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Introduction

Avi Goldfarb, Shane Greenstein, and Catherine Tucker

Research on the economics of digitization studies whether and how digital technology changes markets. Digital technology has led to a rapid decline in the cost of storage, computation, and transmission of data. As a consequence, economic activity is increasingly digital. The transformative nature of digital technology has implications for how we understand economic activity, for how consumers behave, for how firms develop competitive strategy, for how entrepreneurs start new firms, and for how governments should determine policy.

This volume explores the economic impact of digitization in a variety of contexts and also aims to set an agenda for future research in the economics of digitization. While no one volume can be comprehensive, the objective is to identify topics with promising areas of research. The chapters summarize and illustrate areas in which some research is already underway, and warrant further exploration from economists.

Of the various technology drivers enabling the rise of digital technology, growth in digital communication – particularly the internet – has played a central role. It is constructive to focus a volume around digital communication as a key driver of economic activity. In particular, digitization has some features that suggest that many well-studied economic models may not apply, suggesting a need for a better understanding of how digitization changes market outcomes.

The development of a nearly-ubiquitous internet has motivated many new questions. In particular, the internet's deployment and adoption encouraged the growth of digital products and services, and many of these display very low marginal costs of production and distribution. Correspondingly, digital markets are often easy to enter. These features have motivated questions about how digitization has restructured economic activities across a broad array of the economy.

Similarly, low communication costs, even over long distances, also brought about economic restructuring by creating opportunities for new marketplaces. This motivates questions about how new marketplaces can overcome information asymmetries between buyers and sellers in different places, and reduce search costs for either type of participant in a market. Low communication costs also translate into low distribution costs for information services. That means that non-excludable information services resemble public goods that can be consumed at enormous scales, by hundreds of

millions of people, and perhaps by billions in the future. That has focused attention on the incentives to develop public goods and understand how these diffuse. It has also focused attention on the valuation issues that arise when businesses and households reallocate their time to unpriced goods.

While these features of digital markets and service do not generally require fundamentally new economic insight, they do require more than simply taking theoretical and empirical results from other markets and assuming the implications will be the same. For example, digital information can be stored easily and aggregated to improve measurement. This creates previously unseen challenges for privacy and security, and those issues are not salient in other economic analysis because they do not have to be. More broadly, many policies that have been settled for many years seem poorly adapted to digital markets. It is no secret that firms and governments have struggled to apply copyright, security, and antitrust regulations to the digital context, as the reasoning that supported specific policies came under pressure from piracy, or lost relevance in a new set of economic circumstances. General pressures to alter policies are coming from mismatches between historical institutions and the present circumstances, and these mismatches generate calls from private and public actors to make changes. These pressures will not disappear any time soon, nor will the calls for change. Economic research on digitization can inform the debate.

We do not think the economics of digitization is a new field. Rather, digitization research touches a variety of fields of economics including (but not limited to) industrial organization, economic history, applied econometrics, labor economics, tax policy, monetary economics, international economics, and industrial organization. Many of the key contributions to the economics of digitization also have found an intellectual home in these fields. What distinguishes research on the economics of digitization is an understanding of the role of digital technology. Research on the economics of digitization therefore has a consistent framing, even if the applications are diverse.

There are two complementary approaches to motivating new work. One characterizes the progress to date in addressing fundamental research questions, as a Handbook might do (See, e.g., Peitz and Waldfogel, 2012). The other approach, which this volume pursues, stresses different ways to address open research questions by providing extensive examples of how to frame, execute and present research on the frontier. These are not mutually exclusive approaches, and many chapters in this book dedicate substantial attention to the prior literature before providing new analysis and ideas.

As might be expected, the scope of the book is quite broad, and drawing boundaries required several judgment calls. In general, the topics in the book emphasize the agenda of open questions, and also tend to stress unsettled issues in public policy.

A few traits are shared by all the chapters. The topics are representative of many of the active frontiers of economic research today, and are not slanted towards one sub-discipline's approach to the area. More affirmatively, the chapters illustrate that the economics of digitization draws from many fields of economics, and matches the approach to the question. No chapter argues for any form of digitization-exceptionalism – as if this research requires the economic equivalent of the invention of quantum mechanics, or a fundamental break from prior precedents in positive analysis or econometric methods. The internet contains unique features, and that require additional data, as well as sensitivity to new circumstances, not a radical abandoning of prior economic lessons.

The volume's chapters take steps toward building a theoretically grounded and empirically relevant economic framework for analyzing the determinants and consequences of digitization. For example, several chapters examine questions about how digitization changes market structure and market conduct. These changes are especially evident in newspapers, music, movies, and other media. Relatedly, there are many broad questions arising in areas where copyright plays an important role. The application of copyright to online activity has altered both the incentives for innovation and creativity. The advent of piracy has altered the monetization of the products and services. Digitization also has altered the costs of collecting, retaining, and distributing personal information, which is an important development in itself. It is also consequential for the personalization of commerce, such as in targeted advertising.

Many chapters address policy issues related to digitization, including copyright law, privacy law, and efforts to restructure the delivery and access to digitized content and data. There also is a strong emphasis on developing unbiased approaches to economic measurement. Unbiased measurement can assess the extent of digitization, and begin the long term conversation towards understanding the private and social costs of digitization. As a consequence, this will improve understanding of the rate of return on investments in digitization by public and private organizations.

An astute reader will notice that some topics do not make it into the book. Perhaps most directly, all chapters focus on digitization enabled through the internet, rather than other consequences of digital technology, such as increased automation in manufacturing and services, or increased use of digital medical records. In addition, some relevant internet-related topics do not appear. There is only a peripheral discussion about universal service for new communications technology, such as broadband Internet access to homes in high-cost regions or low-income regions. It is an important topic, but the economic issues are not fundamentally unique to digitization, and resemble universal service debates of the past. There is also limited coverage of many issues in the design of markets for search goods (e.g.,

keyword auctions). That is because there is already a robust conversation in many areas related to these services, so the book focuses attention on frontier questions that remain open, such as search and online matching in labor markets.

Finally, the volume also largely eschews the well-known debates about IT's productivity, and what has become known as the Solow Paradox, often stated as "We see the IT everywhere except in the productivity statistics." Again, that is because the literature is large and robust. The contrast is, however, particularly instructive. This volume stresses vexing issues in measuring the value of digital services, where the measurement issues are less widely appreciated by academic economists, and where mainstream economic analysis could shed light.

The remainder of the essay provides some detail. The first set of chapters discusses the basic supply and demand for internet access. The next set of chapters discusses various ways in which digitization reduces economic frictions and creates new opportunities and challenges for business. The final set of chapters lays out some policy issues that these opportunities and challenges create. All the chapters received comments from discussants at a conference held in June, 2013, in Park City, Utah. In some cases the discussants chose to make their commentary available, and these are provided as well.

Internet Supply and Demand

The internet is not a single piece of equipment with components from multiple suppliers. It is a multilayered network in which different participants operate different pieces. Sometimes these pieces are complements to one another, and sometimes substitutes. Many years ago, the 'internet' referred to the networking technology that enables computer networks to communicate. Over time it has come to mean also the combination of standards, networks, and web applications (such as streaming and file-sharing) that have accumulated around the networking technology.

Internet technology has evolved through technological competition. Many firms possess in-house technical leadership that enables them to develop and sell components and services that are valuable to computer users. Firms that do not possess such capabilities can acquire them through the market, for example by hiring a team of qualified engineers. Consequently, multiple firms can possess both the (expensive) assets and the (rare) employees with skills to reach the frontier and commercialize products near the technical frontier. Bresnahan and Greenstein (1999) call this feature of market structure 'divided technical leadership,' contrasting it with earlier eras in which a single firm could aspire to control the vast majority of inputs near the technical frontier. One of the big open research questions is therefore: What are the principles of competition in this area of divided technical leadership?

Computing market segments are typically defined by 'platforms', which Bresnahan and Greenstein define as "a reconfigurable base of compatible components on which users build applications." Platforms are identified by a set of technical standards, or by engineering specifications for compatible hardware and software. The emergence of platforms with many stakeholders (including firms, academics, and non-profits) increased the importance of organizations that design standards and platforms, referred to as 'standard-setting committees' (Mowery and Simcoe, 2002; Simcoe, 2013). The key standard-setting committees for the internet, such as the Internet Engineering Task Force (IETF), the Institute for Electrical and Electronics Engineers (IEEE), and the World Wide Web Consortium (W3C), made decisions that shaped much of the equipment that underlies the internet, with the IETF shaping the infrastructure layer, the IEEE shaping local area network and wireless communications, and the W3C shaping the web-based software and applications layer.

The essay by **Simcoe** (Chapter 1) inquires whether modularity shaped technological competition and specialization. The chapter offers an empirical examination of the consequences of the internet architecture, using data from the IETF and W3C. Both organizations adopted modular architectures, which produced specialized division of labor in designing and operating protocols. The paper analyzes citations between internet standards as further evidence of this specialization. Such specialization is the key to avoiding diminishing marginal returns in scaling up these networks. Modularity helps these technologies adapt to new circumstances and heterogeneous applications, helping them deploy more widely. This particular approach arises frequently with digital technologies and, the chapter argues, warrants attention as a fundamental feature of the digital economy.

In his comments Timothy Bresnahan stresses that modularity should be distinguished from openness. The former is a partitioning of the technical architecture, while the latter arises from the policies and actions of those involved with commercialization, typically making information available. Bresnahan stresses these two aspects of the TCP/IP commercial experience, and argues that these processes turned TCP/IP into what it is today. That leads Bresnahan to raise questions about platform governance and the evolution of general-purpose technologies. In his view, Simcoe's chapter illustrates a major unaddressed question in digitization economics, namely, why processes that depart from strict contractual approaches have had a successful historical record. Modularity's value, therefore, may depend on more than merely the specialization that it permits, but also the institutional processes that guide the specialists. In that sense, Bresnahan speculates that Simcoe has introduced the reader to a potentially rich new agenda.

Many fundamental questions remain open. Competition between platforms determines prices for customers deciding between platforms, and divided technical leadership shapes the supply of vendor services that build on top of a platform. How does such competition shape the division of returns within a platform? How do these two margins differ when a third type of participant, such as an advertiser, plays an important role in creating market value for the platform? If platforms differentiate in terms of their capabilities and approaches to generating revenue, does that alter the composition of returns to its participants? If platforms develop in collective organizations, what type of firm behavior shapes participation in standards committees? How do these incentives shape the direction of innovation in markets connecting multiple platforms? In practice, do most of the returns for new platform development go to existing asset holders in the economy, or to entrepreneurial actors, who create and exploit value opened by the technical frontier? These are rich areas for additional research, and some of the following chapters also touch on these questions.

In addition to understanding how the technology evolved, how the infrastructure was built, and how decentralized platforms develop standards, it is also important to understand demand for digital technology. Without an understanding of the value of the technology to users, it is difficult to tease out policy implications. Several recent studies have examined demand for services. For example, Greenstein and McDevitt (2011) examine the diffusion of broadband internet and its associated consumer surplus, by looking at revenue of internet service providers over time. Rosston, Savage and Waldman (2011) use survey data to estimate household demand.

Wallsten (Chapter 2) examines the micro-behavior comprising demand in household behavior. In particular, he examines what people do when they are online, which often involves many choices between priced and unpriced options, or among unpriced options. The chapter provides detailed insight into the debate about how the internet has changed lives, particularly in households, where many of the changes involve the allocation of leisure time. This allocation will not necessarily show up in GDP statistics, thereby framing many open questions about valuing the changes. The chapter is also novel for its use of the American Time Use Survey from 2003 – 2011 to estimate the crowdout effects. That data shows that time spent online and the share of the population engaged in online activities has been steadily increasing after 2000. At the margin, each minute of online leisure time is correlated with fewer minutes on all other types of leisure. The findings suggest that any valuation of these changes must account for both opportunity costs and new value created, both of which are hard to measure.

Chris Forman's discussion of Wallsten's chapter emphasizes a household's tradeoff in terms of opportunity costs and links it to prior literature on the implications of online behavior on offline

markets. The discussion suggests opportunities for future research to leverage differences across locations in order to understand how the relative value of the internet varies with the availability of offline substitutes.

Many open questions remain. If internet use changes the allocation of leisure time, then what about the converse? How do changes in leisure time (for example, over the life cycle) affect internet use and demand for internet access? Does wireless access and ubiquitous connectivity (for example, in transit) change the relative benefit of different types of internet use? How do particular applications (e.g. social networks, online shopping) affect the adoption and usage intensity of wireless and wireline internet by consumers and businesses? Will improvements in technology, such as speed and memory, change demand and spill over into other areas of economic activity? How do these changes in demand reshape the allocation of supply? Many of these issues arise in other chapters, especially where public policy shapes markets.

Digitization, Economic Frictions, and New Markets

Among the major themes in the literature on digitization is an assessment of how it changes economic transactions. In particular, the literature identifies a variety of economic frictions that are increased or decreased as a consequence of digitization.

Much of the literature on digitization has emphasized the impact of the cost of storage, computation, and transmission of data on the nature of economic activity. In particular, technology makes certain economic transactions easier, reducing several market frictions. This could lead to increased market efficiency and increased competition. At the same time, if the technology reduces some frictions but not others, it could distort market outcomes, helping some players and hurting others. Broadly, changes related to digitization have changed economic measurement, altered how some markets function, and provided an opportunity for new markets to arise.

The influx of data due to the reduced cost of collecting and storing information, combined with improvements in the tools for data analysis, has created new opportunities for firms and policymakers to measure the economy and predict future outcomes. The economics literature on the opportunities presented by data analysis of this kind is relatively sparse. Goldfarb and Tucker (2012) describe the opportunities from internet data with respect to advertising; Einav and Levin (2013) describe the opportunities from internet data for economics researchers; and Brynjolfsson, Hitt, and Kim (2011) document that companies that use data often tend to do better.

Two different chapters in this book emphasize the potential of internet data to improve measurement. In the policy section, two other chapters that emphasize the challenges created by ubiquitous data. Just as predicting the weather had profound consequences for much economic activity, such as agriculture, better measurement and prediction of a wide range of economic activity could generate profound economic gains for many participants in the economy. **Wu and Brynjolfsson (chapter 3)** highlight the potential of online data to predict business activity. They ask whether there is a simple but accurate way to use search data to predict market trends. They illustrate their method using the housing market. After showing the predictive power of their method, they suggest several directions for future work regarding the potential of detailed data to help consumers, businesses, and policymakers improve decision-making.

Scott and Varian (chapter 4) also highlight the potential of online data to improve the information that goes into decision-making. Rather than prediction, they emphasize “nowcasting”, or the ability of online data in general (and search data in particular) to provide early signals of economic and political indicators. They develop an approach to deal with one of the main challenges in using online data for prediction: there are many more potential predictors than there are observations. Their method helps identify the key variables that are most useful for prediction. They demonstrate the usefulness of the method in generating early measures of consumer sentiment and of gun sales.

Together, chapters 4 and 5 demonstrate that online data has the potential to substantially improve the measurement of current economic activity and the ability to forecast future activity. These chapters represent early steps toward identifying (i) what types of economic activity are conducive to measurement with online data, (ii) the specific data that is most useful for such measurement, and (iii) the most effective methods for using digital data in economic measurement. However, as the chapters both note, there is still much work to be done, and open questions remain around refining these methods, developing new methods, and recognizing new opportunities.

The next three chapters discuss ways in which digitization has altered how markets function. Digital technology makes some activities easier, thereby changing the nature of some economic interactions. Perhaps the oldest and largest stream of research on the internet and market frictions emphasized reduced search costs. This literature, still going strong, builds on an older theory literature in economics (Stigler, 1961; Diamond, 1971; Varian, 1980; etc.) that examines how search costs affect prices. This older literature showed that prices and price dispersion should fall when search costs fall. Digitization of retail and marketing meant that consumers could easily compare prices across stores, so the empirical work on internet pricing examined the impact on prices and price dispersion. Initially

hypothesized by Bakos (1997), the first wave of this research empirically documented lower prices, but still substantial dispersion (Brynjolfsson and Smith 2000, Baye, Morgan, and Scholten 2004, Ellison and Ellison 2009).

Baye, De los Santos, and Wildenbeest (chapter 5) is a good example of the newest wave of this research, which collects data about online searches to examine the actual search process that consumers undertake when looking for a product online. They focus on the question of how consumers search for books and booksellers online. This is of itself an interesting topic, both because books have often been the focus of studies that explore the “long tail” and because there have been policy concerns about how the online sales of books has affected offline channels. The chapter asks whether most book search has been conducted on proprietary systems such as Amazon’s Kindle and Barnes & Noble’s Nook rather than consumers searching on general search engines such as Google or Bing, meaning that search might be mismeasured in the literature. This question also emphasizes that the final stage of purchase is often controlled by a more familiar retail environment, and it raises questions about the growing importance of standards and platforms in the distribution of creative content.

As noted earlier, near-zero marginal costs of distribution for information goods might change where and how information goods get consumed. Geographic boundaries might be less important if information can travel long distances for free (Sunstein 2001, Sinai and Waldfogel 2004, Blum and Goldfarb 2006). A big open question concerns the incidence of the impact of low distribution costs. The benefits might vary by location, with locations with fewer offline options generating a larger benefit from digitization (Balasubramanian 1998; Forman, Ghose, and Goldfarb 2009; Goldfarb and Tucker 2011a).

Gentzkow and Shapiro (ch 6) explore the potential of near-zero marginal costs of distribution to affect political participation and the nature of news consumption. In particular, they ask whether technology-driven reductions in the costs of news distribution, both within and across geographic boundaries, affect the diversity of media production and consumption. Digital media could increase the diversity of news consumption because it enables inexpensive access to a broad range of sources; digital media could decrease the diversity of news consumption because it may permit specialized outlets that serve niche tastes that are not viable when physical production costs are high or when demand is limited to a geographically localized market. This contribution addresses an important open question: Whether digitization of news content will exacerbate existing political divisions as consumers access only content that supports their existing political ideology. The work of these authors does not stoke the

worst fears. Their findings suggest that those who have niche tastes in news are still obtaining the majority of their news content from mainstream sources.

For many pure information goods, online platforms link readers to advertisers. Given the challenges of protecting online information content from being shared (a topic we discuss below in the context of policy), advertising has become an important source of revenue for many providers of pure information goods. Because of this, it is important to understand how online advertising works in order to understand the opportunities and challenges faced by providers of digital information goods. Goldfarb and Tucker (2011b) emphasize that online advertising is better-targeted and better-measured because of the ease of data collection.

The study of online advertising continues to attract attention because this is the principal means for generating revenues in much of the internet eco-system. Most of the content on the internet and many of the services (such as search or social networking) rely on advertising revenues for support. **Lewis, Rao, and Reiley (chapter 7)** discuss the methods used for measuring the effects of advertising. To do this, they draw on their previous and current work which has used multiple field experiments to try and measure how effective online display advertising is at converting eyeballs into actual incremental sales. They emphasize that an important challenge to the accurate measurement of advertising is the high noise-to-signal ratio. This chapter suggests that as clients become increasingly sophisticated about measurement, this revenue source may be called into question.

Many other markets have also be changed by digitization. Other promising areas of research include rating mechanisms and quality signals (e.g. Cabral and Hortaçsu 2010; Jin and Kato 2007; Chevalier, Dover, and Mayzlin 2013), niche products and superstar effects (e.g. Brynjolfsson, Hu, and Smith 2003; Fleder and Hosanagar 2009; Bar Isaac, Caruana, and Cunat 2012) and skill-biased technical change and the organization of work (e.g. Autor 2001; Garicano and Heaton 2010).

Chapters 8 and 9 discuss examples of markets that have been enabled by digitization. **Agrawal, Horton, Lacetera, and Lyons (ch 8)** examine online markets for contract labor, another area in which digitization reduces frictions. In particular, digitization makes it easier for an employer to hire someone for information-related work without ever meeting the employee in person. If the work can be described digitally, completed off site, and then sent back to the employer digitally (such as with computer programming), then there might be an opportunity for long-distance North-South trade in skilled labor. The key challenges relate to information asymmetries regarding the quality of the employee and the trustworthiness of the employer. The chapter frames a large agenda about the role of online platforms to reduce these information asymmetries, thereby changing the types of contract labor

transactions that are feasible online. They lay out a clear research agenda around the key players, their incentives, and the potential welfare consequences of this market.

Stanton's discussion extends the agenda behind this finding. His discussion speculates on whether the digitization of labor relationships enables labor outsourcing to other countries even without a platform intermediary.

The Agrawal et al. chapter also extends a fourth stream of research related to frictions and digitization, the potential for new markets and new business models that take advantage of the lower frictions. Many successful internet firms provide platforms that facilitate exchange, including eBay, Monster, Prosper, Airbnb, and oDesk. This is another channel through which digitization has restructured the supply of services. New policies – such as for copyright, privacy, and identity protection – directly shape firm incentives by shaping the laws that apply to these new business models. Several other chapters also touch on these themes.

Addressing an important policy issue for governments, **Gans and Halaburda (chapter 9)** discuss the potential of digitization to create markets for private currencies that support activities on a particular platform, seemingly bypassing state-sponsored monetary authorities. They focus on the viability of the market for private digital currencies with non-currency-specific platforms and speculate on the potential for a privacy-oriented entity to launch a real currency to compete with government-backed currencies such as the dollar and the euro. They lay out a model in which a platform currency offers 'enhancements' to people who spend time on the platform. People allocate time between working and using the platform. They ask whether platforms have incentives to allow users to exchange at full convertibility private digital currency for government-backed currency. Their analysis illustrates the broad open question about whether private currencies in support of a platform are likely to migrate beyond the platform.

Online labor markets and private currencies are just two examples of markets enabled by digitization. Other promising related research areas include markets for user generated content and the provision of public goods (e.g. Zhang and Zhu 2011; Greenstein and Zhu 2012), online banking and finance (e.g. Agrawal, Catalini, and Goldfarb 2013; Rigbi 2013; Zhang and Liu 2012), and "the sharing economy" of hotels and car services (e.g. Fradkin 2013).

Thus, the chapters in this section give a summary of some of the impact of digitization on a variety of markets. This is a big and growing area of research and much remains to be done. As digital technology advances, new opportunities for markets (and new ideas for research) will continue to arise.

Government Policy and Digitization

Increasing digitization has implications for policy, but the literature on the impact of digitization on policy is still in its infancy. As hinted above, ubiquitous data yields new challenges to privacy and security that policymakers need to address (e.g. Goldfarb and Tucker 2012, Miller and Tucker 2011, Arora et al 2010). Near-zero marginal costs of distribution and the non-rival nature of digital goods pose challenges to copyright policy (e.g. Rob and Waldfogel 2006, Oberholzer-Gee and Strumpf 2007). The ease with which digital goods can be transferred over long distances and across borders might affect tax policy (e.g. Goolsbee 2000), financial regulation (e.g. Agrawal, Catalini, and Goldfarb 2013), and trade policy (Blum and Goldfarb 2006).

Privacy and data security are an area where digitization has substantially changed the costs and benefits to various economic actors. The current policy structure was implemented in a different regime, when data sharing was costly and data security was not an everyday concern. It is important to assess whether such laws match with the needs of a digital era in which everyone is of sufficient interest (relative to costs) to warrant data tracking by firms and governments.

Komarova, Nekipelov, and Yakovlev (ch 10) make an important contribution. They combine a technically rich approach to econometrics with the question of how researchers, and research bodies who share data with those researchers, can protect the security and privacy of the people in the data. This is important because, all too often, researchers are unable to make use of the increasing scale and detail of datasets collected by government bodies because access is restricted due to unspecified privacy and data security concerns. This means that potentially many important research questions are being left unanswered, or are being answered using less adequate data, because of our technical inability to share data without creating privacy concerns. The authors develop the notion of the risk of 'statistical partial disclosure' to describe the situation where researchers are able to infer something sensitive about the individual by combining public and private data sources. They develop an example to emphasize there is a risk to individual privacy due to researchers' ability to combine multiple anonymized datasets. However, beyond that, they also suggest that there are ways that data-gathering research bodies can minimize such risks by adjusting the privacy guarantee level.

Mann (ch 11) looks at the question related to data security. She provides several frameworks for analyzing how the question of data breaches should be evaluated in economic terms. She argues that markets for data security are incomplete and suggests that a good market analog to consider is the market for pollution. This market similarly is characterized by negative economies of scale, asymmetric information and systematic uncertainty. She also provides useful data to calibrate just how large the

problem of data breaches actually is, and why breaches tend to occur. Interestingly, despite policy emphasis on external threats such as hacking and fraud, most breaches occur because of carelessness on the part of the data curator. She emphasizes that typically the number of records involved in a data breach is surprisingly small, and that many data breaches stem from the medical sector, though the data breaches which involve the release of a social security number are often from retail. She concludes by emphasizing the complexity introduced into the issue by questions of international jurisdiction.

Miller's discussion of Mann provides a useful synthesis of other literature on this topic. She focuses on the extent to which traditional policy making on data security issues can backfire if it distorts incentives. For example, emphasizing the need for encryption to firms can lead firms to focus only on external outsider threats to data and ignore internal threats to the security data of data from employee fraud or incompetence. She also points to the difficulty of making policy recommendations about differences in US and EU approaches to data security when there is so far scant information about the relative perceived costs to firms and consumers of data breaches.

A second area of policy interest concerns intellectual property. The digitization process resembles the creation of a giant free photocopier that can almost costlessly duplicate any creative endeavor. Varian (2005) supplies a theoretical framework for thinking about this change from an economics perspective. Usually, the economic effect on copyright-holders in the context of free copying is considered to be negative. However, Varian suggests an important counter-argument. If the value a consumer puts on the right to copy is greater than the reduction in sales, a seller can increase profits by allowing that right. Varian also provides a detailed description of several business models which potentially address the greater difficulty of enforcing copyrights as digitization increases. These models span strategies based on: Balancing prices, selling complementary goods, selling subscriptions, personalization, and supporting the good being sold through advertising. Empirical research has not reached the point of having established a set of accepted facts about the merits or demerits of these different strategies, which the earlier sociological and political science literature has discussed in broad terms (Castells, 2003).

This volume provides a sample of the range of new thinking in this area. It complements existing work on the effect of the digitization of music downloads on copyright holders, such as Rob and Waldfogel (2006), Hong (2007), and Oberholzer-Gee and Strumpf (2007). The four chapters on this topic all shed on how business activity changes when the protection of intellectual property changes. Together these chapters demonstrate the importance of copyright policy for market outcomes.

McGarvie and Moser (ch 12) address an argument often made by proponents of stronger copyright terms. Due to the scarcity of data about the profitability of authorship under copyright, they go to historical events to discover whether a historical episode that increased copyright terms did, in fact, encourage creativity by increasing the profitability of authorship. Their historical study also encounters a setting with much shorter copyright lengths than our current copyright length of 70 years after the author's death. That is an advantage, since further extensions today – beyond 70 – may not have any effects on the profitability of authorship, whereas in their study further extensions could have major consequences. The chapter also introduces a new data set of publishers' payments to authors of British fiction between 1800 and 1830. These data indicate that payments to authors nearly doubled following an increase in the length of copyright in 1814.

Further exploring themes related to copyright's influence on the incentives to distribute creative works, this volume also includes a chapter by **Danaheer, Dhanasobhon, Smith, Taleng** (ch 13). It examines research opportunities related to the erosion of copyright caused by internet file-sharing. Digitization has created many new opportunities to empirically analyze open questions by leveraging new data sources. This chapter discusses methodological approaches to leverage the new data and natural experiments in digital markets to address these questions. The chapter closes with a specific proof-of-concept research study that analyzes the impact of legitimate streaming services on the demand for piracy.

Waldfoegel (ch 14) explores another side to these questions, namely, how copyright policy alters incentives to create music. Revenue for recorded music has collapsed since the explosion of file sharing, and, yet, argues Waldfoegel, the quality of new music has not suffered. He considers an explanation that stresses changes on the supply-side, namely, that digitization has allowed a wider range of firms to bring far more music to market using lower-cost methods of production, distribution, and promotion. Prior to the supply change, record labels found it difficult to predict which albums would find commercial success. In that situation many released albums necessarily would fail, and, relatedly, many nascent but unpromoted albums might have been successful. After the change in supply conditions, the increasing number of products released would allow consumers to discover more appealing choices if they can sift through the offerings. The chapter argues that digitization is responsible for such a supply shift: Specifically that internet radio and a growing cadre of online music reviewers provide alternatives to radio airplay as means for new product discovery.

Despite a long history of piracy software markets, researchers have not been able to assemble informative data about the phenomenon, much less their causes. **Athey and Stern (chapter 15)** make a

novel contribution by analyzing data that permits direct measurement of piracy for a specific product – Windows 7. They are able to use anonymized telemetry data to characterize the ways in which piracy occurs, the relative incidence of piracy across different economic and institutional environments, and the impact of enforcement efforts on choices to install pirated versus paid software. The chapter has several provocative new observations. For example, most piracy in this setting can be traced back to a small number of widely distributed “hacks” that are available through the internet. Despite the availability of these hacks to any potential internet user, they do not get used everywhere. The microeconomic and institutional environment appears to play a crucial role in fostering or discouraging piracy. Moreover, piracy tends to focus on the most “advanced” version of Windows (Windows Ultimate). The chapter lays out a broad agenda for this area of research.

These chapters all demonstrate the important role of copyright policy in digital markets. Copyright enforcement affects what is produced and what is consumed. Still, as should be evident from these chapters, many open policy questions remain.

Questions about the role of policy in determining copyright rules, privacy norms, and security practices arise in many markets for digital goods and services. Questions about the principles for redesigning these policies also remain elusive. We hope this book motivates further investigation into the economics underlying these policy issues.

Conclusions

The emerging research area of the economics of digitization improves our understanding of whether and how digital technology changes markets. Digitization enables outcomes that were not possible a few decades earlier. It not only reduces existing costs, but has also enabled the development of new services and processes that did not exist before because they were just too costly or merely technologically infeasible. The opportunities generated by digitization have generated dramatic resource reallocation, and restructuring of routines, market relationships, and patterns of the flow of goods and services. This in turn has led to a new set of policy questions and made several existing policy questions more vexing.

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References

- Agrawal, Ajay, Christian Catalini, and Avi Goldfarb. 2011. *Crowdfunding: Social frictions in the flat world?* Working paper, University of Toronto.
- Agrawal, Ajay, Christian Catalini, and Avi Goldfarb. 2013. Some simple economics of crowdfunding. In *Innovation Policy and the Economy Volume 14*. Eds. Josh Lerner and Scott Stern. NBER, University of Chicago Press.
- Agrawal, Ajay, and Avi Goldfarb. 2008. Restructuring Research: Communication Costs and the Democratization of University Innovation. *American Economic Review*, 98(4), 1578-1590.
- Anderson, E., N. Fong, D. Simester, C. Tucker. 2010. How sales taxes affect customer and firm behavior: The role of search on the internet. *Journal of Marketing Research*, 47(2), 229-239.
- Arora, A. A Nandkumar, C Forman, R Telang. 2010. "Competition and Patching of Security Vulnerabilities: An Empirical Analysis", *Information Economics and Policy*, 10, 164-177
- Acquisti, A. and H. R. Varian. 2005. Conditioning prices on purchase history. *Marketing Science*, 24 (3), 367–81.
- Anderson, C. 2006. *The Long Tail: Why the Future of Business is Selling Less of More*. New York: Hyperion.
- Ansari, A. and C. Mela. 2003. E-customization. *Journal of Marketing Research*, 40 (2), 131–45.
- Bajari, P. and A. Hortacısu. 2003. The winner's curse, reserve prices, and endogenous entry: empirical insights from eBay auctions. *RAND Journal of Economics*, 34 (2, Summer), 329–55.
- Bajari, P. and A. Hortacısu. 2004. Economic insights from Internet auctions. *Journal of Economic Literature*, 42 (2), 457–86.
- Bakos, J. 1997. Reducing buyer search costs: implications for electronic marketplaces. *Management Science*, 43 (12), 1676–92.
- Bakos, Y. and Brynjolfsson, E. 2000. Bundling and competition on the Internet: aggregation strategies for information goods. *Marketing Science*, 19 (1), January, 63–82.
- Balasubramanian, S. 1998. Mail versus mall: a strategic analysis of competition between direct marketers and conventional retailers. *Marketing Science*, 17 (3), 181–95.
- Bar-Isaac, H., G. Caruana, and V. Cunat. 2012. Search, design, and market structure. *American Economic Review*, 102(2), 1140-60.
- Baye, Michael, John Morgan, and Patrick Scholten. 2004. "Price Dispersion in the Small and in the Large: Evidence from an Internet Price Comparison Site," *Journal of Industrial Economics*, Vol. 52, No. 4, December 2004, pp. 463-96.
- Bresnahan, T. and S. Greenstein. 1999. "Technological Competition and the Structure of the Computing Industry," *Journal of Industrial Economics* 47(1), 1-40.
- Blum, and Goldfarb, Avi. 2006. "Does the Internet Defy the Law of Gravity?", *Journal of International Economics*, 70(2), 384-405.
- Brown, J. and A. Goolsbee. 2002. Does the Internet make markets more competitive? Evidence from the life insurance industry. *Journal of Political Economy*, 110 (3, June), 481–507.

- Brynjolfsson, Erik, Yu "Jeffrey" Hu, Michael D. Smith. 2003. Consumer Surplus in the Digital Economy: Estimating the Value of Increased Product Variety. *Management Science*, 49(11) 1580-1596.
- Brynjolfsson, Erik and Smith, Michael. 2000. Frictionless Commerce? A Comparison of Internet and Conventional Retailers, *Management Science*, Vol. 46, No. 4, 563-585.
- Cabral, L, and A. Hortaçsu. 2010. Dynamics of Seller Reputation: Theory and Evidence from eBay, *Journal of Industrial Economics*, 58(1), 54-78.
- Cairncross, F. 1997. *The Death of Distance*. Cambridge, MA: Harvard University Press.
- Castells, M. 2003. The Internet galaxy: reflections on the Internet, business, and society. Abingdon, UK: Taylor and Francis.
- Chen, P.-Y. and L. Hitt. 2002. Measuring switching costs and the determinants of customer retention in Internet-enabled businesses: a study of the online brokerage industry. *Information Systems Research*, 13 (3, September), 255–74.
- Chen, Y. and S. Savage. 2011. The effects of competition on the price for cable modem Internet access. *The Review of Economics and Statistics*, 93 (1), 201–17.
- Chevalier, J. and D. Mayzlin. 2006. The effect of word of mouth on sales: online book reviews. *Journal of Marketing Research*, 43 (3), 345–54.
- Crandall, R. 2005. 'Broadband Communications,' in M. Cave, S. Majumdar, and I. Vogelsang (eds), *Handbook of Telecommunications Economics*, Amsterdam: Elsevier, pp. 156–87.
- Cusumano, M. and D. Yoffie. 1998. *Competing on Internet Time: Lessons from Netscape and Its Battle with Microsoft*. New York: Free Press.
- Diamond, P. 1971. A simple model of price adjustment. *Journal of Economic Theory*, 3, 156–68.
- Downes, T. and S. Greenstein. 2002. Universal access and local Internet markets in the U.S. *Research Policy*, 31, 1035–52.
- Einav, Liran, and Jonathin D. Levin. 2013. The Data Revolution and Economic Analysis. NBER Working Paper #19035.
- Einav, L., D. Knoepe, J. D. Levin and N. Sundaresan. 2012. Sales taxes and internet commerce. Working Paper 18018, National Bureau of Economic Research.
- Elberse, A. and F. Oberholzer-Gee. 2006. Superstars and underdogs: an examination of the long tail phenomenon in video sales. Harvard Business School Working Paper, No. 07–015, September.
- Ellison, G. and S.F. Ellison. 2009. Search, obfuscation, and price elasticities on the internet. *Econometrica* 77(2), 427-452.
- Fleder, D. and K. Hosanagar. 2009. Blockbuster culture's next rise or fall: the impact of recommender systems on sales diversity. *Management Science*, 55 (5), 697–712.
- Forman, C., A. Ghose and A. Goldfarb. 2009. Competition between local and electronic markets: how the benefit of buying online depends on where you live. *Management Science*, 55 (1), 47–57.
- Forman, C., A. Ghose and B. Wiesenfeld. 2008. Examining the relationship between reviews and sales: the role of reviewer identity disclosure in electronic markets. *Information Systems Research*, 19 (3), 291–313.
- Fradkin, Andrey. 2013. Search Frictions and the Design of Online Marketplaces. Working paper, Stanford University.

Fudenburg, D. and J. M. Villas-Boas. 2006. 'Behavior Based Price Discrimination and Customer Recognition,' in T. Hendershott (ed.), *Economics and Information Systems*, Bingley, UK: Emerald Group Publishing, pp. 377–435.

Gandal, N. 2006. The effect of native language on Internet usage. *International Journal of the Sociology of Language*, 182, 25–40.

Garicano, Luis, and Paul Heaton. 2010. Information Technology, Organization, and Productivity in the Public Sector: Evidence from Police Departments. 28(1): 167-201.

Gaspar, J. and Glaeser, E. 1998. Information technology and the future of cities. *Journal of Urban Economics*, 43 (1), 136–56.

Gawer, A. and M. Cusumano. 2002. *Platform Leadership: How Intel, Microsoft and Cisco Drive Innovation*. Boston, MA: Harvard Business School Press.

Gentzkow, M. and J Shapiro. 2011. "Ideological Segregation Online and Offline". *Quarterly Journal of Economics*. 126(4), 1799-1839.

Godes, D. and D. Mayzlin. 2004. Using online conversations to study word-of-mouth communication. *Marketing Science*, 23 (4), 545–60.

Goolsbee, A. 2000. In a world without borders: The impact of taxes on internet commerce. *The Quarterly Journal of Economics*, 115 (2), 561-576.

Goldfarb, A. 2006. State dependence at Internet portals. *Journal of Economics and Management Strategy*, 15 (2), 317–52.

Goldfarb, Avi and Catherine Tucker. 2011a. Advertising Bans and the Substitutability of Online and Offline Advertising. *Journal of Marketing Research*, 48(2), 207-228.

Goldfarb, Avi and Catherine Tucker. 2011b. Privacy Regulation and Online Advertising. *Management Science* 57(1), 57-71.

Goldfarb, A. and C. Tucker. 2012. 'Privacy and Innovation,' in J. Lerner and S. Stern (eds), *Innovation Policy and the Economy, Volume 12*, Chicago, IL: NBER (University of Chicago Press), pp. 65–89.

Goldfarb, B., D. Kirsch and M. Pfarrer. 2005. Searching for Ghosts: Business Survival, Unmeasured Entrepreneurial Activity and Private Equity Investment in the Dot-Com Era. Robert H. Smith School Research Paper, No. RHS 06-027. Available at: <http://ssrn.com/abstract=825687>. Accessed 1 June 2013.

Goldmani, M., A. Hortascu, C. Syverson, and O. Emre. 2010. E-Commerce and the Market Structure of Retail Industries. *Economic Journal*, 120 (545), 651-82.

Goolsbee, A., M. Lovenheim and J. Slemrod. 2010. Playing with fire: cigarettes, taxes, and competition from the Internet. *American Economic Journal: Economic Policy*, 2 (1), 131–54.

Greenstein, S. 2012. 'Internet Infrastructure,' in M. Peitz and J. Waldfoegel (eds), *Handbook of Digital Economics*, New York: Oxford University Press, pp. 3–33.

Greenstein, S. and R. McDevitt. 2011. The broadband bonus: estimating broadband Internet's economic value. *Telecommunications Policy*, 35, 617–32.

Greenstein, Shane. 2000. Building and Developing the Virtual World: The Commercial Internet Access Market. *Journal of Industrial Economics* 48(4), 391-411.

Hong, Seung-Hyun. 2007. The recent growth of the internet and changes in household level demand for entertainment. *Information Economics and Policy*, 3-4, pp. 304-318.

- Jin, G. Z. and A. Kato. 2007. Dividing online and offline: a case study. *Review of Economic Studies*, 74 (3), 981–1004.
- Kenney, M. 2000. *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region*. Stanford, CA: Stanford University Press.
- Lucking-Reiley, D. 2000. Auctions on the Internet: what's being auctioned, and how? *Journal of Industrial Economics*, 48 (3), 227–52.
- Miller, A. and C Tucker. 2011. 'Can Healthcare Information Technology Save Babies?' *Journal of Political Economy*, Vol. 119 No. 2, pp. 289-324.
- Miller, A. and C. Tucker. 2009. Privacy protection and technology diffusion: the case of electronic medical records. *Management Science*, 55 (7), 1077–93.
- Miller, A. and C. Tucker. 2011. Encryption and the loss of patient data. *Journal of Policy Analysis and Management*, 30 (3), 534–56.
- Mowery, D. and Simcoe, T. 2002. The Origins and Evolution of the Internet, in R. Nelson, B. Steil and D. Victor (eds), *Technological Innovation and Economic Performance*. Princeton, NJ: Princeton University Press, pp. 229–64.
- Murthi, B. and S. Sarkar. 2003. The role of the management sciences in research on personalization. *Management Science*, 49 (10), 1344–132.
- Oberholzer-Gee, Felix and Koleman Strumpf. 2007. "The Effect of File Sharing on Record Sales: An Empirical Analysis." *Journal of Political Economy*, Volume 115, Issue 1, Page 1-42.
- Oestreicher-Singer, G. and A. Sundararajan. 2012. Recommendation networks and the long tail of electronic commerce. *MIS Quarterly*, 36 (2), 65–83.
- Ou, G. 2008. A Policy Maker's Guide to Network Management. Available at: <http://www.itif.org/index.php?id=205>. Accessed 1 June 2013.
- Peitz, Martin, and Joel Waldfogel, 2012, *The Oxford Handbook of the Digital Economy*, Oxford University Press; New York.
- Rigbi, Oren. 2013. The effects of usury laws: Evidence from the online loan market. *Review of Economics and Statistics* 95(4): 1238-1248.
- Rob, Rafael and Joel Waldfogel. 2006. "Piracy on the High C's: Music Downloading, Sales Displacement, and Social Welfare in a Sample of College Students." *Journal of Law & Economics*, Volume 49, Issue 1, Page 29-62.
- Romanosky, S., R. Telang and A. Acquisti. 2011. Do data breach disclosure laws reduce identity theft? *Journal of Policy Analysis and Management*, 30 (2), 256–86.
- Rosston, G. 2009. The rise and fall of third party high speed access. *Information, Economics and Policy*, 21, 21–33.
- Rosston Gregory, Scott J. Savage, & Donald M. Waldman, 2010. "Household Demand for Broadband Internet in 2010," *The B.E. Journal of Economic Analysis & Policy*, Berkeley Electronic Press, vol. 10(1), article 79. (46 pages)
- Simcoe, T., Standard Setting Committees: Consensus Governance for Shared Technology Platforms. *American Economic Review*, 102(1): 305-336, February 2012.
- Sinai, T. and J. Waldfogel. 2004. Geography and the Internet: Is the Internet a substitute or a complement for cities? *Journal of Urban Economics*, 56 (1), 1–24.

Stigler, George J. 1961. The Economics of Information. *Journal of Political Economy* 69(3), 213-225.

Sunstein, C. 2001. *Republic.com*. Princeton, NJ: Princeton University Press.

Varian, H. 1980. A model of sales. *American Economic Review*, 70 (September), 651–9.

Varian, H. 2005. Copying and Copyright. *Journal of Economic Perspectives*. 19(2), 121-138.

Waldfogel, J., Chen, L. 2006. “Does Information Undermine Brand? Information Intermediary Use and Preference for Branded Web Retailers,” *Journal of Industrial Economics*, 54(4), pp. 425-449.

Zettelmeyer, Florian, Fiona Scott Morton and Jorge Silva-Risso. 2001. Internet Car Retailing. *Journal of Industrial Economics*. 49(4): 501-519.

Zhang, Juanjuan, and Peng Liu. 2012. Rational Herding in Microloan Markets. *Management Science*, 58(5), 892-912.

Zhang, X and F Zhu. 2011. Group Size and Incentives to Contribute: A Natural Experiment at Chinese Wikipedia. *American Economic Review*, 101(June), 1601-1615.