Economists (and Economics) in Tech Companies*

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Abstract

As online platforms have created new markets and new ways of acquiring information, economists have come to play an increasingly central role in tech companies – tackling problems such as platform design, pricing, and policy. In this paper, we explore the skills that PhD economists apply in tech companies, the companies that hire them, the types of problems that economists are currently working on, and the areas of academic research that have emerged in relation to these problems.

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1. Introduction

PhD economists have long held active positions in government and business, dealing with issues ranging from fiscal and monetary policy to antitrust and labor disputes. In recent decades, as online platforms have created new markets and new ways of acquiring information, economists have now come to play an increasingly central role in tech companies as well – tackling problems such as platform design, pricing, and policy.

We've had the opportunity to spend our careers thus far with one foot in academia studying and teaching about online platforms and the other in practice helping to shape them. Outside of our academic roles, we work closely with tech companies. Susan previously served as consulting chief economist at Microsoft and currently sits on the boards of Expedia, Rover and Ripple. While working with Microsoft, she also helped build the economics group at Microsoft's research arm in New England. Mike works with a variety of tech companies, and created an economic research initiative at Yelp. As academics, we have taught hundreds of students and executives who now work in tech companies. Doctoral students have also become increasingly interested in tech companies – our own students have now worked at companies ranging from Facebook, Microsoft, and Amazon to Wealthfront, Uber, and Airbnb.

Major companies, including Amazon, eBay, Google, Microsoft, Facebook, Airbnb, and Uber, have large teams of PhD economists working to engineer better design choices. Amazon's hiring has been especially notable, as they have hired more than one hundred economists in the past five years, making them the largest employer of tech economists. In fact, Amazon now has more PhD economists than the largest academic economics department. Companies such as Netflix, Pandora, Zillow, Trulia, Expedia, Upwork, AppNexus, Coursera, and Yelp have also hired economists. Figure 1 shows a list of technology companies that have hired PhD economists.

Hiring of PhD economists has happened at all levels, from chief economists down to rookie job market candidates straight out of PhD programs. The types of positions also vary greatly. Companies like Amazon actively discourage academic publishing, and assign economists to business problems they are struggling with in the short term. In contrast, companies like Microsoft have economists operating within the main business, but also have many economists working out of research centers, essentially doing research and development, publishing self-guided research in academic journals comparable to that of economists working in business schools or economics departments. These centers, at their best, provide frontier insights, some of which will yield transformative ideas that will guide the future direction of the company.

Many tech companies now recruit directly through the American Economic Association's Job Openings for Economists platform, which is where much of the recruiting for PhD economists begins. According to data we pulled from AEA, we see that twenty-one tech companies were hiring through the JOE website in the 2017-18 academic year. To put this into context, there are roughly two-thirds as many tech companies hiring through JOE as there are policy schools. Taking into account the fact that many of these companies have multiple positions, this suggests that the market of available positions for economists in tech companies may well exceed the market for economists at policy schools. Moreover, Figure 2 shows that the number of positions in

tech companies has consistently risen in recent years, in contrast to policy schools (which have gone up and down) and economics departments (which have gone down). Job availability has also increased in business schools. Business schools have seen increased demand for faculty specializing in online platforms and digitization, as well as in areas crucial to performing data analysis in technology firms, such as machine learning and experimental methods.

There is little precedent for companies recruiting academic economists as well as new PhDs with strong research skills so heavily for full-time positions. Companies like Rand and Mathematica Policy Research recruit economists at scale, but focus mainly on research. Consulting firms like Cornerstone and the Analysis Group also recruit large numbers of economists, primarily to conduct research in areas such as antitrust and intellectual property litigation.

Perhaps the closest analog to the type of hiring done by tech companies with labs like Microsoft Research would be Bell Labs. Operating as a division of AT&T, Bell Labs created an economics team in 1968. The team grew from a handful of people to about 30 economists. Bell Labs employed a number of high-profile economists, including Elizabeth Bailey, Roy Radner, and Robert Willig, and in 1970, it launched the Bell Journal of Economics and Management Science (which lives on through the date of this publication as the Rand Journal of Economics). The team was phased out in 1983, coinciding with the breakup of the company. At that point, some economists were folded into other parts of the company, while others left for other industry or academic jobs – including at Columbia University, Harvard Business School, New York University, Princeton University, and the University of Pennsylvania.

While companies like Microsoft hire economists using a lab model analogous to Bell, the majority of hiring of economists in tech companies looks very different from this – and ties the work of economists more closely to different parts of the business. Beyond Microsoft Research, the chief economist's team at Microsoft actively recruits PhD economists to work on a range of business problems ranging from cloud computing to search advertising. Amazon assigns economists to specific business problems across divisions, ranging from the e-commerce platform to digital content. Airbnb has economists working on issues ranging from pricing to reputation systems. Uber has teams of economists focused on understanding policy issues in addition to pricing and incentive design. HomeAway has a PhD economist leading market design and data science for the marketplace. Additionally, many economists at tech companies do a combination of external research and internal work.

In addition to drawing on insights from economics, online platforms have given rise to new intellectual questions and a new field within economics, which has come to be called the economics of digitization. The field covers a wide array of questions related to the Internet. For example, what is the best way to design an auction for advertisements on a search engine? What is the best design of a reputation system for platforms like Airbnb or Yelp? How should governments use digital data to improve their policy analyses and operations? Online platforms have also created novel datasets and testing grounds that have been used to inform virtually every field of economics, from market design to industrial organization to labor economics.

In recent decades, the field of economics has become increasingly empirical, focusing on evaluating policies, testing theories, and identifying mechanisms. One

particularly notable focus has been on adopting and adapting approaches to understand causal inference. As the Internet age has helped to usher in an era of unprecedented amounts of data, this has also contributed to the growing demand for economists. Motivated by the need to bring causal inference techniques to the large datasets of technology firms as well as the desire to make full use of these rich datasets, a recent literature has developed combining machine learning and causal inference (Athey, forthcoming).

Tech companies have also created strong demand for undergraduate economics majors, who take roles ranging from product management to policy. Leading universities including Yale, Harvard, Princeton, Dartmouth, Stanford, and MIT teach about online platforms in their introductory microeconomics courses, or have created entire courses related to the economics of digitization (including courses on e-commerce, online platforms, and related areas). MIT's economics and computer science departments have partnered to create a new major in computer science, economics, and data science. Harvard has developed a data science initiative, drawing in computer scientists, economists, and other social scientists. We see opportunities to expand these course offerings, and development of course material for students looking for a career at tech companies. Courses about marketplaces and platforms, taught from an economics perspective, have also proliferated among business schools, such as Harvard, Stanford, Boston University, and New York University.

While economists are well suited to tech careers in many ways, we also see areas for the field to improve the preparation of PhD economists for working with or in tech companies. First, with the importance of prediction, targeting, and precise estimates in tech companies, machine learning plays an important role in tech companies. While the field of economics has long been a leader in causal inference, the field is still in the process of incorporating machine learning into its standard toolkit. Second, economists have historically been weak, relative to computer scientists, at coding. Investing in these skills (and incorporating them into the PhD curriculum) can help to prepare economists to work in this area.

With the rise of economists in tech companies, we're frequently contacted for recommendations about whom to hire and what types of roles economists should take on. We are also asked how undergraduates and PhD students can prepare for such careers, as well as what these careers will be like. In this paper, we describe the skills that PhD economists apply in tech companies, the companies that hire them, the types of problems that economists are currently working on, and the areas of academic research that have emerged in relation to these problems.

2. What tech-relevant skills do PhD economists have?

To draw inspiration from Liam Neeson's line in the movie *Taken*, economists have "a very particular set of skills." Here, we focus on two broad skillsets that we think allow economists to thrive in tech companies: the ability to assess and interpret empirical relationships and work with data, and the ability to understand and design markets and incentives, taking into account the information environment and strategic interactions.

2.1. Assessing empirical relationships

Economists work extensively with data to answer social science questions. Relative to other disciplines, economists generally have two strengths in thinking about data.

First, economists are interested in understanding which relationships are *causal* and, critically, which are not. Over the past thirty years, the field of economics has developed a toolkit to identify causal relationships in real-world data. From a practical perspective, this allows economists to understand what works, what doesn't, and why. Within tech companies, economists have used this toolkit to estimate things ranging from the causal impact of Yelp ratings on restaurant sales to the effect of Google ads on visits to eBay (Luca 2016; Blake, Nosko, and Tadelis 2015). While correlational data led eBay to invest fifty million dollars per year on search ads, a large-scale experiment run by their economics team demonstrated that many of these ads were ineffective. The impact of advertising, taking into account the endogeneity of advertising placements, has now been explored in a variety of contexts (Johnson, Lewis, and Reiley 2015; Blake, Nosko, and Tadelis 2016; Johnson, Lewis, and Nubbemeyer 2017; Dai, Kim, and Luca 2018). While descriptive analysis showed that customer demand for restaurants was correlated with posted health inspection scores, a difference-in-differences approach showed that the effectiveness of providing this information to consumers by posting the scores depends heavily on the salience of scores (Dai and Luca 2018), leading Yelp to update the disclosure initiative.

Second, economists are interested in understanding the tradeoffs involved in different outcome metrics. Outcome metrics are crucial to everything that happens inside firms, particularly technology firms that make decisions primarily based on data (as opposed to subjective criteria). Product design decisions, marketing decisions, and even human resources decisions are determined on the basis of empirical analysis, and the choice of what metrics represent success guides incentives throughout the companies. Economists have sought to better understand the relationship between short-term metrics such as clicks on an advertisement (also called "surrogates," e.g. Athey, Eckles, and Imbens 2016) which are easy to observe, and longer-term metrics (like revenue or the lifetime value of a customer), which are more difficult to observe, but better represent company goals. For example, one technology company described a change in measurement for email marketing. The old measure, customer sales, was noisy, and sometimes consumers took weeks before they purchased. The new measure, opening the email, was immediately observable, and could be incorporated to adjust the content of the email very quickly. The company found that within months, the number of sales per email declined precipitously, because the marketing emails evolved to maximize email opening rates without regard to final sales. For example, the successful emails (using the opening rate metric) had catchy subject lines and somewhat misleading promises.

More broadly, most technology firms make heavy use of A/B testing platforms, where hundreds or thousands of randomized controlled experiments are performed every year. Most or all changes to products are tested using these platforms. In order to innovate rapidly, firms often run many short-term experiments with the set of metrics that are easily measured. The choice of short-term metrics to use to determine success can be crucial for both determining which innovations are adopted, but, anticipating this, product teams often choose to invest in research and development taking into account what

innovations are likely to perform well relative to the company's success metrics. This can have perverse consequences; for example, innovations that look bad according to short-term metrics but might have positive long-term benefits are less likely to be pursued. It is natural for an economist to think about a metric not only as a statistical measure, but also as implicitly governing worker incentives, and to suggest ways to provide incentives for long-term innovation as well as short-term metrics that better capture long-term effects.

In other situations, economists have shed light on unintended consequences that had gone ignored. For example, in contrast with traditional hotels and platforms like Expedia, Airbnb made it very easy for landlords to reject guests after seeing their name and picture, presumably because their experiments heavily prioritized short-run user growth. While this extent of flexibility may have lead to short-term user growth, an experiment run by Edelman, Luca, and Svirsky (2017) showed that it also led to widespread racial discrimination against African-Americans on the platform. To put this into context, the United States made significant progress in reducing discrimination in rental and hotel markets through regulation, enforcement, and shifting norms. Airbnb's market design choices raised the possibility of erasing these gains and reintroducing discrimination to a market that had worked hard to reduce it. Fisman and Luca (2016) proposed a series of market design choices that might reduce discrimination in online markets more generally – such as further automating transactions on platforms. The company created a task force that weighed different options. Recognizing the scope of the problem, Airbnb created a full-time team of data scientists to explore discrimination on an ongoing basis. Ultimately, Airbnb made new design choices taking into account the potential for discrimination, as well as the company's willingness to tolerate some discrimination in order to obtain higher profits.

Harry Truman famously remarked that he wanted to hire a one-handed economist, referring to the fact that economists specialize in tradeoffs ("on the one hand…"). While tradeoffs make decision-making more complicated, the reality is that tradeoffs exist – and it's better to know what they are. Economists' theoretical and empirical training prepares them to think carefully about both intended and unintended consequences of different decisions. Economists also think a lot about the difference between short-term and long-term objectives, which can often lead to dramatically different conclusions. This can lead to broader metrics that are more closely aligned with corporate goals, and more likely to give a complete picture of what is and isn't working. These types of tradeoffs occur both in making product and market design choices, and in developing algorithms (Luca et al 2016).

Additionally, economists care deeply about differentiating between statistical and economic significance, in contrast with fields that tend to focus mainly on statistical significance or ignore it entirely. For example, labor economists want to know both whether education increases earnings and also how large the effect is, so that they can understand the returns to education and how to best allocate education expenditures.

2.2. Designing markets and incentives

The rise of economists in tech companies has also coincided with the rise of market design, a field that was pioneered by Stanford economist Bob Wilson and extended into a variety of application areas by economists such as Paul Milgrom and Al Roth (winner of the 2012 Nobel Prize in Economics). These economists have also promoted the idea of the "economist as engineer," whereby the economist gets deeply

involved in the implementation of economic ideas, and tailors recommendations to the fine details of the problem. Market design has shifted economists away from using a primarily descriptive lens to a more prescriptive one, using the tools of economics to engineer better-functioning markets. Roth once wrote that "economic institutions evolve, but they are also designed." While market design research initially focused on offline marketplaces such as spectrum auctions, residency matching programs, and kidney exchange, the statement aptly describes the role of economics in the tech sector, where we and other economists have now taken this design economics mindset.

In 2002, Hal Varian received a call from Eric Schmidt, the chairman of a young company called Google. Schmidt was intrigued by *Information Rules*, a book Varian had coauthored with Carl Shapiro, his fellow economist and colleague at the University of California, Berkeley. In what turned out to be a productive conversation, Varian spoke with Schmidt and went on to become a consultant for Google, and ultimately, the company's chief economist. Varian was one of the first economists directly involved in the design of an online platform, and helped to design and understand the properties of the generalized second-price auction the company (and many other companies) use to sell its advertisements (Varian 2007) – an issue also explored in Edelman, Ostrovsky, and Schwraz (2007). The idea of studying auctions was not new to economics – in fact, Varian's abstract points out that the Google and Yahoo advertising auctions "closely related to the assignment game studied by Shapley–Shubik, Demange–Gale–Sotomayer and Roth–Sotomayer." But this was a setting in which the details mattered, so Varian tweaked existing models (in ways that turned out to be economically important but technically challenging) to directly inform the issues that Google was grappling with. Varian's work with Google is an early example of design economics within tech companies. In the decade since, more than a thousand papers within economics and computer science have gone on to shed further light on implications of design choices within advertising auctions, and this remains an active area.

More generally, economists have explored the design of a variety of markets, ranging from Microsoft's marketplace for selling advertisements (Athey and Ellison 2011; Agarwal, Athey, and Yang 2009) to Uber's market for rides (Cohen et al. 2016). Much of this work has focused on price mechanisms and reputation systems (Luca 2017). Multi-sided platforms are especially ripe for an economist's skills, since these are exactly the kinds of settings in which it is critical to think through strategic behavior and interactions.

3. Applications of Economics in Technology Firms

Economists now work on a variety of issues pertaining to tech companies. In this section, we highlight two exemplars of economics in tech companies: advertising and reputation systems.

3.1. Economics of Online Advertising

Advertising is one of the areas that have changed dramatically as a result of the involvement of economists. This involvement has been concentrated in two areas: the design of advertising auctions and estimating the returns to advertising.

3.1.1. Designing advertising auctions

Search engines, ranging from general engines like Google and Bing to more specialized search engines like Yelp, generally sell advertising through auctions for specific terms. Bids are expressed in terms of a willingness to pay per outcome, such as a click, and advertisers with higher bids are rewarded with more favorable ad placement.

As mentioned above, some of the earliest work from economists in tech companies had the goal of improving the design of advertising auction – as when Hal Varian led Google to implement generalized second-price auctions for its ad sales, where each advertiser pays the price bid by the next lowest bidder. In traditional second-price auctions – where the result is a single winner rather than a ranking of bidders as in the general case – the best strategy is to bid one's true price. Michael Schwarz of Yahoo! Research, Benjamin Edelman, and Michael Ostrovsky show in a 2007 paper that the generalized second-price auctions lack the same dominant strategy but remain useful in search engine advertising applications. Susan Athey and Glenn Ellison (2011) incorporate rational consumer search into the market design, motivating the use of reserve price not only as an instrument for raising revenue, but also as a tool for managing advertising quality and thus increasing users' incentive to search. One of us, Susan, used this as a framework for advising Microsoft to improve the ad quality on Microsoft's search engine. Later she took the theoretical models to the data and built an econometric model (Athey and Nekipelov 2012) that could be used to infer advertiser valuations and profits from their bidding behavior. This type of model can be used to understand how changes in algorithms affect advertiser well-being and thus forecast their future engagement in the platform.

At Yahoo!, Ostrovsky and Schwarz (2016) observed that the reserve prices the company was setting were lower than what auction theory predicted would be revenue maximizing for the seller. The pair assigned search keywords in the treatment group a theoretically optimal reserve price calculated by the authors, while keywords in the control group used a default reserve price of $0.10 per click. The treatment group increased ad revenue by several percentage points, leading Yahoo! to change its reserve price policies for all of its search advertising – and making the company millions of dollars in additional revenue.

In addition to determining auction formats and parameters, tech firms have hired economists to solve challenges relating to the choice of outcome, such as pay-per-click versus alternatives. Agarwal, Athey, and Yang (2009) explore the benefits and drawbacks of pay-per-click compared to pay-per-action, in which advertisers only pay each time an individual performs an action after clicking the ad link, such as buying a product. Pay-per-action helps to address the problem of click fraud. For example, if a site that hosts Google ads gets a fraction of Google's revenue in return, then that site is incentivized to click the ads they host with no intention of buying the product. However, the ability to bid on multiple types of actions means that firms may bid high on an action that is less likely to occur than the search engine believes, either because of inside knowledge or manipulation, thus gaining a high search position at low cost.

3.1.2. Estimating the returns to advertising

Nineteenth-century department store magnate John Wanamaker once quipped: "Half the money I spend on advertising is wasted; the trouble is I don't know which half." Estimating the returns to advertising had been difficult because of practical challenges in

randomization (and other identification strategies), limited data collected on outcomes, and small sample sizes.

The digital age has raised the potential of better understanding the returns to advertising. Platforms such as Google and Microsoft collect vast amounts of data on user behavior, and regularly run experiments to test the effectiveness of their online advertising systems – allowing them to make important progress on understanding the impact of advertisements, and the conditions under which advertising is most effective. Economists at such firms can thus draw on existing theories of market design, generate new ideas, and rapidly test and evaluate those ideas.

Of course, companies ranging from Gap to eBay advertise online, and would also like to know the effectiveness of these advertising companies. Economists at companies have made significant progress in understanding the effectiveness of advertising. For example, Thomas Blake, Chris Nosko, and Steven Tadelis (2015), of eBay Research Labs, conducted a series of field experiments on a large scale that allowed them to understand the impact of eBay's advertising campaigns on Google and Bing. They found that search engine marketing – purchasing ads to be displayed on search engines when certain search terms are entered – was only effective when ads are viewed by new or infrequent eBay customers and when the search terms do not include already contain the firm being searched for. Since frequent customers drive most sales, the overall returns were negative, a significant result given that eBay's yearly US search engine marketing budget was over $50 million at the time of the experiment.

In different contexts, others have found evidence that advertising can be a positive investment. Lewis, along with Garrett Johnson and David Reiley, reports in a 2016 paper a 3.6% increase in sales among consumers shown advertisements for a large retailer on Yahoo!, with a point estimate, though not statistically significant, of positive returns. Their experiment used a sample size in the millions, a control group shown an irrelevant ad (in addition to a group shown no ads), and a large set of individual covariates in order to achieve power. Dai et al (2018) collaborated with Yelp to randomly display ads for a set of previously non-advertising restaurants, a design that allowed them to include many small businesses rather than a small number of well-known business. Restaurants for which ads were shown had 25% more page views and 5% more reviews, a proxy for actual visits to the restaurant.

Economists have also designed long-term experiments that examine the impact of ads on user engagement; Huang, Riabov, and Reilly (2017) study Pandora consumers over a twenty-one month period, estimating a fairly linear relationship between advertising load and usage, and further showing that increasing the advertising load increases purchases of paid, ad-free subscriptions.

Yet, even though data abounds, it remains challenging to measure the returns to advertising. Randall Lewis and Justin Rao (2015), two economists formerly at Yahoo!, discuss the challenges in a meta-analysis spanning 25 online advertising field experiments. Older media, such as print and television, do not allow showing different advertisements or tracking behavior at the individual consumer level, which makes designing randomized experiments difficult, and non-randomized observational studies are plagued by selection bias. Online advertising seems to solve these problems, but Lewis and Rao argue that we are still held back by the signal-to-noise ratio in individual sales data, where standard deviations are often an order of magnitude higher than means.

Even studies with hundreds of thousands of users tend to produce confidence intervals too wide even to distinguish highly profitable ads from wholly ineffective ones, and identifying a more realistic effect size could only be done at prohibitive cost.

3.2. Reputation Systems

Online reviews and reputation systems have become increasingly prevalent in the past decade, and now cover nearly every product and service imaginable. Platforms like Yelp, TripAdvisor, and ZocDoc contain hundreds of millions of reviews for businesses ranging from plumbers to hotels to physicians. The rise of online marketplaces such as Uber and Airbnb rely heavily on reputation systems in order to facilitate trust between strangers, and traditional retailers ranging from Home Depot to Gap have developed review systems of their own.

Economists have been directly involved in the design and analysis of reputation systems. Broadly, this has focused on three areas. First, how do reviews influence markets? Second, what problems occur in online review and reputation systems, and can design choice economics approach help to mitigate biases? Third, can online reviews and reputation systems help to improve policy and our understanding of the economy? For a full discussion of this topic, see Luca (2015). In this section, we discuss specific examples of the design and impact of review systems.

3.2.1. Designing Review and Reputation Systems

Economists have been involved in the design of reputation systems – focusing on understanding the systematic biases that can occur in reviews, and design choices that can help to overcome them.

For example, many online marketplaces allow reciprocal reviewing, where buyers and sellers review each other. This is a valuable way to build trust on both sides of the market, but can create incentives for upward-biased reporting if reviewers fear retaliation. When Airbnb's allowed renters' reviews to be posted before hosts', guests might have been hesitant to leave bad reviews out of concern that hosts would reciprocate. Bolton, Greiner, and Ockenfels (2013) propose a fix to this dilemma in the context of eBay, which offered reciprocal reviewing where both buyer and seller reviews were immediately posted. The solution eBay (and Airbnb) explored is to not display reviews until both sides have left a review or a certain amount of time has expired. Under this system, however, buyers may still be reluctant to provide negative feedback if they suspect that it would discourage future sellers from transacting with them. Therefore, eBay added an anonymous, one-way review component called a "detailed seller rating," where buyers assign sellers several numerical scores and the results are only viewable in aggregate form. Fradkin, Grewal, and Holtz (2017) test this effect in the context of Airbnb (working within the company), and find consistent results.

Because reviews in online marketplaces are voluntary, they can also suffer from selection bias. In other words, reviews are left by users who chose both to purchase the product or service and to leave a review online. Overcoming this bias is another design challenge. In particular, users may be more likely to leave a review after an especially positive or negative experience, and indeed Hu, Zhang, and Pavlou (2009) find that reviews on Amazon tend to exhibit an asymmetric bimodal (J-shaped) distribution. They argue that experiences for many products are more likely to resemble a normal

distribution, and hence the J-shape suggests that people are more likely to leave reviews after extreme experiences. Building on this, Masterov, Meyer, and Tadelis (2015) – working within eBay's team of economists – find evidence from eBay that positive experiences more often lead to reviews. Review platforms have a variety of tools to tackle the selection problem, such as sending emails to encourage consumers to leave reviews and even paying reviewers. Alternatively, platforms can incorporate information about buyer and seller review frequency into reputation scores – for example, penalizing sellers who receive low rates of feedback. Upon the recommendation of an in-house economist, Upwork developed a system that allowed for both private and public feedback, finding that private feedback was indeed less inflated than public-facing reviews.

A third bias in online reviews occurs when businesses, or individuals hired by businesses, surreptitiously leave reviews about themselves or their competitors. Luca and Zervas (2015) demonstrate that changing economic incentives for a business affect the rate of fraudulent reviews: independent restaurants and restaurants with a declining reputation are more likely to commit fraud, and restaurants with high competition are more often targeted with fake negative reviews. One mechanism for reducing fraudulent reviews is to verify whether a transaction has occurred before allowing a review, as is policy on Airbnb, for example. While this may reduce fake reviews, it may also prevent legitimate reviews on some platforms by increasing the barriers to contributing content. Mayzlin, Dover, and Chevalier (2014) find evidence of this in the context of TripAdvisor (which does not verify that reviewers have stayed at a property) and Expedia (which does).

In addition to creating incentives for people to leave high quality reviews, platforms make strategic decisions about how to aggregate reviews once they are in place, which Dai et al (forthcoming) as the rating aggregation problem. In practice, review platforms often use algorithms to identify and remove content that is thought to be fake or of low quality. Platforms can also adjust and weight ratings to account for the informational content of each review, increasing the overall informational content of average ratings being presented to users.

3.2.2. Impact of Reviews

Empirically, the impact of reviews can be hard to identify because reviews reflect unobservable characteristics of a business that may also affect behavior. For example, hotels with higher TripAdvisor ratings may have higher demand either because ratings drive demand or simply because hotels with higher ratings are better hotels, and consumers are responding to other available information about quality.

Economists have now used a variety of methods to identify the causal impact of online reviews. For example, consider a book that that is sold both on Amazon and on the Barnes & Noble website. The book would almost certainly have different ratings on the two platforms. Moreover, if an Amazon user left a review, the rating would change on Amazon, but not on Barnes and Noble, leading to variation in ratings across platforms and over time. Arguing that the exact timing of incoming reviews is plausibly exogenous, Chevalier and Mayzlin (2006) use this variation to estimate the impact of reviews on online book purchases. Specifically, they look for increases in sales on Amazon (relative to Barnes and Noble) after a review was left on Amazon (but not on Barnes and Noble) –

implementing a difference-in-differences strategy. Using a regression discontinuity design (comparing restaurants just above and below a rounding threshold), Luca (2011) finds that a one-star rating increase at a restaurant leads to a 5% increase in revenue for independent restaurants. Anderson and Magruder (2012) find similar effects of Yelp ratings on restaurant reservations. However, revenue at chains does not respond to rating changes, likely because consumers already have information about quality. Ghose et al. (2012) uses a similar approach to understand the impact of TripAdvisor reviews. Beyond the average rating, other aspects of reviews are also important. For example, Sun (2012) explores the impact of the variance of product reviews, and highlights that if the variation in reviews of a product is driven by heterogeneous preferences, than higher variance ratings may be a better match for some customers, conditional on average rating.

Consumer reviews also have important implications for market structure and consumer welfare. Clemons et al. (2006) argue that information provided in reviews can help to grow demand for products with more differentiated products by increasing the quality of the match, and find generally consistent evidence when looking at reviews for beer and growth in demand. Bar-Isaac et al. (2012) theoretically show that introducing new information into a market will lead to a higher degree of product differentiation in markets. This suggests that the existence of platforms such as Yelp and TripAdvisor may lead to a greater variety of restaurants and hotels. Lewis and Zervas (2018) estimate the welfare effects of TripAdvisor reviews.

These are some of the myriad ways that online reviews are influencing markets, and that economics can help to explore these effects.

4. Positions for Economists at Tech Companies

In the previous section, we provided examples of the contributions of economics to technology firms by subject area. In this section, we explore the specific jobs and roles economists take within tech companies, as well as the critical skills for carrying out these jobs. Although many subject areas require a wide range of economic skills, an individual economist may be more specialized. For example, market design requires both theoretical and empirical skills, and while some expertise in both is a prerequisite for success, economists may specialize in one or the other.

In practice, economists within technology companies take on a number of roles ranging from Chief Economist to Product Manager. Economists often work within inward-facing teams at companies, including forecasting and planning teams, pricing teams, testing teams, and data science teams as well as outward-facing teams including policy teams, public relations teams, and marketing teams. Below we outline some examples of these roles and how economic skills can contribute.

Data Science/Analytics: This is one of the fastest growing sectors within a tech company as companies become more data-driven; economists use observational and experimental data to answer business questions, such as whether to introduce new products, how to understand the effectiveness of large initiatives, and how to evaluate the impact of competitors. Since this work directly informs the decisions of many other departments, some firms have embedded data scientists in product teams while others have centralized data science teams. For example, Amazon currently embeds data

scientists within product teams, while Yelp has a centralized data science team. Economists often help to manage teams of data scientists as well, for example at HomeAway.

Experimentation or A/B Testing: Tech companies are increasingly using experimentation or A/B tests to answer product or platform design questions, such as the launch of a new product or advertising campaign. Members of this team maintain the A/B testing platforms and conduct experiments. Economists here can manage the design, process, and analytics around randomized controlled experiments. Similar to data science/analytics teams, some firms have embedded A/B testing specialists within their functional teams (e.g. in marketing teams) while others have a separate team to manage a larger testing platform. For example, Uber has economists involved in understanding how to design experiments in a context with strong network effects and managing an experimentation platform and process that takes that into account. Other economists have developed and applied techniques for estimating heterogeneous treatment effects in A/B testing platforms (e.g. Athey and Imbens 2016; Wager and Athey, forthcoming).

Advertising/Marketing Analytics: If firms have embedded experimentation or data scientists into their advertising or marketing teams, they typically evaluate the effectiveness of advertising, optimize advertising spending, and predict the success of advertising campaigns. For example, Netflix has a team working on these issues.

Product Manager: Economists are adept at drawing causal inferences from observational data – for example, using difference-in-differences methods to evaluate the impact of a new product or feature. They can also design experiments and surveys that answer questions that guide product designs and other strategic decisions, including ranking algorithms in search platforms or presentation of information in stores.

Regulation/Litigation: In legal and corporate relations teams, the role of an economist includes writing policy white papers that translate theory and empirical work for a legal or policy audience, contributing their knowledge of specific subject areas such as telecommunications policy, intellectual property, and antitrust from an economic perspective. Chief economists often spend a share of time on these issues. Airbnb has economists trying to understand housing markets and policy. Uber has economists investigating the impact of Uber on the taxi industry and quality of rides. Google (and previously, Yahoo! and Microsoft) has had economists studying antitrust issues related to Google's dominant position in the search industry.

Public Policy: tech companies also have economists helping to partner with policymakers, often through data sharing and analysis. For example, Yelp partnered with the City of Boston to develop an algorithm that allowed the city to help target inspections for restaurant health code violations (Glaeser et al. 2016). Yelp data has been used to forecast government statistics, (Glaeser, Kim, and Luca 2017), understand how neighborhoods change during gentrification (Glaeser, Kim, and Luca 2018), and estimate the impact of the minimum wage on restaurant exit and prices (Luca and Luca 2017). Zillow, the online real estate company, creates reports of local housing markets. LinkedIn

is exploring the ways in which their data can help to shed light on labor markets. Uber's public policy team examines issues such as the impact of driving for Uber on driver welfare (Chen et al. 2017), and the impact of Uber on labor markets and local economies (Hall, Horton, and Knoepfle 2017).

Public and Media Relations: Several leading technology companies, including Zillow and Houzz, employ economists to create research designed to inform potential customers and simultaneously create awareness for the company. For example, a primary mechanism for Zillow to attract consumers in its early years was that its chief economist created analyses of real estate markets that was then be covered by local and national news media. Houzz employs PhD economists who analyze and publish trends and data relevant to home remodeling.

Chief Economist Team: This team conducts and oversees many of the roles outlined above and makes strategic decisions for the company. These decisions might include acquisitions and partnerships (one of us, Susan, worked on strategy and empirical analysis for Microsoft's investment in Facebook, the acquisition of Yahoo!'s search business, and the company's strategy for cloud computing), as well as pricing and market entry.

Other Teams: The skills of economists are by no means limited to the teams and roles above. Depending on the size of the company, economists have also gone into forecasting and planning teams (using time-series econometrics and modeling), pricing teams (using market design and supply-and-demand modeling), and academic relations (recruiting academics to fill the economic roles and build academic awareness surrounding policy and PR issues).

5. Discussion

While we have focused mainly on economists working directly in tech firms, the rise of tech companies and emergence of the economics of digitization has important implications for academia as well. The shifting field leads not only to new research questions, but also to new academic positions, opportunities for collaborations, and potential career shifts. In this section, we address these opportunities.

5.1. Partnerships with academics

While a growing number of economists now work within tech companies, collaborations with academics remain central to the strategy of tech firms and to the diffusion of economics within companies. For example, Amazon, Yelp, eBay, Microsoft, Uber, Airbnb, LinkedIn, Indeed, Zillow, Rover, and Facebook have all collaborated with academic economists. These collaborations have several advantages for companies.

First, academics often have deep expertise in focused areas. For example, an econometrician can help a company think through the frontier approaches to experimental methods with network effects (e.g. Athey, Eckles, and Imbens (2017) was written while Eckles was at Facebook). A behavioral economist can shed light on the foundations of how people search for products, to inform better designs of online

marketplaces. At the same time, academics are also well positioned to draw on insight from different contexts, since their work is less concentrated on a single platform.

Second, economists working full time within companies are often under pressure to deal with immediate issues (such as whether to change prices in a given quarter, or whether a specific advertising campaign was productive). By being insulated from these pressures, academics can explore longer-term issues that are of strategic importance, such as whether a company is even tracking the right metrics, or whether it makes sense to shift product composition.

Third, there can be pressure within a company to tow the company line, leading to potential blind spots. Working with academics and allowing a broad degree of autonomy can help to get more credible and objective assessments of issues that companies are dealing with.

5.2. Academic job market for digitization economists

There is a growing set of academic positions for digitization economists as well, many of which are in business schools. While some of these are in economics departments, digitization economists now also teach in strategy departments, marketing departments, information system departments, entrepreneurship departments, and others. Some of these positions recruit through AEA. However, other departments – such as marketing and information systems – are on other timelines and recruit outside of AEA. Doctoral students with interests in these areas should consider this before entering the job market.

5.3. Shifts between academia and practice

There are also growing opportunities for economists to shift between academia and practice. Microsoft, Google, Yahoo!, Facebook, Amazon, eBay, Yelp, Uber, and other companies have all hosted faculty during sabbatical. Tenured faculty members have left academia for positions at Amazon, Google, and elsewhere. Practitioners have also transitioned into academia – for example, leaving Facebook and Microsoft for MIT and Stanford. We believe this is the beginning of a much larger movement in which academics spend time in practice, acquiring a deeper understanding of the day-to-day challenges organizations face. As more PhD economists accept positions at tech companies, clearer paths for spending time (or re-entering) academia will likely appear, for those who are interested in this option.

References

Agarwal, Nikhil, Susan Athey, and David Yang. “Skewed bidding in pay-per-action auctions for online advertising.” *American Economic Review* 99, no. 2 (2009): 441-47.

Athey, Susan. “The impact of machine learning on economics.” Forthcoming in *The Economics of Artificial Intelligence: An Agenda,* University of Chicago Press, Ajay K. Agrawal, Joshua Gans, and Avi Goldfarb, editors.

Athey, Susan, Raj Chetty, Guido Imbens, and Hyunseung Kang, “Estimating treatment effects using multiple surrogates: The role of the surrogate score and the surrogate index.” Working paper. (2016).

Athey Susan, Dean Eckles, and Guido Imbens, “Exact p-values for network interference.” *Journal of the American Statistical Association* (2017 Nov 10): 1-11.

Athey, Susan, and Glenn Ellison. “Position auctions with consumer search.” *The Quarterly Journal of Economics* 126, no. 3 (2011): 1213-1270.

Athey, Susan, and Guido Imbens. “Recursive partitioning for heterogeneous causal effects.” *Proceedings of the National Academy of Sciences* 113, no. 27 (2016): 7353-7360.

Athey, Susan and Denis Nekipelov. “A Structural Model of Sponsored Search Advertising.” Working paper. (2012).

Bar-Isaac, Heski, Guillermo Caruana, and Vicente Cunat. “Search, Design, and Market Structure.” *American Economic Review.* 102, no. 2 (2012): 1140-60.

Blake, Thomas, Chris Nosko, and Steven Tadelis. "Consumer heterogeneity and paid search effectiveness: A large-scale field experiment." *Econometrica* 83, no. 1 (2015): 155-74.

Blake, Thomas, Chris Nosko, and Steven Tadelis. "Returns to consumer search: Evidence from eBay." In *Proceedings of the 2016 ACM Conference on Economics and Computation*, pp. 531-545. ACM, 2016.

Bolton, Gary, Ben Greiner, and Axel Ockenfels. "Engineering trust: Reciprocity in the production of reputation information." *Management Science* 59, no. 2 (2013): 265-285.

Chen, M. Keith, Judith A. Chevalier, Peter E. Rossi, and Emily Oehlsen, “The value of flexible work: Evidence from Uber drivers.” Working paper. (2017).

Chevalier, Judith A., and Dina Mayzlin. “The effect of word of mouth on sales: Online book reviews." *Journal of Marketing Research* 43, no. 3 (2006): 345-354.

Clemons, Eric, Guodong Gao, and Lorin Hitt. “When Online Reviews Meet Hyperdifferentiation: A Study of the Craft Beer Industry,” *Journal of Management Information Systems*, Vol. 23, no. 2 (2006):149-171.

Cohen, Peter, Robert Hahn, Jonathan Hall, Steven Levitt, and Robert Metcalfe. “Using big data to estimate consumer surplus: The case of Uber.” Working paper. (2016).

Dai, Weijia, Ginger Jin, Jungmin Lee, and Michael Luca. “Aggregation of Consumer Ratings: An Application to Yelp.com.” Quantitative Marketing and Economics 2017.

Dai, Weijia, and Michael Luca. “Digitizing disclosure: The case of restaurant hygiene scores.” Working paper. (2018).

Dai, Weijia, Hyunjin Kim, and Michael Luca. “Effectiveness of paid search advertising: Experimental evidence." Working paper. (2018).

Edelman, Benjamin, Michael Luca, and Dan Svirsky. “Racial discrimination in the sharing economy: Evidence from a field experiment.” *American Economic Journal: Applied Economics* 9, no. 2 (2017): 1-22.

Edelman, Benjamin, Michael Ostrovsky, and Michael Schwarz. “Internet advertising and the generalized second-price auction: Selling billions of dollars worth of keywords.” *American Economic Review* 97, no. 1 (2007): 242-259.

Fisman, Raymond and Michael Luca. “Fixing Discrimination in Online Marketplaces.” *Harvard Business Review*, Vol. 94 (2016), no. 12: 88-95.

Fradkin, Andrey, Elena Grewal, and David Holtz. “The determinants of online review informativeness: Evidence from field experiments on Airbnb.” Working paper. (2017).

Glaeser, Edward, Andrew Hillis, Scott Kominers, and Michael Luca. “Crowdsourcing city government: Using tournaments to improve inspection accuracy.” *American Economic Review* 106, no. 5 (2016): 114-118.

Glaeser, Edward L., Hyunjin Kim, and Michael Luca. “Nowcasting gentrification: Using Yelp data to quantify gentrification.” *American Economic Association: Papers and Proceedings,* forthcoming. (2018).

Glaeser, Edward L., Hyunjin Kim, and Michael Luca. “Nowcasting the local economy: Using Yelp data to measure economic activity.” Working paper. (2017).

Hall, Jonathan, John Horton, and Dan Knoepfle, “Labor market equilibration: Evidence from Uber.” Working paper. (2017).

Hu, Nan, Jie Zhang, and Paul A. Pavlou. “Overcoming the J-shaped distribution of product reviews.” *Communications of the ACM* 52, no. 10 (2009): 144-147.

Huang, Jason, Nickolai Riabov, and David Reilly, “Measuring consumer sensitivity to audio advertising: A field experiment on Pandora Internet Radio." Working paper. (2017).

Johnson, Garrett A., Randall A. Lewis, and David H. Reiley. “When less is more: Data and power in advertising experiments.” *Marketing Science* 36, no. 1 (2016): 43-53.

Johnson, Garrett A., Randall A. Lewis, and Elmar I. Nubbemeyer. “Ghost ads: Improving

the economics of measuring online ad effectiveness." *Journal of Marketing Research* 54, no. 6 (2017): 867-884.

Lewis, Gregory and Giorgos Zervas. "Welfare Impact of Consumer Reviews: A Case Study of the Hotel Industry." Working paper. (2018)

Lewis, Randall A., and Justin M. Rao. "The unfavorable economics of measuring the returns to advertising." *The Quarterly Journal of Economics* 130, no. 4 (2015): 1941-1973.

Luca, Michael. "Revenue: The Case of Reviews, Reputation, and Revenue: The Case of Yelp.com." Working paper. (2011).

Luca, Michael. "Designing online marketplaces: Trust and reputation mechanisms." *Innovation Policy and the Economy* 17, no. 1 (2017): 77-93.

Luca, Michael. "User-Generated Content and Social Media." *Handbook of Media Economics*. (2015).

Luca, Michael, Jon Kleinberg, and Sendhil Mullainathan. "Algorithms Need Managers, Too." Harvard Business Review, 94, 1: 96-101.

Luca, Michael, and Georgios Zervas. "Fake it till you make it: Reputation, competition, and Yelp review fraud." *Management Science* 62, no. 12 (2016): 3412-27.

Luca, Dara Lee, and Michael Luca. "Survival of the fittest: The impact of the minimum wage on firm exit." Working paper. (2017).

Masterov, Dimitriy V., Uwe F. Mayer, and Steven Tadelis. "Canary in the e-commerce coal mine: Detecting and predicting poor experiences using buyer-to-seller messages." In *Proceedings of the Sixteenth ACM Conference on Economics and Computation*, pp. 81-93. ACM, 2015.

Mayzlin, Dina, Yaniv Dover, and Judith Chevalier. "Promotional reviews: An empirical investigation of online review manipulation." American Economic Review 104, no. 8 (2014): 2421–55.

Ostrovsky, Michael, and Michael Schwarz. "Reserve prices in internet advertising auctions: A field experiment." *Journal of Political Economy*, forthcoming. (2016).

Varian, Hal R. "Position auctions." *International Journal of industrial Organization* 25, no. 6 (2007): 1163-1178.

Wager, Stefan, and Susan Athey. "Estimation and inference of heterogeneous treatment effects using random forests." *Journal of the American Statistical Association*, forthcoming.

Figure 1: Examples of tech companies that have hired PhD economists

Alibaba	Lyft
AirBnB	Microsoft
Amazon	Netflix
AppNexus	Nuna
Coursera	Pandora
Didichuxing	PoliticalSheepdog.com
Digonex	Quantco
eBay	Redfin
ECONorthwest	Trulia
Facebook	Uber
Forkcast	Upwork
Google	Vericred
Granular	Walmart
Groupon	Wealthfront
Houzz	Yelp
IBM	Zillow
Intel	Indeed
Kensho	Glassdoor
Keystone	

Figure 2: The number of positions in tech companies, policy schools, business schools, and economics departments

	T*ech companies*	**P*olicy schools***	**B*usiness schools***	**E*conomics departments***
Feb 2017-Jan 2018	21	34	162	194
Feb 2016-Jan 2017	20	23	149	199
Feb 2015-Jan 2016	18	31	150	218
Feb 2014-Jan 2015	15	26	133	232

Table 1: Examples of papers related to the economics of digitization

Reviews and Reputation Systems	**Industrial Organization:** Jin, G. Z., & Kato, A. (2006). Price, quality, and reputation: Evidence from an online field experiment. *RAND Journal of Economics, 37*(4), 983-1005. Lewis, G., & Zervas, G. (2016). The welfare impact of consumer reviews: A case study of the hotel industry. Working paper. Luca, M. (2011). Reviews, reputation, and revenue: The case of Yelp.com. Working paper. **Labor Economics:** Pallais, A., & Glassberg Sands, E. (2016). Why the referential treatment? Evidence from field experiments on referrals. *Journal of Political Economy, 124*(6), 1793-1828. Luca, D. L., & Luca, M. (2017). Survival of the fittest: The impact of minimum wage on firm exit. Working paper. **Market Design:** Bolton, G., Greiner, B., & Ockenfels, A. (2013). Engineering trust: Reciprocity in the production of reputation information. *Management Science, 59*(2), 265-285. Chevalier, J. A., & Mayzlin, D. (2006). The effect of word of mouth on sales: Online book reviews. *Journal of Marketing Research, 43*(3), 345-354. Luca, M., & Zervas, G. (2015). Fake it till you make it: Reputation, competition, and Yelp review fraud. *Management Science* 62, no. 12 (2016): 3412-27. **Public Economics:** Dai, D., & Luca, M. (2016). Digitizing disclosure: The case of restaurant hygiene scores. Working paper. Elfenbein, D. W., Fisman, R., & McManus, B. (2012). Charity as a substitute for reputation: Evidence from an online marketplace. *Review of Economic Studies, 79*(4), 1441-1468. Gordon, T. P., Knock, C. L., & Neely, D. G. (2009). The role of rating agencies in the market for charitable contributions: An empirical test. *Journal of Accounting and Public Policy, 28*(6), 469-484.
Social Media	Bailey, M., Cao, R., Kuchler, T., & Stroebel, J. (2016). Social networks and housing markets. Working paper.. Gans, J. S., Goldfarb, A., & Lederman, M. (2016). Exit, tweets, and loyalty. Working paper. Shore, J., Baek, J., & Dellarocas, C. (2017). Network structure and patterns of information diversity on Twitter. Working paper.

Advertising Systems	**Industrial Organization:** Dai, D., Kim, H. & Luca, M. (2018). Effectiveness of paid search advertising: Experimental evidence. Working paper. Sahni, N. S., & Nair, H. S. (2016). Does advertising serve as a signal? Evidence from a field experiment in mobile search. Working paper. **Market Design:** Agarwal, N., Athey, S., & Yang, D. (2009). Skewed bidding in pay-per-action auctions for online advertising. *American Economic Review, 99*(2), 441-447. Edelman, B., Ostrovsky, M., & Schwarz, M. (2007). Internet advertising and the generalized second-price auction: Selling billions of dollars worth of keywords. *American Economic Review, 97*(1), 242-259. Ostrovsky, M., & Schwarz, M. (2016). Reserve prices in internet advertising auctions: A field experiment. *Journal of Political Economy*, forthcoming. Varian, H. R. (2006). Position auctions. *International Journal of Industrial Organization, 25*, 1163-1178.
Online Marketplaces	**Labor:** Gilchrist, D. S., Luca, M., & Malhotra, D. (2016). When 3 + 1 > 4: Gift structure and reciprocity in the field. *Management Science, 62*(9), 2639-2650. Hall, J. V., Horton, J. J., & Knoepfle, D. T. (2017). Labor market equilibration: Evidence from Uber. Working paper. Pallais, A. (2014). Inefficient hiring in entry-level labor markets. *American Economic Review, 104*(11), 3565-3599. **Market Design:** Duarte, J., Siegel, S., & Young, L. (2012). Trust and credit: The role of appearance in peer-to-peer lending. *Review of Financial Studies, 25*(8), 2455-2484. Eckles, D., Kizilcec, R. F., & Bakshy, E. (2016). Estimating peer effects in networks with peer encouragement designs. *Proceedings of the National Academy of Sciences, 113*(27), 7316-7322. Edelman, B., Luca, M., & Svirsky, D. (2017). Racial discrimination in the sharing economy: Evidence from a field experiment. *American Economic Journal: Applied Economics.* Horton, J. J. (2017). Price floors and employer preferences: Evidence from a minimum wage experiment. Working paper.