Dynamic competition between digital markets

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Abstract

There is an ongoing debate on whether policies that increase competition in digital markets are beneficial or detrimental to the welfare brought about by innovation. I investigate this question by focusing on a type of competition through R&D Big Tech firms engage in but remains unmodelled: dynamic competition *between* markets. Firms invest in R&D to develop different market-creating products. If a firm succeeds, it creates and dominates a new, larger market that cannibalizes revenues from already-existing markets. Other firms obtain a smaller market share of the new market. I find that there is a socially-optimal level of R&D investment defined by the intensity of market expansion relative to the cannibalization caused by disruption, provided that markets are winner-takes-most. If market expansion (the positive cross-market externality) is too high relative to the cannibalization caused by disruption (the negative cross-market externality), firms under-invest in R&D relative to the socially-optimal level, and vice-versa. Policies intensifying competition in the market decrease R&D investment, and should therefore be applied only if the digital economy is in an initial state of over-investment. Policies facilitating market entry should be applied only if the initial state is one of under-investment, as they increase R&D investment. I show that while the degree of competition in the market can always be used as an instrument to reach socially-optimal levels of R&D, the porosity of barriers to entry and structural separation can only do so if the inefficiency of firms' R&D investment is limited. Finally, I find that both types of instruments can generate reductions in social welfare before the social optimum is reached.

JEL Classification: L10, L13, O13.

Keywords: dynamic competition, R&D, digital markets, winner-takes-most, cross-market externalities, disruptive innovation, barriers to entry, structural separation

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1 Introduction

Many digital markets are winner-takes-most and dominated by a handful of Big Tech firms. In the past years, regulatory and antitrust agencies concerned about the potential anti-competitive effects of this market structure have multiplied efforts to stimulate competition in digital markets. The European Commission's Digital Markets Act[1] and the United States' American Choice and Innovation Online Act[2] are prominent examples of such endeavours. Following an arrowian rationale and a structure-conduct-performance approach, some scholars consider that these types of measures increase the welfare brought about by innovation (Krämer and Schnurr, 2022; Hoppner, 2022; Federico et al., 2020; Scott Morton et al., 2019; Crémer et al., 2019; Parker et al., 2020). Others, in turn, argue that they are counterproductive because they build on a misconception of the nature of competition in digital markets. They posit that markets being winner-takes-most is not a sign of weak competition. The relevant signal of competition, they argue, is not the degree of competition in the market; it is the intensity of dynamic competition through R&D investment (Teece and Kahwaty, 2021; Gal and Petit, 2021; Miller and Mitchell, 2021; Petit, 2020; Walker, 2020; Bourne, 2019; Evans and Schmalensee, 2002; Salinger and Levinson, 2015). Under this schumpeterian reasoning, by strengthening competition in digital markets, regulators and antitrust authorities might be reducing the expected value the innovator can appropriate. This would make innovation fall short of the socially-optimal level.

In this article I engage in this discussion with a setting that departs from the 'competition in' and 'competition for' the market frameworks underpinning both sides of the debate. I focus instead on a third type of competition through R&D Big Tech firms engage in but remains unmodelled: dynamic competition *between* markets.[3] Under this novel setting, firms compete by investing in R&D to invent *different* market-creating products. If they succeed, they create and dominate a new market that cannibalizes revenues from already-existing markets. Other firms obtain a smaller market share of the new market. The setting is inspired by three salient features of the digital economy: i) substantial secret R&D investments in 'disruptive' market-creating innovation, ii) the fact that new markets cannibalize revenues from old ones and iii) the fact that competition is characterized by multimarket contact in winner-takes-most markets.

Secret R&D investments in disruptive innovation. When firms engage in disruptive innovation efforts, they compete to produce groundbreaking innovations that give birth to new markets (Gans, 2016; Christensen et al., 2013). Apple's iPhone, which gave birth

[1] Entered into force on 1 November 2002. See https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/digital-markets-act-ensuring-fair-and-open-digital-markets$_en$

[2] Introduced in House on 11 June 2021 (H.R:3816 - 117th Congress (2021-2022)). See https://www.congress.gov/bill/117th-congress/house-bill/3816/text

[3] Larouche and De Streel (2021) and Larouche and de Streel (2021) call this type of competition "competition on the market".

to smartphones, is a good illustration. A considerable share of Big Tech's investments follows this pattern. In the 2014-2018 period, Alphabet devoted between 12% and 25% of its substantial research budget (about 16% of its revenue during the period[4]) to exploratory (i.e., non-goal-directed) ventures (Petit, 2020) in order to invent market-creating products. Between 2019 and 2021, Meta invested 38% of its R&D budget (which, in turn, represented 19%-22% of its revenue during the period) to pivot away from a social-media-to a metaverse-focused company.[5] Its CEO, Marc Suckerberg, justified this decision internally as a way to offset Meta's competitive vulnerability "in a primarily mobile world dominated by Google and Apple".[6] Acquisitions, investments and employment data from Amazon, Alphabet, Meta, Apple and Microsoft further confirm that these companies devote substantial R&D resources so as to "win the next big thing".[7]

It is common for Big Tech firms to keep their R&D in disruptive innovation secret. For example, Alphabet has been funding the semi-secret R&D facility 'X' (formerly known as 'Google X') since 2010. Apple is known to have several secret research facilities.[8] The secrecy of disruptive innovation R&D, coupled with the fact that this research process is typically open-ended rather than focused on developing a prefigured product (Petit, 2020), results in rival firms putting research effort into *different* market-creating innovations. For example, when Apple invented the first smartphone, the iPhone, no other competitor was working on developing one because neither Apple (during the initial phases of the R&D process) nor its competitors (during the entire R&D process) knew that the developing of this new product was on the way.

New markets cannibalize old markets. The second salient feature of dynamic competition in digital markets is that the new markets that result from successful disruptive innovation cannibalize already-existing ones. Larouche and De Streel (2021) provide a set of notorious examples:

> *"Google heralded the rise of Internet-centric computing, which turned client operating systems (such as Windows) into a sideshow. Then Facebook turned a social media platform into an alternative portal to search engines such as Google, limiting the impact of Google's dominance. The rise of smartphones —led by the iPhone— not only reshuffled the market for mobile devices but also made computers less central, thereby reducing the impact of dominant positions in CPUs, for instance."*

[4]See `https://colvinconsulting.com.au/insights/why-market-leading-companies-are-also-the-leading-innovators`

[5]See `https://www.businessinsider.com/charts-meta-metaverse-spending-losses-reality-labs-vr-mark-zuckerberg-2022-10?r=US&IR=T`

[6]See `https://techcrunch.com/2019/02/13/facebook-mulled-multi-billion-dollar-acquisition-of-unity-book-claims/?utm_source=substack&utm_medium=email`

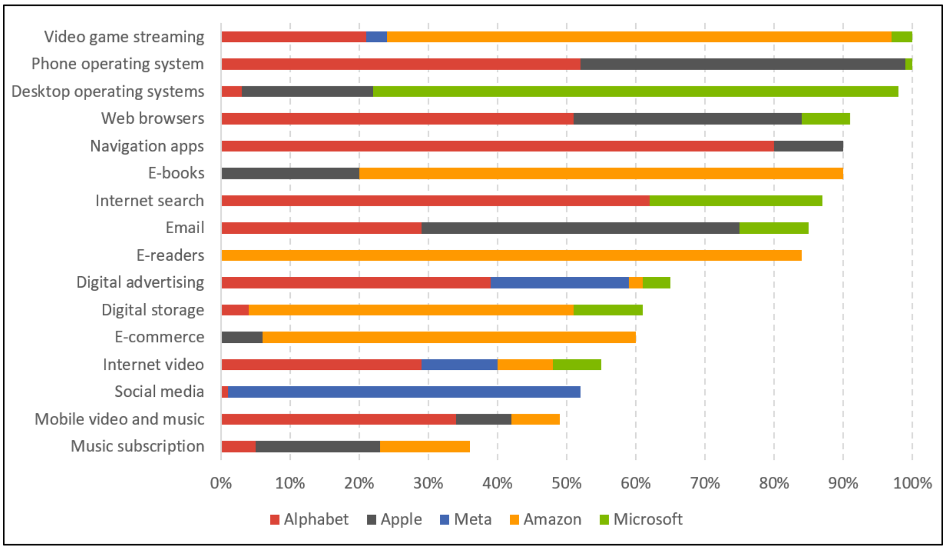
[7]See https://www.economist.com/briefing/2022/01/22/what-americas-largest-technology-firms-are-investing-in.

[8]See https://www.ft.com/content/d9d3b86c-c67f-11e5-808f-8231cd71622e

One of the reasons why new markets cannibalize old ones in the digital economy is the multisided nature of platforms. In many cases, the revenue-making side is the advertisers'. For example, Amazon Marketplace and Apple's app store, iOS, are increasingly siphoning digital advertisement revenues away from Meta's social networks and Alphabet's search engine and video markets.[9]This is particularly true for firms that rely heavily on attention markets such as Alphabet and Meta, who in 2021 obtained 81% and 98% of their revenues from advertising, respectively.[10]. Another reason why new markets cannibalize old ones is that new markets is that, once a market-creating product appears (e.g. the smartphone), it lowers consumers' valuation for products located in other markets, despite the fact that the old and the new products present little (e.g., PC operating systems) or no (e.g., CPUs) substituability.

Multimarket contact in winner-takes-most markets. As shown in Figure 1, competition in the digital economy is characterized by multimarket contact in winner-takes-most markets.

Figure 1: GAFAM's USA market share in selected digital markets (2019)



Source: own elaboration based on Statista.

I make two contributions to the dynamic competition literature and the ongoing policy discussion on the regulation of digital markets. The first one is building the first model of dynamic competition that, to the best of my knowledge, incorporates the three aforementioned features. This setting allows me to understand how the socially-optimal level of investment in disruptive R&D is defined by the interdependencies between the number of competitors, the intensity of competition in the market (i.e., the extent to which a market departs from a winner-takes-most structure) and how 'creative' (market-expanding) or

[9]See `https://www.economist.com/business/2022/09/18/the-300bn-google-meta-advertising-duopoly-is-under-attack`

[10]See `https://www.visualcapitalist.com/how-big-tech-makes-their-billions-2022/`

'destructive' (market-cannibalizing) the creative destruction brought about by disruptive innovation is. The second contribution of this article is determining the conditions for changes in the intensity of competition in the market, on the one hand, and the number of competitors, on the other hand to i) serve as instruments to reach the socially-optimal level of R&D investment and ii) increase welfare.

I build a model in which a discrete number of symmetric firms have to simultaneously decide the level of effort they put into R&D in disruptive innovations. There are as many markets as firms and entry is limited. All firms are present in every market, and each dominates one. Markets are of the same size and have the same intensity of competition in the market. The more competitive a market is, the smaller the market share of the dominant firm is. R&D efforts increase the probability of creating a new market. Once a firm succeeds in innovating, it creates a new market that it dominates. As a result, succeeding in innovating increases the innovators' profits, but it has mixed effects on its rivals', as there are positive and negative cross-market externalities. On the one hand, the new market cannibalizes a share of an already-existing market's revenues the innovating firm does not dominate ('market cannibalization' or 'disruption damage' effect). This creates a negative externality on its rivals. On the other hand, the new market has a higher size than already-existing markets (market expansion effect). This generates a positive externality on the innovating firm's rivals, as it allows them to capture a share of the revenue the new, larger market generates.

I find that there is a socially-optimal level of R&D investment defined by the intensity of market expansion relative to the damage caused by disruption, provided that markets are winner-takes-most. If market expansion (the positive externality) is too high relative to the damage caused by disruption (the negative externality), firms under-invest in R&D relative to the socially-optimal level, and vice-versa. Moreover, this equilibrium ratio decreases over the intensity of competition in the market. As the latter increases, firms can capture a higher share of the markets their rivals create through innovation. This makes the positive externality generated by rivals' R&D too strong relatively to the negative externality of the disruption damage, compared to the socially-optimal level.

I model an increase in competition in two ways: an increment in the number of competitors (resulting from lower barriers to entry or a mandated break-up[11]) and an increase in the market share captured by the non-dominant firms (i.e., fiercer competition in the market). I show that while the latter can always be used as an instrument to reach socially-optimal levels of R&D, the porosity of barriers to entry and structural separation can only do so if the inefficiency of firms' R&D investment is limited. The reason is that, although market entry always leads firms to increase their R&D investments as a response to the higher probability of being disrupted that the presence of more competitors entails, it does so at a declining rate. On the contrary, limiting competition in the market linearly

[11] Some authors and policymakers have suggested the break-up of Big Tech firms as a remedy to restore competition in the digital economy. See for example Khan (2019), Kwoka & Valletti (2021) and Wu (2020).

increases the expected returns from R&D investments. Therefore, there is always a degree of competition in the market for which firms choose the socially-optimal level of R&D investment, provided that markets are winner-takes-most. Finally, I show that both types of instruments can generate reductions in social welfare before the social optimum is reached.

This article relates to the patent race literature in its modelling approach. The model shares four characteristics with patent race models. First, firms invest in R&D to obtain a reward, as posited in the foundational patent race models (Dixit, 1988; Dasgupta and Stiglitz, 1980; Lee and Wilde, 1980; Loury, 1979). Second, market structure is exogenous because there are barriers to entry. Third, like in some formulations of patent race models Delbono and Denicolo (1991); De Bondt et al. (2008); Stewart (1983); Reinganum (1982), I allow for reward sharing. This plays an important role in the analysis of how the extent to which markets are winner-takes-most affects the welfare generated by disruptive innovation. Fourth, R&D efforts can be too high compared to the social optimum. However, I complement the patent race literature by introducing a new possible explanation of over-investment in R&D. In the patent race literature, this phenomenon is explained by the redundancy of parallel research by competing firms. In my model, over-investment occurs because a firm's successful innovation creates a negative externality on other firms. The successful innovator creates a new market that cannibalizes profits from another market another firm dominates. If this cannibalization effect is sufficiently strong, firms will over-invest in R&D compared to the social optimum. This mechanism is close to what, in the context of an endogenous growth model, Jones and Williams (2000) call a "creative destruction effect" whereby "a new good may functionally replace an existing good, causing the current innovator to receive the entire flow of rents while the past innovator gets cut out".

The main departure of my model from the patent race literature is that I focus on a particular subset of innovation, disruptive innovation. When investing in disrupting innovation, firms compete to create *different* markets that generate cross-market positive and negative externalities (competition between markets), rather than to introduce an innovation before their rivals in the same market (competition for the market).[12] Consequently, unlike in the patent race literature, firms compete in multiple markets. Finally, in addition to studying the intensity of competition through the number of competitors, I add a measure of competition of particular interest for the study of digital markets: the degree of competition in the market.

The remaining of the article is structured as follows. Section 2 presents the model and its private equilibrium. Section 3 derives the social planner's equilibrium and the conditions for it to coincide with the private one. It also presents the conditions for market entry

[12] Of course, this does not imply that Big Tech do not engage in competition for or in the market. My model sheds light on a third category of competition through innovation that is particularly relevant in digital markets, along with traditional competition in and for the market.

and an increase in the degree of competition in the market to be an effective instrument in reaching the socially-optimal R&D level. Section 4 explores the impact of changes in the intensity of competition in the market and market entry on welfare. Section 5 sums up the main results and sets out directions for further research.

2 The model

2.1 Set up

There are n symmetric profit-maximising firms present in n markets, with $n \in \mathbb{N}$ and $n \geq 2$. Entry is limited.[13] In stage 1, the n markets generate the same per-stage revenue, denoted by m. Firms face a marginal cost normalized to zero. Each firm dominates one market. The firm dominating the market obtains a market share of $1 - \lambda$, with $0 < \lambda < 1$ being a constant that is identical across markets. The remaining firms that do not dominate the market obtain the same market share of $\frac{\lambda}{n-1}$. Hence, in stage 1, each firm's profit is equal to m. Note that if $\lambda = \frac{n-1}{n}$ all firms have the same market share in each market. Hence, the lower λ is, the more winner-takes-most markets are. If $\lambda > \frac{n-1}{n}$, markets are not winner-takes-most. In this case, the firm that succeeds in innovating does not dominate the newly-created market, as it obtains a lower market share than its competitors. Parameter λ is therefore both a measure of the intensity of competition in the market and the imperfectness of the appropriability of R&D output. In its 'intensity of competition in the market' side, a low value of parameter λ can be interpreted as representing strong (data-driven) network effects characteristic of digital markets.

Firms play an infinitely-repeated simultaneous game. From the second period onward, they have to simultaneously decide the amount x of research inputs (e.g., software developers) to invest.[14] The probability of succeeding in innovating is common to all firms and depends positively on the amount of research inputs. It is given by the concave innovation production function $P(x)$, with $P'(x) > 0$ and $P''(x) < 0$. All firms face the same known convex lump-sum R&D cost[15], which is determined by cost function $C(x)$, with $C'(x) > 0$ and $C''(x) \geq 0$. If firms do not succeed in innovating in stage t, they abandon the research project and start investing in a new one in stage $t + 1$.

When a new market is created, it cannibalizes a share d of an already-existing market's revenues, with $0 < d < 1$. I call this share d the damage caused by disruption. The new

[13]This modelling choice represents different barriers to entry specific to digital markets such as exclusive control over (specific types of) data or the concentration of skilled workers within a handful of firms.

[14]Research inputs x can also represent Big Tech's expenditure in acquiring start-ups with the objective of using their intellectual property and research teams to do disruptive innovation, or in order to bring to the market an innovation already developed by the start-up.

[15]Note that modelling costs as a flow would not be compatible with my setting. In the patent race literature, a firm can pay a flow until it obtains a patent or one of it rivals does. In my model, since firms are researching to create different markets, I can treat research costs as a one-period cost. If the firm does not succeed in innovating at the end of the period, it abandons the project.

market created, in turn, has a value of $(d + e)m$, with $e \in \mathbb{R}_{\geq 0}$ representing the intensity of the market expansion effect.

2.2 Firms' expected gains and losses from disruptive innovation

When deciding the amount x of research inputs to invest, firm i considers the present value of the different expected wins and losses stemming from its own and its $n-1$ rivals' investment decisions. The expected gains derived from the new market created by firm i are equal to:

$$\frac{P(x_i)(1-\lambda)\big((d+e)m)\big)}{1-\delta} \tag{1}$$

Where $0 < \delta < 1$ is a discount factor.

The expected gains derived from the $n-1$ new markets created by firm i's $n-1$ rivals is given by:

$$\Big(\frac{(\frac{\lambda}{n-1}(d+e)m\big)p^e}{1-\delta}\Big)(n-1)$$

Where p^e is the expected probability of a competitor creating a new market. Given that firms do not have information to know or infer in which secret R%D projects their rivals are working on, p^e is an exogenous variable. The equation simplifies to:

$$\frac{(d+e)m\, p^e \lambda}{1-\delta} \tag{2}$$

The expected losses stemming from firm i's competitors creating $n-1$ new markets that cannibalize the n markets in which firm i is present is given by:

$$\frac{\big(1-(1-p^e)^{(n-1)}\big)\frac{\lambda}{n-1}m\, d}{1-\delta}(n-1) + \frac{\big(1-(1-p^e)^{(n-1)}\big)(1-\lambda)m\, d}{1-\delta}$$

Note that $1-(1-p^e)^{(n-1)}$ is the probability of at least one of firm i's $n-1$ competitors succeeding in disrupting a market in which firm i is present. The left term represents the expected loss from the $n-1$ markets that firm i does not dominate, while the right term shows the expected loss from the market that firm i dominates.

This equation simplifies to:

$$-\frac{m\, d\big(-1+(1-p^e)^n + p^e\big)}{(p^e-1)(\delta-1)} \tag{3}$$

When firm i succeeds in creating a new market, it cannibalizes one of the $n-1$ markets it does not dominate.[16] The expected loss from firm i's self-cannibalization is given by:

$$\frac{m\,dP(x_i)\lambda}{(n-1)(1-\delta)} \tag{4}$$

Then, firm i's profit is given by summing Equations (1)-(2) and subtracting Equations (3)-(4) and $C(x_i)$. After simplification, this results in:

$$\begin{aligned}\pi_i = m + \frac{(d+e)m\ P(x_i)(1-\lambda)}{1-\delta} - \frac{d\,m\big(1-(1-p^e)^n - p^e\big)(1-\lambda)}{(1-p^e)(1-\delta)} \\ + \frac{(d+e)m\ p^e\,\lambda}{1-\delta} + \frac{d\,m\big(1-(1-p^e)^n - p^e\big)\lambda}{(1-p^e)(1-\delta)} - C(x_i)\end{aligned} \tag{5}$$

2.3 Stationary equilibrium

Given that firms are symmetric and they face the same initial conditions in stage 1, the stationary equilibrium value of firm i's profits is obtained by finding the optimal level of research inputs $x_i^*(m, d, \lambda, n, \delta)$ that maximizes firm i's expected present value of its profit function π_i (cf. Equation (5)). The first order condition is given by:

$$\frac{P'\big(x_i^*(\cdot)\big)m\Big(e(n-1)(1-\lambda) - d\big(1-n(1-\lambda)\big)\Big)}{(n-1)(1-\delta)} = C'\big(x_i^*(\cdot)\big) \tag{6}$$

The second order condition is given by:

$$\frac{P''\big(x_i^*(\cdot)\big)m\Big(e(n-1)(1-\lambda) - d\big(1-n(1-\lambda)\big)\Big)}{(n-1)(1-\delta)} - C''\big(x_i^*(\cdot)\big) < 0$$

Keeping in mind the restrictions on parameters n, d, e, δ and λ provided above, and that I assume that $P''(x_i) < 0$ and $C''\big(x_i(\cdot)\big) > 0$, the second order condition holds if and only if:

$$\begin{aligned}\frac{e}{d} &> \frac{n-1-n\,\lambda}{(n-1)(\lambda-1)} \\ \frac{e}{d} &> \widetilde{\left(\frac{e}{d}\right)}\end{aligned} \tag{7}$$

Note that $\widetilde{\left(\frac{e}{d}\right)} > 0$.

[16] I assume that, due to Arrow's (1962) replacement effect, firm i will only develop markets that do not cannibalize the market(s) it dominates.

In equilibrium, $x_i = x_i^*(m, d, \lambda, n, \delta)$. Moreover, given that firms are symmetric, in equilibrium $p^e = P(x_i^*)$. Firm i's private equilibrium profits are therefore given by:

$$
\begin{aligned}
{\pi_i}^* =& \frac{d\ m(n-1)\Big(1-P\big(x_i^*(\cdot)\big)\Big)^{n-1}}{(n-1)(1-\delta)} \\
&+ \frac{m\Big(P\big(x_i^*(\cdot)\big)-1\Big)\Big((n-1)(\delta-1+d)+\big((d+e)(n-1)-d\lambda\big)P\big(x_i^*(\cdot)\big)\Big)}{(n-1)(1-\delta)(1-P\big(x_i^*(\cdot)\big)} \\
&- C\big(x_i^*(\cdot)\big)
\end{aligned} \tag{8}
$$

3 Social vs private optimum

After deriving the first best (Section 3.1), this section shows the conditions for the private equilibrium to reach it (Section 3.2). It then analyses whether policymakers can always use regulations that affect the degree of competition in the market (Section 3.3.1) and the porosity of barriers to entry and structural separation (Section 3.3.2) to maximise welfare.

3.1 Socially-optimal R&D investment

The social planner's objective is to maximize total welfare, which is given by $\sum_{i=1}^{n} \pi_i$. Therefore, it does not consider the redistributive effects of disruption. In stage 1, there are n markets that generate a revenue of m each. Hence, the economy's revenue in stage 1 is:

$$n\, m \tag{9}$$

Once the n firms have invested in R&D, the expected revenue of the new markets created is given by:

$$\frac{n\ m\ (d+e)P\big(x(\cdot)\big)}{1-\delta} \tag{10}$$

The expected losses generated by disruption are given by:

$$\frac{P\big(x(\cdot)\big)\ d\ m\ n}{1-\delta} \tag{11}$$

Given the symmetry between firms, the economy's cost of R&D is given by:

$$C\big(x(\cdot)\big)n \tag{12}$$

Then, by summing Equations (9)-(10), subtracting Equations (11)-(12) and dividing by

n, I obtain the per-firm profit equation:

$$\pi_i{}^S = m + \frac{e\ m\ P\big(x_i(\cdot)\big)}{1-\delta} - C\big(x_i(\cdot)\big) \tag{13}$$

The socially-optimal per-firm amount of research inputs $x_i^{S*}(m, d, \lambda, n, \delta)$ is the one that maximises the social planner's per-firm profit. Then, the first order condition is given by:

$$\frac{e\ m\ P'\big(x_i^{S*}(\cdot)\big)}{1-\delta} = C'\big(x_i^{S*}(\cdot)\big) \tag{14}$$

The second order condition is satisfied if:

$$\frac{e\, m\ P''\big(x_i^{S*}(\cdot)\big)}{1-\delta} < C''\big(x_i^{S*}(\cdot)\big)$$

This is equivalent to:

$$\begin{aligned} e &> \frac{C''\big(x_i^{S*}(\cdot)\big)(1-\delta)}{m\, P''\big(x_i^{S*}(\cdot)\big)} \\ e &> \underline{\mathrm{e}}^S \end{aligned} \tag{15}$$

Note that given that $P''(x) < 0$ and $C''\big(x(\cdot)\big) > 0$, $\underline{\mathrm{e}}^S < 0$. Therefore, the second order condition is met for any admissible value of e.

Then, the per-firm profits that maximise social welfare are given by:

$$\pi_i{}^{S*} = \frac{m\Big(1-\delta+e\, P\big(x_i^{S*}(\cdot)\big)\Big)}{1-\delta} - C\big(x_i^{S*}(\cdot)\big) \tag{16}$$

3.2 Comparison between the private and social optima

The private equilibrium level of research inputs coincides with the social optimum if and only if $x_i^* = x_i^{S*}$. By comparing the first order conditions of firm i and the social planner's, I can see this is the case if the left sides of Equations (6) and (14) are equal, provided that the second order conditions are met and the parameters are within their admissible values. Then, the private equilibrium level of of research inputs coincides with the social optimum if:

$$\frac{e}{d} = \frac{1}{\lambda} + \frac{n}{-n+1} \tag{17}$$

With $\frac{e}{d} > \tilde{\left(\frac{e}{d}\right)}$

Note that the ratio $\frac{e}{d}$ can be interpreted as an indication of how 'creative' the creative destruction process triggered by a disruptive innovation is. The larger this ratio is, the larger new markets are compared to the shrinking of already-existing markets their appearance sparks.

From Equation (17), I can easily derive the conditions for the privately-optimal level of R&D to be equal to, below and above the socially-optimal one.

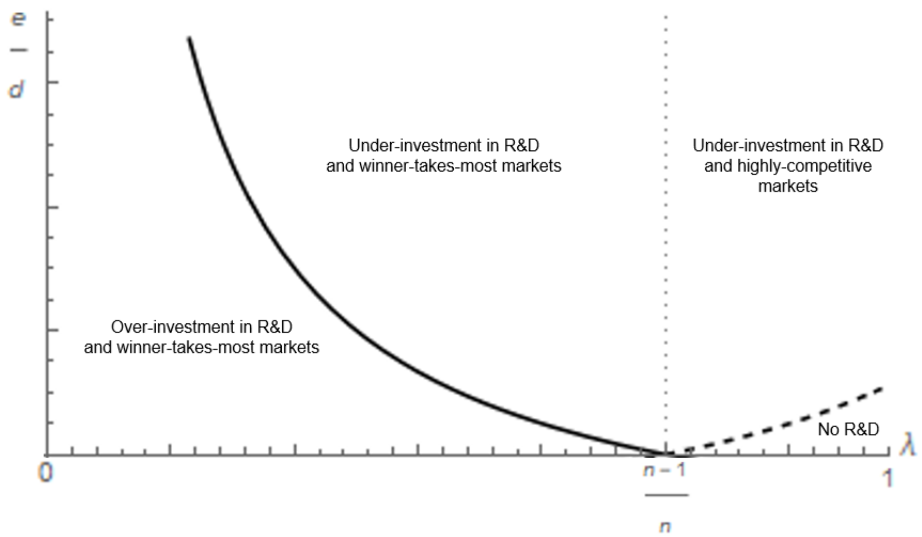
Proposition 1 (Privately- and socially-optimal R&D investment)

The privately-chosen level of R&D investment maximises social welfare if $\frac{e}{d} = \frac{1}{\lambda} + \frac{n}{-n+1}$. *If* $\frac{e}{d} < \frac{1}{\lambda} + \frac{n}{-n+1}$ *there is over-investment in R&D with respect to the social optimum. If* $\frac{e}{d} > \frac{1}{\lambda} + \frac{n}{-n+1}$ *there is under-investment in R&D with respect to the social optimum.*

Definition 1 *Markets are winner-takes-all if* $\lambda = 0$, *winner-takes-most if* $0 < \lambda < \frac{n-1}{n}$ *and highly-competitive if* $\frac{n-1}{n} \leq \lambda < 1$.

Figure 2 illustrates Proposition 1.

Figure 2: Illustration of the regions of socially-optimal, under- and over- investment in R&D



Note: the undashed curve gives the socially-optimal R&D level. The dashed curve represents the minimum level of $\frac{e}{d}$ for the second order condition of the private equilibrium to hold.

Proposition 1 states that there is an optimal ratio between the intensity of market expansion and the damage caused by disruption that guarantees the coincidence between the private and the socially-optimal R&D levels. This ratio is the one for which the positive and negative cross-market externalities that firms generate through innovation balance out. Parameter d is a measure of the negative externality (i.e., the degree of disruption damage) that the innovation by firm i generates on other firms. It creates incentives to over-invest compared to the social optimum. Parameter e, in turn, is a measure of the positive externality (i.e., market expansion) that the innovation by firm i generates on other firms. When firm i generates a new, larger market it dominates, other firms are able to capture a share $\frac{\lambda}{n-1}$ of it. This positive externality creates incentives to under-invest compared to the social optimum.

Proposition 1 also states that the socially-optimal level of R&D investment is defined by a negative relation between the intensity of market expansion relative to the damage caused by disruption ($\frac{e}{d}$), on the one hand, and the degree of competition in the market (λ), on the other hand.

The intuition behind this negative relation is simple. Suppose that the economy is in an initial state of socially-optimal R&D investment (i.e., on the non-dashed curve in Figure 2). As the share of a newly-created market all firms can capture increases (i.e., as λ increases and we move rightwards), the positive externality generated by the innovating firm becomes stronger. Therefore, the market expansion rate e, which determines how much larger the new market is compared to the already-existing ones, is now too high with respect to the negative externality generated by disruptive innovation, represented by d. Therefore, in order to balance out these two cross-market externalities again, market expansion rate e should decrease and/or disruption damage d should increase, so that $\frac{e}{d}$ reaches the socially-optimal level again.

Note that Equation (17) is not defined for $\lambda = 0$. This corresponds to a winner-takes-all market structure. Note also that while the left side of Equation (17) is always positive (since $e > 0$ and $d \, \varepsilon (0, 1)$), the right side is positive if $\lambda < \frac{n-1}{n}$. Recalling that if $\lambda = \frac{n-1}{n}$ all firms obtain the same market share, I obtain Corollary 1:

Corollary 1 *The socially-optimal level of R&D investment can only be reached if markets are winner-takes-most (*$0 < \lambda < \frac{n-1}{n}$*).*

Graphically, Corollary 1 shows that the non-dashed curve representing the socially-optimal level of R&D is only defined to the left of the dashed vertical line and has a vertical asymptote in $\lambda = 0$.

This corollary implies that policymakers should avoid passing regulation making markets highly-competitive. However, when markets are winner-takes-most, the private optimum might result in a situation of over- or under-investment. In those cases, policymarkers should create regulations to reach the first best. In the following sub-section I study their capacity to do so.

3.3 Regulating the intensity of competition to reach the social optimum

If the economy is in an initial state of under- or over-investment, policymakers would want to create incentives to reach the socially-optimal level of R&D investment. From Equation

(17) I can see that policymakers have two instruments to do so[17]: the degree of competition in the market (λ) and the number of firms in the market (n). In order to increase (reduce) the intensity of competition in the market, policymakers can take measures aimed at reducing (increasing) dominant firms' capacity to harness network effects (e.g., facilitating multi-homing, mandating interoperability, etc.) or the pro-concentration effects of access to data (e.g., by mandating that dominant firms share data with its competitors). In the case of the number of competitors, policymakers can take measures aimed at reducing or strengthening barriers to entry, depending on whether the pre-intervention situation is that of under- or over-investment, respectively. In the former case, mandating structural separation can also be used to increase the number of competitors.

In terms of Figure 2, increasing (decreasing) the intensity of competition in the market amounts to moving rightward (leftward) parallel to the x-axis. Market entry (exit), in turn, amounts to displacing the non-dashed curve upwards (downwards). I shall now analyse under which conditions can policymakers reach the socially-optimal level of R&D investment by acting on the number of competitors (either through the porosity of barriers to entry or by mandating structural separation) and the intensity of competition in the market.

3.3.1 Intensity of competition in the market

I now study whether the degree of competition in the market can always be used as an instrument to reach socially-optimal R&D levels. In order to do so, I find the value of λ that satisfies Equation (17) for the admissible values of the parameters. Proposition 2 shows this is always the case.

Proposition 2 (Efficacy of the intensity of competition in the market to reach socially-optimal R&D levels) *Suppose that the intensity of market expansion relative to the damage caused by disruption is sufficiently high for firms to choose a positive level of R&D investment ($\frac{e}{d} > \frac{n-1-n\,\lambda}{(n-1)(\lambda-1)}$). Then, there is always an intensity of competition in the market that satisfies $\lambda = \frac{d(n-1)}{dn+e(n-1)}\ \varepsilon(0, \frac{n-1}{n})$ for which the privately-optimal level of R&D investment is socially optimal.*

Proof. Suppose that $\frac{e}{d} > \frac{n-1-n\,\lambda}{(n-1)(\lambda-1)}$. From Equation (17) I obtain the value of $\lambda = \tilde{\lambda}$ for which the privately-chosen level of R&D inputs is equal to the one chosen by the social planner: $\tilde{\lambda} = \frac{d(n-1)}{dn+e(n-1)}$.

Then, given that $\lambda\ \varepsilon(0, 1)$, the values of $\tilde{\lambda}$ that satisfy Equation (17) are given by the solution to the following equation: $0 < \frac{d(n-1)}{dn+e(n-1)} < \frac{n-1}{n}$, which is verified for all the admissible values of d, n and e. *Q.E.D.*

[17]The other two terms in Equation (17), e and d, are given to the policymakers. They depend on the nature of the innovation process.

Figure 2 provides a first graphical intuition of the result obtained in Proposition 2. Suppose the economy is in an initial state represented by a point located to the left of the dotted vertical line and off the non-dashed curve. This corresponds to a case in which markets are winner-takes-most. As per Corollary 1, this implies that a positive socially-optimal level of R&D exists, but the economy is outside of it. If the initial state is to the left (right) of the non-dashed curve, the latter can be reached by moving rightwards (leftwards) horizontally. In other words, if the initial state is one of over-investment (under-investment), an increase (a decrease) in the intensity of competition in the market can always be used to reach the socially-optimal level of R&D.

To gain an intuition on the mechanisms behind this, let me first show that an increase (a decrease) in the intensity of competition in the market reduces (increases) per-firm R&D investment.

Lemma 1 (Effect of the intensity of competition on disruptive innovation) *An increase in the intensity of competition in the market reduces per-firm R&D investment. Formally, for any* $\lambda \; \varepsilon (0,1)$*,* $x^{*\prime}_{i\,\lambda}(\cdot) < 0$*.*

Proof. *Equation* (6) *can be re-written as:*

$$P'\big(x_i^*(\cdot)\big)A = C'\big(x_i^*(\cdot)\big)$$

where $A = \frac{m\Big(e(n-1)(1-\lambda)-d\big(1-n(1-\lambda)\big)\Big)}{(n-1)(1-\delta)}$.

The derivative of A *with respect to* λ *is negative:*

$$A'_\lambda = \frac{m(dn + e(n-1))}{(\delta-1)(n-1)} < 0$$

Given that $P'_x\big(x_i^*(\cdot)\big) > 0$ *and* $C'_x\big(x_i^*(\cdot)\big) > 0$*, in order for the first order condition to continue holding, we need* $(x_i^*)'_\lambda < 0$*.* Q.E.D.

As shown in Lemma 1, an increase in the intensity of competition in the market has a schumpeterian effect of reducing the incentives to invest in R&D by diminishing the appropriability of successful innovations. This is because, as it can be seen by subtracting Equation (4) from Equation (1), firm i's net gain from innovating decreases linearly with an increase in the degree of competition in the market (λ). When a new market is created through R&D investment, the share of it firm i can appropriate diminishes linearly as markets become more competitive. Hence, policymakers can always regulate the intensity of competition in the market to reach the socially-optimal level of R&D investment. However, as I show in the next subsection, they cannot always reach the socially-optimal level of R&D investment by acting on the porosity of barriers to entry or mandating structural separation.

3.3.2 The number of competitors

I now analyse whether the number of competitors can be used effectively as an instrument to reach optimal R&D investment by facilitating or hindering market entry. In order to do so, I repeat the procedure developed in Section 3.3.1. I find the value of n that satisfies Equation (17) for the admissible values of the parameters. Proposition 3 shows that measures affecting the number of competitors are only effective when inefficiency (be it an under- or an over-investment with respect to the social optimum) is limited.

Proposition 3 (Efficacy of barriers to entry and structural separation to reach socially-optimal R&D levels) . *Suppose that the intensity of market expansion relative to the damage caused by disruption is sufficiently high for firms to choose a positive level of R&D investment* ($\frac{e}{d} > \frac{n-1-n\,\lambda}{(n-1)(\lambda-1)}$). *Then, the number of competitors that guarantees that the private and the socially optima coincide is given by* $n = \frac{e\lambda-d}{d(\lambda-1)+e\lambda}$ *and can only be reached if inefficiency is sufficiently low (i.e., if* $\frac{1-2\lambda}{\lambda} \leq \frac{e}{d} < \frac{1-\lambda}{\lambda}$*).*

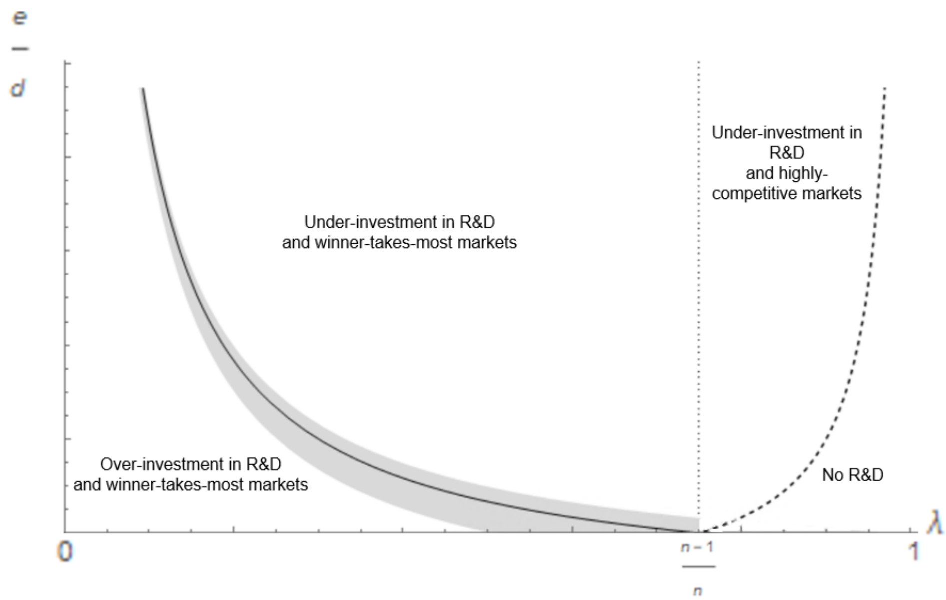
Proof. *Suppose that* $\frac{e}{d} > \frac{n-1-n\,\lambda}{(n-1)(\lambda-1)}$. *From Equation* (17) *I obtain the value of n for which the privately-chosen level of R&D inputs is equal to the one chosen by the social planner:* $n = \frac{e\lambda-d}{d(\lambda-1)+e\lambda}$. *Then, the values of n that satisfy this condition within the admissible parameter space is given by the solution to the following set of equations:*

$$\begin{cases} \frac{e\lambda-d}{d(\lambda-1)+e\lambda} \geq 2 \\ 0 < d < 1 \\ e > 0 \\ 0 < \lambda < 1 \end{cases}$$

The solution is $\frac{1-2\lambda}{\lambda} \leq \frac{e}{d} < \frac{1-\lambda}{\lambda}$. Q.E.D.

Figure 3 illustrates Proposition 3.

Figure 3: Illustration of the regions of socially-optimal, under- and over- investment in R&D



Note: the undashed curve gives the socially-optimal R&D level. The shaded area corresponds to the values of $\frac{e}{d}$ for which a change in the number of competitors can result in firms choosing the socially-optimal level of R&D. The dashed curve represents the minimum level of $\frac{e}{d}$ for the second order condition of the private equilibrium to hold.

In order to provide an intuition of why measures impacting the number of competitors are not always an effective instrument to reach socially-optimal levels of R&D, I first show that market entry always increases per-firm R&D investment.

Lemma 2 (Effect of market entry on disruptive innovation) *The entry of an additional firm always increases per-firm R&D investment. Formally, for $n \in \mathbb{N}$ and $n \geq 2.$, $x^{*\prime}_{i\,n}(\cdot) > 0$.*

Proof. *Equation* (6) *can be re-written as:*

$$P'\big(x_i^*(\cdot)\big)A = C'\big(x_i^*(\cdot)\big)$$

where $A = \frac{m\Big(e(n-1)(1-\lambda)-d\big(1-n(1-\lambda)\big)\Big)}{(n-1)(1-\delta)}$.

The derivative of A with respect to n is positive:

$$A'_n = \frac{d\lambda m}{(1-\delta)(n-1)^2} > 0$$

Given that $P'_x\big(x_i^*(\cdot)\big) > 0$ and $C'_x\big(x_i^*(\cdot)\big) > 0$, in order for the first order condition to continue holding, we need $(x_i^*)'_n > 0$. Q.E.D.

Market entry provides a weak incentive to increase R&D investment. As shown in Equation (3), as additional rivals enter the market, firm i's probability of being disrupted and its concomitant losses increase at a declining rate that is ultimately capped at 1. Therefore, when an additional firm enters the market, as shown in Lemma 2 above, there is an arrowian effect whereby firm i always increases its R&D input, although at a declining rate. Hence, if the necessary increase in per-firm R&D input is too large (if the initial state is located outside of the shaded area in Figure 3), market entry will not suffice to reach the optimal R&D level.

Note that Lemmas 1 and 2 highlight how arrowian and schumpeterian effects of the degree of competition on innovation intensity coexist in a dynamic competition between (digital) markets setting. While an increase in competition in terms of the number of competitors has an arrowian effect of increasing incentives to innovate, an increase in competition measured as an increase in the intensity of competition in the market (which translates into a lower market share for the dominant firm) has the opposite, schumpeterian effect of hindering innovation. The result holds for any level of competition, regardless of the variable considered to measure it. This differs from the inverted-U shape between the degree of market power in terms of mark-up (captured through the Lerner index) and the intensity of innovation (quantified through a citation-weighted patents metric) measured by and rationalized in a competition in the market model by (Aghion et al., 2005).

4 The welfare effect of pro-competition policies

We have seen that while the degree of competition in the market (λ) can always be used as an instrument to reach the socially-optimal level of per-firm R&D, measures affecting the number of competitors (n) are a limited instrument in that endeavour. However, even if the first best can be reached, we do not know whether continuous increases or decreases in either λ or n leading to it generate monotonous increases in social welfare. I investigate this question in this section.

4.1 The welfare effect of the intensity of competition in the market

The social welfare is given by the sum of all firms' profits: $\sum_{i=1}^{n} \pi_i$. Then, in this section I study how changes in the intensity of competition in the market affects per-firm profits, and hence welfare.

In order to analyse the impact of the degree of competition in the market on social welfare, I calculate the derivative of firm i's profits in the private equilibrium (cf. Equation (8)) with respect to λ. After re-arranging the terms and simplifying, I obtain:

$$\pi^{*\prime}_{i\,\lambda} = \overbrace{-\frac{d\,P'_\lambda\big(x_i^*(\cdot)\big)m}{1-\delta}\left(\frac{\lambda}{n-1} + (n-1)\Big(1-P\big(x_i^*(\cdot)\big)\Big)^{n-2}\right)}^{\text{Disruption losses effect (+)}} \overbrace{-C'_\lambda\big(x_i^*(\cdot)\big)}^{\text{Cost effect (+)}} \underbrace{+\frac{P'_\lambda\big(x_i^*(\cdot)\big)m(d+e)}{1-\delta}}_{\text{Market size effect (-)}} \underbrace{-\frac{d\;m\;P\big(x_i^*(\cdot)\big)}{(1-\delta)(n-1)}}_{\text{Cannibalization gains effect (-)}} \tag{18}$$

Equation (18) shows that an increase in the intensity of competition in the market has four distinct effects on firm i's profits. The first one is the "disruption losses effect". As shown in Lemma 1, an increase in the degree of competition in the market decreases per-firm investment. As a result, the probability of being disrupted firm i faces diminishes, and so do the associated expected losses from disruption. The "cost effect" simply states that, as R&D inputs decrease as a result of an increase in the intensity of competition in the market, R&D costs diminish. The "market size effect" shows the impact an increase in the degree competition in the market has on firm i's profits through the market expansion channel. Given that all firms invest less in R&D when the degree of competition in the market increases, less markets are created. Hence, firm i obtains less profits from the markets its rivals create. Finally, the "cannibalization gains effect" tells us that, as firm i reduces its R&D investment when the intensity of competition in the market increases, so does its probability of creating a new market and the concomitant gains from cannibalising an already-existing market.

When the intensity of competition in the market increases (decreases), the disruption losses effect and the cost effect increase (decrease) firm i's profits. Conversely, the market size and the cannibalization gains effects decrease (increase) its profits. Note that the strength of each of these four effects vary over the degree of competition in the market λ, and ultimately depend on the functional forms of the innovation production function $P\big(x(\cdot)\big)$ and the cost function $C\big(x(\cdot)\big)$.

Proposition 4 (Effects of the intensity of competition in the market on welfare) *An increase in the intensity of competition in the market (λ) increases profits for values of λ for which the sum of the disruption losses and the cost effects is stronger than the sum of the market size and cannibalization effect, and decreases them otherwise.*

Formally, $\pi^{*\prime}_{i\,\lambda} > 0$ *if:*

$$\frac{d\,P'_\lambda\big(x_i^*(\cdot)\big)m}{1-\delta}\left(\frac{\lambda}{n-1} + (n-1)\Big(1-P\big(x_i^*(\cdot)\big)\Big)^{n-2}\right) + C'_\lambda\big(x_i^*(\cdot)\big) < \frac{P'_\lambda\big(x_i^*(\cdot)\big)m(d+e)}{1-\delta} - \frac{dmP\big(x_i^*(\cdot)\big)}{(1-\delta)(n-1)}$$

and $\pi^{*\prime}_{i\,\lambda} < 0$ *if:*

$$\frac{d\,P'_\lambda\big(x_i^*(\cdot)\big)m}{1-\delta}\left(\frac{\lambda}{n-1} + (n-1)\Big(1-P\big(x_i^*(\cdot)\big)\Big)^{n-2}\right) + C'_\lambda\big(x_i^*(\cdot)\big) > \frac{P'_\lambda\big(x_i^*(\cdot)\big)m(d+e)}{1-\delta} - \frac{dmP\big(x_i^*(\cdot)\big)}{(1-\delta)(n-1)}$$

for $\lambda\ \varepsilon(0,1)$.

Proof. *Solving* $\pi'_{i\lambda} > 0$ *and* $\pi'_{i\lambda} < 0$. Q.E.D.

Proposition 4 tells us that an increase in the intensity of competition in the market can generate an increase or a decrease in social welfare, depending on the strength of each of the above-mentioned effects. In particular, an increase in the degree of competition in the market will lead to higher profits for values of λ for which the sum of the disruption losses and the cost effects is stronger than the sum of the market size and cannibalization effects.

More importantly, when analyzed in light of Proposition 2, Proposition 4 shows that monotonous changes in the degree of competition in the market can both increase and decrease social welfare before the latter reaches its optimal level. Proposition 2 shows that the maximum per-firm profit can always be reached if $\lambda = \frac{d(n-1)}{dn+e(n-1)}$. This rules out the possibility of changes in the intensity of competition in the market generating monotonous increases or decreases of welfare. Hence, the path towards the social optimum is not necessarily a bed of roses. For example, suppose that the economy is in an initial state of over-investment (i.e., to the left of the non-dashed curve in Figure 2). In that case, an increase in the degree of competition in the market λ (a horizontal rightward movement) can lead to the optimal R&D level (the non-dashed curve), which represents the maximum profit firms can obtain. However, in order to reach that state, as Equation (18) and Proposition 4 show, profits might decrease before they increse again until they reach their socially-optimal maximum.

4.2 The welfare effect of market entry

I now study how market entry affects social welfare. In order to do so, I compare two market structures: one with n firms and one with $n+1$ firms. Recall that in my symmetric setting there are as many firms as markets and each dominates one in every stage. Hence, for this to hold, introducing a new firm implies introducing a new market. This means that the new entrant enters all the already-existing markets and creates a new one in each stage.

Recalling that n is a discrete variable, I first calculate the discrete derivative of Equation (8) with respect to n in order to obtain the variation of per-firm equilbrium profits generated by the entry of an additional firm:

$$\Delta_n {\pi_i}^* = \frac{dmP\big(x_i^*(\cdot)\big)\Big(-\lambda + \lambda P\big(x_i^*(\cdot)\big) + (n-1)n\Big(1 - P\big(x_i^*(\cdot)\big)\Big)^n\Big)}{n(1-\delta)(n-1)\Big(1 - P\big(x_i^*(\cdot)\big)\Big)} \tag{19}$$

By studying the sign of Equation (19), and after re-arranging the terms, I obtain the conditions for market entry to be welfare-enhancing and welfare-decreasing stated in Proposition

5.

Proposition 5 (Welfare effect of market entry) *Market entry is social-welfare-increasing if the probability of one of firm i's markets being disrupted* $\left(1-\Big(1-P\big(x_i^*(\cdot)\big)\Big)^{n-1}\right)$ *is sufficiently high* $\left(1-\Big(1-P\big(x_i^*(\cdot)\big)\Big)^{n-1}>1-\frac{\lambda}{(n-1)n}\right)$ *and social-welfare-decreasing otherwise.*

Proof. *We study the condition for* $\Delta_n \frac{\pi_i{}^*}{n}>0$*. Since the denominator of Equation* (19) *is positive, we focus on its numerator. After re-arranging, this is the case if* $\frac{\lambda}{(n-1)n}>1-\Big(1-P\big(x_i^*(\cdot)\big)\Big)^{n-1}$*. Multiplying by -1 and adding 1 to each side of this inequality, we obtain that* $\Delta_n \frac{\pi_i{}^*}{n}>0$ *if* $1-\Big(1-P\big(x_i^*(\cdot)\big)\Big)^{n-1}>1-\frac{\lambda}{(n-1)n}$ Q.E.D.

Proposition 5 tells us that market entry can only increase firm i's profits (and hence social welfare) as long as the probability of disruption is sufficiently high. The intuition is as follows. When a new firm enters the market, it erodes firm i's profits in three ways. First, by taking a part of the market share of the markets firm i does not dominate. Second, by cannibalizing a share of a market in which firm i is present after the new entrant innovates (disruption damage). Third, as shown in Lemma 2, market entry leads firm i to increase its R&D inputs, which further diminishes its profits by increasing the cost of R&D. However, the new entrant's innovation also creates a positive externality for firm i, as it allows it to capture a share of the new market the new entrant creates. Moreover, since firm i's R&D investment increases, so does the expected profit from creating a new market it will dominate. Then, in order for this positive externality to be strong enough for the net effect of entry on profits to be positive, the probability of being disrupted has to be sufficiently high. Note that the right side of the equation in Proposition 5 is bounded between 0.5 and 1. Then, for entry to be welfare-enhancing, the probability of disruption has to be at least above 0.5.

Note also that both the left and the right side of the condition stated in Proposition 5 are concave over n and have a horizontal asymptote in 1, as it is the maximum probability of disruption that can exist. Therefore, profits can increase or decrease monotonically over n, be U-shaped or inverse-U-shaped, depending on the innovation production function $P\big(x(\cdot)\big)$ chosen. The implication is that even when inefficiencies are sufficiently small for market entry to serve as an instrument to maximize social welfare, the latter might decrease in the process.

5 Conclusions

There is an ongoing debate in the literature and policymaking circles on how an increase in the intensity of competition and market entry in digital markets might impact the welfare generated by innovation. In this article I engage in this debate by introducing a novel model: dynamic competition between markets. The model complements the dynamic competition literature underpinning this debate by capturing three salient features of competition in digital markets: i) the preeminence of R&D investments in disruptive innovation, ii) the fact that new markets cannibalize revenues from old ones and iii) the fact that competition is characterized by multimarket contact in winner-takes-most markets.

I find that there is a socially-optimal level of R&D investment defined by the intensity of market expansion relative to the damage caused by disruption, provided that markets are winner-takes-most. If market expansion (the positive externality) is too high relative to the damage caused by disruption (the negative externality), firms under-invest in R&D relative to the socially-optimal level, and vice-versa. Moreover, this equilibrium ratio decreases over the intensity of competition in the market. I show that while the degree of competition in the market can always be used as an instrument to reach socially-optimal levels of R&D, the porosity of barriers to entry and structural separation can only do so if the inefficiency of firms' R&D investment is limited. Finally, I show that both an increase in competition in the market and market entry can increase or decrease welfare, and provide the conditions for each case to take place.

My results have two policy implications. First, policies aiming at increasing the degree of competition in digital markets should be applied only if the digital economy is in an initial state of over-investment, while policies aiming at facilitating market entry should be applied only if the initial state is one of under-investment, compared to the social optimum. Second, the regulation of the intensity of competition in digital markets is always an effective instrument to reach the socially-optimal level of R&D into disruptive innovation, while the porosity of barriers to entry and structural separation are only effective if inefficiencies are limited. Hence, *ceteris paribus*, the former are preferable to the latter.

The article opens two avenues of research. The first one is theoretical and builds on the model's main limitations. The model introduced has the shortcoming of relying on a symmetry assumption. It could therefore be extended to allow for different types of heterogeneity. For example, firms could differ in the number of markets they dominate. The intensity of competition in the market could also vary across markets. Moreover, the model foregoes differences in terms of innovation capabilities between firms. Firm-level heterogeneity in terms of innovation cost or the innovation production function could be considered in future research. In the same vein, if an increase in n is to be interpreted as the result of a de-merger (rather than entry caused by the lifting of a barrier to entry), it could be assumed that the new, broken up firms could be less capable of innovating than the remaining ones. Finally, the measure of welfare used in this article assumes that the degree of competition in the market does not affect social welfare. A more realistic assumption is that, as markets are more competitive, consumer welfare increases to the detriment of firms' profits. It would be interesting to see how each of these changes to some of the of the model's assumptions affect its predictions.

A second avenue of research could consist in an empirical test of the model. With appropriate metrics of the market expansion effect, the damage caused by disruption and the amount of R&D inputs devoted to disruptive innovation, an assessment of whether the digital economy is currently in a state of over-, under- or socially-optimal disruptive R&D investment could be made. This would allow to test model's predictions. For example, the impact of observed changes in the intensity of competition in the market (e.g., proxied by HHI indeces) and the entry of a new competitor (e.g., Facebook's market entry in 2007) on disruptive R&D efforts and the revenues generated by digital markets could be tested. The recent entry into force of the Digital Markets Act offers another good opportunity to test the model's prediction, provided that the former succeeds in its endeavour.

I hope the model of dynamic competition between (digital) markets introduced in this article will lead to promising avenues for further research and policy-relevant results.

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