Monetization of Innovation*

Missaka Warusawitharana† Francesca Zucchi‡

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Abstract

This paper develops a dynamic model of the innovative firms that invest in monetization, which represents the process of generating revenues out of services provided to customers at no charge. The model reflects the challenges faced by firms that operate primarily on the Internet, a growing segment of the economy. Our model captures the stylized fact that such firms often build a large customer base and become highly valued while continuing to suffer losses. Counterfactual analysis shows that monetization uncertainty slows technological advancement by diverting resources away from innovation.

Keywords: Monetization; Innovation; Internet firms.

JEL Classification Numbers: D20; G31; O31; O32.

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†Federal Reserve Board. E-mail: missaka.n.warusawitharana@frb.gov

‡Federal Reserve Board. E-mail: francesca.zucchi@frb.gov

1 Introduction

Traditional models of the firm, across many fields of economics, use the equality of marginal costs and revenues as a key building block in firm optimization. Yet, such a condition does not appear to determine the quantity of services provided by most high-tech firms that operate via the Internet, such as Facebook, Google, Twitter, and many others. These firms aim to grow rapidly and serve as many customers as possible, typically at no charge. As such, their customer base does not directly map to revenues as in traditional models. Instead, these firms need to "monetize" their customers as a separate activity; for instance, by selling ad spaces or virtual goods to third parties. To the best of our knowledge, we present the first study aimed to analyze the concept of monetization—i.e., generating revenues from customers as a distinct undertaking—in a model of firm dynamics.

The main elements of our model include acquisition of customers through research and development (R&D) advancements and monetization of the existing customer base through risky investments. Both R&D and monetization have uncertain outcomes, and successful monetization is a necessary step towards achieving profitability.[1] We view monetization as a distinctive feature of these firms that operate primarily on the Internet (subsequently referred to as "Internet firms"), whose short history includes many examples of highly valued firms that expanded their customer base quickly but subsequently failed to generate significant revenues. Our calibrated model explains these firms' dynamics—which traditional models would struggle to replicate—and reveals how innovation and monetization interact. Furthermore, our counterfactual analysis examines whether and how monetization uncertainty affects firms' R&D investment and, thus, shapes technological advancement.

The growing prominence of Internet firms, which exhibit a business model that is quite

[1] The development of "AdSense" by Google, which enabled the company to sharply increase advertising revenues from their existing search algorithm, constitutes one prominent example of a monetization breakthrough.

distinct from that of traditional manufacturing or service firms, motivates our study. Using data from Compustat, we document that the market capitalization of Internet firms has more than tripled over the last decade. We also show that these firms are systematically different from firms in other industries, including R&D-intensive firms. In particular, we document that Internet firms sustain substantial selling, general, and administrative expenses, which nest R&D and monetization expenditures. As such, while these firms have, on average, healthy gross margins despite low sales, they have low net profits and often suffer losses. In addition, these firms have high valuations and largely intangible assets. Our model captures these, and other, features of the data.

Specifically, our model focuses on a firm that provides a service to customers via the Internet. Firms build their customer base by improving the quality of their service through R&D expenditures, as in the quality ladder framework of Grossman and Helpman (1991). Yet, 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 previous models of innovation, the key novelty of our framework is that firms invest in developing and maintaining their monetization stock to generate revenues out of the service provided to customers. Essentially, the monetization stock reflects the ideas that enable an Internet firm to earn revenues from its customer base. A firm's monetization stock increases as a stochastic function of its monetization expenditures, reflecting our view that monetization is an inherently uncertain activity, similar to innovation. Firms optimize over both monetization and R&D expenditures each period.

Using our calibrated model, we analyze the dynamics and the interaction between innovation and monetization. We show that a firm's service quality and its monetization stock are highly correlated, with innovation preceding monetization. Firms increase their monetization expenditures substantially right after achieving a technological breakthrough, to take advantage of the associated increase in their customer base. Because of larger monetization expenditures, firms' earnings deteriorate following such breakthroughs. This characteristic contrasts with most models of innovation, where technological breakthroughs directly expand firm profits. Despite this deterioration in profitability, firm value increases after a breakthrough, reflecting the expectation that the firm may eventually monetize the innovation. Notably, our model generates a key feature of Internet firms—a large customer base is necessary but not sufficient to become profitable. As such, our model also explains how large operating losses and high valuation ratios go hand in hand for these firms.

We carry out a number of counterfactual experiments. Reflecting the complementarity between innovation and monetization, we find that improvements in firms' innovative prowess support their ability to successfully monetize their customer base and, thus, attain profitability. Being more efficient on the innovation front, these firms accumulate a large customer base quickly and can allocate more resources to monetization. Furthermore, our analysis shows that the degree of competitive pressure has a substantial impact on firm's tradeoff between innovation and monetization. Indeed, stiffer competition leads firms to devote more resources to innovation, to fend off competitive threats. As a result, these firms invest less on monetization and are less likely to attain profitability.

We also devise a counterfactual setup to understand how the uncertainty associated to monetization affects corporate decisions and outcomes. In this alternative setup, we assume that monetization expenditures generate deterministic (rather than stochastic) increases in the monetization stock, which are equal to the expected monetization increase in our baseline model. We show that removing this uncertainty makes firms more willing to invest in monetization, which has a beneficial impact on firm profitability.[2] Furthermore, the complementarity between monetization and innovation implies that firms also increase their R&D expenditures in this setup, which sustain higher innovation rates and, thus, higher quality of firms' services. Our analysis thus indicates that the uncertainty associated

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

with monetization not only lowers profitability and firm value, but also slows technological advancement.

Related literature. Our paper is related to the literature on technological change and innovation. Many works have demonstrated the key importance of R&D in understanding firm behavior—among others, Aw, Roberts, and Xu (2011) and Doraszelski and Jaumandreu (2013)—as well as economic growth—see Aghion, Akcigit, and Howitt (2014) for a survey. Our paper emphasizes that while Internet firms are innovation-intensive, their technological breakthroughs do not directly lead to greater revenues. Rather, Internet firms have to invest in monetization, which requires resources and has an uncertain outcome. That is, compared to previous models of firm innovation, our model introduces an additional source of uncertainty, related to a firm's inability to draw revenues directly from successful innovation. Our model seeks to unravel the dynamics of these "monetizing" firms and helps understand whether uncertain monetization is indeed slowing the advancement of the technological frontier.

Our paper also relates to the finance and macro literature acknowledging the growing importance of intangible assets for nonfinancial firms (Hall, 2001), being knowledge or innovation capital (Hall, 2010; McGrattan and Prescott, 2010; Belo et al., 2019), organizational capital (Eisfeldt and Papanikolaou, 2013; Lustig, Syverson, and Van Nieuwerburgh, 2011), or customer capital (Gourio and Rudanko, 2014; Dou and Ji, 2018). In particular, our paper singles out a novel component, the monetization stock (or capital), which accumulates because firms need to spend resources to generate revenues out of their non-revenue-generating business. The monetization stock is highly firm-specific—it is largely made of all the relationship with third parties interested in advertising using the firm's customer base—and embedded into the key inputs of firm's employees (especially sales persons and "monetization specialists"). Consistent with Belo et al. (2019), our paper then underscores the importance of non-physical capital to explain firm value, by focusing on monetization and innovation.

Our paper also relates to the literature that investigates the secular change of the U.S. public corporation. As we document in Section 2, the number and market capitalization of public Internet firms increased tremendously over the last two decades. This upward trend is particularly impressive in light of the secular decrease in the number of listed firms observed over this same time period, see Kahle and Stulz (2017) among others. In the meanwhile, as illustrated by Begenau and Palazzo (2017), there has been a compositional change towards R&D-intensive firms, with newly listed firms being smaller, less profitable (see also Fama and French, 2004), and exhibiting higher cash flow volatility (Brown and Kapadia, 2007). As we illustrate in Section 2, Internet firms exhibit all of these characteristics. By analyzing the dynamic of this new type of firms, our paper contributes to the understanding of the changing nature of the U.S. corporations.

The paper is organized as follows. Section 2 motivates our study by illustrating the growing importance of Internet firms along with their key characteristics. Section 3 presents the model as well as describes the model solution and calibration. Section 4 presents the model implications. Section 5 analyzes some counterfactual experiments. And Section 6 concludes.

2 Motivating evidence

The prominence of Internet firms has increased sharply over the last decades. These firms provide a wide array of services to households and businesses. Notably, the business model of Internet firms is quite distinct from that of traditional manufacturing and service firms.[3] First of all, despite being successful on the R&D front—i.e., having devised an innova-

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

tive service utilized by a broad customer base—Internet firms often struggle to become profitable. Furthermore, these firms perform customer acquisition and revenues growth as related, but distinct, activities. Unlike traditional firms, Internet firms often seek customer growth without any direct revenue increases; for instance, by offering free services.

These features indicate the emergence of monetization as a distinct activity that Internet firms need to engage in. Monetization represents all the investments that enable and facilitate the generation of revenues from an existing customer base. We illustrate the growing significance of monetization by following an approach similar to Baker, Bloom, and Davis (2016). Specifically, we turn to the ten major U.S. newspapers and obtain a count of the word "monetize" and variants thereof. Figure 1 shows that the word count has increased steeply starting in 2005, and has more than quadrupled over the last decade. The growing importance of monetization motivates its inclusion as a distinct feature in a model of firm dynamics.

It is worth noting that Internet firms use a range of approaches to monetize their customers. One approach involves selling finely targeted advertisements, which Google and Facebook has mastered. Another approach focuses on selling virtual goods in otherwise free games. Many online gaming platforms have adopted this approach, including Niantic, the provider of "Pokemon Go." A third approach involves providing a free basic service overlaid with a premium product, for instance by Dropbox and Spotify.

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

2.1 Data

Data comes from the annual Compustat/CRSP industrial database. The sample period extends from 1995 to 2018. 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 5 million or missing. We also exclude observations with missing sales and for which we cannot calculate market capitalization.

Given the wide range of their services and the different market segments these firms operate in, defining Internet firms poses a challenge. We address this challenge by taking a parsimonious approach, which is based on SIC codes and time of listing. Specifically, our sample of Internet firms comprises firms listed after 1995 that belong to the four-digit SIC code 7370, which corresponds to "Services: Computer programming, data processing, etc." This definition captures most major Internet firms such as Alphabet (Google), Facebook, and Twitter.[4] Additional details regarding the sample construction are reported in Appendix B.

Figure 2 (left panel) shows that the market capitalization of public Internet firms (adjusted for inflation) has increased steeply over the last two decades. The figure shows that the market capitalization of Internet firms first reached a peak in 1999, ahead of the burst of the dot-com bubble. Internet firms' market capitalization 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 been decreasing during the same time period, see for instance Doidge, Karolyi, and

[4] In unreported results, we have also employed alternative definitions, including starting the sample of Internet firms from the year 2000, or considering firms with SIC codes 7370-7372 (therefore including "Computer Programming Services" and "Prepackaged Softwares"). Note that our definition excludes Amazon (whose SIC code is 5961, "[Retail] Catalog & Mail-Order Houses")—which now embraces several many 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. That is, we emphasize that we do not focus on the high performance technology company, but really on those that need to invest in monetization.

Stulz (2017) and Kahle and Stulz (2017). It is worth noting that the 2019's IPO wave of Internet firms implies that this number is expected to increase further. Finally, the right panel of Figure 2 illustrates that the sales of Internet firms have also increased notably over the last decades, with the steeper increase having occurred in the last decade.

We define some comparison groups to highlight the distinctive features of Internet firms. First, we define "R&D firms" as those belonging to an R&D-intensive industry (i.e., software, business services, chips, and hardware). Notably, to concentrate on the R&D-intensive firms which are closer in focus to Internet firms, we exclude industries such as pharmaceutical and medical equipment from our "R&D firms" definition.[5] Moreover, we define "New firms" as any firm that went public in or after 1995.

2.2 Characteristics of Internet firms

Table 1 displays some key characteristics for the four groups of firms described above (Internet firms, Non-Internet firms, R&D-intensive firms, New firms). It illustrates that Internet firms are systematically different from firms in other industries as well as from pure R&D-intensive firms.

First of all, the table shows that Internet firms are more R&D-intensive than Non-Internet firms. Internet firms are smaller on average, and have less tangible assets. Also, they display a larger *gross* profit margin due to their small operating costs. However, Internet firms have selling, general, and administrative (SG&A) expenditures that are substantially higher than those of Non-Internet firms. As a result, Internet firms are more likely to make operating losses than Non-Internet firms, a feature that has been stressed by several market commentaries. At the same time, the standard deviation of sales growth is greater for Internet firms than for Non-Internet firms. In fact, Internet firms may

[5] Including these industries, whose business model is quite different from that of Internet firms, would widen the gap between R&D-intensive firms and Internet firms.

remain unprofitable for a number of years while they keep improving the quality of their services and garner a critical customer base. Their monetization ability increases as they successfully attain technological breakthroughs that make the firm popular among a large customer base. When this is the case, it becomes relatively easier to sell ad spaces to third parties, just to mention an example. This upside potential translates into larger valuations of Internet firms than Non-Internet firms—specifically, the equity value (normalized by sales) of Internet firms is 82% larger than that of other firms.

Table 1 illustrates that Internet firms are also quite different from pure R&D-intensive firms. Notably, Internet firms and R&D-intensive firms have similar R&D ratios.[6] However, Internet firms have larger SG&A expenditures than R&D-intensive firms. In fact, differently from R&D-intensive firms, Internet firms need to extensively invest in monetization in order to translate their technological breakthroughs—aimed at improving the service provided for free to its customer base—into revenue-generating activities. Monetization expenditure inflate SG&A expenditures. On average, Internet firms are slightly smaller than R&D-intensive firms and have less tangible assets. Whereas Internet firms have greater profit margins thanks to their tiny costs of goods sold, they are more likely to make operating losses due to their large R&D expenditures. Overall, Internet firms have much larger valuation ratios than mere R&D intensive firms, with the mean firm value normalized by sales being about 58% greater. Finally, the table also shows that Internet firms are different from New Firms.[7] Again, we find that Internet firms are smaller and make larger gross profits than New firms. However, Internet firms have much larger SG&A expenditures and, as a result, are more likely to make losses than new firms. Overall, Internet firms' valuation ratios are on average much larger than those of New firms (about 41% larger).

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

[7] These results are robust when varying the year cutoff from the year 1995 to the year 2000 (for the sake of brevity, we do not report the corresponding table).

Thus, our analysis exemplifies that Internet firms exhibit a business model that is quite distinct from that of manufacturing firms as well as of pure R&D-intensive firms. These differences call for the need of a model that can help understand these firms' dynamics, given their growing prominence. We embrace this goal in the next section.

3 The model

We develop a partial equilibrium model of firm dynamics that has two distinctive features. First, firms invest in innovation to acquire customers by improving the quality of their service/product, as in previous quality ladder models. Second, firms invest in monetization to generate revenues and help achieve profitability.

3.1 Assumptions

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

Customer base. We model a firm that provides a service to customers at no charge. The firm's customer base, denoted by C, depends on endogenous and idiosyncratic factors. The endogenous factor is the quality of the firm's service, denoted by q, which the firm can actively improve via innovations obtained through R&D expenditures. Intuitively, more customers are interested in using the firm's service if its quality is greater. The idiosyncratic factor is denoted by c and represents changes in the customers' demand 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

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

Quality improvements via R&D expenditures. The firm seeks to expand its customer base by increasing the quality of its service through innovative improvements. As in previous models of firm innovation, improving quality via R&D expenditures is costly and has an uncertain outcome.[8] If the firm spends the flow cost zq on innovation, it affects the probability of attaining a breakthrough as follows:

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

where θ represents a binary random variable that equals one if the firm attains a breakthrough (and equals zero otherwise), whereas $\delta > 0$ is a positive constant. This specification implies that technological breakthroughs are more costly to attain if the quality of the service is higher. The parameter δ governs how innovation expenditures affect the probability of attaining a breakthrough: For a given R&D expenditure zq, the firm is more likely to attain a technological breakthrough if δ is greater. When the firm attains a breakthrough, the quality of the firm's service jumps from q to

$$q' = q(1 + \lambda),$$

where $\lambda > 0$ represents the ensuing quality improvement. As the customer base is proportional to the quality level (see Equation (1)), an innovation leads to an increase in the customer base.

Competitive threats. The quality of the firm's service q can be interpreted in absolute terms or in relative terms. In the second interpretation, q represents the quality of the firm's service vis-à-vis the quality of similar services offered by competitors. Throughout the model, we embrace this second interpretation, which allows us to model competition

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

in reduced form.

Specifically, we assume that the firm is subject to competitive threats, which materialize in a stochastic fashion and are modeled as a binary random variable, $\Theta \in \{0, 1\}$. That is, if a competitive threat materializes (i.e., Θ equals one), the relative quality of the firm's service (and, thus, of its customer base) declines by a factor $\Lambda \in [0, 1]$, as follows:

$$q' = q(1 - \Lambda).$$

We assume that competitive threats materialize with probability $P(\Theta = 1) = \chi$ each period. If $\Lambda = 0$ or $\chi = 0$, the firm faces no competitive pressure.[9]

Idiosyncratic changes in the customer base. A firm's customer base also varies for idiosyncratic reasons, for example, changes in customers' tastes that lead them to stop using the firm's service. This modeling feature captures the idea that customers randomly try out services provided by different firms, or simply stop using that given service. Specifically, we assume that the idiosyncratic component of the customer base varies over time as follows:

$$\log(c') = \rho \log(c) + \epsilon, \quad \epsilon \sim N(0, \sigma^2). \tag{3}$$

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

Monetization. The success of Internet firms depends both on their ability to innovate and their ability to effectively monetize such innovations. As a result, firms need to invest

[9] As our focus is on the dynamics and decision-making process of a single firm, we take into account competitive threats in reduced form—as a result, the probability χ is exogenous. We leave the full-fledged study of industry dynamics for future research.

in both activities. We capture the challenges involved in monetization by assuming that monetization expenditures have an uncertain outcome. Also, we allow monetization advancements to persist by modeling the firm's monetization stock, which reflects the ideas that enable a firm to earn revenues from its customer base. For example, these ideas may include platforms for selling advertisements, portals for vending virtuals goods, and relationships with business partners.

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

$$\eta' = \eta\,(1-\phi) + SM, \quad M \sim Exp(\nu). \tag{4}$$

In this equation, S denotes the firm's monetization expenditure, which is optimally choosen in each period. Equation (4) captures the uncertain returns to monetization through the random variable M, which follows an exponential distribution with inverse scale parameter ν. As a firm spends more on monetization, the expected increase in the monetization stock is larger. In expectation, the firm attains an increase in the monetization stock equal to S/ν if it spends S on monetization.[10] If a firm were to cease spending on monetization ($S = 0$), the monetization stock would decrease over time at a rate denoted by ϕ, which represents the depreciation rate. The depreciation of the monetization stock reflects potential deterioration in the infrastructure and relationship that enable the firm to successfully monetize their customer base.

Revenues and operating costs. A firm's revenues depend on its monetization stock η as well as on its customer base C, as follows:

$$\pi(C,\eta) = \eta^{\alpha} C^{1-\alpha}. \tag{5}$$

[10]This implies that monetization expenditures have a larger upside potential for smaller values of ν.

In this Cobb-Douglas specification, the parameter α denotes the elasticity of revenues with respect to the monetization stock. Intuitively, a greater monetization stock or a larger customer base result in more revenues. This specification captures the fact that a larger customer base facilitiates monetization by increasing the audience for ads or the number of potential buyers of virtual goods. At the same time, it also captures the idea that a firm that neglects monetization will struggle to generate revenue.[11]

The firm incurs operating costs in any period, which we denote by γq. This modeling implies that while operating costs rise as firms build their customer base through increases in service quality, they do not vary with idiosyncratic fluctuations in customers, c.[12]

3.2 Discussion of the assumptions and modeling approach

The key aspect of our setup is the explicit modeling of 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, Internet firms face uncertainty at the innovation stage *and* at the monetization stage—i.e., both activities involve trials and errors.

The reason why firms in the model need to monetize is that their customer base does not map to revenues as in the traditional models of firm dynamics. Rather, it serves as an input of production. Indeed, Internet firms' customer base can be viewed as the catalyst that helps the firm turn non-revenue-generating services into actual revenues—i.e., by increasing the firm's visibility, it makes monetization easier. For example, a third party is more willing to buy an ad space from an Internet firms that has a large user (customer) base, because more people will be viewing that ad.

Consistent with Internet firms' low asset tangibility—as illustrated in our analysis in

[11] For simplicity, our model does not capture demand for the services provided by firms, and as such, does not separate prices from revenues.

[12] Our specification of operating costs is similar to Barlevy (2007), who assumes that operating costs scale in proportion to the rate at which output increases.

Section 2—our model emphasizes the key role of non-physical capital at Internet firms. In a similar vein, Belo et al. (2019) show that the importance of physical capital for explaining firm value has decreased in the last decade, while the importance of knowledge capital increased, especially in high-tech industries. In our model, we focus on the technology capital embedded in the service quality level and the monetization stock. In addition, the monetization stock/capital represents all the activities, infrastructure, and resources accumulated with the goal of providing the firm with a source of revenues—connections with third parties interested in buying ad spaces or other virtual goods—and is largely embodied in labor inputs of sales people and the so-called monetization managers.

Whereas our model abstract from a full-fledged analysis of industry dynamics, we recognize that Internet firms do not operate in a vacuum and capture competition in reduced form. In fact, Internet firms race on the innovation dimension to improve the quality of their service vis-à-vis competitors and maintain and expand their customer base. Whenever competitors innovate the quality of a similar service (an event that happens with exogenous probability in our model), the relative quality of the firm's service decreases. The direct impact of this type of innovations by competitors is an immediate reduction in the firm's customer/user base (i.e., the firm's service becomes relatively less attractive to customers), which in turn decreases the firm's revenues for a given monetization level.

Finally, it is worth noting that our model does not aim to describe startups, whose business ideas are at a preliminary stage. Very often, startups do not have a (finalized and polished) service that customers can directly access. Startups are very much at the stage of struggling to get financing from venture capitalists, angel investors, or just family and friends, while they develop their business idea. Instead, our paper aims at understanding the behavior and decisions of those firms that already provide virtual services to users, which are becoming ubiquitous and cover an immense array of needs. Moreover, it is worth noting that our paper abstracts from the financial decisions of these firms, that we leave for future research.[13]

3.3 Firm problem

The firm's objective is to maximize the expected present value of dividends to shareholders. The Bellman equation is given by:

$$V(c, q, \eta) = \max_{S,z} \quad \pi(C, \eta) - \gamma q - zq - S + \beta E[V(c', q', \eta')] \tag{6}$$

subject to equations (3), (4), and

$$q' = q(1 + \lambda\theta - \Lambda\Theta). \tag{7}$$

Equation (6) illustrates that the state variables of the firm problem include the customer base, which embeds its idiosyncratic and endogenous components c and q, as well as the firm's monetization stock η. Current dividends are given by revenues (the first term in Equation (6)) net of operating costs, R&D expenditures, and monetization expenditures (second through fourth terms). In the following, we will refer to the sum of R&D and monetization expenditures as SG&A expenditures. The last term in Equation (6) equals the continuation value of the firm. The firm returns any positive cash flow remaining after operating, monetization, and innovation expenditures as dividends to shareholders; negative dividends capture equity issuances.

As in previous innovation models, R&D expenditures decrease current dividends while increasing the probability of attaining a technological breakthrough, as shown by Equation (2). A technological breakthrough increases the relative quality of the firm's service by a factor λ (see Equation (7)),[14] which helps the firm expand its customer base. At the

[13] In unreported results, we find that Internet firms' leverage ratios are much smaller than those of Non-Internet firms.

[14] The probability of a technological breakthrough, θ, and the likelihood of a competitive threat, Θ, are

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 (6) with respect to z, we get the firm's optimal R&D expenditures (See Appendix A for a proof).

Proposition 1 *The firm's optimal R&D expenditures satisfy*

$$z = \frac{1}{\delta} \log \frac{\beta\delta\Big(E[V(c', q', \eta')|\theta = 1] - E[V(c', q', \eta')|\theta = 0]\Big)}{q}. \tag{8}$$

Intuitively, if the increase in firm value following a technological breakthrough is expected to be greater (the difference in the numerator of Equation (8)), the firm will spend more on R&D. The denominator of Equation (8) captures the idea that when relative quality is already large, returns to innovation may diminish, consistent with the existing literature.[15]

The firm's revenue function (Equation (5)) implies that, in the limit, the firm generates no revenues from its customers base as the monetization stock approaches zero.[16] As a result, firms have incentives to invest in monetization. Equation (6) illustrates that S is also an endogenous choice variable, which affects the monetization stock in a stochastic fashion, as shown by the transition equation for η (see Equation (4)). Similar to R&D, monetization expenditures also reduce current dividends while entailing expected future increases in the monetization stock and, thus, higher 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.

both Bernoulli random variables.

[15] For example, see Acemoglu and Cao (2015), among others.

[16] Indeed, the Inada conditions apply to the monetization stock.

3.4 Calibration

We calibrate the model using firm-level data from Compustat, as described in Section 2.1. The calibration focuses on minimizing the difference between a selected set of moments for our empirical sample of Internet firms with the same moments from an artificial data set obtained by simulating the model. We choose moments aimed at capturing the key characteristics of Internet firms described in Section 2.

Table 2 reports the empirical moments as well as those obtained by simulating the model. It illustrates that the model reproduces the empirical characteristics of Internet firms well. In particular, the model replicates the notable gross profit margin of these firms as well as their substantial SG&A expenditures. Because of these large SG&A expenditures, Internet firms' net profit margin is negative on average,[17] and a large fraction of firms, about 40%, suffers losses. At the same time, the model also reproduces the elevated valuation ratios of these firms. Standard models would struggle to replicate the combination of frequent losses and high valuation ratios. In addition, the model replicates some key characteristics of Internet 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 the empirical counterpart. Finally, the model's autocorrelation of the organizational capital normalized by sales is somewhat larger than in the data.

Table 3 reports the values of the calibrated parameters that enable this close matching. The monetization share in the Cobb-Douglas function, α, is set to 0.26, which implies that while the customer base has a greater impact, monetization also plays a vital role. The size of quality improvements upon a technological breakthrough, λ, is set to 0.11.[18] Moreover,

[17]We do not match net profit margin as a separate moment due to the fact that it equals gross profit margin net of SG&A expenditures.

[18]The value of the parameter λ is greater than in some other innovation models, for instance Akcigit and Kerr (2018) or Akcigit, Hanley, and Serrano-Velarde (2019), to reflect the sustained growth in the quality

the sensitivity of technological breakthroughs to R&D expenditures, δ, is equal to 4.57. The idiosyncratic component of the customer base, c, has an autoregressive coefficient ρ equal to 0.33, with the standard deviation of the normally-distributed shock σ equal to 0.41. These two parameters capture the customer churn faced by Internet firms. The operating cost coefficient, γ, equals 0.52, which helps the model match the gross profit margin in the data.

Turning to the monetization-related parameters, we set ν to 0.44. For any given monetization expenditure S, a smaller ν implies a larger expected increase in the monetization stock. Moreover, the value of ϕ, which equals 0.23, 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 intangibles.[19]

We set the parameters describing the firm's competitive threats, χ and Λ, respectively to 0.15 and 0.23. The values associated with these parameters imply that firms face a 15% probability of a 23% decrease in the relative quality of its service because of technological breakthroughs by competitors. This calibration implies that expected increases in service quality from endogenous innovations about equal the expected decreases in quality from competitive threats.

4 Model implications

In this section, we detail various implications of our model. In particular, we examine additional moments of interest from our simulated model; the interaction between innovation and monetization; firm dynamics after an innovation; and the role of the customer base in this setting.

of services in this segment of the economy.

[19] In comparison, Gourio and Rudanko (2014) assume a depreciation rate of 10% for physical capital and of 15% for customer capital.

4.1 Additional moments

Table 4 showcases additional features of the model. In particular, we focus on simulated moments that help illustrate the firm dynamics implied by the model, but that are not clearly comparable with the data.

The firm's mean innovation rate equals 0.32, which reflects that Internet firms continually seek to increase the quality of their services. Decomposing SG&A expenditures into R&D and monetization, our model implies that Internet firms invest more on innovation than on monetization, on average. In fact, monetization expenditures constitute about 32% of SG&A expenditures. In the following, we provide a deeper examination of which firm characteristics lead firms to engage more on monetization versus innovation. The table also illustrates that the average increase in monetization stock is about 9% on a given time interval (year), on average. This increase in monetization represents the combination of monetization expenditures, S, and realizations of monetization increments, M, net of depreciation.

Furthermore, Table 4 shows that the growth rate of the firm's customer base has a larger standard deviation than the growth rate of sales, as reported in Table 2. This result reflects the higher volatility of the customer base compared to the monetization stock, in part due to the presence of idiosyncratic shocks to the customer base as well as competitive threats. Comparing Table 2 with Table 4 illustrates that, while firms' gross profit margin is positive due to their relatively small operating costs, their net profit margin is negative on average. The negative net profit margin reflects Internet firms' large SG&A expenditures. Thus, our model reproduces the surprising combination of high valuations and persistent negative profitability of Internet firms.[20]

[20] Appendix C reports commentaries from the financial press expressing puzzlement at this empirical pattern.

4.2 The dynamics of innovation and monetization

We first investigate the correlation between innovation and monetization. Our calibrated model shows that innovation and monetization expenditures have a weak correlation of -0.12. This negative correlation reflects the key tradeoff in the model—firms allocate resources between monetization and R&D expenditures. I.e., firms do not heavily invest in both innovation and monetization simultaneously. By contrast, the correlation between the quality level and the monetization stock equals 0.88. This strong positive correlation reflects that firms tend to build up their monetization stock when they have a large customer base, which occurs when the quality of their service is high.

We sort firms into bins of high/low quality levels and high/low monetization stock, where "high" and "low" are respectively defined to be above and below their medians in the simulated model. Consistent with the positive correlation between monetization stock and quality levels, Table 5 shows that about 46% of firms have both monetization stock and quality levels above the median (henceforth, denoted as HH firms), and 44% of firms have both of these quantities below the median (henceforth, LL firms). The remaining ten percent of firms is almost equally split between firms with low quality and high monetization (henceforth, LH firms) and firms with high quality and low monetization (henceforth, HL firms). Unsuprisingly, HH firms have the highest sales, and LL firms the lowest.

Table 5 illustrates that firms differ substantially in their optimal expenditures across these bins. It shows that LL firms spend the largest share of their sales on SG&A expenditures (monetization plus innovation expenditures), whereas HH firms spend the least. This result reflects the decreasing-returns-to-scale dynamics of the model, as innovation becomes more challenging at higher quality levels.[21] Decomposing SG&A expenditures into R&D and monetization expenditures shows that LL firms spend a large fraction of their

[21] Among others, see Acemoglu and Cao (2015).

SG&A, about 86%, on innovation. As these firms have low quality—and, thus, a relatively small customer base—LL firms focus on increasing the quality of their service, and devote little resources to monetization. By contrast, HH firms spend about equal amounts on monetization and innovation, on average, reflecting the complementarity between monetization and quality levels in the firm's revenue function. Having attained a solid customer base and large monetization stock, HH firms continue to invest in innovation to fend off competitive pressure that could decrease the relative quality of the firm's service. In addition, they invest in monetization to preserve their monetization stock, which is subject to depreciation.

Firms in the remaining bins exhibit SG&A to sales ratios in between those of HH and LL firms. This result reflects that HL and LH firms have more growth potential than HH firms, but less than LL firms.[22] HL firms, who have built up a solid customer base via innovation, spend a larger proportion of their SG&A expenditures to monetize their customer base. One can view the quality level as a catalyst that spurs monetization expenditures by firms. In comparison, LH firms devote almost all of their SG&A expenditures on innovation. These firms are those which have suffered losses in quality due to advances by competitors and, therefore, focus on rebuilding their customer base.

Overall, monetization expenditures are highest for HH and HL firms, i.e., the firms characterized by high quality level. This result reflects that firms first attain a high quality level—and, therefore, a large customer base—before turning to monetization. Our analysis then implies that innovation precedes monetization; i.e., innovation alone is not sufficient for Internet firms to attain profitability.

We next delve into how firms in different quality and monetization bins differ along measures of profitability. We examine both gross profitability—sales net of operating costs—as well as net profitability—sales net of operating costs and SG&A expenditures. Table 5

[22] Note that the sales of LH and HL firms lie in between those of HH and LL firms.

shows that firms in the high-monetization bins—the HH and LH firms—are highly profitable and display the lowest fractions of firms making losses. Within the high-monetization bins, HH firms have a lower gross profit margin than LH firms, as they have greater operating costs.[23] However, HH firms earn the highest net profit margin, as their SG&A expenditures are notably smaller than LH firms.

Despite having positive gross profit margins, firms in the low monetization bins (LL and HL) make substantial losses, primarily due to their large SG&A expenditures. Specifically, Table 5 shows that about 65% of firms in the HL bin suffer losses, and this fraction increases to 75% for the LL firms. As such, this analysis shows that the monetization stock is a key driver of profitability of Internet firms, whereas having a large customer base is not sufficient.

The table also shows that the average rate of sales growth varies substantially across the different bins.[24] HL firms have the highest growth rate, equal to 4.6%, as these firms have built a large customer base and focus on monetization, which has a larger impact on revenues. LH firms have the next highest sales growth, as these firms can grow sales relatively quickly by improving the quality of their service and regaining their customers. In comparison, LL and HH firms have slightly negative sales growth rates. LL firms have negative sales growth as quality increases, by themselves, do not translate into sizeable revenues absent monetization. In turn, HH firms have slightly negative growth rates as these are mature firms that invest less in SG&A relative to sales.

Turning to valuations, Table 5 shows that HL firms are those with the largest ratio of firm value to sales, on average. While these firms have increased firm value via innovation, they have yet to monetize these innovation. Successful monetization enables them to increase sales and firm value and, thus, become HH firms. The table also shows that firms

[23] Recall that operating costs equal γq in the model.
[24] Sales growth is reported in log terms.

in the LL bucket have the lowest valuations, both in absolute terms and relative to sales. This reflects that these firms need to build both their quality level and their monetization stock.

One striking feature of our model is that, across all bins, firms have a high valuation ratio. This result reflects the growth potential of Internet firms, which supports high valuations for firms with low quality or monetization levels. As such, our model successfully replicates the puzzling observation that Internet firms have high valuation ratios even in the presence of persistent losses.

4.3 Firm dynamics after a technological breakthrough

We next seek to understand firm dynamics in the aftermath of a technological breakthrough. Figure 3 illustrates how firm decisions—R&D and monetization expenditures—and outcomes—net profit margin and firm value to sales—react to such an event. It plots average values for the above quantities around a technological breakthhorugh, which occurs during the transition from time 0 to 1.

The figure shows that R&D expenditures slightly decrease after a technological breakthrough, on average. Conversely, monetization expenditures increase following a breakthrough, and then return to their pre-breakthrough levels. This pattern reflects firms attempting to monetize the larger customer base stemming from the increase in their service quality. On net, total SG&A expenditures increase upon a breakthrough and subsequently decrease. As a result, net profitability declines sharply following the breakthrough, becoming more negative, on average. Subsequently, reflecting successful monetization as well as lower SG&A expenditures, firm profitability increases above the pre-breakthrough levels. This result is consistent with the empirical observation that Internet firms suffer persistent losses despite their successful innovations and technological advancements. Overall, firm value increases immediately following a breakthrough despite the immediate drop in profitability, as investors anticipate that the firm may eventually monetize the innovation. Overall, our model's dynamic pattern of profitability and valuation following an innovation differs from that implied by traditional models of innovation.

We next investigate whether firms exhibit different dynamics, conditioning on their quality level and monetization stock. To this end, we return to the four groups of firms analyzed in Table 5. Figure 4 shows the dynamics of R&D expenditures, monetization expenditures, net profit margin, and firm value after a breakthrough. The top left panel shows that R&D expenditures decrease slightly across the different groups of firms. The top right panel shows that most firms, other than LH firms, increase monetization expenditures following a breakthrough.[25] Consistent with Table 5, the figure shows that HL firms maintain elevated monetization expenditures, while LH firms essentially do not invest in monetization, irrespective of the occurrence of a technological breakthrough.

The bottom left panel shows that, due to the pickup in monetization expenditures, the net profit margin of LL and HH firms decrease following a breakthrough. Their profit margins subsequently rebound to their pre-breakthrough level. It is worth noting that the net profit margins of HH and LH firms—i.e., the firms with high monetization stock—remain quite close in magnitude.[26] This result suggests that monetization is key to profitability, whereas high service quality is not sufficient to attain it. Finally, the bottom right panel illustrates that firm value increases after technological breakthroughs, across all of the different bins.

4.4 The role of the firm's customer base

In most of our analysis, we condition on q and η, which are the endogeonus state variables that firms affect through their R&D and monetization expenditures. We next look at

[25]This reflects the emphasis of LH firms on generating innovations to regain their customer base.

[26]Recall that LH firms mainly arise from firms whose quality level has decreased due to the realizations of competitive threats.

firm characteristics by conditioning on firm customer base, $C = qc$, which is affected by idiosyncratic fluctuations on top of the service quality level. Table 6 shows that firms with high customer base display a much larger monetization stock on average, which is about four times larger than the average monetization stock of low-customer-base firms. This result shows the complementarity between the customer base and the monetization stock in the model.

Firms with a low customer base have significantly lower sales than those with a high customer base. The low-customer-base firms spend a larger fraction of their sales on SG&A, in part due to their greater growth prospects. These firms also spend significantly less on monetization. In fact, low-customer-base firms put a larger emphasis on innovation than on monetization, as they attempt to build their customer base through increases in service quality. This result indicates that innovation precedes monetization.

Table 6 also illustrates that low-customer-base firms suffer net losses, on average, largely due to their heavy SG&A expenditures. Conversely, high-customer-base firms exhibit a healthy profit margins, both gross and net. While both firm value and sales vary sharply across these two groups of firms, their ratios remain fairly similar, reflecting the growth potential of low-customer-base firms.

5 Counterfactuals

This section presents some model counterfactuals. First, we examine the effect of eliminating uncertainty from monetization. Next, we investigate the effect of changes to the monetization-related parameters. And last, we vary the innovation environment by changing a firm's innovation efficiency and the likelihood of competitive threats.

5.1 Eliminating uncertainty from monetization

Monetization and monetization uncertainty set Internet firms apart from pure R&D-intensive firms and constitute the distinctive elements of our model. These features imply that firms may need to divert resources from innovation to monetization, as they seek to attain profitability. Furthermore, the uncertainty in monetization implies that these expenditures will not always bear fruit.

We isolate the effect of monetization uncertainty by considering a counterfactual setup in which increases in the monetization stock are deterministic. Specifically, we modify Equation (4) to:

$$\eta' = \eta(1-\phi) + SE[M] = \eta(1-\phi) + S\nu^{-1}. \tag{9}$$

That is, for a given monetization expenditure S, the increase in the monetization stock equals the expected increase in the baseline model. As such, the firm does not face the risk of low (or zero) realizations of M, nor does it gain from large increases in M.

Table 7 compares selected moments from the baseline setup—which embeds monetization uncertainty—with those associated with the counterfactual environment with no monetization uncertainty. It illustrates that, absent monetization uncertainty, firms reach a higher monetization level on average, which leads to greater sales and firm value. This result reflects that, fixing the customer base, revenues are a concave function of the monetization level. This implies that 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] As a result, firms have larger monetization expenditures in the counterfactual with no uncertainty.

Absent monetization uncertainty, firms spend a smaller fraction of their sales on SG&A expenditures; of these SG&A expenditures, firms spend a larger fraction on monetization.

[27] One obtains this result from an application of Jensen's inequality.

As such, while both R&D and monetization expenditures rise substantially in absolute terms, the ratio of R&D to sales falls, and the ratio of monetization expenditures to sales remains about unchanged. Thus, our analysis suggests that removing uncertainty from monetization shifts resources from innovation to monetization.

Due to their larger sales and smaller SG&A expenditures, firms are less likely to make operating losses absent monetization uncertainty. In fact, Table 7 shows that about 26% of firms suffer losses in this counterfactual, which is notably smaller than the 44% of firms suffering losses in the baseline model. On average, the net profit margin of firms rises substantially absent monetization uncertainty, and becomes positive. This increase in net profits significantly increases firm value.

Notably, even if firms spend a smaller fraction of their sales on R&D in this counterfactual, they display higher innovation rates than in the baseline model. This result is driven by the higher sales associated with this counterfactual compared to the baseline model. An important question then arises as to whether monetization uncertainty affects the relative quality of the firm's service and, thus, the rate of technological advancement. To address this question, Figure 5 shows the distribution of quality levels for firms in the baseline case (the left panel) versus the counterfactual without monetization uncertainty (the right 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 ability to monetize technological breakthroughs discourages innovation. In fact, when monetization is uncertain, firms need to divert substantial resources from innovation to attain profitability, then slowing technological advancement.

5.2 Sensitivity to monetization

In this section, we further investigate our baseline setup and analyze counterfactuals in which we vary the monetization-related parameters: ν, which drives the expected increase in monetization; ϕ, which represents the depreciation rate of the monetization stock; and α, denoting the monetization share in the firm's revenue-generating function. In these counterfactual, we vary these parameters by 10% compared to the values in Table 3.

Varying the distribution of monetization increases, ν. For a given monetization expenditure S, the ensuing increase in monetization is expected to be larger when ν is smaller—i.e., monetization is more efficient. Table 8 shows some selected moments associated with counterfactual environments with higher or lower values of ν than in the baseline.

The following patterns emerge. First, firms spend a lesser fraction of their sales on SG&A expenditures when ν is smaller; however, firm sales are much larger in this case. Of these expenditures, almost half is devoted to monetization if ν is smaller, whereas only 15% of them is spent on monetization if ν is larger. These results indicate that the expectation of attaining greater increases in the monetization stock for a given S makes firms more willing to invest in monetization. As a result, the mean monetization level is notably larger in the counterfactual with smaller ν, being almost four times as big.

Moving on to innovation, our analysis illustrates that firms' innovation rate is greater when ν is smaller and, as a result, average service quality is larger, on average.[28] That is, when monetization is more efficient, the firm's inventiveness also improves, reflecting the complementarity between innovation and monetization in our model.

Overall, profits and firm values increase noticeably as monetization becomes more efficient. This analysis thus highlights the key role that monetization plays in determining the outcomes of the firms in our model.

[28] As ν decreases, R&D expenditures rise in absolute terms. However, as sales also increase, R&D expenditures to sales declines.

Varying the monetization depreciation rate, ϕ. Our model introduces the concept of monetization stock, which may be viewed as part of the overall intangible capital of the firm. We next investigate counterfactuals with higher or lower depreciation rates of this monetization stock.

Table 8 report the counterfactuals varying the depreciation rate ϕ, in the columns denoted as ϕ^+ and ϕ^-. It shows that when the monetization stock depreciates at higher rate, firms invest considerably less in monetization. As a result, firms have lower monetization stocks on average and, thus lower sales. While firms shift resources from monetization to innovation, the overall drop in sales implies a lower absolute level of R&D expenditures, which leads to a lower innovation rate. The large difference in quality and monetization levels across the two counterfactuals leads to a sizable gap in profitability. The table shows that about 20% of firms make losses in the counterfactual with smaller ϕ, whereas this number increases to a striking 60% of firms in the counterfactual with larger ϕ. The differences in profitability map into substantial differences in firm value.

Overall, these counterfactual experiments confirm that conditions that makes monetizing the customer base—thus achieving profitability—more challenging also reduces firms incentives to innovate.

Varying the elasticity of the monetization stock in the revenue function, α. We next study the impact of varying the elasticity of revenues to the monetization stock, α. Table 8 illustrates that firms spend more on monetization in the counterfactual with larger α—in absolute terms and as fractions of sales or SG&A expenditures. Indeed, because the monetization capital has a larger weight on revenues in this environment, firms invest more on monetization, all else equal, leading to a higher monetization stock.

Consistent with the patterns observed above, the higher monetization stock encourages firms to spend more on R&D, leading to a higher innovation rate. As a result, an increase in the share of monetization in the revenue function, α, leads to higher sales, profits, and firm values.

5.3 Innovative edge and competitive pressure

We next investigate counterfactual environments in which we vary the parameter δ—which represents how efficiently the firm translates R&D expenditures into technological breakthroughs—as well as the parameter χ—which represents the likelihood that competitors will launch innovative products, thus decreasing the relative quality of the firm's service. As before, we examine counterfactuals varying these parameters by 10%.

Varying the firm's R&D efficiency, δ. For a given R&D expenditure, the likelihood of attaining a technological breakthough increases with δ. Thus, the parameter δ can be interpreted as a measure of the firm's R&D efficiency. Table 9 illustrates that R&D-efficient firms display larger innovation rates, equal to 35% in the counterfactual with larger δ versus about 24% in the counterfactual with smaller δ. Indeed, the average quality of firm's service in the counterfactual with higher δ is more than five times larger than in the counterfactual with lower δ.[29]

Moreover, firms spend a greater fraction of their SG&A expenditures on monetization if firms are more R&D efficient: About 50% of SG&A expenditures are devoted to monetization if δ is larger, compared to only 13% when δ is smaller. In fact, because R&D-efficient firms need to invest comparatively fewer resources on R&D in order to attain a technological breakthrough, these firms have more resources for monetization. On average, firms display a larger monetization level in the counterfactual with larger δ—about five times bigger—than in the counterfactual with smaller δ. Greater quality and monetization levels

[29] Whereas R&D expenditures normalized by sales are smaller when δ is larger—reflecting the significant increase in sales—they are larger in absolute terms.

in turn imply that firms have a positive (and large) net profit margin if δ is larger, are less likely to make losses, and have greater valuation ratios.

These results illustrate that an innovative edge helps Internet firms build a customer base, successfully monetize it, and attain profitability.

Varying the degree of competitive pressure, χ. While abstracting from a full description of industry dynamics, our model embeds competitive threats in reduced form by assuming that firms can experience a decrease in their relative quality with probability χ. If χ is larger, firms face stiffer competition as they are more likely to face reductions in the relative quality of their services, which result in decreases in their customer base.

Table 9 shows the effect of varying the parameter χ. When χ is greater, firms have lower sales, on average. Furthermore, firms invest a lower fraction of their sales—and of their SG&A expenditures—on monetization and a higher fraction on R&D. This reflects firms being more proactive in seeking innovative improvements in their service, to keep up with competitors. However, absolute R&D expenditures decline when χ is higher, leading to slightly smaller innovation rates.[30] The higher frequency of competitive threats combined with the lower innovation rates lead to a lower average quality level, which implies a smaller customer base. In addition, firms have a smaller monetization stock, on average, in the counterfactual with larger χ, which is unsurprising given the smaller investment in monetization.

Lower monetization stocks and quality levels imply that firms are less profitable and have lower valuations when competition is stiffer. Table 9 indeed shows that almost half of firms make operating losses when χ is larger. Overall, increased competition weakens innovation and monetization outcomes.

[30] While R&D to sales increases, the flow of R&D declines due to the drop in sales.

6 Concluding Remarks

Over the last two decades, the market capitalization and prominence of Internet firms—i.e., those firms providing services via the Internet—have increased tremendously. These firms typically provide services to their customers at no charge, and face significant challenges deriving revenues out of—or monetizing—their customer base. Indeed, several key features make Internet firms quite different from other firms. First, despite having devised an innovative service with a broad customer base, Internet firms are often unprofitable, as Internet firms' customer base does not map to revenues as in traditional models of firm dynamics. Second, these firms have large SG&A expenditures, which nests their monetization and R&D expenditures. This paper provides a novel model of firm dynamics that examines the monetization of innovations and the associated uncertainties.

Our analysis explains puzzling empirical features of these firms, including their high valuations despite lingering unprofitability and their low revenues despite a large customer base. Furthermore, our model shows that monetization and service quality are highly correlated, with innovation expenditures preceding monetization expenditures. Our analysis shows that having a large customer base is a necessary but not sufficient condition to attain profitability. Counterfactual analysis suggest that monetization uncertainty causes firms to be less innovative, less profitable, and less valuable, overall slowing technological advancement.

Appendices

A Proof of Proposition 1

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

$$-q+\beta\frac{\partial}{\partial z}E[V(c',\eta',q')]=0. \tag{10}$$

The first term represents the first derivative of direct R&D cost (recall that it is more costly to innovate if the relative quality of the service is greater). The second term is the impact of R&D expenditures on the expected value of the firm in the next period. To solve for z, note first that the expected value of the firm in the next period can be re-written as follows:

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

i.e., as the sum of the expected value of the firm if the firm indeed 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 of the firm if the firm does not attain a breakthrough in the next period. Using the expression for $P(\theta=1)$ in equation (2), the above equation 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 gives

$$\frac{\partial}{\partial z} E[V(c', \eta', q')] = \delta e^{-\delta z} \Big(E[V(c', q', \eta')|\theta = 1] - E[V(c', q', \eta')|\theta = 0] \Big) \tag{11}$$

Substituting this expression into (10) gives and solving by z 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 our samples described in Section 2. We start by providing definitions of the samples analyzed in Table 1:

Internet firms: Firms that went public in or after 1995 and with SIC code 7370.

Non-Internet firms: All the firms that do not meet the definition of Internet 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 we believe that their key features of firms in these industry are structurally different from Internet firms. That is, if we included Pharmaceuticals and Medical Equipments among R&D-Intensive firms, the differences betweeen Internet and R&D-intensive firms would have been even more striking.

New Firms: Firms that went public in or after 1995, with an SIC code different from 7370.

Next, we provide definitions of the key variables analyzed in Table 1 (in parentheses, we report the Compustat items employed):

Firm size: Logarithm of total sales (SALE) .

Profit margin to sales: Mean of the ratio of a firm's gross profits (GP) to sales (SALE).

Equity value to sales: Mean of the ratio of equity value (calculated by mulitplying outstanding common shares by fiscal year closing price, CSHO*PRCC_F) to sales (SALE).

Fraction Making Loss: Mean fraction of firms that have negative operating income (OIBPD).
SG&A expenditures to sales: Mean of the ratio of a firm's selling, general, and administrative expenses (XSGA) to sales (SALE).
R&D expenditures to sales: Mean of the ratio of a firms research and development expenditures (XRD) to its total sales (SALE).
Sales Growth (std): Standard deviation of firms' real sales (SALE) growth.

The definitions above are also employed to generate the data moments reported in Table 2. In that table, we also employ the autocorrelation of organizational capital to sales. Specifically, we exploit the definition of Eisfeldt and Papanikolaou (2013) (see section II.A) and normalize it by sales (SALE) (see also Lev and Radhakrishnan (2005)).

C Monetization: Anecdotal evidence and some examples

Our model is motivated by the observation that Internet firms have distinctive features that set them apart from mere R&D-intensive firms: (1) Despite being successful on the R&D front—i.e., having devised an innovative service with a braod customer base—these firms have a hard time attaining profitability; (2) Profitability can only be attained via monetization, but monetization has a largely uncertain outcome; (3) Monetization is easier if the firm has a large customer base, but having a large customer base is not enough 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 exmples of these key features by reporting excerpts from the financial press.

The troubles of these firms in attaining profitability in spite of a broad customer base are exemplified by the *Wall Street Journal* article "Tumblr and the Death of the Old Internet" (by Christopher Mims, August 17, 2019). 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." The article also emphasizes another aspect: that the service was "never a very polished or particularly reliable service to begin with, had a hard time going mobile" then emphasizing how R&D is also important for these firms (as in our model, monetization needs to go hand in hand with innovation). The article then concludes that "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 *Wall Street Journal* 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." Indeed, these lines provide a crisp illustration that building a large customer base is just not enough for Internet firms—monetization requires investment in an ad-hoc infrastructure, but the outcome is largely uncertain. Our model is capable of capturing these features.

Similarly, the *Wall Street Journal* article "Snapchat must hit more angles with advertisers" (September 19, 2019) 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 Snap's users are young, older brand executives don't necessarily use Snapchat frequently, he said, 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" by S. Needleman, *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." That is, this article reflects the difficulty of firms in attaining profitability. Similarly, talking about Slack technologies, the *Wall Street Journal* article "Slack Shares Jump in Trading Debut" (by Maureen Farrell and Corrie Driebusch, June 20, 2019) reports: "instant-messaging software has supplanted email as the main method of communication for some office workers" then emphasizing the firm's large customer base. The article also depicts the firm by brushing the key chracteristics of Internet firms: Having a "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" By Sarah Needleman, *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, said Wedbush analyst Michael Pachter. " The article also note that ""Advertising is very high-margin revenue, so when your advertising isn't growing as fast, your profitability will be impacted by a greater amount," said JMP Securities analyst Ron Josey."

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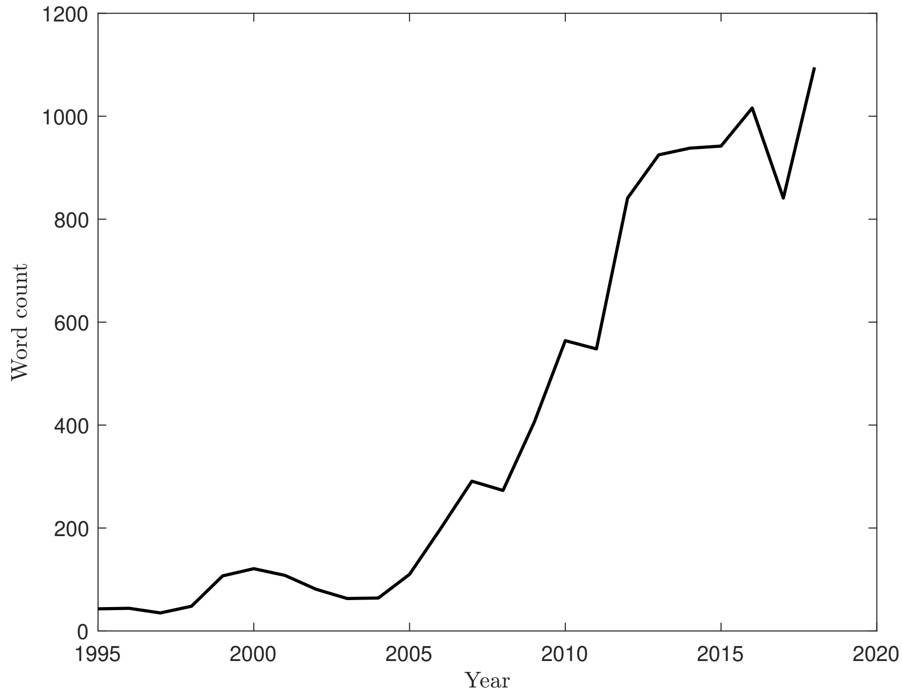

Figure 1: Monetization in the press. The figure shows the word count for "monetize/monetization" since 1995 in the following newspaper: USA Today, Chicago Tribune, Washington Post, Los Angeles Times, Boston Globe, San Francisco Chronicle, Dallas Monring News, New York Times Financial Times, and Wall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

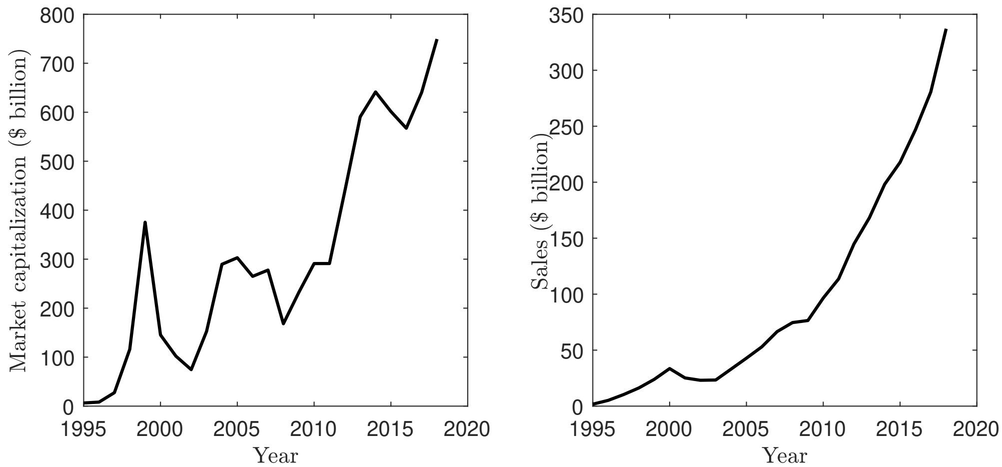

Figure 2: SECULAR GROWTH OF INTERNET FIRMS. The figure shows the inflation-adjusted market capitalization (left panel) and sales (right panel) of Internet firms since 1995.

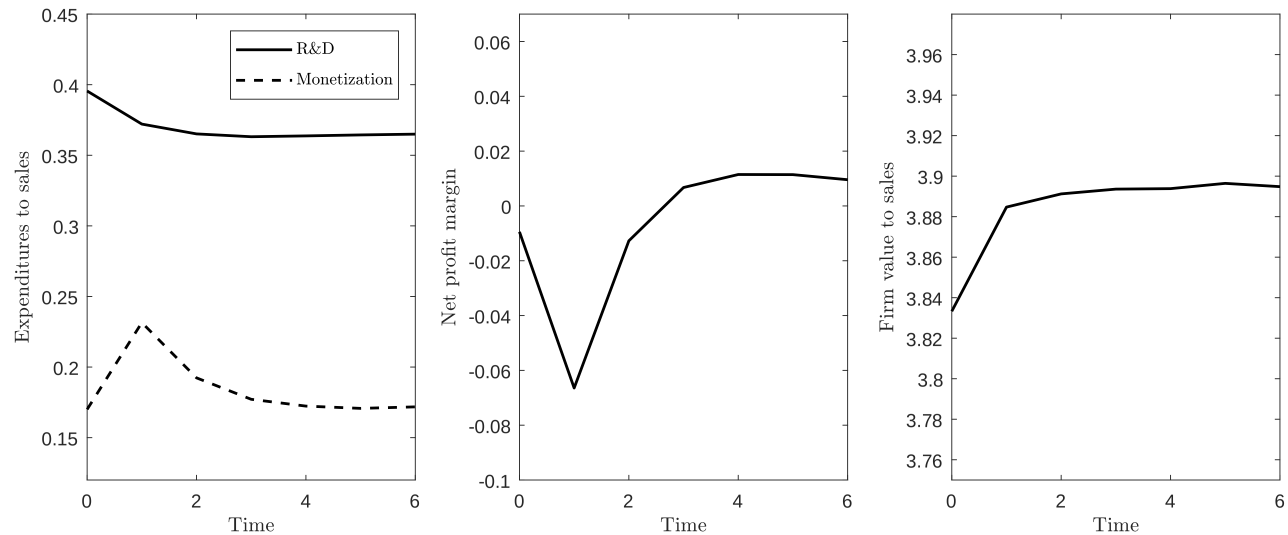

Figure 3: FIRM DYNAMICS AROUND A TECHNOLOGICAL BREAKTHROUGH. The figure shows the dynamics of R&D and monetization expenditures to sales (left panel), of the net profit margin (middle panel), and of firm value to sales after a technological breakthrough (happening between time 0 and 1).

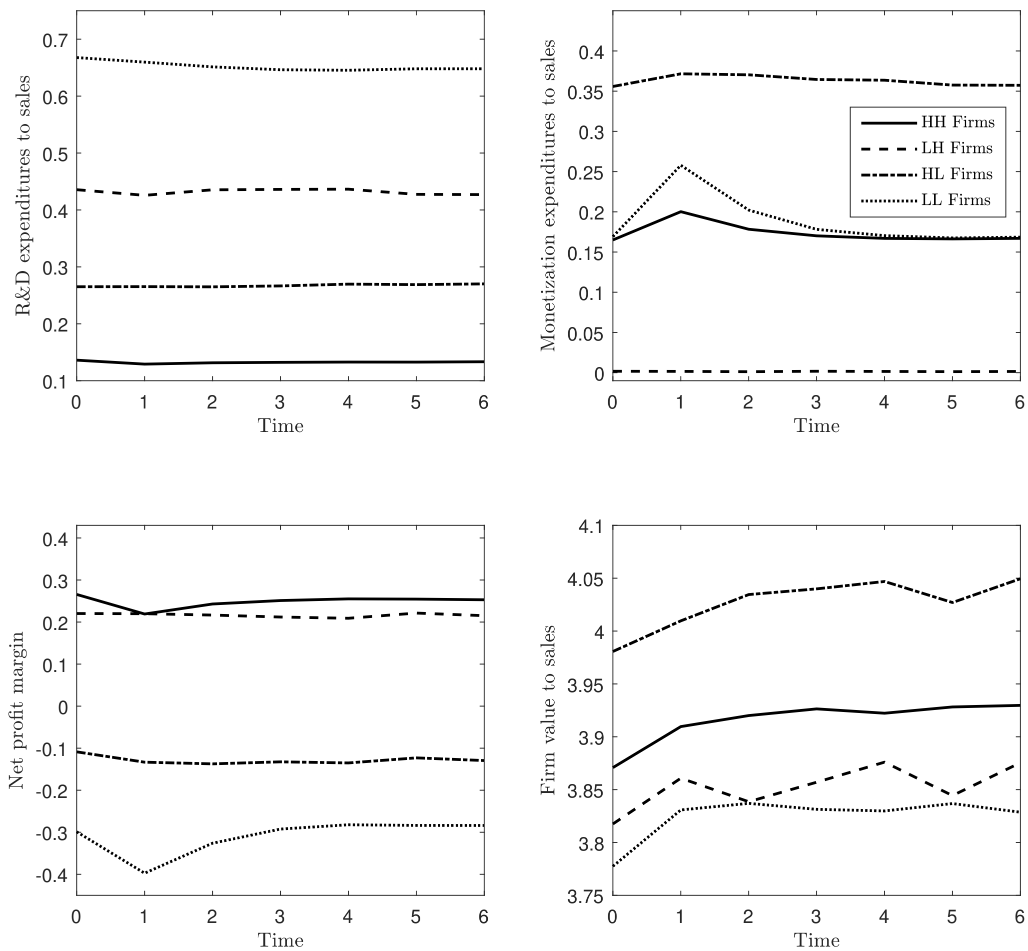

Figure 4: Firm dynamics around a technological breakthrough, conditioning on service quality level and monetization stock. The figure shows the dynamics of R&D expenditures to sales (top left panel), of monetization expenditures to sales (top right panel), of net profit margin (bottom left panel), and of firm value to sales (bottom right panel) after a technological breakthrough (happening between time 0 and 1).

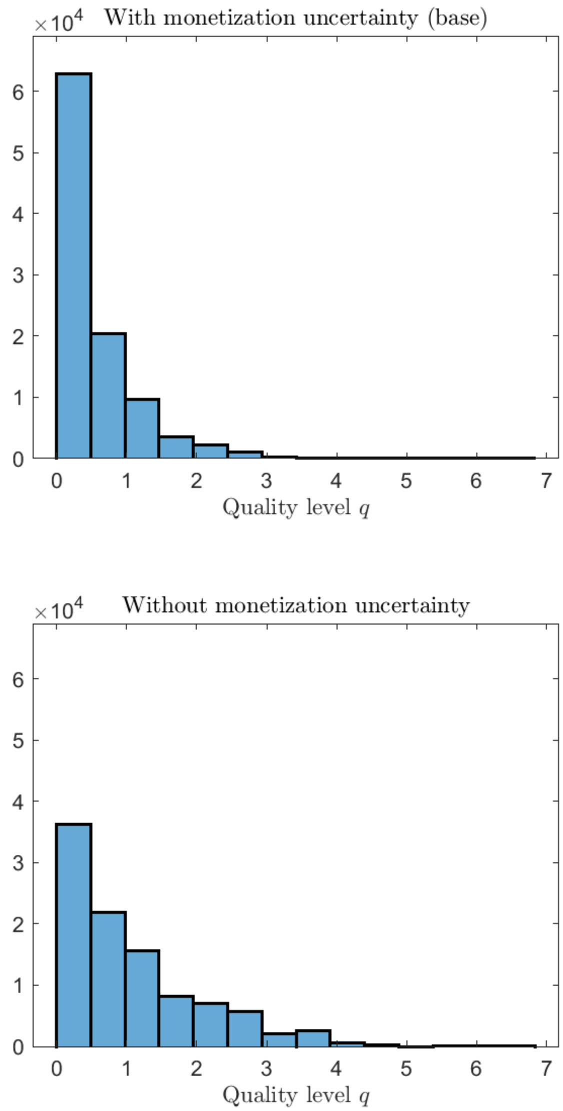

Figure 5: Distribution of service quality. The figure represents the histogram of service quality level in the baseline setup with monetization uncertainty (top panel) and in the counterfactual environment with no monetization uncertainty (bottom panel).

Table 1: Key characteristics of Internet firms. The table shows the key characteristics of Internet firms versus Non-Internet firms, R&D-intensive (Non-Internet) firms, and New (Non-Internet) firms. *Firm size* is defined as the logarithm of sales. *Equity valuation ratio* is the mean of the ratio of equity value (calculated by mulitplying outstanding common shares by fiscal year closing price) to sales. *Fraction Making Loss* is the mean fraction of firms that have negative operating income. *Gross profit margin* is the mean of the ratio of a firm's gross profits to sales. *Sales Growth (std)* is the standard deviation of firms' sales growth. *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.

	Internet Firms	Non Internet Firms	R&D-intensive (Non Internet)	New Firms (Non Internet)
Firm size	4.850	5.538	5.041	5.228
Equity valuation ratio	3.974	2.182	2.518	2.801
Fraction making losses	0.394	0.198	0.263	0.274
Gross profit margin	0.539	0.346	0.445	0.348
Sales growth (std)	0.361	0.307	0.326	0.350
SG&A expenditures	0.605	0.326	0.439	0.391
R&D expenditures	0.166	0.162	0.171	0.247
Asset tangibility	0.188	0.468	0.308	0.429
Number of obs.	2678	84138	20614	33538

Table 2: MOMENTS: DATA VERSUS 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
Gross profit margin (mean)	0.539	0.545
Gross profit margin (autocorrelation)	0.449	0.395
Equity value to sales (mean)	3.974	3.884
Equity value to sales (autocorrelation)	0.373	0.338
Sales growth (std. deviation)	0.361	0.380
Fraction making losses (mean)	0.394	0.436
SG&A expenditures to sales (mean)	0.605	0.560
SG&A expenditures to sales (std. deviation)	0.352	0.357
Sensitivity of SG&A expenditures to revenues	0.235	0.271
Sensitivity of sales growth to SG&A expenditures	0.244	0.240
Organizational capital to sales (autocorrelation)	0.664	0.768

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	0.26
ρ	Persistence of customer base	0.33
σ	Standard deviation of shocks to customer base	0.41
γ	Operating cost coefficient	0.52
λ	Quality improvements due to technological breakthroughs	0.11
δ	Sensitivity of breakthrough probability to R&D expenditures	4.57
Λ	Quality reductions due to competition	0.23
χ	Probability of competitive threats	0.15
ϕ	Depreciation rate of the monetization capital	0.23
ν	Uncertainty in increase in the monetization capital	0.44

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

Statistic	Value
Innovation rate (mean)	0.320
R&D to SG&A expenditures (mean)	0.678
Quality level (mean)	0.537
Monetization stock (mean)	1.142
Increase in monetization stock (mean)	0.091
Customer base (mean)	0.590
Customer base growth (std dev)	0.509
Sales (mean)	0.681
Net profit margin (mean)	-0.016

Table 5: Firm characteristics by bins of monetization and quality. This table sorts firms 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.

Quantity	HH	LH	HL	LL
Bin probability	0.458	0.048	0.053	0.441
SG&A expenditures to sales	0.301	0.434	0.629	0.839
Monetization expenditures to SG&A	0.506	0.005	0.560	0.141
Monetization expenditures to sales	0.167	0.002	0.359	0.157
R&D expenditures to sales	0.133	0.432	0.270	0.683
Sales	1.213	0.370	0.483	0.212
Sales growth	-0.003	0.017	0.046	-0.007
Gross profit margin	0.554	0.649	0.500	0.529
Net profit margin	0.253	0.215	-0.129	-0.311
Fraction making losses	0.143	0.161	0.654	0.750
Firm value to sales	3.929	3.853	4.041	3.816
Firm value	4.455	1.333	1.831	0.763

Table 6: Firm characteristics by bins of customer base. This table sorts firms into bins of high and low customer base C, where high and low levels are defined to be above and below the sample median, respectively.

Quantity	High customer base	Low customer base
SG&A expenditures to sales	0.336	0.786
Monetization expenditures to SG&A	0.513	0.130
Monetization expenditures to sales	0.188	0.144
Monetization level	1.824	0.466
R&D expenditures to sales	0.149	0.642
Sales	1.143	0.221
Sales growth	0.069	-0.077
Gross profit margin	0.592	0.494
Net profit margin	0.256	-0.292
Firm value to sales	3.698	4.086
Firm value	4.103	0.900

Table 7: The effect of monetization uncertainty. This table compares moments from the baseline version of the model with those from the counterfactual environment in which monetization increases are not uncertain.

Quantity	Baseline	No uncertainty
SG&A expenditures to sales	0.560	0.434
Monetization expenditures to SG&A	0.322	0.462
Monetization expenditures to sales	0.166	0.171
Monetization level	1.142	2.279
R&D expenditures to sales	0.394	0.263
Innovation rate	0.320	0.339
Sales	0.681	1.357
Gross profit margin	0.545	0.556
Net profit margin	-0.016	0.122
Fraction making losses	0.436	0.258
Firm value to sales	3.884	4.088
Firm value	2.495	5.148

Table 8: MONETIZATION COUNTERFACTUALS. This table reports the counterfactual environments obtained when varying the monetization-related parameters—ν, which drives the expected increase in monetization; ϕ, which represents the depreciation rate of the monetization stock; and α, denoting the monetization share in the firm's revenue-generating function—up and down by ten percent compared to the baseline environment reported in Table 3.

Quantity	ν^+	ν^-	ϕ^+	ϕ^-	α^+	α^-
SG&A expenditures to sales	0.544	0.435	0.614	0.330	0.497	0.536
Monetization expenditures to sales	0.096	0.182	0.087	0.172	0.201	0.108
Monetization expenditures to SG&A	0.148	0.465	0.108	0.554	0.438	0.202
Monetization level	0.472	2.056	0.366	2.576	1.722	0.699
Innovation rate	0.246	0.345	0.248	0.325	0.340	0.273
R&D expenditures to sales	0.448	0.253	0.527	0.159	0.296	0.428
Quality level	0.252	0.898	0.188	1.243	0.720	0.380
Sales	0.308	1.160	0.232	1.566	0.958	0.458
Gross profit margin	0.522	0.561	0.524	0.552	0.575	0.515
Net profit margin	-0.022	0.126	-0.090	0.222	0.079	-0.021
Fraction making losses	0.465	0.275	0.609	0.186	0.319	0.494
Firm value to sales	3.609	4.145	3.568	4.130	4.028	3.762
Firm value	1.064	4.463	0.790	5.993	3.616	1.637

Table 9: INNOVATION COUNTERFACTUALS. This table reports the counterfactual environments obtained when varying the parameter δ—which represents how efficiently the firm translates R&D expenditures into technological breakthroughs—and the parameter χ—which represents the likelihood that competitors will launch innovative products, thus decreasing the relative quality of the firm's service—up and down by ten percent compared to the baseline environment reported in Table 3.

Quantity	δ^+	δ^-	χ^+	χ^-
SG&A expenditures to sales	0.381	0.644	0.594	0.521
Monetization expenditures to sales	0.180	0.113	0.156	0.174
Monetization expenditures to SG&A	0.515	0.130	0.267	0.373
Monetization level	2.162	0.418	0.901	1.396
Innovation rate	0.348	0.244	0.305	0.331
R&D expenditures to sales	0.201	0.532	0.439	0.347
Quality level	1.100	0.194	0.419	0.663
Sales	1.365	0.246	0.532	0.838
Gross profit margin	0.544	0.535	0.542	0.546
Net profit margin	0.163	-0.109	-0.052	0.025
Fraction making losses	0.242	0.593	0.472	0.383
Firm value to sales	4.019	3.667	3.756	4.012
Firm value	5.091	0.860	1.902	3.148