NBER Productivity, Innovation and Entrepreneurship Program
The Digitization Grant Research Proposal

"The Advent of New Technology and its Implications on Digital Media Markets: Evidence from Smartphones, Tablets and Computers"

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The advent of mobile innovation including smartphones and tablets has revolutionized how individuals consume digital media and has brought significant changes to the media markets. Smartphones and tablets' portability, multi-functionality, connectivity, and convenience distinguish this recent digital technology from other prior consumer technology. In the United States, by 2014 mobile devices accounted for 55% of Internet usage and overtook the computer Internet usage time (O'Toole, 2014). Smartphones and tablets, along with traditional computers, have become the major digital technologies through which individuals read newspaper, listen to music, search for information, play games, shop online, do banking, and engage in various digital activities. The goal of our research is to empirically examine the impact of mobile innovation on individuals' media consumption, and to quantify the extent to which computer, smartphone, and tablet complement and substitute one another.

Each digital technology offers different features and experience, and we seek to address following research questions: do individuals engage in similar activities on different digital devices? Or do individuals choose to use different digital devices to engage in different types of digital activities? Which media market has changed the most with the advent of mobile innovation? For example, how was online newspaper market affected by the mobile innovation? To what extent have smartphones and tablets substituted computers and to what extent have smartphones and tablets have expanded consumers' overall digital media consumption? To address the research questions, we use a unique individual-level German panel data that tracks and monitors individuals' smartphone, tablet, and computer usage. We further combine the usage data with app and domain characteristics data.

The proposed research will expand and complement current other research by Stephanie Lee that uses panel survey data collected by Korean government. Using the time-use survey data, Lee (2016) finds that smartphone adoption significantly reduces the ownership and usage of other devices, and the effects are stronger for portable special purpose devices such as MP3 players and digital cameras. Lee estimates a structural model to quantify the consumer surplus of smartphones and identify substitution and expansion effects of smartphone usage.

The German click-stream data allows us to examine in depth how media markets have changed with the advent of smartphones and tablets. The data covers approximately 30,000 individuals from January 2014 to August 2015. For more than 17,000 individuals, we track both their computer and smartphone usage. The data includes both Android and iOS smartphone users. For approximately 7,000 individuals, we track their computer, smartphone, and tablet usage. This novel data provides a unique opportunity to empirically examine how individuals spend their time across different digital devices. Each time an individual uses a mobile app on a smartphone or a tablet, we observe exact time at which the app is opened, the identity of the app, and the duration of app usage. Top apps we observe in the data include WhatsApp Messenger, Facebook, Gmail, Candy Crush Saga, and YouTube. Similarly, each time an individual uses a web browser on a smartphone, tablet, or computer, we observe the exact time at which the browser is launched, the web domain, url, and the duration of usage.

We combine the app usage data with app characteristics data that we obtain from the Google Play Store (https://play.google.com/) and Apple App Store

(http://www.apple.com/itunes/), which are the app markets for Android and iOS devices, respectively. Information we have collected include app category, app reviews, the number of installs given in bins, app price, ranking of the app, the availability of in-app purchases, and app developer. We also classify web domains into different categories including games, education, entertainment, online shopping, finance/banking, radio, and travel.

From the German data, we additionally observe individuals detailed sociodemographic information including their gender, age, education level, occupation, income, and city. Data on their sociodemographic information allows us to examine in depth the heterogeneity in device usage across different age groups and socioeconomic status. Younger individuals may spend more time on digital media consumption, and how they allocate their time across devices may differ from older individuals. Furthermore, individuals with different income levels may use devices differentially.

We plan to first present important descriptive statistics on smartphone, tablet, and computer usage. We will document the proportion of time spent on different categories of app and web domain and compare the statistics across different digital devices and over time. The statistics would allow us to understand how media consumption behavior differs across devices. For instance, we would explore which device individuals are most likely to use to engage in a particular media activity such as reading online newspaper or doing online shopping. We also seek to understand daily and weekly patterns of usage, and examine if individuals are more likely to use computer or mobile devices at certain time in the day or week. Furthermore, we plan to focus on individuals for whom we observe usage of multiple devices and carefully document how usage time of different digital devices is correlated.

We will also use the regression analysis to examine how mobile device usage time affects computer usage time. The panel nature of the data allows us to control for individuals' unobservable heterogeneity. Using the group of individuals for whom we observe usage of multiple devices, we plan to estimate how daily smartphone or tablet usage time affects daily computer usage time. The positive relationship would suggest that mobile device usage increases computer usage, and suggests that mobile devices complement computer. We will also examine how the relationship differs for different categories of digital activities. For example, we plan to examine how daily smartphone usage time spent on reading online newspaper is related with daily computer usage time spent on reading online newspaper.

Furthermore, we plan to estimate a digital device usage model similar to the model that is applied to the Korean time-use survey data in Lee (2016). The model would allow us to measure and quantify the extent to which smartphones and tablets have substituted computers and the extent to which smartphones and tablets have expanded consumers' overall digital media consumption. We plan to use a mixed logit framework and allow individuals to have persistent heterogeneous taste for media activity. Using the model, we will also seek to quantify utility gains and consumer surplus from mobile innovation.

The project builds on existing data collaboration with European Commission's Joint Research Centre Institute for Prospective Technological Studies (IPTS). We plan to use the grant to support our travels to our data partners, purchase complementary or extended datasets, and support research assistants. The media markets have undergone huge transitions with the rapid adoption of smartphones and tablets. It is important to understand and explore the impact of mobile innovation on individuals' media consumption, and we hope to assess the recent transitions in media markets with our novel data sets.

References

O'Toole, James. 2014. "Mobile Aps Overtake PC Internet Usage in U.S." *CNN*. Retrieved from http://money.cnn.com/2014/02/28/technology/mobile/mobile-apps-internet/

Lee, Stephanie. 2016. "Smartphone Adoption: Digital Device Substitution and Digital Reliance Expansion."

STEPHANIE LEE

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EDUCATION

Ph.D. in Economics, Stanford University,
Expected Completion: June 2017
DISSERTATION: "*Smartphone Adoption: Digital Device Substitution and Digital Reliance Expansion*"

B.A. in Economics, Stanford University, 2007-2011 (with Honors and Distinction).

RESEARCH AND TEACHING FIELDS

Primary field: Industrial Organization.
Secondary fields: Economics of Technology, Public Economics.

TEACHING EXPERIENCE

2015 Teaching Assistant for Prof. Scott McKeon, Stanford University, Econ 102A (Introduction to Statistical Methods (Post Calculus) for Social Scientist).
2014 Teaching Assistant for Prof. Scott McKeon, Stanford University, Econ 102A (Introduction to Statistical Methods (Post Calculus) for Social Scientist).

RELEVANT POSITIONS

2014-15 Research Assistant for Prof. Timothy F. Bresnahan, Stanford University.
2013-14 Research Assistant for Profs. Liran Einav and Jonathan Levin, Stanford University.
2012-13 Research Assistant for Prof. Petra Moser, Stanford University.
2010 Research Assistant for Prof. Daniel Ho, Stanford Law School.
2009-10 Research Assistant for Prof. Petra Moser, Stanford University.

SCHOLARSHIPS, HONORS AND AWARDS

2014 Gregory Terrill Cox Summer Research Fellowship, John M. Olin Program in Law and Economics, Stanford Law School.
2011-12 Graduate Fellowship, Stanford University Department of Economics.
2011 Firestone Medal for Excellence in Undergraduate Research, Stanford University.
2011 J. E. Wallace Sterling Award for Scholastic Achievement, Stanford University.
2010 Phi Beta Kappa.
2008 President's Award for Academic Performance, Stanford University.

RESEARCH PAPERS

Smartphone Adoption: Digital Device Substitution and Digital Reliance Expansion

Smartphones, with their multi-functionality and mobility, have revolutionized how individuals use consumer electronics and consume digital goods. Using a detailed time-use survey data from Korea Information Society Development Institute, I empirically examine the extent to which smartphones substitute other digital devices and expand overall digital media consumption, and quantify utility gains from smartphones. First, using a difference-in-differences framework, I find that smartphone adoption significantly reduces the ownership and usage of other digital devices. The effects are stronger for portable special purpose digital devices such as MP3 player, portable game device, and portable media player. Then, I introduce and estimate a model of demand for digital activity choice to examine how substitution and expansion effects differ across digital activities, locations, and sociodemographic factors. Using the model estimates for public transportation, I find that 43% of listening to music on smartphone is from substitution and 57% is from expansion. In the case of searching for information on the web, the expansion effect accounts for the most of the effect. I additionally use the model to quantify consumer surplus from smartphones, and find that the expected utility gains from smartphones are highest when individuals are physically outside, such as when they are using public transportation, walking or waiting, or at restaurants. I also find that individuals who are expected to gain more by adopting a smartphone, as predicted based on their digital device usage and geographic time use, are more likely to have adopted a smartphone.

Does Bundling Decrease the Probability of Switching Telecommunication Service Providers?, revised and resubmitted, *Review of Industrial Organization*

I examine whether bundling of telecommunications services makes individuals less likely to switch their service provider by increasing switching costs. Using a detailed survey dataset from the Korea Information Society Development Institute, I find that Internet subscribers who previously bundled are about 10 percent less likely to switch their Internet service provider than those who did not bundle. Having one extra service included in the past bundle decreases the probability by about 5 percent. The finding that bundling reduces the probability of switching service providers and locks-in existing users can have important implications for market competitiveness and consumer welfare.

RESEARCH IN PROGRESS

Have vs. Want: Mobile App Complementarity and Substitution in Installation and Usage (with Timothy F. Bresnahan and Pai-Ling Yin).
Can Financial Incentives Reduce Healthcare Costs and Improve Health? (with Liran Einav and Jonathan Levin).
Are Returns to Innovation Cumulative or Decreasing in Scale? Evidence from Human Embryonic Stem Cells (with Petra Moser).
Compulsory Licensing and U.S. Innovation after WWII (with Petra Moser).

Pai-Ling Yin

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Pai-Ling Yin is a Social Science Research Scholar at the Stanford Institute for Economic Policy Research. She co-founded the Mobile Innovation Group (MIG: mig.stanford.edu) with Tim Bresnahan of Stanford and Jason Davis of INSEAD, studying all the aspects of the mobile app ecosystem, from industry evolution to platform competition to entrepreneurial strategy. MIG was awarded a 3 year NSF grant.

In August 2016, Pai-Ling will be an Associate Professor of Clinical Entrepreneurship in the Greif Center for Entrepreneurship at the University of Southern California's Marshall School of Business. She will also be the Director of the Technology Commercialization Initiative.

Pai-Ling received a PhD in Economics from Stanford and was a professor of strategy at both Harvard Business School and MIT Sloan School of Management. She has written numerous cases on technology and strategy and research papers on platform competition (eBay, trading exchanges) and diffusion of innovation. She is also the co-owner of a FitLab Pilates in Cambridge, MA.

Her close work with industry has led her to partner local firms with students at Stanford. In her strategy course for undergrads, students work with a firm to analyze a strategic problem and present recommendations. Partners have included Intel, Swift Navigation (GPS devices), Gooru (educational platform), EQI (outsourcing), and Unspoken Tales (mobile gaming). Intel implemented recommendations from their project, and a student started a business from his project.

Pai-Ling also organizes a speaker series and field trips to local firms (Facebook, Intel, Google, Square, Airbnb, Lookout Security, DocuSign, consulting, startups, venture capital) to help current and prospective economics majors understand the wide range of opportunities available given their field of study, connect them to area alumni, and articulate the assets they bring to tech firms with their non-tech backgrounds. Despite recent declines in all majors relative to computer science, enrollments in economics increased 15% the first year of the speaker series.

Education

Stanford University, Stanford, CA
Ph.D. Economics, 2005, "Using Surveys to Measure Information in Auctions: Evidence for Rational Behavior, Informative Prices, and the Importance of Credibility in eBay Computer Auctions," Advisors: Tim Bresnahan, Pat Bajari, Susan Athey.

London School of Economics and Political Science
M.S. Regulation, emphasis in Utilities & Telecommunications, 1997

Indiana University, Bloomington, IN
B.A. Economics and French, *summa sum laude*, 1995
B.S. Mathematics, *summa cum laude*, 1995

Professional Experience

2016	**University of Southern California Marshall School of Business** Associate Professor of Clinical Entrepreneurship and Director of the Technology Commercialization Initiative, Greif Center for Entrepreneurship
2013-2016	**Stanford Institute for Economic Policy Research** Social Science Research Scholar
April-June 2014	**Stanford Department of Economics** Assistant Visiting Professor
2010-2013	**MIT Sloan School of Management** Richard S. Leghorn (1939) Career Development Professor of Management in Technological Innovation, Assistant Professor of Technological Innovation, Entrepreneurship & Strategic Management
2007-2010	**MIT Sloan School of Management** Assistant Professor of Strategy
2004-2007	**Harvard Business School** Assistant Professor of Strategy

Honors and Professional Activities

- National Science Foundation (NSF) Grant 1431276, three-year-award for "Strategy and Organization of Mobile Innovation and Entrepreneurship," shared with colleagues, Tim Bresnahan and Jason Davis.
- Best Paper Award at the Atlanta Competitive Advantage Conference, May 20-22, 2014 for "Experimentation Strategies and Entrepreneurial Innovation: Inherited Market Differences from the iPhone Ecosystem."
- MIT Sloan Karl Chang (1965) Innovation Fund
- Edward B. Roberts (1957) Fund
- Associate Editor, *Information Economics and Policy*
- Guest Editor, Special Issue on The Economics of Information and Communication Technologies, *International Journal of Industrial Organization*, 2013
- Scientific Committee, ICT Conference, Munich, Oct. 14-16, 2013

- Scientific Committee, Consortium on Financial Systems and Poverty's RFP process for "Applying Economic Theory to a New Industry: Mobile Banking in Developing Countries", Nov 2012
- EARIE Young Economists Essay Award, Amsterdam, The Netherlands, 2006
- NSF Graduate Fellowship in Economics, 1998-2001
- Truman Scholar, 1994
- Herman B Wells Scholar, 1991

Publications

"Mobile Applications, The Economics of" with Timothy Bresnahan, Jason Davis and Tim Jaconette, *The New Palgrave Dictionary of Economics*. Online Edition, Eds. Steven N. Durlauf and Lawrence E. Blume. Palgrave Macmillan, 2015.

"Economic Value Creation in Mobile Applications" with Timothy F. Bresnahan and Jason P. Davis, *The Changing Frontier: Rethinking Science and Innovation Policy*, edited by Adam Jaffe and Benjamin Jones, University of Chicago Press, Chicago, 2015.

"Entrepreneurial Innovation: Killer Apps in the iPhone Ecosystem" with Jason P. Davis and Yulia Muzyra, *American Economic Review*, 104:5 (May 2014) pp. 255-59.

"Competition between Exchanges: A Research Agenda" with Estelle Cantillon, *International Journal of Industrial Organization* (May 2011) pp. 329-336.

"Reallocating innovative resources around growth bottlenecks" with Timothy F. Bresnahan, *Industrial and Corporate Change* 19:5 (October 2010) pp. 1589-1627.

"Empirical Tests of Information Aggregation," *International Journal of Industrial Organization* Vol. 25, Issue 6 (December 2007) pp. 1179-1189.

"Standard Setting in Markets: The Browser War" with Timothy F. Bresnahan, *Standards and Public Policy*, edited by Shane Greenstein and Victor Stango, Cambridge University Press, 2007.

"Innovation and Incumbent Industry Structure: TiVo," *Industry and Firm Studies*, edited by Victor J. Tremblay and Carol Horton Tremblay, Routledge, 2007

"Economic and Technical Drivers of Technology Choice: Browsers" with Timothy F. Bresnahan, *Annales d'économie et de statistique* No. 79:80 (2005) pp. 629-670.

"Building Firm Trust Online" with Detlef Schoder, *Communications of the ACM* 43:12 (December 2000) pp. 73-79.

Papers in Progress or Under Review

"Experimentation Strategies and Entrepreneurial Innovation: Inherited Market Differences from the iPhone Ecosystem" with Jason Davis and Yulia Muzyrya, 2015 (R&R at *Strategic Management Journal,* ACAC 2014 Best Paper Award).

"Competition between Exchanges: Lessons from the Battle of the Bund" with Estelle Cantillon, 2015 (R&R at *American Economic Review*).

"Demand Heterogeneity, Inframarginal Multihoming, and Platform Market Stability: Mobile Apps" with Timothy Bresnahan and Joe Orsini, 2015.

"Paying Incumbents and Customers to Enter an Industry: Buying Downloads" with Timothy Bresnahan and Xing Li, 2015.
"Escalation of Commitment and the Scope of New Firms: Entrepreneurial Diversification in the iPhone Application Ecosystem" with Jason Davis and Yulia Muzyrya, 2015.

Power Dynamics: The Fundamentals of Strategy with Hamilton Helmer, 2015.

"Information Acquisition and Consumer Choice" with Timothy F. Bresnahan and Timothy Landvoigt, 2013.

"Anticompetitive Price Effects of Competition and Uncertainty," 2010.

"Uncertainty or Heterogeneity? Identifying the Source of Variation through Surveys," 2008.

"Information Dispersion and Auction Prices," 2009 (EARIE Young Economists Essay Award 2006).

HBS Course Materials

"Technology Strategy," *Core Curriculum: Strategy*, Ramon Casadesus-Masanell, editor, forthcoming.

"Cellular Service" with Abigail Tinker, Harvard Business School Case 707-424 and Harvard Business School Teaching Note 707-576.

"SAP: Industry Transformation (A)" with Andrei Hagiu, Daniela Beyersdorfer and Vincent Marie Dessain," Harvard Business School Case 707-435 and Harvard Business School Teaching Note 707-578, with Andrei Hagiu.

"Online Auction Markets," Harvard Business School Case 705-411 and Harvard Business School Teaching Note 705-577.

"Bringing OTC back to the Exchange: Euronext.liffe's launch of ABC" with Estelle S. Cantillon, Harvard Business School Case 706-489.

"Bringing OTC Back to the Exchange: Euronext.liffe's Launch of ABC (TN)" with Estelle S. Cantillon, Harvard Business School Teaching Note 706-490

"Principles of Microeconomics for Strategists" with Felix Oberholzer-Gee and Elizabeth Raabe, Harvard Business School Online Case Products 705-801.

"Principles of Microeconomics for Strategists Tutorial" with Felix Oberholzer-Gee and Elizabeth Raabe, Harvard Business School Courseware 705-801.

"A Note on Applying Dimensional Analysis to Understand Cost Drivers," Harvard Business School Note 706-492.

"Interpretation of Elasticity Calculations," Harvard Business School Note 705-412.

"Ice-Fili (Abridged)" with Michael G. Rukstad and John R. Wells, Harvard Business School case 705-441.

"QUALCOMM, Inc. 2004" with David B. Yoffie and Elizabeth Kind, Harvard Business School Case 705-401.

"PalmSource, Inc." with David B. Yoffie and Christina L. Darwall, Harvard Business School Case 704-473.

"Strategic Inflection: TiVo in 2005" with David B. Yoffie and Barbara J. Mack, Harvard Business School Case 706-421.

"Strategic Inflection: TiVo in 2003 (A & B) TN" with David B. Yoffie, Harvard Business School Teaching Note 704-497.

"Strategic Inflection: Tivo in 2003 (A)" with David B. Yoffie and Christina L. Darwall, Harvard Business School Case 704-425.

"Strategic Inflection: TiVo in 2003 (B)" with David B. Yoffie and Christina L. Darwall, Harvard Business School Case 704-429.

"Strategic Inflection: TiVo in 2003 (B)" with David B. Yoffie and Christina L. Darwall, Harvard Business School Course Software 704-751.

Teaching

Stanford	Economics and Strategy (undergraduate)	2014-present
Stanford	Stanford Economics Alumni Speaker Series	2014-present
MIT	Competitive Strategy (MBA)	2008-2013
MIT	Doctoral Seminar in Technology and Strategy	2010
HBS	Technology Strategy (MBA)	2005-2007
HBS	Strategy (MBA)	2003-2005

Executive Education

Accenture 2015-present
IBM Global Sales (Boston Toronto Group) 2012-present
Chinese-speaking programs (bilingual) 2012-present
China Telecom
Peking University HSBC Business School EMBA
Hubei Science & Technology
Taiwan University EMBA
Jiaotong Executive Development Program
Sun Yat-sen University
EPOCH

Press

Marketplace radio interviews on exchanges and technology (2011-present)
Cited in Salz, Peggy-Anne, and InMobi. *Apponomic: The Insider's Guide to a Million Dollar App Business* (London: Tyson Press, 2014)
WGBH "Innovation Hub" radio interview on online commerce, 2012
"Lessons from the battle of the Bund" with Estelle Cantillon, *Vox*, September 2, 2008.
"What Are the Lessons of the Blu-Ray/HD-DVD Battle?" *New York Times*, Freakonomics Blog, March 4, 2008.

References

Prof. Tim Bresnahan, Stanford, tbres@stanford.edu
Prof. Michael Cusumano, MIT Sloan, cusumano@mit.edu
Prof. Jason Davis, INSEAD, Jason.davis@insead.edu