The Role of Compatibility for Market Competition and Quality Mix: the Lessons from Mobile Application Markets

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Multiple competing platforms have become a common market phenomenon in the digital era. Examples include operating systems such as Windows, iOS and Ubuntu, video game consoles, and wireless cellular networks that have adhered to different wireless frequencies. A distinctive feature of these markets is that the platforms have their own "ecosystems" of competing firms that develop software or devices for the users while this software and devices are not compatible across the platforms. Historically, we have observed a spectrum of outcomes for these markets from market tipping to one single platform to the coexistense of several dominant platforms in a likely equilibrium.

While basic Economic theory indicates serious advantages of the market competition for the social welfare, in the context of competing platforms where each platform creates a market for innovation the answer to this question is not straighforward. The difference in the technological or software standard leads to the incompatibility of the platforms and generates barriers to transition the products developed for one platform to another platform. In the context of markets for innovation, such barriers can foster the production of better quality products. At the same time, the co-existence of multiple platforms can potentially hurt market efficiency by dispersing consumer demand away from the most innovative producers.

In the proposed work, we aim to study empirically the role of compatibility of technological standards on the quality and variety of the market product mix. The set of objectives that are of our central interest include the analysis of counterfactual adherence to common standards on efficiency and consumer welfare and the empirical analysis of market tipping on market structure and firm behavior. The answers to these questions, especially from the empirical perspective, are largely unclear, despite substantial existing literature (e.g. Farrell and Saloner (1985), Farrell and Saloner (1986), Chou and Shy (1990), Church and Gandal (1992b), Church and Gandal (1992a), Boudreau (2010), Scotchmer (2004), Casadesus-Masanell and Llanes (2015)).

We propose to shed the new light on these important questions by studying a highly innovative two-sided market with incompatible platforms – the market for mobile applications (a.k.a. "apps").

The market for mobile apps has become extremely popular over the past few years, and it represents a dramatic showcase of innovations in a highly competitive marketplace. The app market is dominated by two major players, Apple App Store and Google Play, which distribute mobile apps for two competing and incompatible operating systems: iOS and Android. Each platform has over one million highly heterogeneous apps and they are developed by a large number of independently operating developers. Because iOS and Android operating systems are incompatible, the apps are not portable between the two platforms without a substantial change in the source code. In addition, unlike iOS, Android is an open source platform, which leads to less standardization among its apps as well as more flexibility for the developers. Furthermore, the entry threshold of the Google app store is very low, while the Apple app store sets a very strict screening process for new apps.

These features – the incompatibility between the two platforms and the differences in their characteristics – are likely key determinants of the developers' pre-entry innovation decisions, such as which apps to develop, whether to multi-home or single-home, which platform to enter (in case of single-homing), and whether to introduce the new apps on the platforms simultaneously or sequentially (in case of multi-homing), as well as their post-entry innovation decisions, such as frequency of updates and development of sequel or complementary apps.

In the proposed research, we will examine these issues empirically. We have access to a unique dataset containing comprehensive information on Apple and Google app stores. The data cover the entire universe of apps on both platforms for two years on a daily basis.

Our proposed work will also have a methodological component. Since the markets that we propose to study involve thousands of competitors, we plan to take advantage of modern Machine Learning methods for empirical analysis of best responses and payoffs. These methods have already been shown to have good performance in the context of market demand estimation (see Bajari et al. (2015)). Given that the answers to our policy questions require counterfactual market analysis, we need to have efficient methods for computing market equilibria. While commonly used equilibrium computation frameworks from the Industrial Organization literature do not perform well with more than 10 competitors, we aim to rely on new results on equilibrium approximation from the Computer Science literature that proved to be highly efficient and scalable in the context of auction markets, e.g. Hoy et al. (2015).

References

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Kevin Boudreau. Open platform strategies and innovation: Granting access vs. devolving control. *Management Science*, 56(10):1849–1872, 2010.

Ramon Casadesus-Masanell and Gastón Llanes. Investment incentives in open-source and proprietary two-sided platforms. *Journal of Economics & Management Strategy*, 24(2):306–324, 2015.

Chien-fu Chou and Oz Shy. Network effects without network externalities. *International Journal of Industrial Organization*, 8(2):259–270, 1990.

Jeffrey Church and Neil Gandal. Integration, complementary products, and variety. *Journal of Economics & Management Strategy*, 1(4):651–675, 1992a.

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Joseph Farrell and Garth Saloner. Standardization, compatibility, and innovation. *The RAND Journal of Economics*, pages 70–83, 1985.

Joseph Farrell and Garth Saloner. Standardization and variety. *Economics Letters*, 20(1):71–74, 1986.

Darrell Hoy, Denis Nekipelov, and Vasilis Syrgkanis. Robust data-driven efficiency guarantees in auctions. *Available at SSRN 2601928*, 2015.

Suzanne Scotchmer. *Innovation and incentives*. MIT press, 2004.

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EDUCATION

Ph.D., Agricultural and Resource Economics, University of California, Berkeley, 2015

M.A., Statistics, University of California, Berkeley, 2011

M.S., Economics, Chinese Academy of Sciences, China, 2009

B.A., Economics & B.S., Statistics, Peking University, China, 2006

EMPLOYMENT

UCL School of Management, University College London
Assistant Professor, August 2015 - Present

FIELDS OF CONCENTRATION

Quantitative Marketing, Empirical Industrial Organization
Digital Markets, Economics of Innovation

WORKING PAPERS

Mobile App Platform Choice: An Application of Strategic Games on Big Data

Timely versus Quality Innovation: The Case of Mobile Applications on iTunes and Google Play (with Denis Nekipelov and Minjung Park)

How Can Firms Benefit From Disclosing Innovations? Evidence from IBM Technical Disclosures

SEMINARS & PRESENTATIONS

Leeds School of Business, University of Colorado, Boulder, 2016
Mendoza College of Business, University of Notre Dame, 2015
School of Economics and Political Science, University of St. Gallen, 2015
Department of Economics, University of British Columbia, 2015
Department of Management Science and Innovation, University College London, 2014
Guanghua School of Management, Peking University, 2014
Economics of Digitalization Conference, NBER, 2014
Marketing Science Conference, 2014
Tsinghua-Berkeley workshop on IPR and Innovation Policy, Tsinghua University, 2013
Center for Climate Change Economics and Policy, London School of Economics, 2012

TEACHING EXPERIENCE

University of California, Berkeley
- Statistics (Graduate level), Department of Statistics, Teaching Assistant, Fall 2014
- Probability (Graduate level), Department of Statistics, Reader, Fall 2014
- Macroeconomic Analysis, Department of Economics, Teaching Assistant, Summer 2011

AWARDS AND GRANTS

Chinese Government Award for Outstanding Students Abroad(2013)
IBER Mini Grant, UC Berkeley(2012)
Graduate Division Summer Grant, UC Berkeley(2012)
Liu Graduate Research Fellowship, UC Berkeley(2011)
Chancellor's Scholarship, Chinese Academy of Sciences(2009)
Shin Research Excellence Award, International Insurance Society (2008)
Outstanding Research Award, Samsung Economic Research Institute(2006)
Sinosure Scholarship, Peking University(2006)
National Scholarship, Peking University(2004, 2005)
Citibank Scholarship, Peking University(2004)

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Curriculum Vitae

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Employment

July 2014 – present, *Associate Professor of Economics and Computer Science*, University of Virginia
July 2009 – present, *Visiting researcher*, Microsoft Research – New England
July 2009 – June 2014, *Assistant professor*, Department of Economics, UC Berkeley
June 2008 – June 2009, *Post-doctoral researcher*, Microsoft research – Silicon Valley

Education

Ph.D. in Economics, *Duke University*, Durham, NC, USA, 2008
M.A. in Economics (Cum Laude), *New Economic School*, Moscow, Russia, 2003
M.Sc., B.Sc. in Applied Physics and Mathematics (with distinctions), *Moscow Institute of Physics and Technology*, Moscow, Russia, 2003

Teaching

Interests:
Structural Econometrics for Big Data, Computational Methods of Industrial Organization
Previous teaching:
UC Berkeley: Graduate Econometrics (1st year Ph.D. sequence); Computational and Statistical Methods of Industrial Organization (2nd year Ph.D. elective); Econometric Theory (advanced undergraduate course). *Duke*: Mathematics for Economists (1st year Ph.D. course). *ZEW Workshop (Mannheim)*: Computational methods for industrial organization (2-day course). *EC'10 Tutorial (Harvard)*: Statistical analysis of structural models for applied computer scientists (2-lecture workshop).
Current teaching:
University of Virginia: Econometric Methods (Econ 4720), Econometrics for Data-Rich Environments (Econ 8995)

Publications

Estimating Static Models of Strategic Interactions (with Patrick Bajari, Han Hong and John Krainer), *Journal of Business and Economic Statistics*, 28 (4), pp. 469-482, *2010*.

Semiparametric Efficiency in Nonlinear LATE Models (with Han Hong), *Quantitative Economics*, 1(2), pp.179-304, *2010*.

Nonlinear Models of Measurement Errors (with Xiaohong Chen and Han Hong), *Journal of Economic Literature*, 49(4), pp. 901-937, *2011*.

Efficient Local IV Estimation of an Empirical Auction Model (with Han Hong), *Journal of Econometrics*, 168(1), pp. 60-69, *2012*.

Econometrics for Game Theory (with Patrick Bajari and Han Hong), in *Advances in Economics and Econometrics: Theory and Applications, 10th World Congress, 2013*.

Approximation Properties of Laplace-type Estimators (with Anna Kormilitsina), in *Advances in Econometrics, 2013*.

Mechanism Design for Data Science (with Jason Hartline and Shuchi Chawla), *Proceedings of the fifteenth ACM conference on Economics and computation. ACM, pp. 711–712, 2014* (peer reviewed)

Eliciting Preferences of Sponsored Search advertisers, *SIGCOM Exchanges, vol 13.1, 2014*

Recovering Treatment Effects from Combined Data: Identification versus Data Security (with Tatiana Komarova and Evgeny Yakovlev), in *Economic Analysis of the Digital Economy*, eds. A. Goldfarb, S. Greenstein, C, Tucker, *The University of Chicago Press*, 2015.

Extremum Estimation and Numerical Derivatives (with Han Hong and Aprajit Mahajan), forthcoming at *Journal of Econometrics*

Consistent Variance of the Laplace Type Estimators: Application to DSGE Models (with Anna Kormilitsina), forthcoming at *International Economic Review*

Machine Learning Methods for Demand Estimation (with Patrick Bajari, Stephen Ryan and Miaoyu Yang), *American Economic Review: P&P*, 105(5), 2015.

Econometrics with Learning Agents (with Vasilis Syrgkanis and Eva Tardos), forthcoming at *Proceedings of the sixteenth ACM conference on Economics and computation. ACM, 2015* (ACM EC Best Paper Award)

A/B Testing of Auctions (with Shuchi Chawla and Jason Hartline), forthcoming at *Proceedings of the sixteenth ACM conference on Economics and computation. ACM, 2015*

Inference and Auction Design in Online Advertising (with Tammy Wang), forthcoming at *Communications of the ACM*

Research Papers

Designing Large Advertising Markets Where Agents Have Heterogeneous Objectives: A Structural Empirical Approach (with Susan Athey)

Semiparametric Estimation of a Finite Horizon Discrete Choice Model with Application to the Analysis of Subprime Mortgage Defaults (with Sean Chu and Minjung Park)

A Structural Model of Sponsored Search Advertising (with Susan Athey), R&R at Journal of Political Economy (4th revision)

Numerical Gradients and Extremum Estimation with U-statistics (with Han Hong and Aprajit Mahajan), R&R at Econometric Theory (2nd revision)

Identification, Data combination and the Risk of Disclosure (with Tatiana Komarova and Evgeny Yakovlev) R&R at Quantitative Economics (3rd revision)

Private Extremum Estimation (with Evgeny Yakovlev and Tatiana Komarova), conditionally accepted at *Annals of Statistics*

Information Structure and Statistical Information in Discrete Response Models (with Shakeeb Khan), R&R at Quantitative Economics (4th revision)

A Note on the Role of Regularity Conditions in a Class of Models with Inverse Weighting

Nonparametric and Semiparametric Estimation of Dynamic Games of Incomplete Information (with Patrick Bajari, Victor Chernozhukov, and Han Hong) , R&R at Journal of Business and Economic Statistics (1st revision)

All-Solution Homotopy Methods for Computing Equilibria in Static Games of Incomplete Information (with Patrick Bajari, Victor Chernozhukov, and Han Hong) , R&R at Journal of Business and Economic Statistics (1st revision)

Robust Data-Driven Efficiency Guarantees in Auctions (with Darrell Hoy and Vasilis Syrgkanis), submitted to ACM EC'16 conference

Mechanism Redesign (with Shuchi Chawla and Jason Hartline), submitted to ACM EC'16 conference

Classification Trees for Heterogeneous Moment-Based Models (with Sam Asher, Paul Novosad and Stephen Ryan)

Presentations

2016 ASSA Winter; Google Research New York), Booking.com, U Pompeu Fabra, Collegio Carlo Alberto, Google Research Europe (Zurich), U of Iowa, Bellairs Institute (McGill U)
2015 ASSA Winter, Georgetown, UW-Madison, Harvard, Michigan, Indiana, Wharton, Simons Institute (Berkeley), LSE, UCL**; 2014** Cornell, McGill, U of Toronto, Columbia, Zillow Inc., Microsoft Research, Harvard, U of Virginia, USC, UC Riverside, Johns Hopkins U, PennState, SMU
2013 Microsoft Research, Stanford, Rochester, Ohio State, HEC Montreal, U of Toronto, NYU
2012 UCLA, LSE, Northwestern, Cornell, Microsoft Research, Berkeley, UW-Madison, U of Washington;
2011 UPenn, Duke, MIT, Microsoft Research, eBay labs, Yale, LSE**;**
2010 EC 2010 Meetings, LSE, UCL, Harvard, Yale, Cowles foundation Conference, WCES in Shanghai, University of Melbourne, LaTrobe, UNSW, University of Technology Sydney, Maqcuire, UC Berkeley, USC, UC Davis, SICS 2010, Microsoft Advertising, Cowles foundation, NBER winter meetings, SITE;
2009 Cowles foundation, Georgetown, University of Maryland, University of Alicante, University of Amsterdam, Tilburg, UC Davis, UCSD, LSE, UCL, SMU, Northwestern;
2008 Princeton, Microsoft Research, Stanford GSB, Berkeley, UPenn, Carnegie Mellon (Tepper), Chicago GSB, Rice, Penn State, Georgia State (Robinson), University of Minnesota, Washington University (Olin), NYU, NYU (Stern), Columbia, UCLA, MIT (Sloan), Stony Brook, Northwestern, Microsoft Research, Berkeley (Haas), Harvard (IO), Harvard/MIT (Econometrics), Rochester

Advising

Pedro Gardete (2011, *Stanford GSB*), Evgeny Yakovlev (2012, *New Economic School*), TI Kim (2013, *Emory Business School*), Yongdong Liu (2015, *University College London*)

Grants

2016 NSF collaborative research grant (awarded for 2016-2020), $1.48 million
2016 Google faculty research grant (awarded for 2016-2017), $66k
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2014 NSF collaborative research grant (awarded for 2014-2015), $125k
2012 Sloan Foundation research grant (awarded for 2012-2015), $650k
2011 NSF collaborative research grant (awarded for 2011-2015), $998k
2010 NSF collaborative research grant (awarded for 2010-2013), $145k

Honors and Awards

2015 ACM EC Best Paper Award
2011 US Patent US 2011/0313851 "A Tool for Analysis of Sponsored Search Auctions"
2008 Review of Economic Studies European Tour
2003 -2008 H. Gregg Lewis fellowship, Duke University

Professional Activities

2015-present, Advisory Board Member, Data Science Institute, University of Virginia
2014-present, Associate Editor, Quantitative Marketing and Economics
2013-2015, Senior Program Committee Member, ACM Economics and Computation Conference
2015 Co-Organizer, Algorithmic Game Theory and Data Science Workshop, Portland OR

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ACADEMIC POSITIONS

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University of Minnesota, Department of Economics, Assistant Professor, August 2007 – May 2010

OTHER POSITIONS

Federal Reserve Bank of Minneapolis, Visiting Scholar, June 2008 – May 2010
Federal Reserve Board of Governors, Visiting Scholar, May 2009

EDUCATION

Stanford University	Ph.D. in Economics, September 2007 Thesis: Essays on Incentives and Firm Behavior Committee: Timothy Bresnahan (Principal Advisor), Liran Einav, Jonathan Levin, Eric Zitzewitz, Takeshi Amemiya
Ewha Woman's University, Korea	B.A. *Summa Cum Laude* in Economics, 2002

RESEARCH INTERESTS

Industrial Organization, Competitive Strategy, Applied Microeconomics, Health Economics

RESEARCH

"Industry Shock Expectations, Inter-Industry Linkages and Merger Waves: Evidence from the Hospital Industry" (2014) *Journal of Economics & Management Strategy*, 23(3): 548-567 (joint with Robert Town)

"Understanding Merger Incentives and Outcomes in the Mutual Fund Industry" (2013) *Journal of Banking and Finance*, 37: 4368-4380

"The Impact of Health Insurance Mandates on Drug Innovation: Evidence from the United States" (2013) *European Journal of Health Economics*, 14(2): 323-344 (joint with Natalie Chun)

"The Impact of Clinical Trial Insurance Mandates on Racial Minorities and Low Income Individuals" (2012) *Applied Economics*, 44(15): 1977-1984 (joint with Natalie Chun)

"The Economic Impact of Wireless Number Portability" (2011) *Journal of Industrial Economics*, 59(4):714-745

"Semiparametric Estimation of a Finite Horizon Dynamic Discrete Choice Model with a Terminating Action" (joint with Pat Bajari, Sean Chu and Denis Nekipelov), R&R

"Advertising and Market Share Dynamics," working paper

"An Empirical Model of Subprime Mortgage Default from 2000 to 2007" (joint with Pat Bajari and Sean Chu), working paper

"Estimating Price Sensitivity of Economic Agents Using Discontinuity in Nonlinear Contracts" (joint with Pat Bajari, Han Hong and Robert Town), R&R

HONORS AND AWARDS

UC Regents' Junior Faculty Fellowship, Summer 2011
Club 6 Member (Full-Time MBA program), Spring 2011, Spring 2012, Spring 2013
Invited to Young Economists' Jamboree in Empirical Microeconomics, 2009
Grant-in-Aid, University of Minnesota, 2009 –2011
Koret Foundation Doctoral Dissertation Fellowship, Stanford University, 2006 - 2007
Outstanding Teaching Assistant Award, Stanford University, Fall 2003 & Winter 2005
Forman Family Fellowship for Outstanding First Year Student, Stanford University, 2004 - 2005
Best Ph.D. Candidacy Paper Prize, Stanford University, Fall 2004
21st Century Leaders Scholarship, Ewha Woman's University, Korea, 2002 - 2006
Graduation with Highest GPA, Ewha Woman's University, Korea, 2002

PRESENTATIONS

- 2012: Berkeley ARE, Chicago Booth, Marketing Science Conference, Tohoku University, Kyung Hee University

- 2011: American Economic Association, Marketing Science Conference, Stanford GSB, Olin Business School at Washington University, St. Louis

- 2010: HEC Montreal Conference on Industrial Organization of Health Care, CAPCP Conference on Auctions and Procurements (Penn State)

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REFEREEING

Journal of Political Economy, RAND Journal of Economics, Journal of Public Economics, Journal of Econometrics, International Journal of Industrial Organization, Marketing Science, Management Science, Journal of Marketing Research, Journal of Business and Economic Statistics, Review of Economics and Statistics, American Economic Journal: Applied Economics, Economics Letters, Journal of Applied Econometrics, Journal of Economic Behavior & Organization, Applied Economics, European Economic Review