over 50 years), in which embedded government agents re-architect social networks among researchers so as to identify and influence new technology directions in the U.S. to achieve their organizational goals.

26. **Fuchs, E.**, Field, F., Roth, R., and Kirchain, R. 2008. Strategic Materials Selection in the Automotive Body: Economic Opportunities for Polymer Composite Design. *Composite Science and Technology.* 68(9): 1989-2002.

27. **Fuchs, E.**, Bruce, E., Ram, R., and Kirchain, R. 2006. Process-Based Cost Modeling of Photonics Manufacture: The Cost-Competitiveness of Monolithic Integration of a 1550nm DFB Laser and an Electro-Absorptive Modulator on an InP Platform. *Journal of Lightwave Technology*. 24(8): 3175-3186.

28. Veloso, Francisco and **Fuchs, E.** 2002. The Future of the Asian Auto Industry: Regional Integration, Alternative Designs, and Chinese Leadership. *International Journal of Vehicle Design*. 35(1): 111-136.

29. **Fuchs, E.** and Johnsson, P. 2000. Inclusion Characteristics in Bearing Steel and During Ingot Casting. *High Temperature Materials and Processes*. 19(5): 333-344

4.C Papers in Symposium or Conference Proceedings Fully Reviewed Prior to Publication

30. Ventura, S., Nugent, R., and Fuchs, E. 2014. Hierarchical Linkage Clustering with Distributions of Distances for Large-Scale Record Linkage. *Privacy in Statistical Databases*. (Lecture Notes in Computer Science 8744), ed. J. Domingo-Ferrer, Springer, pp. 283-298.

4.D Other Papers in Symposium or Conference Proceedings

4.E Sections or Chapters in Edited Monographs or Similar Volumes

31. **Fuchs, E.**, Combemale, C., Orr, A., Whitefoot, K. 2019. The Weighty Manufacturing Sector: Challenges Transforming from Raw Materials to Physical Products in the Innovation Economy. Beyond 140 Characters: The Role of Innovation and Entreprenuership in

Economic Growth. Edited Volume. Eds Scott Stern, Aaron Chatterji, and Josh Lerner. National Bureau of Economic Research. https://www.nber.org/chapters/c14373

32. Azoulay, P, Goldstein, A., Kearney, M., Fuchs, E. 2018. Funding Breakthrough Research: Promises and Challenges of the "ARPA Model." National Bureau of Economic Research (NBER). Innovation Policy and the Economy Series. Editors Scott Stern and Josh Lerner. MIT Press. Volume 19.

33. Argote, L. Dennome, C. and **Fuchs, E.** 2011. Organization Learning across Boundaries: The Effect of Geographic Distribution on Organizational Learning and Knowledge Transfer. *Handbook on Organizational Learning and Knowledge Management.* Wiley-Blackwell.

34. **Fuchs, E.** 2011. DARPA Does Moore's Law: The Case of DARPA and Optoelectronic Interconnects. Invited chapter in *State of Innovation: The U.S. Government's Role in Technology Development*. Ed. by Fred Block and William Keller. Paradigm Publishers.

35. **Fuchs, E.** 2009. Remembering Comparative Advantage: Leveraging National Differences in Technology Competitiveness. Report by CMU and the Atlantic Council to the G-20 Leaders.

4.F Published Abstracts, Discussions, Reviews

4.G Other Writings (Technical Reports and Testimony)

36. **Fuchs, E.**, Karplus, V., Kalathil, N., Morgan, G. 2020. To respond to the pandemic, the government needs better data on domestic companies that make critical medical supplies. Issues in Science and Technology. December 18, 2020. https://issues.org/pandemic-response-government-needs-better-data-critical-medical-supplies/

37. **Fuchs, E.**, Karplus, V., Kalathil, N., Morgan, G. 2020. Inadequate Data on Manufacturers of Critical Medical Supplies Weakens U.S. Capabilities for Pandemic Response. Testimony. U.S. International Trade Commission. Investigation No. 332-580. COVID-19 Related Goods: The U.S. Industry, Market, Trade, and Supply Chain Challenges. September 23, 2020. Prehearing Brief | Oral Remarks

38. **Fuchs, Erica R.H.**, Testimony. Hearing on Trade, Manufacturing, and Critical Supply Chains: Lessons from COVID-19. House Ways & Means Committee. Subcommittee on trade. July 23, 2020. Written Testimony | Oral Remarks | Video Recording of Full Hearing

39. Funk, P., Cowhey, P., Gallagher K.S., and **Fuchs, E.** Benefits and Costs of International Data Sharing: The Case of the Environment and Policy to Reduce Air Pollution. US Expert Memo from Peter Cowhey, Erica Fuchs, and Kelly Sims Gallagher. *US-China Innovation Dialogue*. June 5, 2016.

40. **Fuchs, E.** Why the future of manufacturing matters. Blog. World Economic Forum. September 11, 2013.

41. **Fuchs, E.** (with contributions by J. Andersen, R. Laureijs, J. Chuang, S. Kurup, W. Chang, P. Bissert, K. Chow, C. LaMontagna, and X. Yan) Man or Machine? A Strategic Toolset to Quantify and Accelerate the Economic Viability of U.S. Science and Technology Adaptive Make Capabilities. Year 1 Interim Progress Technical Report. Prepared for the Defense Advanced Research Projects Agency. July 8, 2013.

42. **Fuchs, E.** 2012. On the relationship between manufacturing and innovation: Why not all technologies are created equal. http://ssrn.com/abstract=2103827 (Previous version written for CONNECT Innovation Institute with the title "The Implications of Manufacturing Offshore on Technology Competitiveness: Implications for U.S. Policy." Feburary 2012 http://connect.org/wp-content/uploads/2013/08/fuchs-white-paper-0212.pdf)

43. **Fuchs, E**. Help Startups Be Gardens of Innovation. Room for Debate. Should the U.S. Seek More Tech Manufacturing? The Opinion Pages. *The New York Times*. August 6, 2012.

44. **Fuchs, E.** 2009. Cloning DARPA Successfully. *Issues in Science and Technology*. Volume XXVI. Number 1. Fall 2009.

Working Papers

45. Ales, L., Combemale, C., Fuchs, E., Whitefoot, K. How It's Made: A General Theory of the Labor Implications of Technological Change

46. Laureijs, R., Syversen, C., Fuchs, E., and Whitefoot, K. Mix and Match: Exploring Person-Product Match Effects in High Variety Manufacturing.

47. Khan, H., Hounshell, D. and **Fuchs, E.** 2017. Scaling Moore's Wall: A Public Private Partnership in Search of a Technological Revolution. http://ssrn.com/abstract=2497218 *Revise and Resubmit. Research Policy.*

Notable Paper: The decline of corporate research and vertical disintegration of supply chains in many industries has led to an innovation ecosystem increasingly reliant on linkages between institutions. These shifts present new challenges for long-term technology development. Pre-commercial public-private research consortia offer one policy response, and yet the majority of past research has focused on public-private consortia focused on short-term (1-3 year out) technology developments and technology catch-up. Based on unprecedented access to archives of the Semiconductor Research Corporation (SRC), publically available data, 38 semi-structured interviews, and participant observation, we examine how one public-private partnership, the Nanoelectronics Research Initiative (NRI),

emerges in response to arguably the most significant presumptive anomaly (Constant 1980) of our time: NRI seeks to bridge the semiconductor industry's past forty years of unprecedented technology development—i.e., Moore's Law—with radically new (and, as of today, not-yet-discovered) technology that will maintain this development indefinitely. We unpack the processes by which, building on a long history of such programs within the Semiconductor Research Corporation, NRI may be playing an important coordinating function within the scientific community. We conclude by questioning the extent to which the current effort is well-suited to the size and nature of the challenge, and to which it may be generalizable to a broader set of industrial contexts requiring coordination in long-term technology development through technical discontinuities.

48. Treado, C. and **Fuchs, E.** Manufacturing Variety: Scale Economies in a Low-Volume High Mix Environment. http://ssrn.com/abstract=2619490

49. Akinsanmi, W., Reagans, R., and **Fuchs, E.** Seeing Rainbows while Others Flee: How innovation in the most advanced optoelectronics technology grew after the burst of the telecommunications bubble.

50. Yang, C. and **Fuchs, E.** Bought but not played with: IP Licensing, Acquisitions and Dormant technological opportunities.

51. **Fuchs, E.** 2014. Platform Leaders, True Believers and Coordinated Innovation: The Role of Key Architects in Influencing Technology Trajectories for Moore's Law.

Book Draft

52. Michalek, J. and **Fuchs, E.** *Quantitative Entrepreneurship: Analysis for New Technology Commercialization.*

5. Grants and Contracts Awarded to Date

5.A Principal Investigator

1. With co-PIs Valerie Karplus and Granger Morgan. An Open-Source Decision Tool to Identify and Support Responses to Emergent Constraints in the Medical Supply Chain. **Block Center for Technology and Society. Carnegie Mellon University**. Approved. Requested amount: $75,000. Final amount to be determined.

2. Accelerating U.S. Competitiveness in Integrated Photonics: Quantifying Workforce Training Needs. **SUNY (Albany) / U.S. Air Force Research Lab (AFRL).** Contract funded through AIM Photonics. $100,000

3. Worker Resilience and Innovation in U.S. Manufacturing. **The Keystone Research Center.** $40,000 gift.

4. EPP Project Course on Technology Development Zones: The Case of Neighborhood 91. **The Barnes Group Advisors.** $5000 gift.

5. EPP Project Course on Technology Development Zones: The Case of Neighborhood 91. **Allegheny County Airport Authority.** $20,000 gift.

6. With Co-PIs Laurence Ales, Brian Kovak, Katie Whitefoot. Not all Technologies are Equal: Measuring and Disentangling the Labor Effects of Technology Change in Manufacturing. **NSF Science of Science and Innovation Policy Program.** $649,959

7. With co-PIs Alex Davis, Parth Vaishnav, and Aarti Singh. Accelerating Navy Readiness: Expert Guided Machine Learning Algorithms for AM Candidates. **U.S. Navy (NAVSUP)** Sole Source Agreement funded through America Makes. July 2019-November 2019. $250,000. ($200,000 to CMU, $50,000 to America Makes.)

8. With co-PI Katie Whitefoot. The Cost of Complexity and the Value of Simplification. **Kennametal Corporation.** September 2018-August 2019. $140,000 gift.

9. With co-PIs Laurence Ales, Brian Kovak, and Katie Whitefoot. Technology Change in Manufacturing and Labor Outcomes: Not all Technologies are Equal. **National Bureau of Economic Research** (funds from the Kaufmann Foundation). July 2018-June 2019. $20,000

10. With co-PIs Alex Davis and Parth Viashnav. Identifying Product Opportunities: Expert heuristics in scientific decision-making. CMU **Manufacturing Futures Initiative**. September 2017-August 2018. $107,091.

11. With co-PI Katie Whitefoot. Technology Change in Manufacturing: Implications for the Magnitude & Nature of Work. CMU **Manufacturing Futures Initiative**. September 2017-August 2018. $99,434

12. With co-PI Katie Whitefoot. The Cost of Complexity and the Value of Simplification. **Kennametal Corporation**, July 2017-June 2018. $105,067 gift.

13. With co-PI Katie Whitefoot. Is More Less? Firm and Workforce Implications of High-Variety Production in the Greater Pittsburgh Region. **PITA.** January 2016-December 2017. $69,679.

14. With co-PI Katie Whitefoot. The Cost of Complexity and the Value of Simplification. **Kennametal Corporation**, July 2016-June 2017. $105,067.

15. With co-PI Katie Whitefoot. Science Policy Research Report: On the Relationships between Manufacturing, Innovation, National Competitiveness, and the Magnitude and Nature of Work. **NSF Science of Science and Innovation Policy Program**, July 2017 – June 2018, $50,000.

16. CAREER: Rethinking National Innovation Systems – Economic Downturns, Offshoring, and the Global Evolution of Technology. **NSF Science of Science and Innovation Policy Program**, May 2011 – May 2016, $624,517.

17. With co-PI D. Hounshell. Beyond SEMATECH as the Model for Public-Private Partnerships: Insights from the Semiconductor Research Corporation (SRC). **National Institute of Standards and Technology (NIST)**. Sept. 2012-Aug. 2015. $311,405.

18. Man or Machine? A Strategic Toolset to Quantify and Accelerate the Economic Viability of Emerging U.S. Science & Technology Adaptive Make Capabilities. **Defense Sciences Office (DSO)**, **Defense Advanced Research Projects Agency (DARPA).** Collaborative Grant with the Army Research Office. June 2012 – May 2015. Year 1: $188,034, Year 2: $231,626.

19. With co-PI D. Hounshell. RAPID: What Model for Public-Private Partnerships?: Lessons from Existing Consortia for Administration of the U.S. National Network for Manufacturing Innovation. **NSF Science of Science and Innovation Policy Program.** October 2012 – September 2013. $83,974

20. With co-PI J. Michalek. Institutionalizing & Disseminating Engineering Entrepreneurship **Dean's Innovation Across the Curriculum Development Fund. Carnegie Institute of Technology**. Carnegie Mellon University. Sept. 2012 – Aug. 2013. $63,265.

21. Global Entrepreneurship and the Future of Advanced Manufacturing. **Corporate Sponsorship. Ciena Corporation.** $25,000 gift.

22. Global Entrepreneurship and the Future of Advanced Manufacturing. **Corporate Sponsorship. Kennametal Corporation.** $15,000 gift.

23. With co-PIs J. Michalek and Y. Liu. GOALI: Think Globally, Act Locally: China and the Future of Energy-Saving Vehicle Technologies. **NSF Science of Science and Innovation Policy Program** and **NSF Grants Opportunities for Academic Liason with Industry (GOALI).** June 2011 – June 2013. $192,816.

24. With co-PIs L. Argote, and D. Epple. Learning Across Product, Workgroup, and Geographic Boundaries, **NSF Science of Science and Innovation Policy** & **Innovation and Organization Science Programs**, January 2010 – January 2013, $707,807

25. The Role of DARPA in Seeding and Encouraging New Technology Trajectories, Robert W. Gore Materials Innovation Case Study Project, **Chemical Heritage Foundation**, June 2009 – May 2010, $9000

26. Quantifying the Resilience of Innovation Ecosystems: The Impact of Manufacturing Offshore on Firm Technology Trajectories and the Institutional Locus of Innovation, **NSF Science of Science and Innovation Program**, September 2008 – September 2010, $208,068; *2009 NSF Research Highlight; August 2010 Feature in SciSIP newsletter.*

27. The Global Disintegration of Firm Activities: Understanding the Managerial and Technological Underpinnings of Firm Outsourcing, **Berkman Faculty Development Fund**, June 2008 – May 2010, $10,000

28. An Innovation Ecosystem in Flux: Innovation Trajectories and Institutional Shifts in the Optoelectronics Industry, **Oak Ridge Associated Universities (ORAU) Ralph E. Powe Junior Faculty Enhancement Award**, June 2008 – May 2010, $10,000

29. The Global Disintegration of Firm Activities: Understanding the Managerial and Technological Underpinnings of Firm Outsourcing, **Sloan Industry Studies Site Visit Grant**, The Sloan Foundation, June 2008 - May 2009, $5000

30. INFORMS session: Knowledge Networks & the Emergence of New Technologies, **Sloan Industry Studies Travel Grant**, Sloan Foundation, Oct. 12-15, 2008, Speakers' travel.

31. Decision Tools for Engineering Design and Entrepreneurship, **Corporate Sponsorship. RHM International**, January 2008 – May 2010, $5000 gift plus all-expense trip for three-student project team to collect data on-site at the company in China (~$10,000).

5.B Co-Principal Investigator

32. PI: Anthony Rollett, co-PIs Fuchs, E., Beuth J., Holm, L. Shimada, Wicker, To, Lewandowski, Stebner, Narra. Development of an Ecosystem for Qualification of Additive Manufacturing Processes and Materials in Aviation. **NASA-ULI.** September 2019-August 2022. $5,975,829

33. PI: Kovak, Brian, Co-PIs Ales, L., Fuchs, E., Whitefoot, K. Emerging Manufacturing Technologies and the Demand for Skills. **Russell Sage Foundation**. Grant # 1808-07627. April 1, 2019 – November 30, 2020. $149,244

34. PI: Kovak, Brian, Co-PIs Ales, L., Fuchs, E., Whitefoot, K. Emerging Manufacturing Technologies and the Demand for Skills. **CMU Manufacturing Futures Initiative**. September 2018-August 2019. $132,931.

35. PI: Davis, Alex, Co-PIs Fuchs, E., Kara, B., Poczos, B., Singh, A., Whitefoot, K. Accelerating Metal Additive Manufacturing Commercialization and Military Readiness: Expert guided machine learning to identify candidate parts and subassemblies for additive manufacturing. **CMU Manufacturing Futures Initiative**. September 2018-August 2019. $177,799

36. PI: Whitefoot, Katie, Co-PI Fuchs, E. Cost-competitive Mass Customization for Non-Assembly Manufacturing Environments in the Greater Pittsburgh Region. **PITA.** January 1, 2018-December 31, 2018. $70,000.

37. PI: Fedder, Gary (Vice Provost of Research), Co-PI: Fuchs, E. Manufacturing Futures Initiative. **Richard King Mellon Foundation.** July 2017 – June 2020, $20,000,000. (Founding Faculty Director and lead on $9.25M earmarked in budget for research and engagement.)

38. PI: Mendonca, Joana, CMU Co-PIs: Morgan, G., Fuchs, E., Apt, J, Fischbeck, P. Innovation Dynamics in aeronautics and Embraer in Evora: towards a distributed platform for entrepreneurial initiatives, new employment, and skills development. **Portugal Science and Technology Foundation.** June 2014-May 2018. $627,354

39. PI: Lewandowski, J. Co-PIs: Beuth, J., Fuchs E. plus 15 additional industry, university, and government participants. Rapid Qualification Methods for Powder Bed Direct Metal AM Processes. **National Additive Manufacturing Innovation Institute. (**now renamed **America Makes)** $278,982

40. PI: Whitacre, J. Co-PIs: Fuchs, E. and Michalek, J. Manufacturing Modeling Tools for Domestic Energy Storage Production: Process Based Cost Modeling. **Research for Advanced Manufacturing in Pennsylvania.** Industry Partner: Aquion Energy $26,440

5.C Faculty Associate

41. PI: Veloso, F. E. Fuchs, and J. Michalek, Decision Tools for Engineering Design and Entrepreneurship, Course Outreach to Carnegie Mellon University's Technology Transfer Office, **R.K. Mellon Foundation**, August 2008 – August 2009, $25,000

6. Professional Activities

6.A Seminars

1. Panelist. Critical Considerations for Restarting a More Resilient and Robust U.S. Economy Post COVID-19. Carnegie Mellon University. Virtual Hill Briefing. June 12, 2020.

2. Invited Speaker. Opening Plenary. Challenges and Opportunities Arising from COVID-19: Industry Studies Perspectives. June 5, 2020.

3. Invited Speaker. "Fourth Industrial Revolution: Whose Opportunity? Whose Threat?" Opening Plenary. Atlanta Conference on Science and Innovation Policy. October 14, 2020.

4. Invited Speaker. The Weighty Manufacturing Sector: Challenges in Innovation in the Transformation of Raw Materials to Physical Goods. National Bureau of Economic Research. Pre-Conference: Beyond 140 Characters: The Role of Innovation and Entrepreneurship in Economic Growth. January 6-8, 2020.

5. Invited Speaker. The Weighty Manufacturing Sector: Challenges in Innovation in the Transformation of Raw Materials to Physical Goods. National Bureau of Economic Research. Pre-Conference: Beyond 140 Characters: The Role of Innovation and Entrepreneurship in Economic Growth. July 22-23, 2019.

6. Invited Speaker. National Bureau of Economic Research Innovation Division Summer Institute Panel on "National Innovation Leadership: Is it changing and does it matter?"

7. Invited Speaker. Launch by the Joint Research Centre of the European Commision (JRC)'s report on China: Challenges and Prospects from an Industrial Powerhouse. Brussels, Belgium. May 23, 2019.

8. Invited Speaker. Opening Plenary Session on What governments can do to support more radical innovation. Nesta Innovation Growth Lab Annual Conference. Berlin, Germany. May 22, 2019.

9. Invited Speaker and Participant. Expert Workshop with the European Commission on the Implementation of the European Innovation Council ("a DARPA-like organization focused on market-oriented technologies). Workshop launched and concluded by Carlos Moedas, European Commissioner for Research, Science, and Innovation. Brussels, Belgium. February 22, 2019.

10. Invited Seminar. Global Manufacturing and the Future of Technology and Jobs. Bloomberg Headquarters. Washington, D.C. November 14, 2018.

11. Keynote Speaker. Another Brick in the Wall. [sic] DARPA Electronic Resurgence Initiative Launch Event. July 23, 2018.

12. Funding Breakthrough Research: Promises and Challenges of the "ARPA Model." (paper joint with Azoulay, Goldstein, Kearney) NBER Conference on Innovation Policy and the Economy. Washington, D.C. April 17, 2018

13. Overseas Manufacturing and Innovation. Innovation Policy Forum: Symposium on Securing Advanced Manufacturing in the United States: The Role of Manufacturing USA. The National Academies. May 23, 2017.

14. National differences in technology decision-making and the diffusion of tacit knowledge. Panel I - Arms Race Dynamics in Advanced Nuclear Weapon States. Private Workshop: Evolution or Revolution? The Impact of Additive Manufacturing (AM) on Nuclear Proliferation (Part II). The Carnegie Endowment for International Peace. May 17, 2017.

15. Manufacturing Location and Technology Decision-making. Global Freight Workshop. Carnegie Mellon University, Pittsburgh, PA. February 28, 2017.

16. Global Manufacturing and the Future of Technology and Work. AAAS Forum on Science and Technology Policy. Boston, MA. February 19, 2017.

17. Manufacturing Futures, Energy, and Economic Growth. Tri-State project on Shale Gas in the Appalachian Valley. Canonsburg, PA. December 30, 2016.

18. Global Manufacturing, Innovation, and International Collaboration. China's Science, Technology and Innovation: Canada/US Roundtable. Ottawa, Canada. November 29, 2016.

19. Global Manufacturing and the Future of Technology and Work. Babbage Conference. University of Cambridge. Cambridge, UK. September 2016.

20. A new role for public-private partnerships in long-term technology development?: Insights from the nanoelectronics research initiative. Symposium: Scientific Communities, Public R&D, and Technology Trajectories. Academy of Management 2015 Annual Meeting. Vancouver, BC. August 10, 2015. (Presented by Hassan Khan.)

21. Economic downturns, Inventor Mobility, and Technology Trajectories: A Compilation. NSF Knowledge Conference co-sponsored by the Mack Institute of the Wharton School. University of Pennsylvania. July 27-28, 2015.

22. Competing in a global future: who will manufacture what, where? Plenary Session: From Made to Making in America: Perspectives on U.S. Manufacturing Over 25 Years. Industry Studies Association Annual Meeting. Kaufmann Foundation Conference Center. Kansas City, MO. May 28, 2015.

23. Scaling Moore's Wall [sic.]: A public private partnership in response to a presumptive anomaly in a world of declining fundamental research.. Industry Studies Association Annual

Meeting. Kaufmann Foundation Conference Center. Kansas City, MO. May 28, 2015. (Presented by Hassan Khan.)

24. Scaling Moore's Wall [sic.]: A public private partnership in response to a presumptive anomaly in a world of declining fundamental research. Social Science and Technology Seminar Series. Stanford University. Stanford, CA. May 13, 2015

25. Discussant: Can Marshall's Cluster's Survive Globalization? By Buciuni, G. and Pisano, G. Global Business Models for Speed and Scale Conference. Center for Global Enterprise / Center for the Globalization of Education & Management. Stern School of Business. New York University. April 16, 2015

26. Economic downturns, Inventor Mobility, and Technology Trajectories. Conference on Inequality in Anglo-American Democracies. Munk School of Global Affairs. Toronto, Canada. March 13, 2015

27. Global Manufacturing and the Future of Technology: Implications for U.S. Funding Policy. Invited Seminar. Engineering Directorate. National Science Foundation. Washington, D.C., December 5, 2014

28. Is there a role for the State in influencing the direction of innovation?: Lessons from the Defense Advanced Research Projects Agency and the Semiconductor Research Corporation. Presentation to the Committee on Future Research Goals and Directions for Foundational Science in Cybersecurity. Computer Science and Telecommunications Board. Division on Engineering and Physical Sciences. The National Academies. September 29, 2014

29. Why the global redistribution of manufacturing matters for the future of products. Invited International Lecturer and Scholar. China's Innovation Circles and Academy – A Network on Learning, Innovation, and Competence Building Systems (CICALICS Academy) Research Center for Technological Innovation and China Institute for Science and Technology Policy. Tsinghua University. Beijing, China. August 27-31, 2014

30. Is there a role for the State in influencing the direction of innovation?: Lessons from the Defense Advanced Research Projects Agency and the Semiconductor Research Corporation for technologically-nuanced R&D policies. Invited International Lecturer and Scholar. China's Innovation Circles and Academy – A Network on Learning, Innovation, and Competence Building Systems (CICALICS Academy) Research Center for Technological Innovation and China Institute for Science and Technology Policy. Tsinghua University. Beijing, China. August 27-31, 2014

31. Seeing the Non-Stars: (Some) Sources of Bias in Past Disambiguation Approaches and a New Public Tool Leveraging Labeled Records. Annual Meeting of the Academy of Management, Philadelphia, PA, August 3-5, 2014.

32. Will Subsidies Drive Electric Vehicle Adoption?: Measuring Consumer Preferences in the U.S. and China. Business Policy and Strategy Division Symposium. Annual Meeting of the Academy of Management, Philadelphia, PA, August 3-5, 2014. (Presented by J. Helveston)

33. Seeing rainbows while others flee: how innovation in the most advanced technology grew after the burst of the telecommunications bubble. Cross-Division Symposium (Technology Innovation Management, Behavior Policy and Strategy, Organization and Management Theory) Annual Meeting of the Academy of Management, Philadelphia, PA, August 3-5, 2014. (Presented by E. Akinsanmi)

34. Seeing the Non-Stars: (Some) Sources of Bias in Past Disambiguation Approaches and a New Public Tool Leveraging Laveled Records. National Bureau of Economic Research. Summer Institute. Innovation and the Economy Workshop, July 15-16, 2014.

35. A new role for public-private partnerships in long-term technology development?: Insights from the Nanoelectronics Research Initiative. Industry Studies Association Annual Conference in Portland, OR, May 28-30, 2014. (Presented by H. Khan)

36. Seeing rainbows while others flee: how innovation in the most advanced technology grew after the burst of the telecommunications bubble. Industry Studies Association Annual Conference in Portland, OR, May 28-30, 2014.

37. Bought but not played with: Acquisitions and dormant technology opportunities. Industry Studies Association Annual Conference in Portland, OR, May 28-30, 2014. (Presented by C. Yang)

38. Seeing rainbows while others flee: how innovation in the most advanced technology grew after the burst of the telecommunications bubble. Wharton Technology & Innovation Conference. Philadelphia, PA. April 11-12, 2014 (Presented by E. Akinsanmi)
39. Why not all technologies are made equal when it comes to the internationalization of research. Panelist on "Future Trends." Understanding Research Globalization in the Context of National Security and Prosperity. Government-University-Industry Research Roundtable (GUIRR). National Academy of Sciences. Washington, D.C. October 22, 2013.

40. Comparing consumer preferences for electrified vehicles in China and the U.S. INFORMS Annual Meeting. October 9, 2013. (Presented by J. Helveston)

41. Why the shift in manufacturing matters for the global future of technology. Strategic Shifts in Manufacturing Ecosystems. World Economic Forum Summer Davos. September 10, 2013.

42. Methods Matter: Rethinking USPTO Inventor Disambiguation Algorithms with Classification Models and Labeled Inventor Records. Academy of Management Annual Meeting. August 13, 2013.

43. Comparing consumer preferences for electrified vehicles in China and the U.S. Industry Studies Association Annual Meeting. May 29, 2013. (Presented by J. Helveston)

44. Why and Which Manufacturing Matters: Innovation and Production in the U.S. Keynote Speaker. Global Midwest Alliance. Innovation and Opportunities for Manufacturers, Additive Manufacturers, and Global Production. Industry Focus Series: Manufacturing Sector Technology Innovation, Growth, and Globalization. Chicago, IL. April 3, 2013

45. Methods Matter: Revamping Inventor Disambiguation Algorithms in the USPTO Database. Research in Engineering Entrepreneurship Roundtable (REER). Atlanta, GA. November 9, 2012. (Presented by S. Ventura)

46. On the relationship between manufacturing and innovation: why not all technologies are created equal. Invited Seminar. Technology and Operations Management. Harvard Business School. Cambridge, MA. November 1, 2012.

47. Gains from Other's Losses: Technology Trajectories and the Global Division of Firms. INFORMS Annual Meeting. Phoenix, AZ. October 17, 2012. (Presented by C. Yang)

48. The Mobility of Scientists after an Economic Downturn and Its Impact on Technology Trajectories. INFORMS Annual Meeting. Phoenix, AZ. October 17, 2012. (Presented by E. Akinsanmi)

49. The Benefits of Bounded Diversity: Organizational Learning in a Multi-product Manufacturing Environment. INFORMS Annual Meeting. Phoenix, AZ. October 17, 2012. (Presented by C. Denomme)

50. On the relationship between manufacturing and innovation: why not all technologies are created equal. Invited Seminar. University of California San Diego. San Diego, CA. October 12, 2012.

51. What should be made in America? What role, if any, is there for government in U.S. manufacturing? CONNECT Business Forum in partnership with Industrial Relations / Political Science, CONNECT Institute, Sponsored by Sheppard Mullin. San Diego, CA. October 11, 2012.

52. On the relationship between manufacturing and innovation: why not all technologies are created equal. Plenary Speaker. Science of Science and Innovation Principle Investigator's Workshop. Committee on National Statistics. Division of Behavioral and Social Sciences and Education. The National Academies. Washington, D.C. September 20-21, 2012.

53. On the relationship between manufacturing and innovation: why not all technologies are created equal. Keynote Speaker. Materials and Manufacturing Technologies Branch Offsite Meeting. Army Research Laboratory. Auberdeen, MD. August 23, 2012.

54. Gains from Other's Losses: Technology Trajectories and the Global Division of Firms. Annual Academy of Management Meeting. Boston, MA. August 6, 2012. (Presented by C. Yang)

55. Methods Matter: Revamping Inventor Disambiguation Algorithms in the USPTO Database. Annual Academy of Management Meeting. Boston, MA. August 3, 2012. (Presented by S. Ventura)

56. Gains from Other's Losses: Technology Trajectories and the Global Division of Firms. Annual Industry Studies Meeting. Pittsburgh, PA. May 31, 2012. (Presented by C. Yang)

57. The Mobility of Scientists after an Economic Downturn and Its Impact on Technology Trajectories. Annual Industry Studies Meeting. Pittsburgh, PA. May 31, 2012. (Presented by E. Akinsanmi)

58. Methods Matter: Revamping Inventor Disambiguation Algorithms in the USPTO Database. Annual Industry Studies Meeting. Pittsburgh, PA. May 30, 2012. (Presented by S. Ventura)

59. Organizational Learning and Knowledge Transfer in a Multi-Product Overseas Manufacturing Environment. Annual Industry Studies Meeting. Pittsburgh, PA. May 30, 2012. (Presented by C. Denomme)

60. Gains from Others Losses: Technology Trajectories and the Global Division of Firms. Wharton Technology Conference. Philadelphia, PA. April 20-21, 2012.

61. On the relationship between manufacturing and innovation: why not all technologies are created equally. Invited Seminar. Production in the Innovation Economy Series. M.I.T. Cambridge, MA. April 4, 2012.

62. The Future of Advanced Manufacturing: Insights from Optoelectronics and Beyond. Manufacturing Workshop. Optoelectronics Industry Development Association. OFC/NFOEC. Los Angeles, CA. March 5, 2012.

63. What manufacturing should we really be keeping in the U.S.?: The relationship between manufacturing and innovation and why U.S. policy cannot treat all technologies equally. Forum on *Why – and Which – Manufacturing Matters.* Brookings Institution. Washington, D.C. February 22, 2012.

64. Economic Downturns, Technology Trajectories, and the Careers of Scientists. INFORMS Annual Meeting. Charlotte, North Carolina. November 14, 2011. (Presented by E. Akinsanmi)

65. Rethinking the Role of Government in Technology Development: DARPA and the Case for Embedded Network Governance. Leaders Program. 21st New Generation Seminar. East-West Center. Washington, D.C. October 14, 2011.

66. Reflections on an Interdisciplinary Ph.D. Academic Panel. M.I.T. Engineering Systems Division First 50 Ph.D.s Alumni Symposium. September 16, 2011.

67. The Future of Photonics: Implications from and for Telecommunications. Finisar Corporation. Santa Clara, CA. June 16, 2011.

68. Economic Downturns, Technology Trajectories, and the Careers of Scientists. Industry Studies Association Annual Meeting. Pittsburgh, PA. June 1-2, 2011. (Presented by E. Akinsanmi)

69. The Impact of Offshoring on Firm versus Individual Technology Trajectories. Industry Studies Association Annual Meeting. Pittsburgh, PA. June 1-2, 2011. (Presented by C. Yang)

70. Rethinking Distributed R&D Management: DARPA and the Case for Embedded Network Governance. Intel Corporation. Video Conference to Santa Clara, CA. May 26, 2011.

71. Concluding Comments. Workshop on the Department of Defense as a catalyst for energy technology innovation. Consortium for Science, Policy & Outcomes. Washington, D.C. May 25, 2011.

72. Economic Downturns, Technology Trajectories, and the Careers of Scientists. Production and Operations Management Society (POMS) Annual Meeting. Reno, NV. April 30, 2011. (Presented by E. Akinsanmi)

73. The Future of Photonics: Implications from and for Telecommunications. National Research Council. Harnessing Light II. Second Committee Meeting. Washington, D.C. April 7, 2011.

74. The Impact of Offshore Manufacturing on Technology Competitiveness: Implications for U.S. Policy. Connect Innovation Institute. San Diego, CA. April 27-28, 2011.

75. The Impact of Offshore Manufacturing on Technology Competitiveness: Implications for U.S. Policy. Invited Briefing. Secretary Gary Locke. National Advisory Council on Innovation and Entrepreneurship. Department of Commerce. December 8, 2010.

76. The Impact of Offshore Manufacturing on Technology Competitiveness: Implications for U.S. Government Investment. Invited Seminar. ARPA-E. December 8, 2010.

77. The Future of Photonics: Implications From and For the Telecommunications Industry. Invited Talk. Optoelectronics Industry Development Association Annual Forum. November 16. 2010.

78. Economic Downturns, Technology Trajectories, and the Careers of Scientists. INFORMS Annual Meeting. Austin, TX. November 10, 2010. (Presented by E. Akinsanmi)

79. The Impact of Offshoring on Firm versus Individual Technology Trajectories. INFORMS Annual Meeting. Austin, TX. November 6, 2010. (Presented by C. Yang)

80. The Impact of Offshoring on Innovation: Implications for U.S. Policy. AAAS Science and Policy Programs NSF SciSIP Grantees Workshop: Towards a Community of Practice. Washington, D.C. October 19, 2010

81. Rethinking the Role of Government in Technology Development: DARPA and the Case for Embedded Network Governance. Global Innovation and Development Lecture Series. The Nunn School of International Affairs. Georgia Institute of Technology. September 14, 2010

82. Rethinking the Role of Government in Technology Development: DARPA and the Case for Embedded Network Governance. China Institute for Science and Technology Policy. School of Public Policy. Tsinghua University. August 17, 2010

83. Rethinking the Role of Government in Technology Development: DARPA and the Case for Embedded Network Governance. Defense Advanced Research Projects Agency (DARPA). Washington, D.C., June 7, 2010

84. The Impact of Manufacturing Offshore on Technology Competitiveness. Stanford University, Social Science and Technology Seminar Series. Stanford, CA. June 2, 2010.

85. Design for Location: The Impact of Manufacturing Offshore on Technology Competitiveness in the Optoelectronics Industry. Sumantra Ghoshal Strategy Conference. London, U.K. May 16, 2010.

86. Moore's Law, Technology Mafias, and Radical Architectural Change. Industry Studies Association Annual Conference. May 6, 2010.

87. Organizational Learning in a Multi-Product Overseas Manufacturing Environment. Industry Studies Association Annual Conference. May 6, 2010. (Presented by C. Denomme)

88. The Impact of Product Mix and Employee Turnover on Organizational Learning. Organization Science Winter Conference. Steamboat Springs, CO. February 4-7, 2010.

89. The Impact of Manufacturing Offshore on Innovation: Implications for U.S. Policy. Information Technology Innovation Foundation Forum. Rayburn Office Building, United States House of Representatives. Washington, D.C. February 3, 2010.

90. The Impact of Manufacturing Offshore on Technology Competitiveness: Implications for U.S. Policy. Science Technology Policy Institute Seminar Series. Institute for Defense Analysis. Washington, D.C. February 2, 2010.

91. The Impact of Manufacturing Offshore on Technology Competitiveness. Engineering, Science, and Technology Policy (ESTeP) Committee Meeting. Photonics West. SPIE. San Francisco, CA. January 25-27, 2010.

92. The Impact of Manufacturing Offshore on Technology Competitiveness. Invited Talk. M.I.T. Sloan Technology Innovation and Entrepreneurship Seminar. Cambridge, MA. December 7, 2009.

93. From Ph.D. to Prof. (In Under 20 Minutes). Invited Talk. M.I.T. Course on Academic Careers: ESD.944. Cambridge, MA. December 24, 2009.

94. The Impact of Employee Turnover and Product Mix on Organizational Learning in Offshore Manufacturing. INFORMS Annual Meeting. San Diego, CA. October 11, 2009. (Presented by C. Denomme)

95. Design for Location: The Impact of Manufacturing Offshore on Technology Competitiveness. Atlanta Conference on Science and Innovation Policy. Atlanta, GA. October 2-3, 2009

96. Rethinking the Role of the State in Technology Development: The Case of DAPRA and Embedded Network Governance. Atlanta Conference on Science and Innovation Policy. Atlanta, GA. October 2-3, 2009

97. Remembering Comparative Advantage: Leveraging National Differences in Technology Competitiveness. Conference by CMU and the Atlantic Council in Preparation for the G-20 Summit. Pittsburgh, PA. September 23, 2009

98. The Impact of Manufacturing Offshore on Technology Competitiveness: Implications for U.S. and China Policy. The Cosmos Club. Washington, D.C. September 10, 2009

99. Rethinking the Role of the State in Technology Development: The Case of DAPRA and Embedded Network Governance. Annual Meeting of the Academy of Management. Chicago, IL. August 7-11, 2009

100. Rethinking the Role of the State in Technology Development: The Case of DAPRA and Embedded Network Governance. International Risk Governance Society. Washington, D.C., June 30, 2009

101. The Impact of Manufacturing Offshore on Technology Competitiveness: Lessons from Automobiles and Semiconductors. Algorithmic Automation Workshop. Robotics Science and Systems 2009. Seattle, WA. June 28, 2009

102. The Impact of Employee Turnover and Product Mix on Organizational Learning in Offshore Manufacturing. Interactive Session. Sloan Industry Studies Annual Meeting. May 28, 2009. (Presented by C. Denomme)

103. Emerging Trends in Organization Science: Commentary on Common Themes. Organization Science Senior Editors Conference. Pittsburgh, PA. May 22, 2009

104. Design for Location: The Impact of Manufacturing Offshore on Technology Competitiveness. AAAS. Workshop on Science of Science and Innovation Policy. Washington, D.C. March 24, 2009

105. The Impact of Manufacturing Offshore on Technology Competitiveness: Implications for U.S. and China Policy. China Today. University of Pittsburgh. Pittsburgh, PA. March 20-22, 2009

106. The Impact of Manufacturing Offshore on Technology Competitiveness: Implications for U.S. and China Policy. Development Students Organization. Carnegie Mellon University. Pittsburgh, PA. March 20, 2009

107. The Role of DARPA in Seeding and Encouraging New Technology Trajectories: Pre- and Post Tony Tether in the Innovation Ecosystem. Chemical Heritage Foundation. Philadelphia, PA. February 27, 2009

108. The Geography of Design: Lessons from Automobiles and Optoelectronics. Center for Product Strategy and Innovation. Corporate Members Meeting. Pittsburgh, PA. Feb. 18, 2009

109. The Role of DARPA in Seeding and Encouraging New Technology Trajectories: Pre- and Post Tony Tether in the Innovation Ecosystem. Council on Foreign Relations. New York, NY. November 25, 2008

110. Modeling the Economics of Photonics Manufacture: Strategic Trade-offs in Integration, Offshoring, and Material Platforms. Workshop on 10GPON, MIT Center for Integrated Photonics, Cambridge, MA, November 18, 2008

111. The Geography of Design: Lessons from Automobiles and Optoelectronics. Center for Product Strategy and Innovation, CMU, Pittsburgh, PA. November 11, 2008

112. The Global Competitiveness Lab: The Impact of National Diversity on Technology Change. Department of Engineering and Public Policy, CMU, Pittsburgh, PA. October 24, 2008

113. The Role of DARPA in Seeing and Encouraging New Technology Trajectories: Pre- and Post Tony Tether in the Innovation Ecosystem. Information Technology and Innovation Foundation. Washington, D.C. October 14, 2008

114. The Role of DARPA in Seeing and Encouraging New Technology Trajectories: Pre- and Post Tony Tether in the Innovation Ecosystem. INFORMS Annual Meeting, Washington, D.C. October 13, 2008

115. The Role of DARPA in Seeing and Encouraging New Technology Trajectories: Pre- and Post Tony Tether in the Innovation Ecosystem. Panel on Science and

Technology Policy. Annual Meeting of the Society for the Advancement of Socio-Economic Research (SASE). San Jose, Costa Rica. July 21-23, 2008

116. Modeling the Economics of Photonics Manufacturre: Strategic Trade-offs in Integration, Offshoring, and Material Platforms..Integrated Photonics & Nanophotonics Research Applications Topical Meeting, Optical Society of America. Boston, MA, July 13-16 2008

117. The Role of DARPA in Seeing and Encouraging New Technology Trajectories: Pre- and Post Tony Tether in the Innovation Ecosystem. Sloan Industry Studies Annual Meeting. Boston, MA. April 30, 2008

118. The Impact of Manufacturing Offshore on Technology Competitiveness. Innovation and Manufacturing in the 21st Century. Optoelectronics Industry Development Association. San Jose, CA. April 16-17, 2008

119. Platform Leaders, True Believers, and Coordinated Innovation: The Role of Key Architects in Influencing Technology Trajectories. INFORMS Annual Meeting 2007 Seattle, WA, November 4-7, 2007

120. Modeling the Economics of Photonics Manufacture: Strategic Trade-Offs in Integration, Offshoring, and Materials Platforms. Invited Talk. Photonics North. Ottawa, Canada, June 4-7, 2007

121. Changing Paths: The Impact of Manufacturing Offshore on Technology Trajectories. Sloan Industry Studies Annual Conference. Cambridge, MA April 26-27, 2007.

122. Moore's Law: Platform Leaders, True Believers, and Coordinated Innovation – Implications for the Upcoming Decade. Bi-Annual Microphotonics Center Industry Consortium Meeting. April 17-18, 2007

123. Innovation Strategies for a Global Economy: The Role of DARPA in Seeding and Encouraging Technology Trajectories. Invited Seminar. Engineering and Public Policy. Carnegie Mellon University. Pittsburgh, PA, December 18, 2006

124. The Impact of Manufacturing Off-shore on Technology Trajectories. Invited Presentation. INFORMS Annual Meeting 2006 Pittsburgh, PA, November 5-8, 2006

125. Innovation Strategies for a Global Economy: The Role of Government Initiatives in Technology Trajectories. Bi-Annual Microphotonics Center Industry Consortium Meeting. October 19-20, 2006

126. The Geography of Design: Insights from Automobile Bodies and Optoelectronic Components. Invited Presentation. TMS Annual Meeting. Materials Science & Technology 2006. Cincinnati, OH, October 15-19, 2006

127. Modeling Photonics Manufacture: Economic Insights into Design, Process, and Production Strategy. Invited Talk. Optoelectronics Industry Association Forum – Micropackaging for the Next Generation of Optical and Electrical Components. San Jose, CA, August 30, 2006.

128. Innovation Myopia: Beyond Labor Savings in Off-shore Manufacturing. The Innovation Research Network. Boston, MA, May 13, 2006

129. Innovation Myopia: Beyond Labor Savings in Off-shore Manufacturing. Invited Seminar. Engineering and Public Policy. Carnegie Mellon University. Pittsburgh, PA, March 8, 2006

130. Innovation Myopia: Beyond Labor Savings in Off-shore Manufacturing. Technology and Operations Management Seminar. Harvard Business School. Harvard University. Pittsburgh, PA, February 23, 2006

131. Innovation Myopia: Beyond Labor Savings in Off-shore Manufacturing. Operations Management Seminar. Sloan School of Management. Massachusetts Institute of Technology. Cambridge, MA, February 16, 2006

132. Changing Paths: The Impact of Manufacturing Off-shore on Technology Development Incentives. Invited Presentation. INFORMS Annual Meeting 2005 New Orleans, November 13-16, 2005

133. Challenges for Emerging Technologies in Mature Industries: The Case of Polymer Composite Vehicles in China. Panel on The Future of the Car – The Car of the Future. M.I.T. International Science and Technology Initiative. Cambridge, MA, September 22, 2005

134. Innovation Myopia: Beyond Labor Savings in Off-shore Manufacturing. 4th Annual Technology Management and Policy Consortium. Cambridge, MA, June 26-28, 2005

135. Modeling Photonics Manufacture: Economic Insights into Design, Process, and Production Strategy. Invited Presentation. Intel Corporation. Santa Clara, CA, June 5, 2005

136. Structural Shackles: The Importance of Maintaining a Problem-Oriented Approach in the Early Development Stages of Engineering Systems. Student Panel. Engineering Systems Division Department Off-site. Dedham, MA, May 27, 2005

137. Modeling Photonics Manufacture: Economic Insights into Design, Process, and Production Strategy. Microphotonics Center Industry Consortium Meeting. May 16, 2005

138. Consolidate? Integrate? Go East? Or Get Out?: Mapping the Drivers of Optoelectronics Production Costs. Photonic Systems Graduate Series, M.I.T. Center for Integrated Photonics, Cambridge, MA, March 17, 2005

139. Device-Enabled Network Architectures: The Economic Implications of Emerging Optoelectronic Device Technologies in Network Architectures. M.I.T. Communications Futures Program. Cambridge, MA, March 16, 2005

140. Consolidate? Integrate? Go East? Or Get Out?: Mapping the Drivers of Optoelectronics Production Costs. Bi-Annual Microphotonics Center Industry Consortium Meeting. Cambridge, MA, December 4, 2004

141. Process-Based Cost Modeling of Photonics Manufacture. Bi-Annual Microphotonics Center Industry Consortium Meeting. Cambridge, MA, November 3, 2003

142. The Significance of Production Cost Inputs in Regional Technology Choice: Composite Automotive Body-In-Whites in the U.S. versus China. 2nd Annual Technology Management and Policy Consortium. Arlington, VA, July 7-8, 2003

6.B Government Committees, Civic Appointments, and Board Memberships

Co-Chair (joint with Eric Lander.) US Science and Innovation Leadership for the 21st Century: Challenges and Prospects. National Academies Consensus Study. October 2019-present) https://www8.nationalacademies.org/pa/projectview.aspx?key=51225. Committee received a stop work order from the Department of Defense after its first three meetings, and is on hold.

Member. M.I.T. Corporation Visiting Committee. M.I.T. Institute for Data, Systems, and Society (IDSS) (which includes the M.I.T. Technology Policy Program (TPP)) 2020-2022.

Advisory Editorial Board. *Research Policy*. (Journal) 2014-Present

Academic Advisory Board (AAB). M.I.T. Institute for Data, Systems, and Society (IDSS) and M.I.T. Technology Policy Program (TPP). (Advise IDSS as a whole and also join the subgroup focused on IDSS's TPP program.) 2018-2020.

Scientific Advisory Board (SAB). Institute for Research on Innovation & Science (IRIS) 2018-2020.

National Academies Materials and Manufacturing Board. 2017-2019

Member, Future of Production Global Futures Council, World Economic Forum. 2017-2019

Member, Advanced Materials Global Agenda Council, World Economic Forum. 2017-2019

Committee Member. National Academy of Science Evaluation of ARPA-E. Board on Science, Technology, and Economic Policy. The National Academy of Sciences. 2015-2017.

Expert. Innovation Dialogue. US-China Strategic and Economic Dialogue. Oct. 2015-July 2016

Judges (Advisory) Panel, United States Patent and Trademark Office and American Institutes for Research PatentsView Initiative. 2015.

Member-at-Large. U.S. Advisory Committee to the International Commission for Optics. The National Academies. International Council for Science. February 14, 2013 – December 31, 2015

Committee Member. National Research Council Committee on *Harnessing Light: Capitalizing on Optical Science Trends and Challenges for Future Research*. Board of Manufacturing and Engineering Design, National Materials Advisory Board, National Academy of Sciences. February 2011 – July 2012.

Participant. National Academies of Engineering. Invitation-Only Workshop. *Making Value: Integrating Manufacturing, Design, and Innovation to Thrive in the Changing Global Economy.* Washington, D.C. June 11-12, 2012.

Member. Committee of Visitors. Science of Science and Innovation Policy Program 3-year Review. National Science Foundation. Washington, D.C. December 15-16, 2011

Invited 30-minute brief on the future of advanced manufacturing to Secretary Gary Lock's National Advisory Committee on Innovation and Entrepreneurship. Department of Commerce. December 8, 2010.

One of 23 Invited Participants. President's Council of Advisors on Science and Technology (PCAST) Advanced Manufacturing "Discussion Workshop". Led by PCAST members Eric Schmidt, Chairman and CEO of Google, Inc. and Shirley Ann Jackson, President of Rensselaer Polytechnic Institute. Washington, D.C. March 19, 2010.

6.C Membership and Activities in Honorary Organizations, Professional Societies

Activities:

Reviewer. Industrial Assessment Centers Field Manager Program submissions. Office of Energy Efficiency and Renewable Energy. Department of Energy. February 2017.

Reviewer. Manufacturing Extension Program submissions. National Institute of Standards and Technology. May 2016.

Panel Member. Review of 2011 grant submissions. Science of Science and Innovation Policy Program. National Science Foundation. December 8-9, 2012

Advisor. Photonics community letter to the President's Council of Advisors on Science and Technology and the Office of Science and Technology Policy: "Recommendations for Federal Support of Photonics to Advance U.S. Manufacturing, April 19, 2010." Initiated and created the first draft of the letter. Revision and completion of the letter led by SPIE (International Society for Optics and Photonics). Letter signed by all three major photonics professional society presidents.

Committees:

Member. SPIE (International Society for Optics and Photonics) Data Collection Task Force. Goal: Providing recommendations to the National Academies on their plans for a revised edition of the 1998 publication, Harnessing Light: Optical Science and Engineering for the 21st Century

Membership:

1. INFORMS
2. Academy of Management
3. Industry Studies Association

6.D Editorial Roles on Publications, Major Activities in Professional Meetings

Advisory Editor and Advisory Board Member, *Research Policy*, April 2014-April 2017

Ad-hoc Reviewer:

Journals –

Management Science
Organization Science
Research Policy
Journal of Policy Analysis and Management
Industry and Innovation
International Journal of Production Economics
Management Science and Operations Management (MSOM)
Research in Engineering Design

By Special Invitation –

Chapter 11: Assessing Competitiveness of U.S. Clean Energy Technologies in Global Markets. Quadrennial Technology Review. Department of Energy. May 4, 2015.

Rising to the Challenge: U.S. Innovation Policy for the Global Economy. Ed. Wessner, C. National Research Council. Policy and Global Affairs Division. National Academies Press. February 15, 2012 – May 29, 2012.

Atkinson, R. and Wial, H. Boosting Productivity, Innovation, and Growth through a National Innovation Foundation. Blueprint for American Prosperity. Brookings Institution. Oct. 2007

Conferences –

Atlanta 2009 Conference on Science and Technology Policy (Globalization Track

Activities in Professional Meetings:

Committee Member:

Best Paper and Best Student Paper Award Committee, Technology and Innovation Management (TIM) Division, 2015 Annual Academy of Management Conference

Industry Studies Early Career Development Committee. May 2011 – May 2013. Participant in best dissertation award decision and organization of Industry Studies Annual Early Career Professional Development Workshop.

Best Paper Committee, Technology and Innovation Management (TIM) Division, 2011 Annual Academy of Management (AOM) Conference

Founder, Industry Studies Association "Rising Stars" Best Paper Award. Ran inaugural year (2013) competition, worked with the Industry Studies Association board to determine the call for submissions, recruited the award panel to select winners, and arranged the special 2013 session at which the winner and runners up would present with guest discussant.

Committee Chair (Inaugural Year):
Best Paper Award, Technology Management Division, INFORMS 2012 Annual Meeting

Best Dissertation Award Reviewer:
Technology Management Division, INFORMS 2010 Annual Meeting.

Session Chair:
INFORMS 2012 Annual Meeting: Technology Management Division Best Paper Session
INFORMS 2011 Annual Meeting. Technology Management Division
INFORMS 2010 Annual Meeting. Technology Management Division
INFORMS 2009 Annual Meeting. Technology Management Division
INFORMS 2008 Annual Meeting. Technology Management Division. P.I. on Sloan Travel Grant to cover flight and hotel expenses for all '08 session speakers.
INFORMS 2007 Annual Meeting. Technology Management Division.

6.F Awards, Prizes, Honors

2014-present Advisory Editorial Board, *Research Policy*

2017 Reading High School Alumni Association, Distinguished Alumus

2015 Philip L. Dowd Fellowship Award

2013 Carnegie Institute of Technology Dean's Early Career Fellow

2012 World Economic Forum Young Scientist (top 40 under 40 internationally; in conjunction with the International Academies Panel)

2012 Lead, One of three example projects that together created the body of the winning "Tech Belt" National Additive Manufacturing Innovation Initiative (NAMMI) Proposal; "Tech Belt" – which involves over 30 entities (university, industry, and government) from the Ohio-Pennsylvania-West Virginia region – was the winning proposal nationally, to be awarded $30 million in federal funding to be matched by another $40 million from the consortium; Example project title: E. Fuchs, S. Smith, (CMU); D. Frangepol, E. Zimmers (Lehigh U.); T Harrison, PSU) Computational Models to Guide and Accelerate Commercialization.

2011 Greeted President Barack Obama on behalf of Carnegie Mellon University along with Carnegie Mellon President Jared Cohon during President Obama's visit to announce the Advanced Manufacturing Partnership. Provided a brief synopsis of my offshoring research.

2011 National Science Foundation (NSF) Faculty Early Career Development (CAREER) Award

2010 SPIE (Society for the Advancement of Light) 2010 "Women in Optics"

2010 Participant, President's Council of Advisors on Science and Technology (PCAST) Workshop on the Future of Advanced Manufacturing in the U.S.

2008 Oak Ridge Associated Universities Ralph E. Powe Junior Faculty Enhancement Award

2006 Finalist, Sloan Industry Studies Dissertation Award

2005-2006 Alfred P. Sloan Industrial Performance Center Fellowship

2005 Best Doctoral Presentation, 4th Annual Technology Management and Policy Consortium

2004 Anthony Sun Fellowship

2003 Best Masters Thesis, MIT Technology and Policy Program

6.F Service on CMU Committees

Fall 2017	Chair, Engineering and Public Policy Part B written qualifying exam committee
2015-2016	Co-Lead (with Gary Fedder), Manufacturing Futures Initiative proposal development and submission to Richard King Mellon Foundation
2016-2017	Member, School of Engineering Promotion and Tenure Ad-Hoc Committee.
2013-2015	Chair, Faculty Search Committee. Faculty Hire in the Management, Economics, or Organization of Technology. Department of Engineering and Public Policy

2008-2010 & 2014-2015	Co-Coordinator. Seminar in Strategy Entrepreneurship and Technological Change
Fall 2014	Founding Committee, CIT Minor in the commercialization of breakthrough technologies, (replaced by a university-wide initiative)
2008-present	Admissions Committee Member. Engineering and Technology Innovation Management Masters Program, Department of Engineering and Public Policy
2014-2015	First-round Ph.D. admissions reviewer. "Other Technology Policy," Ph.D. Applicant Category. Department of Engineering and Public Policy.
2012-2014	Founder and Organizer. Carnegie Mellon University STEM Junior Women Faculty Lunches (three times per year – paid for by the STEM deans.)
2013-2014	Member, Department Head Search Committee. Department of Engineering and Public Policy.
2011-2013	First-round Ph.D. admissions reviewer. "Other Technology Policy," "International" and "Strategy, Entrepreneurship, and Technological Change" Ph.D. Applicant Categories. Department of Engineering and Public Policy.
2008-2013	Graduate Education Committee Member. Ph.D. Program. Department of Engineering and Public Policy.
2008-2013	Co-organizer. Junior Faculty Rotating Home Get-togethers. Department of Engineering and Public Policy
2008-2013	Co-organizer. Carnegie Institute of Technology Women's Monthly Junior Faculty Lunches
2011-2012	Member. CMU committee supporting the Advanced Manufacturing Partnership "Policy Workstream" (Chaired by President Jared Cohen and Prof. Gary Fedder.)
2011-2012	Member. Ad-Hoc Carnegie Institute of Technology (CIT) Committee on ways to enhance CIT undergraduate education in the areas of innovation and internationalization.

7. Other

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Bobkoff, Dan. What is Advanced Manufacturing and Why is it The Future? Changing Gears. National Public Radio (NPR). September 30, 2011.

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Lane, J. "Feature" article highlighting our design for location research. Annual Science of Science and Innovation Policy newsletter (only grant recipient highlighted), August 2010.

Lane, J. *Science*. Policy Forum. June 5, 2009

On DARPA Pre- and Post- Tony Tether:

Matthews, Bill. *Defense News*. February 13, 2009.

Reppert, Barton. *IEEE Today's Engineer*. November 8, 2008.

Norr, Melissa. *Computing Research Association's Policy Blog*. October 14, 2008.

On Decision Tools for Engineering Design and Entrepreneurship:

Swaney Chris. *The Piper Newsletter*. June 2008.

On Professional Achievements:

Luttrell, Sharron. Understanding how manufacturing location impacts technology development. *Technology Review*. April 2014.

Silmore, Melissa. Global Partners. Feature Stories. *Carnegie Mellon Today*. January 2014.