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The Monetization of Innovation*

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Abstract

We develop a dynamic model for digital service firms, which invest in monetization to generate revenues from services provided to customers for free. Our model captures and explains why such firms often build a large customer base and become highly valued while continuing to suffer losses—traditional models would struggle to explain this pattern. Counterfactual analysis reveals that monetization uncertainty slows technological advancement by diverting resources away from innovation. We also show that regulation aimed at protecting user privacy has sizable adverse effect on firm size and the quality of the offered service but, perhaps surprisingly, makes firms less unprofitable. On the other hand, regulation encouraging competition supports innovation.

Keywords: Monetization; Innovation; Digital service firms; Data privacy; Regulation.

JEL Classification Numbers: D21; G31; O31; O32.

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1 Introduction

The importance of digital services has grown dramatically over the last decade. Digital services span many different aspects of everyday life, as reflected by the large number of apps on people's smartphones. Importantly, these sophisticated and innovative services are offered to billions of customers mostly for free. The mere fact that customers generally do not pay for these services demonstrates that the economics of digital service companies are very different from that of traditional firms—i.e., whereas standard theories of the firm are based on the assumption that customer acquisition directly translates into revenues growth, this assumption fails to hold for most digital firms, such as Facebook, Google, Twitter, and many others. Given the increasing weight and welfare contributions of digital firms, understanding their economics is clearly important.

The key point we emphasize in this study is that digital service firms seek to "monetize" their customers as a separate activity from acquiring them; for instance, they sell finely-targeted advertising spaces to third parties by taking advantage of customers' data. Our paper aims at introducing and understanding monetization—defined as the process of generating revenues from existing customers as a distinct undertaking—in a model of firm dynamics. Monetization, like R&D, is an uncertain endeavor, as illustrated by the many examples of highly-valued firms that gained a large customer base but subsequently struggled (and sometimes failed) to attain profitability. By combining acquisition of customers through research and development (R&D) and the monetization of these customers through risky investments, our calibrated model explains the dynamics of these firms. Moreover, it investigates the impact of regulations aimed at protecting customer privacy or fostering competition in the digital service sector on innovation and firm outcomes, a topic of growing interest.

We start by documenting stylized facts about digital service firms. Using Compustat data, we document that the market capitalization of these firms has boomed over the last decade. Digital service firms are systematically different from firms in other industries—

including R&D-intensive firms—as well as from other firms that went public since the turn of the millennium. For example, digital service firms have largely intangible assets. They often suffer persistent operating losses for a number of years, struggling to attain profitability. At the same time, digital firms enjoy generous valuations. These joint characteristics constitute a challenge to traditional models of firm dynamics, which we tackle by explicitly modeling monetization.

Our model focuses on a firm that provides an innovative service to customers. Building on the quality ladder framework of Grossman and Helpman (1991), a firm invests in R&D to improve the quality of this service and, thus, attract and retain customers. A firm's customer base also fluctuates for idiosyncratic reasons and may decline due to competitors' technological advancements, similar to Aghion and Howitt (1992). Compared to existing models of innovation, the key novelty of our framework is that the firm invests in monetization in order to derive revenues from its customers. The outcome of monetization expenditures is uncertain, and the accumulation of monetization breakthroughs gives rise to a new type of intangible capital—the monetization stock—which represents the collection of ideas and technologies that enable the firm to earn revenues from its customer base.[1] For example, platforms aimed at selling virtual goods or advertising spaces would be part of the monetization stock, as would relationships with third parties interested in buying these virtual goods. In the model, firms dynamically optimize over both R&D and monetization expenditures. Overall, our model is closely related to growing literatures on customer acquisition, data economy, and the changing nature of the firm (see, e.g., Gourio and Rudanko, 2014; Einav et al., 2022; Farboodi and Veldkamp, 2020; Aghion et al., 2019).

We calibrate the model to match selected moments of digital service firms, and illustrate that our framework captures salient features of the data. Using this calibrated

[1] The development of "AdSense" by Google, which enabled the firm to generate advertising revenues from its existing search algorithm (available for free), constitutes a prominent example of a monetization breakthrough.

model, we analyze the intertwined dynamics of innovation and monetization and the effects on corporate outcomes. We show that, because innovation is not enough for digital service firms to become profitable, these firms sustain substantial monetization expenditures. As in the real world, our model illustrates that firms with a large customer base and cutting-edge technology often suffer sizable operating losses because of their significant monetization expenditures.[2] Despite being unprofitable, these firms are highly valued, which reflects the growth potential embedded in these expenditures and the ensuing prospect of successfully monetizing their customers. That is, our model can reproduce and explain why persistent operating losses coexist with a large customer base and generous firm valuations.

Our analysis shows that monetization affects the dynamics and timing of firm responses to shocks, in ways that are different from traditional models of firm dynamics. We show that positive exogenous shocks such as idiosyncratic customer windfalls lead to an immediate drop in profitability. The reason is that customers act as a catalyst for monetization, for instance, by making firms relatively more visible to third parties interested in buying virtual goods. Thus, customer windfalls encourage firms to sharply increase monetization expenditures. As a result, profitability first declines, and subsequently improves if these expenditures successfully expand the firm's monetization stock. We also show that innovation and monetization breakthroughs trigger different dynamics. Whereas innovation breakthroughs alone do not help improve firm's profitability—which, again, is at odds with existing models of firm innovation—it is the monetization breakthroughs that stimulate immediate improvements in net profit margin and firm value.

Given the growing importance of digital firms, we use a counterfactual setup in which monetization expenditures give rise to deterministic (rather than stochastic) increases in the monetization stock to examine how the uncertainty associated with monetization affects incentives to invest in technological progress. We show that firms are more will-

[2] See the article "Airbnb Swings to a Loss as Costs Climb Ahead of IPO" (*The Wall Street Journal*, February 11, 2020). Appendix D reports additional examples.

ing to invest in monetization in this counterfactual environment, which has a beneficial impact on firm profitability.[3] Furthermore, removing monetization uncertainty provides firms with greater incentives to invest in R&D—reflecting complementarities between monetization and R&D—which steers firms toward attaining greater service quality. Our analysis thus indicates that the uncertainty associated with monetization hampers profitability and innovation.

Digital firms have recently been under growing legal and legislative scrutiny, ranging from regulatory proposals aiming at protecting the privacy of users to antitrust lawsuits and schemes to foster competition. We study the impact of such regulations by means of counterfactual experiments. We show that regulation aimed at protecting consumer privacy (such as the General Data Protection Regulation in the European Union or the California Consumer Privacy Act) would make firms considerably smaller and would substantially reduce the innovativeness of their offered service. Yet, by reducing the upside potential from monetization, it would lead firms to invest less in monetization, which lowers firm unprofitability. That is, while firms would be smaller and less innovative with this type of regulation, they would be less risky. In turn, we show that policies aimed at making the digital sector more competitive would lead firms to increase their R&D ratios, then boosting their innovation rates.

The paper is organized as follows. Section 2 reviews the related literature. Section 3 motivates our study by illustrating the key characteristics of digital service firms. Section 4 presents the model and the calibration. Section 5 examines the model implications. Section 6 reports some counterfactual exercises. Section 7 concludes.

[3] This result reflects the concavity of returns to monetization, fixing service quality.

2 Related literature

Our paper contributes to several different strands of the literature. First, it relates to studies on digital service firms. Brynjolfsson, Collis, and Eggers (2019) find that digital goods generate consumer welfare that is currently not captured in GDP and Brynjolfsson et al. (2019) develop a measure that addresses this limitation (see also Byrne and Corrado (2019)).[4] Hulten and Nakamura (2018, 2020) propose an "Expanded GDP" measure to include free information goods available over the Internet. These studies highlight an important gap in the literature—namely the lack of models of aiming to understand the dynamics of digital service firms—that our study aims to fill.

In tackling such goal, our paper relates to models of customer acquisition, the data economy, innovation, and the changing nature of the firm. Gourio and Rudanko (2014), an influential early study on customer acquisition, examines the dynamics of customer acquisition using a search theoretic framework. Arkolakis (2016) study the growth of exporters in a setting with increasing marginal costs of acquiring customers. Gilchrist et al. (2017) investigate price dynamics in a general equilibrim model with customer markets. Einav et al. (2022) examine the role of the customer margin for innovation and growth, finding that the customer margin increases the size and growth contribution of the largest firms, but lowers the aggregate growth rate by diverting resources from research to customer acquisition. In comparison to these studies, we examine the interplay between acquiring customers via innovation and generating revenues from an existing customer base via uncertain investments in monetization.

Farboodi and Veldkamp (2020) build a model where firms accumulate data instead of capital. In their model, firms do not innovate and may choose to produce with negative profits because the production of goods also produces data. Differently, our model embeds endogenous innovation and the uncertain monetization of an existing pool of customers.

[4] Namely, Brynjolfsson, Collis, and Eggers (2019) show that the median Facebook user would need a compensation of about $48 to give it up for one month.

In our model, firms often face negative profits because it takes time and resources to accumulate monetization stock—e.g., to build the infrastructure making it possible to translate non-paying customers into revenues. Other studies on the role of data include Jones and Tonetti (2020), who study the implications of the nonrivalry of data, and Cong, Xie, and Zhang (2021), who examine how consumer data supports innovation and growth.

By recognizing that digital service firms are innovative, our paper is then also related to the literature on technological change and innovation, e.g., Aghion and Howitt (1992); Aghion and Tirole (1994); Klepper (1996) or Van Reenen (1996), among many others.[5] In a recent contribution, Aghion et al. (2019) investigate how IT advances may spur rising concentration and reduce incentives to innovate. In comparison to extant models of firm innovation, this study introduces an additional optimization margin, related to a firm's need to monetize successful innovations, and examines the impact of potential regulation of this dimension on innovation and firm characteristics.

More generally, our paper adds to the literature emphasizing the growing importance of intangible assets for nonfinancial firms (Hall, 2001; Corrado, Hulten, and Sichel, 2005; Corrado and Hulten, 2010), which may include knowledge or innovation capital (Hall, 2010; McGrattan and Prescott, 2010; Belo et al., 2021), organizational capital (Eisfeldt and Papanikolaou, 2013; Lustig, Syverson, and Van Nieuwerburgh, 2011), customer capital (Gourio and Rudanko, 2014; Dou and Ji, 2020; Fitzgerald, Haller, and Yedid-Levi, 2020), digital capital (Tambe et al., 2020), artificial intelligence (Babina et al., 2022) or automation capital (Martinez, 2019). In particular, we single out a novel component—the monetization stock—that accumulates as firms spend resources to generate revenues from their core services, which are provided to customers for free. Consistent with Belo et al. (2021) and Crouzet and Eberly (2020), we underscore the importance of non-physical capital to explain firm value by focusing on the nexus between monetization and innovation.

[5] Klette and Kortum (2004), Luttmer (2011) and Akcigit and Kerr (2018) examine firm dynamics and innovation in endogenous growth models.

Lastly, our paper contributes to the literature that investigates the secular change of the U.S. public corporation and of the economy. Over the last decades, there has been a striking increase in service firms (see Buera and Kaboski, 2012; Hsieh and Rossi-Hansberg, 2020) and R&D-intensive firms (Begenau and Palazzo, 2020), with newly-listed firms being smaller, less profitable (see also Denis and McKeon, 2018), and exhibiting higher cash flow volatility (Brown and Kapadia, 2007). Aghion et al. (2019) study how IT advances is changing the competitive landscape and growth. In the meanwhile, the number and market capitalization of public digital service firms—which largely possess all of these characteristics—increased sharply over the last two decades. By analyzing the dynamic of this new type of firms, our paper contributes to understanding the secular shift to a service-oriented, digital economy.

3 Motivating evidence

Digital service firms typically offer innovative services to customers, typically for free. This distinctive feature implies a separation between customer acquisition and revenues growth and, notably, marks the emergence of "monetization" as a distinct activity aimed to generate revenues from customers (often referred to as "users"). The growing significance of monetization is well exemplified in Figure 1, showing the count of the word "monetize" in the ten major U.S. newspapers.[6] The figure shows a steep increase starting in 2005, with the word count having more than quadrupled over the last decade.

Digital service firms use a range of monetization approaches, which can broadly fall into three categories. The first approach involves selling finely-targeted advertisements to third-parties by exploiting customer's data, which companies like Google and Facebook have mastered. The second approach focuses on selling virtual goods through otherwise free services. Many online gaming platforms have adopted this approach. A third approach involves providing a free basic service overlaid with a premium product accessible

[6] A similar approach is adopted, for instance, by Baker, Bloom, and Davis (2016).

at a recurring fee. For instance, companies like Dropbox have adopted this third approach. In all these approaches, customers do not initially bring revenues to the firm, but make monetization more effective. As an example, in the first approach, third parties are more willing to buy advertisement spaces from firms that have a large customer base, as potentially more people will display such advertisement.

Monetization breakthroughs should then be intended as achievements that enable the firm to make revenues from its customer base. For instance, the development of AdSense by Google was a major monetization breakthrough, as it enabled the company to significantly increase the advertising revenues from their search engine. As another example, one major challenge that Facebook faced and successfully overcame was generating advertisement revenues from its mobile users, which also constituted a monetization breakthrough. Conversely, Twitter may be viewed as a firm with a large customer base that has yet to fully monetize it. Yahoo! is another example of a firm that struggled with monetizing despite being one of the pioneers of the Internet era in the Ninties.

In the rest of this section, we look at firm-level data from Compustat and explore the key characteristics of digital service firms. We illustrate how these firms are fundamentally different from other firms, including R&D-intensive firms in other industries and other firms that went public around the turn of the century.

3.1 Data

Data comes from the annual Compustat/CRSP industrial database. The sample period extends from 1995 to 2019. We exclude foreign firms as well as financial firms (SIC code 6000-6999) and utilities (SIC code 4000-4999). We drop observations with real sales or real total assets smaller than $10 million or missing. We also drop observations with missing SG&A expenditures, operating income and for which we cannot calculate the firm's market value and sales growth.

Given the wide range of services offered by these firms—then potentially spanning several industries—defining digital service firms poses a challenge. We adopt a parsimonious approach based on SIC codes and time of listing. Specifically, our definition of digital service firms comprises firms listed since 1995 that belong to the four-digit SIC code 7370, which corresponds to "Services: Computer programming, data processing, etc." Among these firms, we only include those that offer services through the Internet. This definition captures most major digital service firms such as Google's parent Alphabet, Facebook, and Twitter.[7] Additional details regarding the sample construction are reported in Appendix B.

Figure 2 (left panel) shows that the (inflation-adjusted) market capitalization of public digital service firms has increased steeply over the last two decades. The figure shows that the aggregate market value of these firms first reached a peak in 1999, before the burst of the dot-com bubble. It then picked up again and increased steeply after the 2007–2009 financial crisis, more than tripling from 2009 to 2018. This upward trend is particularly impressive given that the total number of listed firms has decreased during the same time period, as documented by Doidge, Karolyi, and Stulz (2017) and Kahle and Stulz (2017) among others. The right panel of Figure 2 illustrates that the sales of digital service firms have also increased notably over the last decades.

3.2 Key characteristics of digital service firms

To single out the distinctive features of digital service firms, we define some comparison groups. The "Non digital service" group (henceforth, labeled as "Non-DS") encompasses all the firms in our sample that do not meet the definition of digital service firms. The "R&D" group refers to firms belonging to the R&D-intensive industries that are close

[7] In unreported results, we also employ alternative definitions, including starting the sample of digital service firms from the year 2000 or, among the digital service firms, excluding those that charge customers a fee. Note that our definition excludes Amazon—which embraces several businesses including grocery stores (after the acquisition of Whole Foods Market Inc.) and whose primary source of profits is given by its Cloud services—and Netflix—which indeed *does* make revenues out of its user base.

in focus to digital service firms—i.e., software, business services, chips, and hardware.[8] Finally, "New" firms are those that went public since 1995 (to just we exclude digital service firms, to avoid double counting).

Table 1 shows that digital service firms are more R&D-intensive than Non-DS firms. Digital service firms have assets that are less tangible. Also, they display a larger *gross* profit margin thanks to their small marginal costs of production. Yet, digital service firms exhibit much larger selling, general, and administrative (SG&A) expenditures than Non-DS firms.[9] Furthermore, digital service firms are more likely to suffer operating losses than Non-DS firms, a feature that has been stressed by several market commentaries.[10] Notably, the fraction of firms suffering losses is more than twice as large for digital service firms compared to Non-DS firms. Moreover, their net profit margin is on average negative, and thus much lower than the positive net profit margin of Non-DS firms. Despite this striking unprofitability, digital service firms enjoy larger valuations than Non-DS firms. In fact, the table shows that the average value (normalized by sales) of digital service firms is almost twice as large than that of Non-DS firms.

Digital service firms are also quite different from R&D firms. In spite of having similar R&D intensities,[11] Digital service firms have larger SG&A expenditures than R&D-intensive firms. In fact, differently from R&D firms, digital service firms invest in monetization to derive revenues from their technological breakthroughs. Digital service firms' monetization expenditures inflate SG&A expenditures compared to R&D firms—as a result, R&D firms are less likely to suffer losses and, on average, have a positive net profit margin. Although digital service firms suffer losses and have a negative net profit margin, they exhibit a greater gross profit margin, on average, thanks to their small costs

[8] That is, we exclude pharmaceutical and medical equipment companies from our definition of R&D firms, because their business model is quite different from that of digital service firms. Including these industries would widen the gap between R&D-intensive firms and digital service firms further.

[9] As noted by Peters and Taylor (2017) and Belo et al. (2021), Compustat almost always adds R&D expenses to SG&A (and even if firms report SG&A and R&D separately), reporting them together in the variable XSGA.

[10] We report anecdotal evidence and some examples from the financial press in Appendix D.

[11] In unreported results, we look at R&D expenditures normalized by assets (rather than by sales).

of goods sold. Overall, they have much larger valuation ratios than R&D firms.

Finally, Table 1 shows that digital service firms are largely distinct from firms in the "New" group too. Digital service firms earn larger gross profits than new firms. However, digital service firms exhibit much larger SG&A expenditures—as a result, they are more likely to suffer losses than new firms. Furthermore, digital service firms' valuation ratios are on average much larger than those of new firms.

This analysis illustrates that digital service firms are systematically different from firms in other industries as well as from other R&D-intensive firms. In the next section, we develop a model that is explicitly designed to understand the dynamics of these firms.

4 The model

To understand the economics of digital service firms, we develop a model that has two distinctive features. First, investment in innovation improves a firm's service quality and, thus, helps the firm expand its customer base. Second, investment in monetization is vital to generate revenues from the firm's customer base and, thus, achieve profitability.

4.1 Assumptions

Time is discrete, and the horizon is infinite. Agents are risk neutral and discount payoffs at the constant rate β.

Customer base. We consider a firm that provides a service to customers at no charge. The size of the firm's customer base, denoted by C, depends on endogenous and idiosyncratic components. The endogenous component is the firm's service quality, denoted by q. Intuitively, more customers are drawn to the firm's service if its quality is higher. As we describe below, the firm can actively improve its service quality q by investing in R&D. In turn, the idiosyncratic component of the customer base, denoted by c, represents changes in the customers' demand for the firm's service that are beyond the firm's control.

We assume that the customer base is multiplicative in the firm-specific (endogenous) and idiosyncratic components, which yields

$$C = qc. \tag{1}$$

Innovation through R&D investment. The firm actively seeks to retain and expand its customer base by increasing its service quality q through R&D investment. As in previous models of firm innovation, improving quality via R&D expenditures is costly and has an uncertain outcome.[12] If the firm spends the flow cost zq on innovation, it affects the probability of attaining a breakthrough as follows:

$$\Psi(z) \equiv P(\theta = 1) = 1 - e^{-\delta z}, \tag{2}$$

where θ represents a binary random variable that equals one if the firm attains a breakthrough, and zero otherwise. Equation (2) implies that the larger the firm's R&D expenditures, the higher the probability of attaining a technological breakthrough. The parameter $\delta > 0$ governs the sensitivity of this probability to R&D expenditures: if δ is greater, the firm is more likely to attain a technological breakthrough for any given R&D expenditure z. The flow cost zq implies that technological breakthroughs are more costly to attain if the quality of the service is higher, as in previous models of firm innovation. When the firm attains a breakthrough, the firm's service quality jumps from q to

$$q' = q(1 + \lambda), \tag{3}$$

where $\lambda > 0$ represents the size of the quality improvement. As the customer base is proportional to the quality level (see Equation (1)), a technological breakthrough effectively

[12] Among many others, see Warusawitharana (2015), Malamud and Zucchi (2019), and Bustamante and Zucchi (2022).

leads to an increase in the customer base.[13]

Competitive pressure. The firm's service quality q represents its degree of technological advancement, which stems from the accumulation of successful breakthroughs. We assume that the firm's technological edge is threatened by competitors, who also invest in R&D and may launch higher-quality services. Breakthroughs by competitors then make the firm's service obsolete. We model this obsolescence as a reduction in the firm's service quality, which leads to some customer churn.

Specifically, we assume that competitive threats due to technological advancements by competitors materialize in a stochastic fashion and are modeled as a binary random variable, $\Theta \in \{0, 1\}$. If a competitive threat materializes (i.e., Θ equals one), the firm's service quality declines by a factor $\Lambda \in [0, 1]$, as follows:

$$q' = q(1 - \Lambda). \tag{4}$$

This leads to a reduction in the firm's customer base, as per Equation (1). We assume that the probability of competitors' technological advancements is given by $P(\Theta = 1) = \chi$ on each period. If $\Lambda = 0$ or $\chi = 0$, the firm faces no competitive pressure.[14]

Idiosyncratic shocks. Equation (1) illustrates that a firm's customer base has an idiosyncratic component. This modeling feature captures the idea that customers may try out services provided by competitors. For instance, they may switch from one social media service to another, or may simply stop using a given service—e.g., they may close an online social media account because of privacy concerns.

To capture these fluctuations, we assume that the idiosyncratic component of the

[13]Our model emphasizes the acquisition of customers through stochastic innovations. Other studies that model deterministic acquisition of customers include Foster, Haltiwanger, and Syverson (2016) and Fitzgerald, Haller, and Yedid-Levi (2020).

[14]As our focus is on the dynamics and decision-making process of a single firm, competitive threats are modeled in a parsimonious, reduced-form fashion.

customer base c exhibits the following dynamics:

$$\log(c') = \rho \log(c) + \epsilon, \quad \epsilon \sim N(0, \sigma^2). \tag{5}$$

In this equation, ϵ represents a normally-distributed shock with zero mean and variance σ^2. The parameter ρ denotes the persistence of the idiosyncratic component of the customer base.

Monetization. The firm's success depends on both its ability to innovate its service—which helps the firm retain and expand its customer base—*and* to monetize such innovations. As a result, the firm needs to invest in innovation *and* monetization. Like innovation, we assume that monetization expenditures have an uncertain outcome. We allow monetization advancements to persist by modeling the firm's monetization stock, which reflects the collection of ideas, technologies, and relationships with third parties that enable the firm to earn revenues from its customer base. For example, platforms aimed at selling advertisement spaces, relationships with third parties interested in buying these advertisement spaces, and portals for vending virtuals goods all constitute a firm's monetization stock.

The dynamics of the monetization stock, denoted by η, are described by the following transition equation:

$$\eta' = \eta (1 - \phi) + SM, \quad M \sim Exp(\nu). \tag{6}$$

In this equation, S denotes the firm's monetization expenditure, which is chosen by the firm each period. Equation (6) captures the uncertain outcome of monetization expenditures through the random variable M, which is exponentially distributed with inverse scale parameter ν. As a firm spends more on monetization, the expected increase in the monetization stock is greater. Namely, if the firm spends S on monetization, it expects to attain an increase in the monetization stock equal to S/ν—i.e., monetization expenditures have a larger upside potential for smaller values of ν. If a firm were to cease spending on monetization ($S = 0$), the monetization stock would decrease over time at the depreciation rate ϕ. The depreciation of the monetization stock reflects potential deterioration in the technological infrastructure and relationship that enable the firm to derive revenues from its customer base.

The following example illustrates our modeling of monetization. Suppose that the firm makes a monetization expenditure S to improve, for instance, its algorithm aimed at selling finely-targeted advertisements. The larger the monetization expenditure, the greater the *expected* increase in the monetization stock. However, the realized increase in the monetization stock is uncertain. In fact, if the algorithm does not end up working as hoped, the expenditure S will yield little or no increase in the firm's monetization stock—i.e., the realization of the random variable M will be small. Conversely, if the new algorithm is developed successfully, it has the potential to boost the firm's ability to make revenues if the firm attracts third parties interested in buying its advertising spaces. The algorithm and the business relationships with third parties will wear (i.e., they depreciate at rate ϕ) over time unless they are periodically maintained or nurtured.

The firm's revenue function. The firm's revenues stem from selling virtual goods or advertising spaces to third parties, whose price is normalized to one.[15] Intuitively, a larger customer base makes the firm more visible and, thus, helps attract third parties to whom the firm can sell virtual goods or advertising spaces. Yet, the customer base is not sufficient for the firm to make revenues. In fact, the firm needs to accumulate monetization stock. Notably, and in contrast with traditional models of firm dynamics, the firm's customer base is an input of the revenue function.

Thus, we assume that the firm's revenue function depends on its monetization stock

[15] Because we abstract from general equilibrium effects and just focus on the optimal policies of a single firm, our model does not capture effects stemming from the demand for the virtual goods/advertising spaces and, thus, does not separate prices from quantities sold.

η as well as on its customer base C as follows:

$$\pi(C, \eta) = \eta^{\alpha} C^{1-\alpha}, \tag{7}$$

where the parameter α denotes the elasticity to the monetization stock. This Cobb-Douglas specification captures the complementarity between customer base and monetization stock. All else equal, firms offering more innovative products will have a larger customer base and, thus, should find it easier to make revenues. However, a firm also needs to invest in monetization to generate revenues.

On top of monetization and R&D expenditures, the firm sustains operating costs in any period. Specifically, we assume that operating costs scale with the firm's service quality by a factor $\gamma > 0$ and are therefore equal to γq.[16] Similar to Barlevy (2007), we adopt this specification to avoid that the firm outgrows its operating cost.

4.2 Discussion of assumptions

The key aspect of our setup is the explicit modeling of the firm's investment in monetization. Similar to innovation, monetization absorbs resources and has an uncertain outcome. That is, differently from pure R&D-intensive firms, digital service firms face substantial uncertainties not only at the innovation stage but also at the monetization stage. To the best of our knowledge, this is the first paper that explicitly takes this additional source of uncertainty into account.

The need to invest in monetization stems from the fact that the customer base of digital service firms does not map to revenues as in traditional models of firm dynamics. Rather, a firm's customer base serves as an input of production, and can be viewed as the catalyst that helps digital service firms turn non-revenue-generating services into

[16]This modeling implies that while operating costs rise as firms build their customer base through increases in service quality, they do not depend on idiosyncratic fluctuations in customers. This assumption captures infrastructure and labor needed to support the customer base, net of idiosyncratic fluctuations.

revenues—i.e., by increasing the firm's visibility, a larger customer base makes monetization more valuable. For example, a third party is more willing to buy an advertising space from a firm that has a large customer base. Notably, our modeling can embrace the three real-world monetization approaches discussed at the beginning of Section 3.

Consistent with the observation that digital service firms exhibit low asset tangibility—as illustrated in Section 3—our model emphasizes the key role of non-physical capital in understanding firm dynamics. In a similar vein, Belo et al. (2021) show that the importance of physical capital in explaining firm value has decreased in the last decade, while the importance of knowledge capital has increased, especially in high-tech industries. In our model, we have two distinct components of intangible capital: the technological capital embedded in the firm's service quality and the monetization stock. To the best of our knowledge, this is the first paper to embed this dual dimension.

Whereas our model abstract from a full-fledged analysis of industry dynamics, we recognize that digital service firms do not operate in a vacuum and capture competitive pressure in reduced form. In fact, digital service firms compete on the innovation dimension to improve the quality of their service vis-à-vis competitors, in order to maintain and expand their customer base. Whenever competitors innovate the quality of a similar service, the firm's service becomes less attractive, causing some customer loss.

We emphasize that our model does not aim to describe early-stage startups, whose business ideas are at a preliminary stage. Startups typically do not have a well-developed service that customers can access. Startups are still at the stage of struggling to get financing from venture capitalists, angel investors, or family and friends, while they develop their business idea. Rather, our paper aims to understand the decisions of firms with an established business idea, which already provide virtual services to customers. In addition, our paper abstracts from the financing decisions of these firms, which we leave for future research.

4.3 The firm problem

The firm maximizes the expected present value of payouts to shareholders. The ensuing Bellman equation is given by:

$$V(c, q, \eta) = \max_{S,z} \quad \pi(C, \eta) - \gamma q - zq - S + \beta E[V(c', q', \eta')] \tag{8}$$

subject to equations (5)-(6) and with the endogenous dynamics of service quality satisfying

$$q' = \begin{cases} q(1+\lambda) & \text{with prob.} \quad \Psi(z)(1-\chi) \\ q(1-\Lambda) & \text{with prob.} \quad \chi(1-\Psi(z)) \\ q(1-\Lambda)(1+\lambda) & \text{with prob.} \quad \chi\Psi(z) \\ q & \text{with prob.} \quad (1-\chi)(1-\Psi(z)) \end{cases} \tag{9}$$

Equation (8) shows that the state variables of the firm problem are the customer base, which embeds its idiosyncratic and endogenous components c and q, and the firm's monetization stock η. Current dividends to shareholders are given by revenues (the first term in Equation (8)) net of operating costs, R&D expenditures, and monetization expenditures (second through fourth terms, respectively).[17] In the following, we refer to the sum of R&D and monetization expenditures as SG&A expenditures. The last term in Equation (8) is the continuation value of the firm.

As in previous innovation models, larger R&D expenditures decrease dividends and increase the probability of attaining a technological breakthrough, as shown by Equation (2). A technological breakthrough increases the quality of the firm's service by a factor λ (see Equation (9)), which leads to an increase in the firm's customer base. At the same time, competitive pressure can lead to a reduction in the relative quality of the firm's service by a factor Λ with probability χ. By differentiating Equation (8) with respect to

[17]Negative dividends to shareholders should be interpreted as equity issuances.

z, we obtain the firm's optimal R&D expenditures (see Appendix A for a proof).

Proposition 1 *The firm's optimal R&D expenditures is given by:*

$$z = \frac{1}{\delta} \log \frac{\beta\delta\Big(E[V(c', q', \eta')|\theta = 1] - E[V(c', q', \eta')|\theta = 0]\Big)}{q}, \tag{10}$$

with $E[V(c', q', \eta')|\theta = 1]$ *representing expected firm value conditional on attaining a technological breakthrough, and* $E[V(c', q', \eta')|\theta = 0]$ *being expected firm value conditional on failing to attain a technological breakthrough.*

Intuitively, Proposition 1 suggests that if the expected increase in firm value following a technological breakthrough is greater (the numerator of Equation (10)), the firm has greater incentives to invest in R&D expenditures. The term q at the denominator of Equation (10) captures the idea that when quality is already large, returns to innovation diminish, consistent with the existing literature (see, e.g., Aghion and Howitt, 1992).

Consider now the firm's optimization over monetization expenditures, S. Equation (7) implies that the firm generates no revenues from its customer base as the monetization stock approaches zero.[18] As a result, firms have strong incentives to invest in monetization. Yet, the firm's monetization expenditures translate into uncertain increases in the firm's monetization stock, as shown by the transition equation for η (see Equation (6)). Like R&D expenditures, monetization expenditures also drain current dividends but have the potential of leading to greater increases in the firm's monetization stock and, thus, to higher future revenues. The complexity of the dynamics of the monetization stock, including the uncertainties therein, imply that one cannot derive a closed-form expression for the optimal monetization expenditure S. Therefore, we solve the model numerically.

[18] Indeed, the Inada conditions apply.

4.4 Calibration

We calibrate the model using firm-level data from Compustat, as described in Section 3.1. We aim at minimizing the difference between a selected set of moments calculated from our empirical sample of digital service firms and from our simulated model.[19] We choose moments that capture the key characteristics of digital service firms described in Section 3.2.[20]

Table 2 reports the moments from the data and from the simulated model. It illustrates that the model reproduces the empirical characteristics of digital service firms well. The model captures the healthy gross profit margin of these firms as well as their substantial SG&A expenditures, which nest R&D and monetization expenditures.[21] Notably, the model captures the average share of R&D expenditures to SG&A expenditures, which is 17.1% in the data versus 17.9% in the model simulation. Our model also reproduces well the autocorrelation of R&D to sales.

Large SG&A expenditures imply that a notable fraction of firms makes operating losses. In the simulated model, this fraction is equal to 36.4%, which is slightly lower than its empirical counterpart (equal to 39.9%). At the same time, the model reproduces well the elevated valuation ratios of these firms. The model also replicates some key characteristics of digital service firms' sales growth—in particular, its high standard deviation as well as its sensitivity to SG&A expenditures. The model's sensitivity of SG&A expenditures to revenues is also fairly close to its empirical counterpart.

Table 3 reports the parameter values that enable this matching. The monetization

[19] Following previous studies, the discount rate β is not calibrated. We follow Gomes (2001) and set $\beta = 1/1.065$.

[20] In Appendix C, we show that our calibration is robust to excluding digital service firms that charge some fees (of different types) to their customers.

[21] The average SG&A expenditures to sales are smaller than its empirical counterpart. In our model, SG&A expenditures only include R&D and monetization expenditures, whereas in the real world they include, among others, expenses related to labor and IT, as emphasized by Eisfeldt and Papanikolaou (2013). Whereas monetization expenditures in the model can be seen as including the wages of "monetization specialists" and engineers as well as the cost of maintaining platforms deemed to sell virtual goods, we abstract from the wages of other IT costs or administrative costs (e.g., directors' fees and remuneration, legal expenses).

share in the Cobb-Douglas function, α, is equal to 0.55, which implies that the monetization stock has a pivotal impact on revenues. The operating cost coefficient, γ, is equal to 0.74. The idiosyncratic component of the customer base, c, has a positive autoregressive coefficient ρ, implying some persistence in the customer base. The standard deviation σ of the normally-distributed shock is about 0.67.

The size of quality improvements upon a technological breakthrough, λ, is set to 9%. This value is greater than that in a number of models of innovation-driven growth,[22] which reflects the sustained improvement in service quality in this segment of the economy. Moreover, the sensitivity of the probability of technological breakthroughs to R&D expenditures, δ, is about 2.6. The probability of competitive threats, χ, is equal to 0.23, whereas the associated size of quality drops, Λ, is equal to 8.2%. Overall, these parameters imply that expected increases in service quality from the incumbents' endogenous innovations are about equal to the expected decreases in quality from competitive threats, which confirms that we focus on a stationary distribution of firms.

Turning to the monetization-related parameters, we set ν to 0.92. For any given monetization expenditure S, a greater ν implies a smaller expected increase in the monetization stock, albeit less dispersed. Moreover, the value of ϕ, which equals 0.26, implies that the monetization stock depreciates at a rate consistent with the range reported by Hall (2010) and Corrado, Hulten, and Sichel (2009) for different categories of intangible assets.

Table 4 reports additional moments from our calibrated model, focusing on those for which the empirical counterpart is not available due to data limitations. The table shows that the average innovation rate is 23%, which reflects the idea that digital service firms continually seek to increase service quality. The ratio of monetization expenditures to sales is 49%, illustrating that digital service firms heavily spend on monetization. Also, the model's monetization-to-SG&A ratio confirms that monetization expenditures

[22] For instance Akcigit and Kerr (2018) or Akcigit, Hanley, and Serrano-Velarde (2019).

represent the lion's share of SG&A expenditures.

Table 4 also reports revenues per customers, which has become a metric of interest to summarize digital service firms' gross profitability. On average, revenue per customers is about 2.5, with a standard deviation about equal to 1.2. Furthermore, Table 4 shows that the growth rate of the firm's customer base has a larger standard deviation than that of sales growth (which is reported in Table 2). Not surprisingly, the results show that the customer base is more volatile than service quality. This result reflects that a firm's customer base is not only driven by service quality, but also by idiosyncratic changes in customers' preferences.

5 Model implications

5.1 Analyzing firms along innovation or monetization progress

In our model, service quality represents the firm's degree of technological advancement through innovation. In turn, the monetization stock represents the collection of ideas, technologies, and resources that allow the firm to make revenues out of innovation. To understand firms' differences along the technological and monetization dimension, Table 5 shows selected moments for firms sorted by quartiles of service quality (top panel) and monetization stock (bottom panel).

Confirming the importance of monetization expenditures for digital service firms, the table shows that firms spend much more on monetization than on innovation, which is true across quartiles of both monetization stock and service quality. Monetization expenditures increase in absolute value across quartiles of service quality, and the ratio of monetization expenditures to sales remains quite large throughout. The reason is that a large service quality does not bring revenues to the firm unless is backed by monetization. Further reflecting the complementarity between innovation and monetization, the bottom panel shows that R&D expenditures increase in absolute level across quartiles of monetization stock—i.e., greater ability to monetize (as summarized by the magnitude of the monetization stock) spurs firm's investment in innovation. As a result, the firm's innovation rate increases notably across quartiles of monetization stock, and so do the average service quality and the firm's customer base.

Turning to profitability, the table shows that the fraction of firms making losses varies sharply across quartiles of monetization stock and much more than across quartiles of service quality. This fraction goes from more than 80% in the lowest monetization quartile to virtually zero in the highest quartile, whereas it goes from about 44% in the lowest quality quartile to 27% in the highest one. Furthermore, whereas revenues per customer decrease across quartiles of service quality, these quantities *increase* as the monetization stock grows. These results illustrate how excelling in the innovation dimension (i.e., attaining a high service quality) is not sufficient for digital service firms to become profitable, in sharp contrast with existing models of firm innovation in which technological advancements lead to direct improvements in firm's profitability. That is, by unbundling R&D success and customer acquisition from revenues growth, our model can reproduce the puzzling real-world observation that many digital service firms remain largely unprofitable in spite of offering a cutting-edge service utilized by a large customer base.

We next study firms along the dual dimension of innovation and monetization. To this end, Table 6 sorts our simulated firms into bins of high/low service quality and high/low monetization stock, where "high" and "low" are defined to be above and below their sample medians, respectively. Table 6 shows that about 36% of firms have both monetization stock and quality levels above the median (henceforth, denoted as HH firms), and 35% of firms have service quality and monetization stock below this median (henceforth, LL firms)—that is, firms tend to advance their monetization stock together with their service quality. The remaining firms are quite evenly split between firms with low quality and high monetization (henceforth, LH firms) and firms with high quality and low monetization (henceforth, HL firms).

Table 6 shows that firms differ substantially in their optimal monetization and R&D expenditures across these bins. HL firms, which have attained a high service quality (and, thus, a solid customer base), display the largest monetization expenditures in the cross section (in absolute terms and relative to sales). These firms spend 76% of their sales on monetization expenditures, followed by LL firms, which spend about 65% of their sales on monetization (and only 5% on innovation). These large expenditures make these groups of firms (i.e., those in the low monetization bins) unprofitable, in spite of their healthy gross profit margins. Strikingly, about 80% of firms in the HL bin suffer losses, and about 60% of LL firms do. In turn, firms in the high-monetization bins (the HH and LH firms) exhibit the greater gross profit margins and the lowest frequencies of firms making losses.

Finally, the table shows that the ratio of firm value to sales is the largest for HL firms. Having a high service quality (and, thus, a large customer base) but low monetization stock, these firms have a high growth prospects despite their large operating losses. Our model is therefore capable of reproducing another important characteristic of digital service firms: They display high valuation ratios in spite of large and persistent losses. Indeed, these high valuations reflect the upside potential should the firm be able to monetize its customer base.

5.2 Profitable vs. unprofitable firms

We further analyze a pivotal characteristic of digital service firms: their frequent operating losses, which are suffered even by highly-valued firms. Table 7 shows selected moments for profitable versus unprofitable firms—respectively, those exhibiting a positive and negative net profit margin.

As in the data (see Table 2), a large fraction of firms sustains operating losses in our simulated sample. Table 7 illustrates that the average net profit margin of unprofitable firms is strikingly low. At the opposite side of the spectrum, the net profit margin of profitable firms is quite elevated. Several factors contribute to this huge gap. First, compared to profitable firms, unprofitable firms have smaller sales, which translate into tighter gross profit margins. Second, unprofitable firms sustain much larger SG&A expenditures than profitable firms, both in absolute terms and relative to sales. The lion's share of SG&A expenditures is due to monetization expenditures, which are larger for unprofitable firms.[23] Monetization expenditures, in turn, boost the growth potential of unprofitable firms. In fact, whereas profitable firms are more valuable in absolute terms, unprofitable firms exhibit larger valuation ratios, on average.

The table also shows that unprofitable firms exhibit a smaller monetization stock than profitable firms, on average. In turn, profitable and unprofitable firms exhibit similar service quality. This observation confirms that success along the innovation dimension is not enough for digital service firms to attain profitability. In fact, it is the success in the monetization dimension that spurs profitability. Notably, the lower sales of unprofitable firms are primarily driven by their smaller monetization stock rather than by a markedly-worse service quality.

5.3 Firm dynamics

We next investigate how the need to accumulate monetization stock affects the dynamics of digital service firms following exogenous shocks or endogenous breakthroughs.

We first consider the effect of an exogenous customer windfall on corporate decisions and outcomes. Specifically, Figure 3 studies the effect of a sizable increase in the idiosyncratic component of the firm's customer base c.[24] The top panel shows that whereas the gross profit margin increases after the customer inflow, the net profit margin immediately drops, becoming largely negative. The reason is that firms sharply increase their monetization expenditures after this shock (as shown by the middle left panel), in the attempt to monetize the new customers.[25] This increase in monetization expenditures

[23] In turn, R&D expenditures are slightly larger for profitable firms.

[24] We define the increase to be sizable if the change in c lies in the top quartile of its distribution.

[25] This effect is reminiscent of Gourio and Rudanko (2014), in which a productivity shock leads to an

results in a subsequent (lagged) rise in the firm's monetization stock (as illustrated in the bottom left panel), which rationalizes the lagged improvement in the firm's net profit margin (displayed in the top right panel). At the same time, firms on average increase their R&D expenditures too, which reflects the complementarity between monetization and innovation.

These results illustrate that digital service firms do not follow the typical dynamics implied by traditional models of the firm (for instance, neoclassical adjustment cost models or models of firm innovation). In fact, the decoupling of customer acquisition and revenues growth implies that positive idiosyncratic shocks lead to an immediate deterioration in profitability, due to a sharp surge in SG&A expenditures. As a result, the improvement in profitability is uncertain and lags the initial shock.

Next, Figure 4 investigates firm dynamics after technological (left panel) or monetization breakthroughs (right panel). Recall that these endogenous breakthroughs are the (uncertain) outcome of the firm's own monetization or R&D expenditures. The top left panel illustrates that, following a technological breakthrough, the firm's net profit margin remains largely unchanged, on average. A technological breakthrough leads to an increase in the firm's operating costs,[26] but leads to a modest decline in SG&A expenditures, as illustrated in the middle left panel. Firm value increases only slightly after the innovation breakthrough, and it subsequently reverts and declines, following the same downward pattern of the gross profit margin (see the bottom left panel). This decline reflects the various forms of mean reversion in the model, either due to exogenous shocks to the customer base, decreases in service quality due to competitors' innovations, or the depreciation of the monetization stock.

Finally, the right panel of Figure 4 shows that monetization breakthroughs entail quite different dynamics. The top panel shows that the firm's net profit margin increases

increase in selling expenses as the firm can effectively profit from the ensuing increase in production capacity by expanding its customer base.

[26]Recall that operating costs are equal to γq in our model.

sharply after a monetization breakthrough, in sharp contrast with the dynamics following an innovation breakthrough or a customer windfall (in Figure 3). Notably, the net profit margin goes from negative to positive, and remains positive for the subsequent time periods. Following the monetization breakthrough, firms reduce their SG&A expenditures, largely driven by a decrease in monetization expenditures. Overall, firm value sharply increase following a monetization breakthrough. This analysis then suggests that innovation and monetization breakthroughs generate different firm dynamics, with profitability improvements largely stemming from increases in the monetization stock.

5.4 The sources of value of digital service firms

We next investigate the determinants of the market value of digital service firms through the lens of our calibrated model. To this end, we run the following regressions on our simulated data:

$$V_{jt}(c, q, \eta) = a_0 + a_i X_{i,jt} + u_{jt} \tag{11}$$

where $X_{i,jt}$ represents the three state variables of the model—i.e., the firm's monetization stock η_{jt}, service quality q_{jt}, and the idiosyncratic component of the customer base c_{jt}—considered either individually or jointly. To facilitate comparisons, we normalize the variables by subtracting the sample median and dividing by the interquartile range.

Table 8 reports the regression coefficients as well as the R^2 of these regressions. The top panel shows the results using the whole sample. As expected, all the state variables of the model contribute to firm value with a positive coefficient. Yet, in the univariate regressions (first to third columns), using the monetization stock η as regressor gives the largest R^2, whereas using service quality q gives the smallest. Notably, the regression coefficient a_η is larger than those associated with the other state variables.

The second and third panels of Table 8 analyze the same regressions when sampling firms by profitability—as in Table 7, profitable (respectively, unprofitable) firms are those with positive (negative) net profit margin. Our analysis illustrates that unprofitable firms exhibit a greater sensitivity of firm value to the monetization stock—both the regression coefficient a_η and the R^2 are greater for this subsample. Recall that unprofitable firms exhibit generous valuation ratios despite their poor operating performance. Table 8 then illustrate that the growth potential embedded into the monetization stock is pivotal to explain the value of these firms.

Overall, by effectively enabling the firm to derive revenues from its customer base, the monetization stock represents a novel components of the firm's intangible capital, which helps explain the large valuation ratios of digital service firms despite their lingering unprofitability.

6 Counterfactuals

6.1 The impact of monetization uncertainty

Monetization and monetization uncertainty set digital service firms apart from pure R&D-intensive firms. First, the need to invest in monetization implies that digital service firms need to deflect some resources from innovation to monetization. Second, monetization expenditures translate into uncertain increases in the monetization stock—i.e., not only R&D expenditures have an uncertain outcome as in previous models of firm innovation, but also monetization expenditures do.

To isolate the effect of monetization uncertainty, we consider a counterfactual setup in which, for a given monetization expenditure S, the ensuing increase in the monetization stock is deterministic. Specifically, we modify Equation (6) to:

$$\eta' = \eta(1-\phi) + SE[M] = \eta(1-\phi) + S\nu^{-1}. \tag{12}$$

This specification implies that, for a given S, the increase in η is equal to the expected increase in the baseline model with monetization uncertainty. As a result, the firm does not face the risk of low (or zero) realizations of M. However, it does not gain from large realization of M either.

Table 9 compares selected moments from our baseline setup featuring monetization uncertainty with those associated with this counterfactual environment with no monetization uncertainty. Absent monetization uncertainty, the monetization stock is more sizable on average, which spurs larger sales compared to the baseline setup. This result reflects that, fixing the customer base, revenues are a concave function of the monetization level. As such, the expected rise in revenues stemming from a deterministic increase in monetization is greater than the expectation of the rise in revenues from stochastic increases in monetization.[27] In other words, absent monetization uncertainty, firms have greater incentives to spend on monetization. In fact, the table shows that monetization expenditures are on average much larger absent monetization uncertainty. Moreover, without uncertainty, sales growth is more sensitive to monetization and R&D expenditures.

An important related question is whether monetization uncertainty affects the firm's technological advancement and its service quality. The table shows that, on average, firms exhibit larger R&D expenditures absent monetization uncertainty, which results in a higher service quality. Figure 5 further illustrate the effect of monetization uncertainty on the endogenous distribution of service quality in the baseline case with monetization uncertainty (top panel) versus the counterfactual without monetization uncertainty (bottom panel). The figure shows that the distribution of service quality shifts to the right absent monetization uncertainty. In other words, our analysis illustrates that the uncertainty in the firm's monetization ability slows technological advancements.

Absent uncertainty, the larger monetization stock and service quality lead to higher sales. Greater service quality, however, also leads to larger operating costs, which implies

[27] This result stems from an application of Jensen's inequality.

that the firm's gross profit margins are quite similar with/without monetization uncertainty. At the same time, because monetization and R&D expenditures absorb a lower fraction of sales absent monetization uncertainty (as illustrated by the lower share of SG&A to sales), firms are less likely to make operating losses. In fact, Table 9 shows that about 33.5% of firms suffer losses in this counterfactual, which is smaller than the 36.4% in the baseline case with monetization uncertainty.

6.2 Regulating monetization

The way digital service firms monetize their customers has recently been at the heart of several policy discussions. Some key examples are regulations aimed at protecting customer's privacy and data, targeting content moderation, or imposing standards on ads transparency. For example, the introduction of data privacy laws such as the General Data Protection Regulation in Europe or the California Consumer Privacy Act imposed burdens on digital service firms by requiring businesses to get consumer consent before collecting their data to serve them ads or to share customer data with advertisers, analytics services, or vendors and service providers.

Such regulations can directly impact digital service firms by: (1) making it harder to accumulate monetization stock, (2) causing a faster depreciation of the monetization stock, (3) inflating operating costs. The first type of effects can materialize, for instance, with the enforcement of privacy rules making it harder for digital service firms to sell finely-targeted ads (which makes use of customer's data) or sell customer data to third parties. The second type of effects can be triggered, for instance, by regulation allowing digital service firms to retain customer's data for a limited time only. The third type of effects can be triggered by rules imposing so-called investment in security—requiring Internet security teams or imposing privacy tools on virtual platforms—which results in higher operating costs. We study these different types of regulations by means of counterfactual experiments. Specifically, the first type of regulation can be seen as leading to an increase in the parameter ν—namely, for a given monetization expenditure S, the ensuing increase in monetization is expected to be smaller if ν is larger. The second type of regulation is modeled as an increase in the depreciation parameter ϕ. The third type as an increase in the operating cost γ.

Table 10 shows that the first and second type of regulations have similar impact on firm outcomes. By reducing the upside from monetization investment or simply by causing the monetization stock to depreciate more quickly, these regulations can reduce the firm's optimal SG&A-to-sales ratio through a reduction in both monetization and R&D expenditures. The decrease in R&D investment results in a lower innovation rate and in a sharp decrease in the firm's service quality. In turn, the lower investment in monetization implies that firms accumulate a smaller monetization stock, which leads to a considerable decrease in sales. Perhaps surprisingly, however, these regulations would help firms become profitable. Indeed, the table shows that if the increase in ν or ϕ is sufficiently high so that it leads to a decrease in the SG&A-to-sales ratio, then the fraction of firms making losses declines. That is, by reducing the upside potential from monetization, these regulations curb firms' incentives to intensively invest in it, leading to a healthier SG&A-to-sales ration. Overall, while these regulations would make firms smaller and less innovative, they would also make them financially sounder. That said, firm valuation ratios would decline, as firms have a lower upward potential.

Consider now the third type of regulation. In this case, the SG&A-to-sales ratio remains pretty large and, thus, the fraction of firms making losses is higher than in the case with no regulation. At the same time, monetization and R&D expenditures decrease in absolute value, which leads to lower monetization stock and service quality compared to the case with no regulation, which in turn leads to smaller sales.

6.3 The impact of competitive pressure

Another type of policy discussion stems from the need to increase competition in the digital sector, urging more supervision of the largest firms while giving space to the smaller ones.[28] The goal is to promote competition that fuels innovation and expands choice for consumers. We then devise a counterfactual experiment to study the impact of this type of policy provisions. Namely, we study the impact of increasing the parameter χ, which implies a greater likelihood of competitors launching higher-quality products, then effectively eroding the firm's customer base.

Table 11 shows our result. As for regulation affecting monetization (see Section 6.2), policy provisions affecting competition make firms smaller, as illustrated by the associated reduction in firm's sales. Differently, competition regulation leads to higher SG&A-to-sales ratios, driven by an increase in both monetization-to-sales as well as R&D-to-sales ratios. As a result, the firm's innovation rate *increases* with competition regulation. That is, stiffer competition encourages firms to be more proactive in seeking innovative improvements in their service quality. As such, firms exhibit a larger innovation rate with competition regulation. Yet, average service quality is smaller with competition regulation, which implies that the decrease in service quality driven by competitors' advancements more than offsets the firm's larger innovation rate. As a result, the firm's customer base is, on average, smaller with competition regulation.

7 Concluding Remarks

Since the turn of the millennium, the market capitalization and prominence of digital service firms—defined as firms providing free services to customers via the Internet—have increased tremendously. These firms are quite different from firms in other industries,

[28]The Federal Trade Commission have brought a lawsuit against Facebook arguing that it illegally monopolized the social networking industry by buying its major social media rivals to put out competition. Conversely, in the United Kingdom, a panel of experts has made recommendations on changes to competition and devise pro-competition policies in the digital sector.

including the R&D-intensive ones, which makes it difficult to employ existing models of firm dynamics to understand their optimal decisions. Most importantly, technological breakthroughs and customer acquisition do not directly translate into revenues growth for digital service firms. Instead, digital service firms invest in monetization to generate revenues out of their innovative services offered to customers for free.

This paper provides a dynamic model of corporate decisions that embeds and examines the concept of monetization. Our model rationalizes several puzzling characteristics of digital service firms, including their lingering unprofitability while exhibiting a broad customer base and high valuations. Our analysis illustrates that having a large customer base is necessary but not sufficient for such firms to attain profitability. We also illustrate that the need to invest in monetization affects the dynamics and timing of corporate responses to shocks. Notably, we show that monetization uncertainty has a significant impact on firm's decision-making, causing firms to be less innovative, less profitable, and less valuable. We also show that regulation targeting monetization (e.g., aimed at protecting customer privacy, targeting content moderation, or imposing standards on ad transparency) would make firms smaller and less innovative but, by curbing the upside potential from monetization, it would lead firms to be more conservative in their SG&A expenditures and, then, less unprofitable. In turn, regulation targeting competition in this sector would support firm's inventiveness. Our findings indicate that understanding the general equilibrium effects of monetization—in particular, the implications for the advancement of the technological frontier and economic growth—would be a fruitful avenue for future research.

Appendices

A Proof of Proposition 1

The first-order condition for the optimal R&D expenditures, z, gives:

$$-q + \beta \frac{\partial}{\partial z} E[V(c', \eta', q')] = 0. \tag{13}$$

The first term illustrates that it is more costly to innovate if service quality is greater. The second term represents the impact of R&D on expected firm value. To solve for z, note first that the expected firm value can be rewritten as follows:

$$E[V(c', q', \eta')] = E[V(c', q', \eta')|\theta = 1]P(\theta = 1) + E[V(c', q', \eta')|\theta = 0]P(\theta = 0), \tag{14}$$

i.e., as the sum of the expected value if the firm attains a breakthrough in the next period times the probability of this event (equal to $P(\theta = 1)$, see equation (2)) and the expected value if the firm does not attain a breakthrough in the next period. Using equation (2), equation (14) can be re-written as follows:

$$E[V(c', q', \eta')] = E[V(c', q', \eta')|\theta = 1] - e^{-\delta z}\Big(E[V(c', q', \eta')|\theta = 1] - E[V(c', q', \eta')|\theta = 0]\Big).$$

Now, recall that R&D expenditures do not bear effect on the conditional expectation of $V(c', q', \eta')$ given θ (in fact, z affects $V(c', q', \eta')$ through θ). The first derivative of $E[V(c', \eta', q')]$ with respect to z then is

$$\frac{\partial}{\partial z} E[V(c', \eta', q')] = \delta e^{-\delta z}\Big(E[V(c', q', \eta')|\theta = 1] - E[V(c', q', \eta')|\theta = 0]\Big). \tag{15}$$

Substituting this expression into equation (13) yields the expression for z reported in Proposition 1.

B Empirical samples and moments definition

In this section, we provide additional details as to how we build samples and quantities used in Section 3. The samples analyzed in Table 1 are defined as follows:

Digital service firms: Firms that went public in or after 1995 and with SIC code 7370.
Non-DS firms: All the firms that do not meet the definition of Digital service firms.
R&D-intensive firms: Firms in the following industries: Software, Business Services, Chips, and Hardware. We intentionally do not include Pharmaceuticals and Medical Equipments, as their business is very different from digital service firms. If we included Pharmaceuticals and Medical Equipments in our definition of R&D-Intensive firms, the differences betweeen digital service and R&D-intensive firms would be even more striking.
New firms: Firms that went public (identified by the year of their IPO) in or after 1995, and with SIC code different from 7370.

We next provide definitions of the variables in Table 1 (Compustat items are reported in parentheses):
Firm size: Logarithm of total sales (SALE) .
Gross profit margin: Mean of the ratio of a firm's gross profits (GP) to sales (SALE).
Fraction Making Loss: Mean fraction of firms that have negative operating income before depreciation (OIBPD).
Net profit margin: Mean of the ratio of the firm's operating income before depreciation (OIBDP) to sales (SALE).
SG&A expenditures: Mean of the ratio of a firm's selling, general, and administrative expenses (XSGA) to sales (SALE).
R&D expenditures: Mean of the ratio of a firms research and development expenditures (XRD) to its total sales (SALE).
Firm value to sales: Mean of the ratio of equity value (calculated by multiplying outstanding common shares by fiscal year closing price, CSHO*PRCC_F) plus the book value

Table 1: Moments: Data versus Simulated model. The table shows selected moments calculated from the data as well as those calculated from the simulated model. Differently from Table 2, we exclude digital service firms that charge some fees to their customers.

Moment	Data	Model
Fraction making losses (mean)	0.390	0.364
Sales growth (std. deviation)	0.354	0.361
Gross profit margin (mean)	0.664	0.614
Gross profit margin (std. deviation)	0.221	0.237
R&D to SG&A expenditures (mean)	0.168	0.179
R&D to sales (autocorrelation)	0.529	0.596
SG&A expenditures to sales (mean)	0.695	0.532
SG&A expenditures to sales (std. deviation)	0.333	0.415
Sensitivity of SG&A expenditures to revenues	0.332	0.280
Sensitivity of sales growth to (lagged) SG&A expenditures	0.275	0.229
Sensitivity of profit margin to (lagged) SG&A expenditures	0.090	0.041
Firm value to sales (mean)	5.172	4.935

of debt (current liabilities and long-term debt, DLC +DLTT) to sales (SALE).

Asset Tangibility: Mean of the ratio of a firm's net valuation of property, plant and equipment (PPENT) plus inventory (INVT) to its total assets (AT) net of cash (CHE).

C Robustness

As a robustness exercise, we check the performance of our calibration when removing from our sample of digital service those firms that charge some fees (or various types) to their customers. Table 1 shows the data moments vis-à-vis those coming from the simulated model. Using this subsample too, the model continues to perform well in reproducing empirical characteristics of digital service firms.[29]

D Monetization: Anecdotal evidence

Our model is motivated by the observation that digital service firms have distinctive features that set them apart from other R&D-intensive firms: (1) Success on the R&D front—i.e., having devised an innovative service with a broad customer base—is not sufficient to attain profitability; (2) Profitability can only be attained via monetization expenditures, but monetization has a outcomes; (3) Monetization is easier if the firm has a large customer base, but having a large customer base is not sufficient for firms to monetize their innovations; (4) Continued investment in innovation is necessary to maintain and expand their customer base; (5) Unprofitability often goes hand in hand with large valuations. Below we provide anecdotal evidence and practical examples of these key features, by reporting excerpts from the financial press.

Digital service firms' difficult path to profitability in spite of a broad customer base are exemplified by the article "Tumblr and the Death of the Old Internet" (August 17, 2019, *Wall Street Journal*). The article reports:

"On the business side, it [Tumblr] operated under the assumption that it could make money off its users the same way people had since the invention of the banner ad: Build a big enough audience, and "monetization" will take care of itself. Alas, Tumblr was inherently ill-suited to advertising [...]. Its impenetrability was a challenge to advertisers."

Furthermore, this article emphasizes how R&D is also important for these firms (as in our model, monetization needs to go hand in hand with innovation). It highlights that the service was "never a very polished or particularly reliable service to begin with, had a hard time going mobile." The article then concludes:

[29] In an alternative version, we have also checked the robustness of our model when defining Digital Service firms based on a SIC code definition—i.e., including all firms in the SIC code 7370. The results are available upon request.

"the real scandal of Tumblr isn't that it's now worth a fraction of its former selling price. The scandal is that Tumblr was ever valued so highly at all. [...] Having a very popular product and only the vaguest idea how to make money on it doesn't, it turns out, a world-changing business model make."

The same article also reports the case of Yahoo. It notes that:

"[Yahoo] hemorrhaged talent throughout the 2010s at both the engineering and executive level, couldn't attract and retain the sort of people that could help its revenue-generating engine, that is its ailing ad network, to compete. More or less the same thing occurred once Yahoo joined AOL, sorry Oath—oh wait, I mean Verizon Media—whose parent company essentially wrote down its entire value to zero in late 2018. Eyeballs, which this combined network had plenty of, weren't enough in a climate in which advertisers had moved beyond the kind of cut-rate programmatic display advertising its sites were running."

These lines provide a crisp illustration that building a large customer base is not sufficient for digital service firms—monetization requires additional investment, but the outcome is largely uncertain. Our model captures these features.

Similarly, the article "Snapchat must hit more angles with advertisers" (September 19, 2019, *Wall Street Journal*) illustrates that having a large customer/user base does not imply that advertisers flock to the firm. Talking about Snapchat, the article reports:

"Because the largest segment of Snaps users are young, older brand executives don't necessarily use Snapchat frequently, [...] if ever. This can mean that they don't understand the platform and, therefore, may not see the value in advertising there. Snap has been working to combat friction between its platform and advertisers to boost sales. [...] Earlier this year, Snap rolled out Instant Create, which enables advertisers to make ads in three steps. In April, Snap announced a partnership with e-commerce tech company Shopify allowing merchants to purchase Snapchat ads directly through Shopify's platform. [...] This is evident in recent results. Snap grew overall sales in the second quarter by 48% year-over-year—its best growth since the first quarter of 2018."

These all can be seen as examples of monetization efforts, which are necessary to convert a free service into a revenue-making machine, but have a highly uncertain outcome. In a subsequent article ("Snap posts gains in Users, Revenue" *Wall Street Journal*, October 22, 2019), it is reported:

"Adding more users is critical for Snap as it looks to attract more advertisers and, in turn, generate more revenue. [...] Snap, whose Snapchat app turned eight years old in September, has yet to turn a profit as a public company."

This article reflects the difficulty of firms in attaining profitability. Similarly, talking about Slack technologies, the article "Slack Shares Jump in Trading Debut" (June 20, 2019, *Wall Street Journal*) reports: "instant-messaging software has supplanted email as the main method of communication for some office workers" and emphasizes the firm's large customer base. The article also depicts the firm by noting the key characteristics of digital service firms: "fast-growing revenue but significant net losses as the company seeks scale by pouring money into sales and marketing."

While not sufficient to attain profitability, having a broad customer base is a necessary condition. The importance of the user base to attain profitability is exemplified by the article "Instagram is breaking hearts" (*Wall Street Journal*, August 17, 2019), which reports:

"Instagram says it doesn't receive compensation directly for the sales it enables through hosting influencers' posts. Instead, it basks in the traffic they bring. The more people engage on their platform, the greater its value to advertisers. [...] Popularity begets popularity."

The importance of continued monetization expenditures (to maintain the firm's monetization stock) is exemplified by the article "Twitter Shares Plunge as Ad-Business Troubles Weigh on Growth" (*Wall Street Journal*, October 24, 2019). The article reports:

"Technical glitches in Twitter Inc.'s advertising software roiled the social-media company in the third quarter, as a pullback in spending from some buyers and weaker pricing for ads also cut into revenue and profit even though it added millions of new users. [...] Twitter, similar to other social-media and Internet firms, has been jockeying to increase its share of the growing digital-advertising business, albeit one that is dominated by larger players such as Alphabet Inc.'s Google and Facebook Inc. The company said malfunctions in ad-targeting software as well as weaker-than-expected spending in July and August hurt its performance. The software problems meant that Twitter couldn't serve ads to users with the same level of precision as it normally does, prompting some advertisers to pause or reduce spending. For example, a burger restaurant's ads might have been delivered to a wide swath of users, including vegetarians and people who live long distances away, making them less effective than if they were sent to meat lovers who live near the restaurant. [...] Advertising is very high-margin revenue, so when your advertising isn't growing as fast, your profitability will be impacted by a greater amount,

Similarly, the article "Etsy updates advertising offerings" (*Wall Street Journal*, February 26, 2020) exemplifies how digital service firms continue to try and refine their advertisement platforms, which is one of the most prominent way digital service firms make profits:

"Etsy, Inc. (Nasdaq: ETSY), which operates two-sided online marketplaces [...], announced today that it is evolving its advertising offering to help sellers more effectively drive traffic to their listings. Etsy is introducing a new advertising service, called Offsite Ads. Etsy will pay the upfront costs to promote sellers' listings on multiple internet platforms without any upfront costs for sellers."

Finally, SG&A expenditures can weigh on firm profitability. The article "Airbnb Swings to a Loss as Costs Climb Ahead of IPO" (*The Wall Street Journal*, February 11, 2020) reports:

"Investors have grown increasingly suspicious of companies with losses and no clear path to profitability. [...] Airbnb's drooping profitability is causing concern within the firm, according to people close to the company. The board in recent weeks grilled executives on why expenses are outpacing revenue, the people said. Airbnb increased its revenue to $1.65 billion in the third quarter, up almost $400 million from a year earlier, one of the people said. But costs rose faster. Net profit for the quarter was $266 million less than the $337 million profit for the same period in 2018, and not enough to cover losses for the first six months of the year, the person added. Costs are likely to increase further, as a result of Airbnb's recent move to spend more on safety issues affecting its platform. Airbnb is also spending heavily on upgrading the technology of its platform, with costs running at more than $100 million a year, a person close to the company said. One category of costs that has grown particularly fast is general and administrative expenses, which more than doubled year-over-year to total $175 million in the third quarter, according to another person close to the company."

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Table 1: Key characteristics of digital service firms. The table shows selected characteristics of digital service firms versus Non-DS firms, R&D firms, and New firms. *Size* is defined as the logarithm of sales. *Gross profit margin* is the mean of the ratio of a firm's gross profits to sales, and *Net profit margin* is the mean of the ratio of a firm's net profits to sales. *Fraction Making Loss* is the average fraction of firms that have negative operating income. *SG&A expenditures* is the mean of the ratio of a firm's selling, general, and administrative expenses to sales. *R&D expenditures* is the mean of the ratio of a firms research and development expenditures to its total sales. *Asset tangibility* is the mean of a firm's net valuation of tangible fixed property plus its inventories to its total assets. *Firm value to sales* is the mean of the ratio of firm value (market value of equity plus book value of debt) to sales.

	Digital service	Non DS	R&D	New
Size	5.124	5.752	5.166	5.473
Gross profit margin	0.606	0.391	0.471	0.415
Net profit margin	-0.020	0.082	0.051	0.054
Fraction making losses	0.399	0.165	0.235	0.219
SG&A expenditures	0.624	0.305	0.418	0.355
R&D expenditures	0.122	0.051	0.105	0.066
Asset tangibility	0.195	0.467	0.290	0.432
Firm value to sales	4.595	2.171	2.667	2.605
Number of observations	2470	82995	18789	36335

Table 2: MOMENTS: DATA VERSUS SIMULATED MODEL. The table shows selected moments calculated from the data as well as those calculated from the simulated model. The definitions of the empirical sample and of the moments are reported in Appendix B.

Moment	Data	Model
Fraction making losses (mean)	0.399	0.364
Sales growth (std. deviation)	0.331	0.361
Gross profit margin (mean)	0.606	0.614
Gross profit margin (std. deviation)	0.214	0.237
R&D to SG&A expenditures (mean)	0.171	0.179
R&D to sales (autocorrelation)	0.533	0.596
SG&A expenditures to sales (mean)	0.624	0.532
SG&A expenditures to sales (std. deviation)	0.321	0.415
Sensitivity of SG&A expenditures to revenues	0.317	0.280
Sensitivity of sales growth to (lagged) SG&A expenditures	0.314	0.229
Sensitivity of profit margin to (lagged) SG&A expenditures	0.073	0.041
Firm value to sales (mean)	4.595	4.935

Table 3: CALIBRATED PARAMETERS. The table shows the values of the calibrated parameters that allow the moment matching reported in Table 2.

Parameter	Description	Value
α	Elasticity of revenues to monetization stock	0.552
ρ	Persistence of customer base	0.673
σ	Standard deviation of shocks to customer base	0.665
γ	Operating cost coefficient	0.740
δ	Sensitivity of breakthrough probability to R&D expenditures	2.628
λ	Service quality improvements due to technological breakthroughs	0.090
Λ	Service quality reductions due to competitive pressure	0.082
χ	Probability of competitors' breakthroughs	0.229
ϕ	Depreciation rate of the monetization stock	0.263
ν	Parameter of the distribution of monetization increases	0.917

Table 4: Additional Statistics. This table reports additional statistics calculated from the simulated model, using the parameters reported in Table 3.

Moment	Value
Service quality and innovation	
Service quality (mean)	0.654
Service quality (median)	0.639
Service quality (std deviation)	0.193
Innovation rate (mean)	0.232
Monetization (expenditures and stock)	
Monetization stock (mean)	3.142
Monetization stock (median)	2.794
Monetization stock (std deviation)	1.727
Monetization expenditures to sales (mean)	0.494
Monetization expenditures to SG&A (mean)	0.821
Customer base	
Customer base (mean)	1.003
Customer base (median)	0.639
Customer base (std deviation)	1.236
Customer base growth (std deviation)	0.723
Revenues per customer (mean)	2.480
Revenues per customer (median)	2.254
Revenues per customer (std deviation)	1.168

Table 5: Success along the innovation and monetization dimensions. This table studies firms sorted into quartiles of service quality q (top panel) and of monetization stock η (bottom panel). The quantities reported are means from our simulated model.

Service quality, q	1st	2nd	3rd	4th
Sales	1.069	1.541	1.832	2.517
SG&A expenditures	0.589	0.797	0.883	1.056
SG&A expenditures to sales	0.592	0.549	0.515	0.460
Monetization expenditures	0.529	0.725	0.812	0.991
Monetization expenditures to sales	0.538	0.508	0.483	0.439
R&D expenditures	0.060	0.071	0.071	0.065
R&D expenditures to sales	0.054	0.041	0.033	0.021
Innovation rate	0.294	0.255	0.226	0.159
Monetization stock	2.052	2.899	3.390	4.315
Gross profit margin	0.588	0.614	0.618	0.644
Revenues per user	2.578	2.524	2.487	2.316
Fraction making losses	0.437	0.388	0.356	0.266
Firm value to sales	5.200	4.984	4.891	4.625
Firm value	4.888	6.879	8.078	10.632

Monetization stock η	1st	2nd	3rd	4th
Sales	0.754	1.301	1.882	2.963
SG&A expenditures	0.736	0.878	0.916	0.788
SG&A expenditures to sales	0.872	0.584	0.426	0.245
Monetization expenditures	0.697	0.821	0.844	0.688
Monetization expenditures to sales	0.828	0.546	0.391	0.212
R&D expenditures	0.039	0.056	0.072	0.100
R&D expenditures to sales	0.045	0.038	0.035	0.032
Innovation rate	0.184	0.215	0.238	0.292
Service quality	0.512	0.627	0.701	0.776
Gross profit margin	0.402	0.592	0.686	0.776
Revenues per user	2.408	2.451	2.478	2.582
Fraction making losses	0.825	0.492	0.136	0.001
Firm value to sales	5.924	5.059	4.602	4.153
Firm value	4.176	6.255	8.227	11.624

Table 6: Interacting monetization and innovation. This table studies firms sorted into bins of high/low quality level and high/low monetization stock, where "high' and "low' are defined to be above and below the sample median. HH denotes firms with high quality and monetization levels, HL denotes firms with high quality and low monetization levels, LH denotes firms with low quality and high monetization levels, and LL denotes firms with low quality and monetization levels. The quantities reported in the table are sample means.

	HH	LH	HL	LL
Bin frequency	0.356	0.145	0.148	0.351
Sales	2.598	2.082	1.259	0.911
SG&A expenditures	0.952	0.641	1.048	0.686
SG&A expenditures to sales	0.362	0.275	0.783	0.702
Monetization expenditures	0.872	0.544	1.009	0.635
Monetization expenditures to sales	0.335	0.229	0.760	0.652
R&D expenditures	0.080	0.097	0.039	0.051
RD expenditures to sales	0.027	0.046	0.023	0.050
Innovation rate	0.214	0.374	0.118	0.240
Customer base	1.551	1.067	0.819	0.523
Revenues per user	2.432	2.730	2.298	2.485
Gross profit margin	0.708	0.781	0.448	0.521
Net profit margin	0.346	0.506	-0.335	-0.181
Fraction making losses	0.102	0.006	0.799	0.587
Firm value to sales	4.422	4.266	5.530	5.473
Firm value	10.718	8.345	6.495	4.573

Table 7: Profitable vs. unprofitable firms. This table compares profitable firms (defined as those that have positive net profit margin) with the unprofitable ones (defined as those that have negative net profit margin). The reported quantities are sample means unless otherwise specified.

Quantity	Profitable	Unprofitable
Frequency	0.636	0.364
Sales (mean)	2.071	1.120
Sales (std dev)	1.261	0.558
SG&A expenditures to sales	0.308	0.923
SG&A expenditures	0.700	1.055
Monetization expenditures	0.625	1.002
R&D expenditures	0.075	0.053
Monetization stock	3.916	1.788
Service quality	0.673	0.621
Gross profit margin	0.686	0.489
Net profit margin	0.378	-0.434
Firm value to sales	4.628	5.471
Firm value	8.676	5.636

Table 8: Understanding firm value. The table reports the regression coefficients (with standard errors reported in parentheses) and R^2 for the regressions specified in equation (11), using our simulated sample. The top panel focuses on the whole sample. The middle and bottom panel focus on subsamples of profitable and unprofitable firms, respectively.

	η_t	q_t	c_t	$(\eta_t,\ q_t, c_t)$
Whole				
a_0	0.02	0.11	-0.01	-0.08
	(0.001)	(0.002)	(0.002)	(0.001)
a_η	0.81			0.52
	(0.002)			(0.001)
a_q		0.56		0.29
		(0.002)		(0.001)
a_c			0.39	0.29
			(0.001)	(0.000)
R^2	0.66	0.35	0.46	0.95
Profitable firms				
a_0	-0.04	0.30	0.18	-0.09
	(0.003)	(0.003)	(0.002)	(0.001)
a_η	0.84			0.52
	(0.003)			(0.001)
a_q		0.59		0.31
		(0.003)		(0.001)
a_c			0.36	0.28
			(0.001)	(0.001)
R^2	0.59	0.36	0.49	0.94
Unprofitable firms				
a_0	0.28	-0.25	-0.32	0.01
	(0.002)	(0.002)	(0.002)	(0.001)
a_η	1.22			0.69
	(0.004)			(0.003)
a_q		0.37		0.21
		(0.002)		(0.001)
a_c			0.34	0.29
			(0.002)	(0.001)
R^2	0.72	0.42	0.33	0.93

Table 9: THE EFFECT OF MONETIZATION UNCERTAINTY. This table compares moments from the baseline version of the model (labeled as "With uncertainty") with those from the counterfactual environment in which monetization increases are deterministic (labeled as "Without uncertainty").

Moment	With uncertainty	Without uncertainty
Sales	1.725	2.668
SGA expenditures to sales	0.532	0.474
SGA expenditures	0.829	1.253
Monetization expenditures	0.763	1.147
R&D expenditures	0.067	0.105
Monetization stock	3.142	4.737
Service quality	0.654	0.990
Customer base	1.003	1.524
Innovation rate	0.232	0.240
Gross profit margin	0.614	0.608
Fraction making losses	0.364	0.335
Firm value to sales	4.935	4.822
Firm value	7.571	11.335
Sensitivity of sales growth to SGA	0.229	0.266

Table 10: The impact of privacy regulation. This table reports selected moments obtained under the baseline parameterization (with no regulation) and when considering regulation reducing the upside potential of monetization increases (increasing ν), the depreciation rate of the monetization stock (increasing ϕ), and increasing firm operating cost (increasing γ). These parameters are varied by 5%, 10%, 15%, and 20% compared to the baseline environment reported in Table 3.

Quantity	No Reg.	$\uparrow \nu$ 5%	$\uparrow \nu$ 10%	$\uparrow \nu$ 15%	$\uparrow \nu$ 20%	$\uparrow \phi$ 5%	$\uparrow \phi$ 10%	$\uparrow \phi$ 15%	$\uparrow \phi$ 20%	$\uparrow \gamma$ 5%	$\uparrow \gamma$ 10%	$\uparrow \gamma$ 15%	$\uparrow \gamma$ 20%
Sales	1.725	0.947	0.261	0.110	0.087	1.082	0.410	0.147	0.098	1.363	0.926	0.523	0.277
SG&A exp.	0.829	0.469	0.124	0.040	0.023	0.540	0.203	0.065	0.033	0.667	0.457	0.256	0.133
SG&A exp. to sales	0.532	0.536	0.453	0.275	0.164	0.547	0.515	0.389	0.235	0.535	0.534	0.520	0.490
Mon. exp.	0.763	0.433	0.116	0.037	0.021	0.497	0.190	0.061	0.030	0.615	0.423	0.239	0.125
Mon. exp. to sales	0.494	0.501	0.430	0.255	0.154	0.511	0.488	0.368	0.220	0.500	0.502	0.493	0.468
R&D exp.	0.067	0.037	0.008	0.003	0.002	0.042	0.014	0.004	0.002	0.052	0.034	0.017	0.008
R&D exp. to sales	0.037	0.035	0.023	0.019	0.010	0.036	0.027	0.020	0.015	0.036	0.033	0.027	0.022
Innovation rate	0.232	0.225	0.164	0.135	0.080	0.230	0.185	0.145	0.110	0.234	0.225	0.198	0.174
Service quality	0.654	0.359	0.102	0.046	0.038	0.411	0.159	0.058	0.041	0.501	0.331	0.184	0.097
Monetization stock	3.142	1.701	0.457	0.185	0.139	1.951	0.726	0.255	0.163	2.529	1.749	0.998	0.534
Customer base	1.003	0.553	0.157	0.070	0.058	0.632	0.244	0.090	0.063	0.770	0.510	0.284	0.149
Revenues per customer	2.480	2.405	2.305	2.208	2.136	2.414	2.325	2.279	2.184	2.524	2.555	2.570	2.581
Gross profit margin	0.614	0.596	0.579	0.571	0.565	0.597	0.578	0.576	0.568	0.598	0.582	0.564	0.545
Net profit margin	0.083	0.060	0.125	0.296	0.401	0.050	0.063	0.187	0.333	0.063	0.048	0.043	0.055
Fraction making losses	0.364	0.392	0.326	0.192	0.123	0.398	0.378	0.267	0.167	0.385	0.402	0.396	0.370
Firm value to sales	4.935	4.597	4.111	3.660	3.403	4.600	4.148	3.657	3.330	4.685	4.411	4.093	3.732
Firm value	7.571	3.898	0.993	0.382	0.282	4.440	1.554	0.503	0.310	5.708	3.695	1.978	0.985
Sens. sales growth to SG&A	0.229	0.219	0.180	0.123	0.088	0.236	0.222	0.177	0.136	0.224	0.219	0.212	0.195

Table 11: THE IMPACT OF COMPETITION REGULATION. This table reports selected moments obtained under our baseline parameterization (with no regulation) and when allowing for competition regulation (obtained by increasing χ by 5%, 10%, 15%, and 20% compared to the baseline environment reported in Table 3.

Quantity	No Reg.	$\uparrow \chi$ 5%	$\uparrow \chi$ 10%	$\uparrow \chi$ 15%	$\uparrow \chi$ 20%
Sales	1.725	1.605	1.480	1.341	1.184
SGA expenditures	0.829	0.781	0.727	0.665	0.592
SGA expenditures to sales	0.532	0.537	0.541	0.544	0.547
Monetization expenditures	0.763	0.716	0.664	0.606	0.538
Monetization expenditures to sales	0.494	0.497	0.499	0.500	0.501
RD expenditures	0.067	0.065	0.063	0.059	0.054
RD expenditures to sales	0.037	0.040	0.042	0.044	0.046
Innovation rate	0.232	0.245	0.256	0.268	0.277
Service quality	0.654	0.602	0.550	0.493	0.431
Monetization stock	3.142	2.941	2.731	2.491	2.213
Customer base	1.003	0.925	0.844	0.758	0.663
Revenues per customer	2.480	2.496	2.512	2.527	2.540
Gross profit margin	0.614	0.615	0.616	0.618	0.619
Net profit margin	0.083	0.078	0.076	0.074	0.072
Fraction making losses	0.364	0.370	0.372	0.376	0.381
Firm value to sales	4.935	4.914	4.885	4.853	4.820
Firm value	7.571	7.003	6.419	5.779	5.069
Sensitivity of sales growth to SGA	0.229	0.226	0.225	0.222	0.222

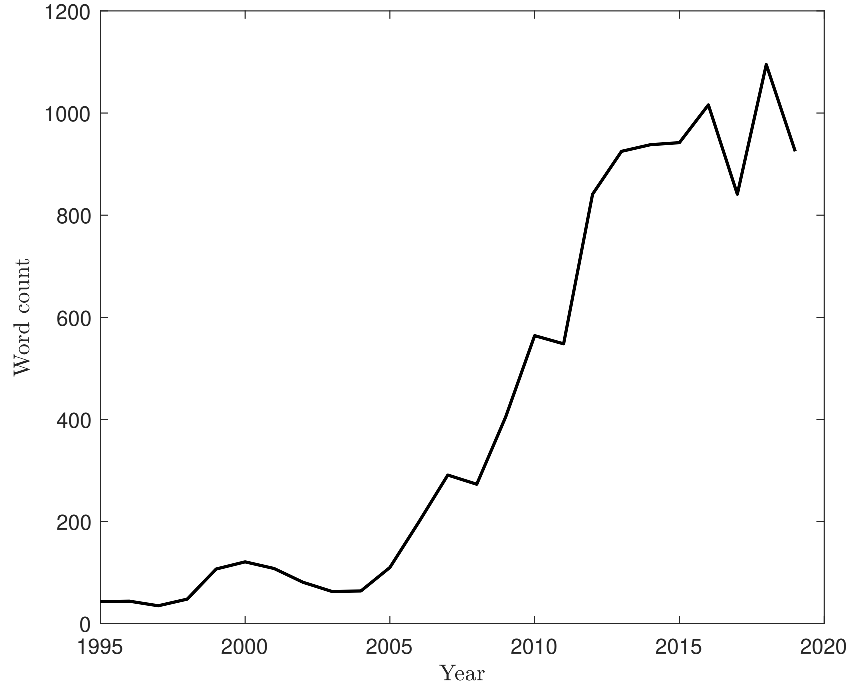

Figure 1: "MONETIZATION" IN THE PRESS. The figure shows the word count for "monetize/monetization" since 1995 in the following newspaper: USA Today, Chicago Tribune, Washington Post, Los Angeles Times, Boston Globe, San Francisco Chronicle, Dallas Monring News, New York Times Financial Times, and Wall Street Journal.

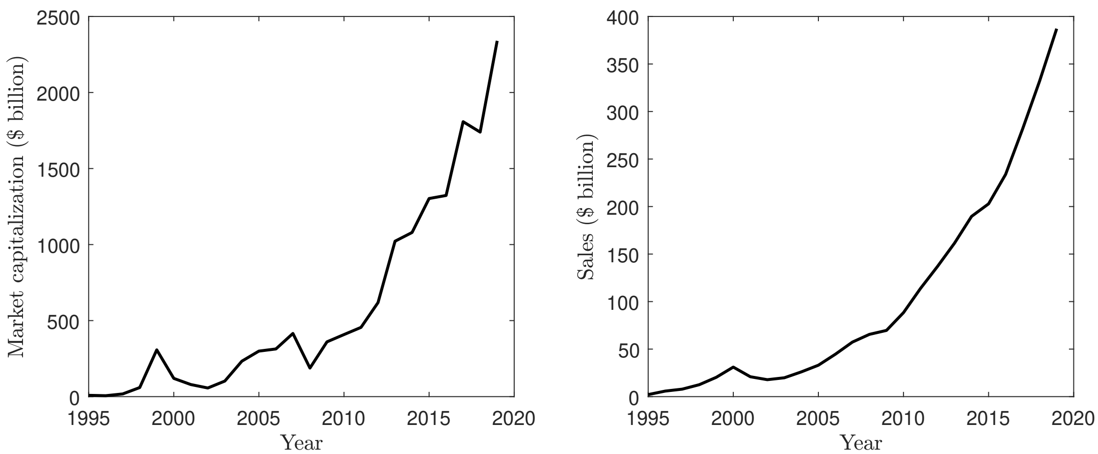

Figure 2: Secular growth of digital service Firms. The figure shows the inflation-adjusted market capitalization (left panel) and sales (right panel) of digital service firms since 1995 until 2019.

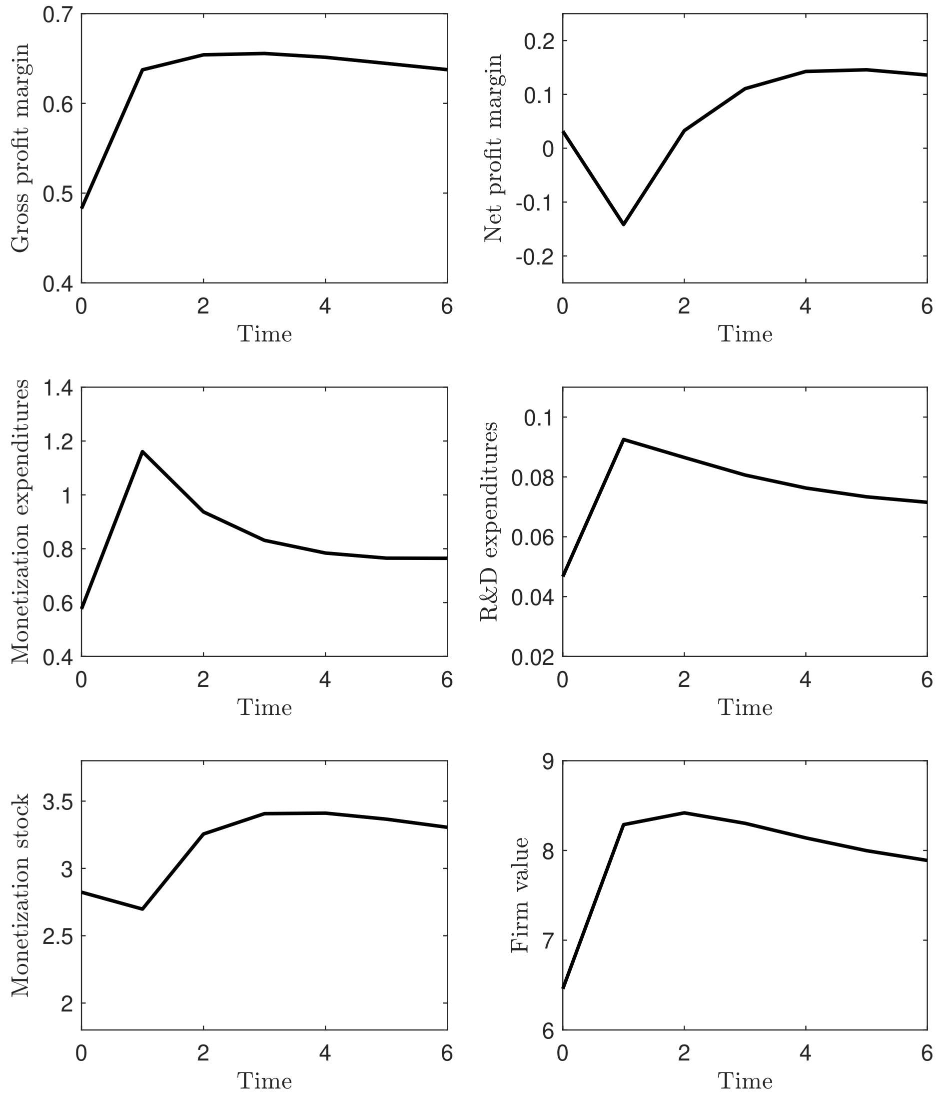

Figure 3: Firm dynamics following a customer windfall. The figure shows the dynamics of the firm gross and net profit margin (top panels), of monetization and R&D expenditures (middle panels), of the monetization stock (bottom left panel), and of firm value (bottom right panel) following a sizable increase in the idiosyncratic component of customer base (defined to be in the top quartile of the distribution of one-period changes). The horizontal axis displays periods after the shock, where the shock is assumed to happen between time 0 and 1.

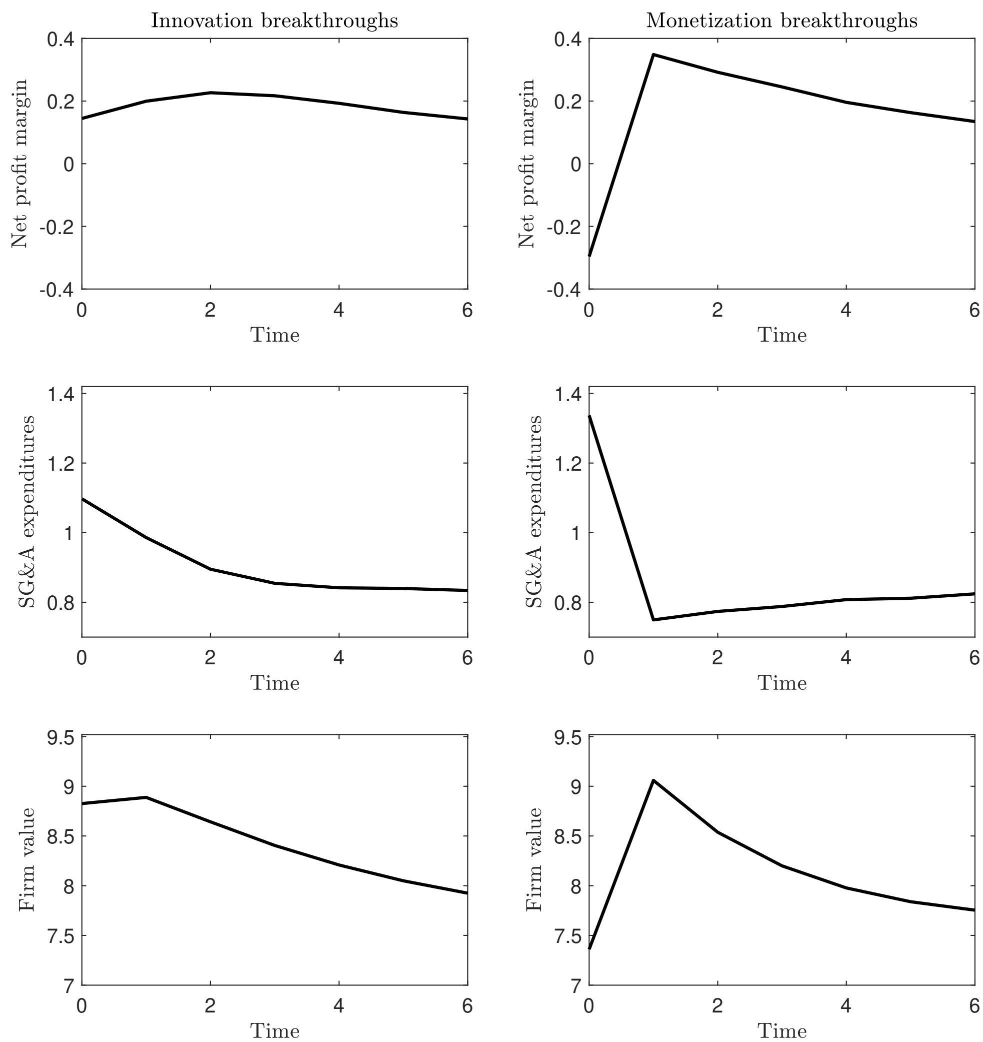

Figure 4: Firm dynamics after an endogenous breakthrough. The figure shows the dynamics of profitability (top panel), SG&A expenditures (middle panel), and firm value (bottom panel) in the aftermath of an innovation breakthrough (left panel) or a monetization breakthrough (right panel). The horizontal axis displays periods after the shock, where the shock is assumed to happen between time 0 and 1.

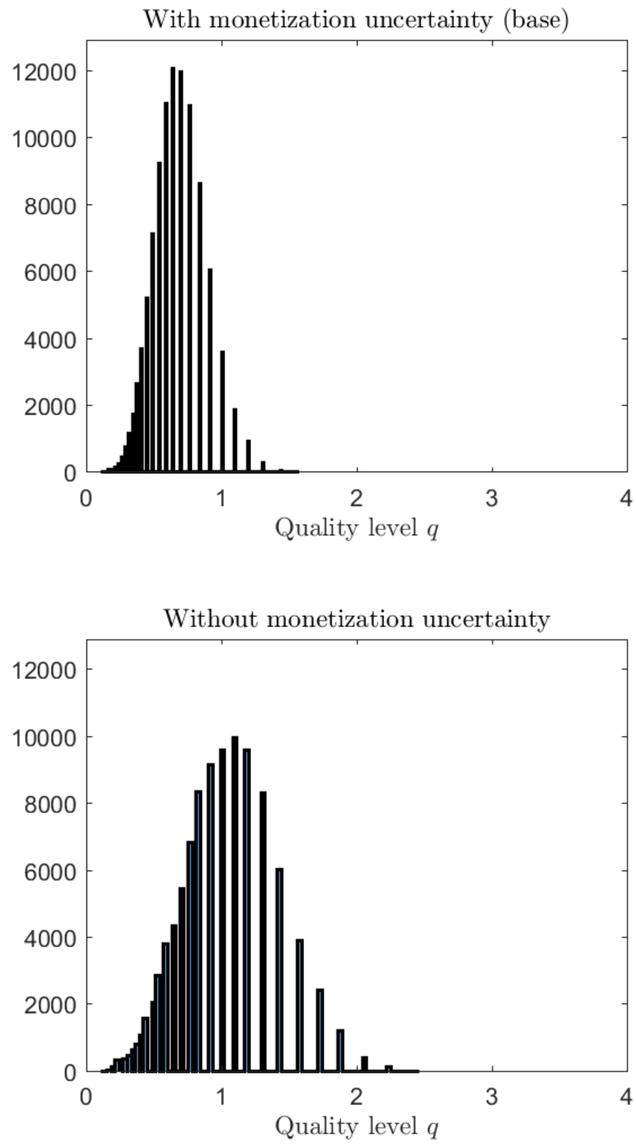

Figure 5: Distribution of service quality. The figure represents the distribution of service quality in the baseline setup with monetization uncertainty (top panel) and in the counterfactual environment with no monetization uncertainty (bottom panel).