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Network Externalities and Market Dominance*

Robert Akerlof[†] Richard Holden[‡] Luis Rayo[§]

November 28, 2021

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1 Introduction

A core objective of economics is to understand the nature of market competition as efficiency, consumer welfare, the intensity of innovation, and appropriate anti-trust policy all depend upon how competition plays out.[1] Competition differs markedly between the "old economy" (where average costs are U-shaped and demand is downward-sloping) and the "new economy" (where average costs are decreasing and demand is subject to network externalities). Despite the new economy's increasing importance—it includes, for instance, the five largest publicly-traded companies (Apple, Amazon, Google/Alphabet, Microsoft, and Facebook)—it is not yet fully understood.

A key challenge is understanding consumer behavior in these markets, as the presence of network externalities means that demand need not be downward sloping and there may be multiple equilibria in demand. Modeling competition therefore requires taking a stance on the shape of the demand curve and when firms will be "in" or "out." We address this challenge by focusing on (and micro-founding) an intuitively-appealing demand curve and introducing a new focality concept, based upon level-k thinking, that is highly tractable and yet flexible enough to accommodate heterogeneous consumers. Under this focality concept, consumers' "impulses"—or level-0 thinking—determine the level of demand.

We show that duopoly competition in these markets is potentially quite different from standard markets. Rather than competing for the *marginal consumer*, firms may instead compete for the *market itself* (i.e. for a large block of consumers). When this occurs, a novel form of limit pricing arises—from within rather than from outside the market—where the losing firm captures a positive market share (a "consolation prize") even when it does not supplant its rival and where competition is modulated by consumer beliefs.

We characterize how competition changes with firms' technologies, consumers' impulses, and the strength of network externalities. Specifically:

1. Improvements in the technology/quality of the "dominant firm" (i.e., the firm

[1] For instance, there is a long tradition in economics of analyzing the relationship between market structure and innovation, dating to the celebrated contributions of Schumpeter (1942) and Arrow (1962).

with the larger market share) have no effect on consumer surplus but increase the dominant firm's profits, while improvements in the non-dominant firm's technology/quality increase consumer surplus but have no effect on the non-dominant firm's profits.

2. A change in consumers' impulses in favor of the dominant firm leads to higher prices, lower consumer surplus, and lower total surplus.

3. An increase in network externalities strengthens competition and reduces prices when consumers' impulses favor the non-dominant firm, but may have the opposite effect when impulses favor the dominant firm.

These results have a number of policy implications, which we discuss in Section 5. Point (3) suggests that network externalities are not bad for competition per se—they may even strengthen it—however, it is possible for large firms to become entrenched. One way this can occur is through the purchasing of startups with new technologies. Point (1) highlights that the dominant firm has an incentive to improve its technology while the non-dominant firm does not—even though consumers benefit from improvements in the non-dominant firm's technology but not the dominant firm's. Another way firms can become entrenched is through their high past sales, which may generate a high consumer impulse. Our theory therefore points especially to the reduction of entrenchment as an important policy goal.

Related Literature. Our paper contributes to the large literature on network externalities spawned by the classic models of Katz and Shapiro (1985), and Becker (1991).[2] A major theme in this literature, which was only superficially explored in those classic models, and where our contribution lies, is how consumer beliefs affect equilibrium outcomes.

The more systematic study of the impact of beliefs, starting with Caillaud and Jullien (2003), has centered around the idea of "focality" (the degree to which consumers are biased in favor of a given firm) and has explored the extent to which this bias grants market power and allows inefficient incumbents to survive. Jullien

[2] These papers showed that network externalities can generate demand curves with both downward- and upward-sloping regions(depending on whether the traditional price effect or the network effect dominates) together with the possibility of multiple equilibria.

(2011) uses notions of focality to study the value of divide-and-conquer strategies in multi-sided markets; Halaburda and Yehezkel (2019) consider a dynamic model of platform competition where a firm's current focality — modeled there as all or nothing — depends on past sales; Halaburda et al. (2020) extend this framework to the case where focality can take intermediate values and thus firms can enjoy a partial belief advantage; and Markovich and Yehezkel (2021) explore how a firm can rely on a user group to cement its dominance.[3] Our innovation relative to this work is that we introduce a notion of focality that is flexible enough to accommodate a heterogeneous set of consumers, rather than a single consumer type. This leads to richer market structures than "winner-take-all". Indeed, in our model, the losing firm captures a positive market share even when it does not overtake its rival.[4]

Biglaiser and Crémer (2020), like us, allow for more than one consumer type (in their case, two types), and thus are also able to study competition from *within* the market, where the losing firm captures a positive market share. In contrast to a belief-based approach to equilibrium selection, they consider a platform migration protocol that, in essence, chooses the best possible equilibrium from an incumbent's point of view. What distinguishes our model relative to theirs is that by focusing on beliefs, it allows for a continuous, rather than a single, level of focality, as modulated by the consumers' impulse. In addition, our analysis allows for quality differences across competing firms and a richer (continuous) set of consumer types, which may differ along both vertical and horizontal dimensions. All of these extra features play a role in our policy implications in Section 5.

Our approach to equilibrium selection relies upon level-k thinking (e.g. Stahl and Wilson (1994), Nagel (1995), Ho et al. (1998), Crawford (2003), Crawford and Iriberri (2007)) and, in particular, on the notion of "introspective equilibrium" developed by Kets and Sandroni (2021). Our innovation is to apply this framework to the new economy environment and to consider in that setting the role of impulses.[5]

[3] Ambrus and Argenziano (2009) instead use coalitional rationalizability to select equilibria. They restrict the amount of coordination failure across consumers and show that multiple asymmetric networks can exist in equilibrium.

[4] Argenziano and Gilboa (2012) consider dynamics in an abstract model without firms or pricing decisions; Biglaiser and Crémer (2020) consider dynamic competition between two platforms in an environment where migration between platforms is affected by coordination failures.

[5] In the special case where consumers are homogeneous, our equilibrium selection coincides with

Also related is the literature on switching costs, beginning with Von Weizsäcker (1984) and Klemperer (1987) (see also Klemperer (1995), Fudenberg and Tirole (2000), and Farrell and Klemperer (2007)). Switching costs generate an incumbency advantage and mean that transitioning from "out" to "in" may require charging a low initial price. In our model, there is an incumbency advantage despite the absence of switching costs. Moreover, in contrast to switching-cost models, transitions can occur very quickly, may involve quantity overshooting, and are triggered by changes in impulses as well as prices.[6]

Our paper relates as well to a growing applied literature on the new economy. For instance, Gompers and Lerner (1999) show that a sizeable share of R&D investment is done by new-economy startups. Gans et al. (2002) study incumbents' expropriation of the intellectual capital of startups, and the resulting impact on incentives to innovate. There is also an emerging debate in law and economics on appropriate anti-trust policy in the new economy. The so-called "New Brandeisian Movement" (see Khan (2017)) argues that there is too much focus on short-run consumer welfare, which misses the possibility that a firm may raise prices after building up a network (for the classic welfarist approach, see Kovacic and Shapiro (2000)). Finally, Brynjolfsson and McAfee (2014) argue that both network externalities and income inequality are magnified by artificial intelligence.[7]

The remainder of the paper proceeds as follows. Section 2 specifies our model of the economic environment. Section 3 considers price setting when there is a single firm and explores, in particular, the role of the impulse. Section 4, which is the heart of the analysis, considers competition between two firms. We characterize equilibrium, and show how changes in the economic environment affect competition, and consumer and producer surplus. Section 5 highlights a number of policy implications stemming from our analysis. Section 6 concludes.

that of Halaburda et al. (2018).

[6]A broader literature on platforms, initiated by Rochet and Tirole (2003), analyzes markets that are multi-sided and involve externalities within and between sides (e.g. Rochet and Tirole (2006), Armstrong (2006), and Weyl (2010)).

[7]See Edelman (2015, June 21, 2017) and Edelman and Geradin (2016) for examples of how nefarious or illegal practices can be used to harness network externalities.

2 Model

Consider a market with either a single seller (firm 1) or two sellers (firms 1 and 2), each with constant (perhaps zero) marginal costs, and a unit mass of consumers, each with unit demand, with types $z \in [\underline{z}, \overline{z}]$ distributed according to c.d.f. F with density f. N denotes the number of firms.

When there is a single seller, consumer z's demand is $D_z(p_1, Q_1) \in \{0, 1\}$, where p_1 is price and Q_1 total sales. Network externalities are reflected in the assumption that demand depends upon total sales. Aggregate demand at price p_1 and quantity Q_1 is:

$$D(p_1, Q_1) := \int_z D_z(p_1, Q_1) dF(z).$$

For any given price p_1, an equilibrium quantity Q_1^D satisfies:

$$Q_1^D = D(p_1, Q_1^D). \tag{1}$$

This equation may in principle admit more than one solution as the presence of network effects may lead consumers to coordinate on a higher or lower level of demand. We will shortly address this equilibrium multiplicity by introducing a simple equilibrium refinement.

When instead there are two sellers, assuming consumers prefer to consume from one of the firms rather than not at all, consumer z's demand for firm 1 is $D_z(p_1 - p_2, Q_1) \in \{0, 1\}$, where $p_1 - p_2$ is the difference in firms' prices, and consumer z's demand for firm 2 is $1 - D_z(p_1 - p_2, Q_1)$.[8] Aggregate demand for firm 1 at prices p_1, p_2, and quantity Q_1 is:

$$D(p_1 - p_2, Q_1) := \int_z D_z(p_1 - p_2, Q_1) dF(z),$$

and aggregate demand for firm 2 is $1 - D(p_1 - p_2, Q_1)$. The equilibrium quantities Q_1^D and Q_2^D satisfy:

$$Q_1^D = D(p_1 - p_2, Q_1) = 1 - Q_2^D. \tag{2}$$

[8] We shall assume throughout that the consumers' outside options are immaterial for their decisions. In our micro-foundation below, a sufficient condition for this is that the intrinsic quality of the firms' products is sufficiently high.

This equation may admit multiple solutions as well.

We adopt the convention that $p_2 = Q_2 = 0$ when there is only one firm and assume throughout that $D(p_1 - p_2, Q_1)$ is continuous, decreasing in $p_1 - p_2$, and strictly increasing in Q_1 whenever $Q_1 < 1$. For convenience, let $p := p_1 - p_2$ denote firm 1's relative price.

The *inverse demand curve* (or more compactly, *demand curve*) for firm 1, denoted $P(Q_1)$, satisfies for all Q_1:

$$Q_1 = D(P(Q_1), Q_1), \tag{3}$$

where $P(Q_1)$ measures the relative price p needed for firm 1's demand to equal Q_1, provided such a price difference exists.

In/Out Demand. In order to capture markets where firms seek to attract large swaths of consumers *en masse*, and where more than one firm is active at once, we shall assume that the demand curve $P(Q_1)$ has an "In/Out" shape as shown in Figure 1(a).[9] This shape was first suggested by Becker (1991) in his classic (monopolistic) restaurant model. Loosely speaking, when overall consumption is low, the network effect is weak and demand has standard negative slope; when consumption exceeds a first threshold, Q_L, the network externality becomes sufficiently strong that marginal value grows with consumption; and when total consumption exceeds a second threshold, Q_H, the externality is mostly exhausted and demand again has negative slope. When there are two firms, notice that firm 2's inverse demand curve (i.e. $p_2 - p_1$ plotted against Q_2) is In/Out whenever firm 1's inverse demand curve is In/Out.

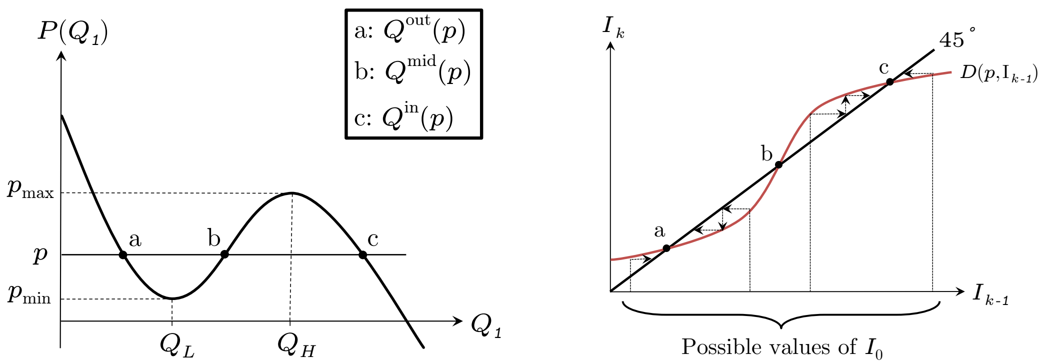
While the In/Out shape may in principle seem arbitrary, it is actually easy to micro-found (something Becker (1991) did not address). Two possibilities follow:

Micro-foundation #1: Suppose consumer z buys firm 1's product if and only if

$$\mu_1 - \mu_2 + z + \alpha(Q_1 - Q_2) \geq p_1 - p_2, \tag{4}$$

[9] That is, between 0 and Q_L, P is strictly decreasing and weakly convex; between Q_L and Q_H, P is strictly increasing; between Q_H and 1, P is strictly decreasing and weakly concave; finally, $p_{\max} < P(0)$ and $|p_{\max}| > P(1)$.

Figure 1



(a) In/Out Demand Curve

(b) Evolution of I_k

where μ_i is the *intrinsic quality* of firm i's product, z is a horizontal preference toward firm 1, and the parameter $\alpha > 0$ measures the strength of the network effect. When there is only one firm ($N = 1$), we adopt the convention that $\mu_2 = 0$ (and recall that $Q_2 = 0$ in this case). Under this formulation, demand is In/Out whenever:

1. f is single-peaked: that is, maximal at some intermediate value of z and strictly monotone elsewhere.
2. The network externality is large: specifically, $\frac{1}{N\alpha}$ is below the peak of f.
3. The tails of f are thin: specifically, $\frac{1}{N\alpha}$ is above both $f(\underline{z})$ and $f(\overline{z})$.

Intuitively, the initial negative slope arises because the density of types is relatively low, and so even as a price drop attracts additional consumers, these are not sufficiently numerous so as to produce, in the margin, a sufficiently strong network effect. Then, as sales continue to grow and we approach the denser middle part of the type distribution, those new consumers are sufficiently numerous that their network effect exceeds the price effect, and hence the slope turns positive. Finally, the slope again turns negative once the density of types again falls.[10]

[10]More formally, letting $\hat{z}$ denote the marginal type who is indifferent between the two firms (or when there is only one firm, indifferent between firm 1 and not consuming), we obtain $1 - Q_1 = F(\hat{z}) = F(-(\mu_1 - \mu_2) - \alpha(Q_1 - Q_2) + (p_1 - p_2))$. Upon rearranging terms, $P(Q_1) = (\mu_1 - \mu_2) + \alpha(Q_1 - Q_2) + F^{-1}(1 - Q_1)$. Given that $Q_1 - Q_2 = 2Q_1 - 1$ when there are two firms and $Q_1 - Q_2 = Q_1$ when there is a single firm, we find that $P'(Q_1) = N\alpha - \frac{1}{f(F^{-1}(1-Q_1))}$, from which the claim immediately follows.

Micro-foundation #2: A similar micro-foundation is obtained for the case of two firms if we assume that consumer z buys firm 1's product if and only if

$$\mu_1 - \mu_2 + z(Q_1 - Q_2) \geq p_1 - p_2, \tag{5}$$

where $z \geq 0$ now represents the extent to which a consumer cares about the network effect. In this case, demand is guaranteed to be In/Out whenever f is symmetric, single-peaked, and its mass is sufficiently concentrated around its peak. The intuition is similar to that of the first micro-foundation: in regions of the type space where consumers are sparse, the negative price effect dominates the positive network effect; in regions where consumers are dense, the opposite happens. The difference is that as more consumers join a firm, the marginal consumer likes the firm's product more both because the network becomes larger and because their own marginal value for the network is greater than that of their infra-marginal peers.[11]

2.1 Multiple Equilibria and Equilibrium Selection

As illustrated in Figure 1(a), if firm 1's relative price p is strictly between $p_{\min}$ and $p_{\max}$, demand intersects price three times; hence there are three equilibria. In the first one, denoted $Q^{out}(p)$, we say that firm 1 is "out" and firm 2 is "in"; in the second one, denoted $Q^{mid}(p)$, no firm is fully dominant; in the third one, $Q^{in}(p)$, firm 1 is "in" and firm 2 is "out." Similarly, if p is equal to either p_{min} or p_{max}, there are two equilibria, with one firm "in" and the other one "out."

We shall address this multiplicity using a refinement concept based upon "level-k reasoning" (see Crawford et al. (2013) for a survey). Specifically, we invoke a version of Kets and Sandroni (2021)'s "introspective equilibrium" where each player (in our case, each consumer) starts with an exogenously-given "impulse" that determines how they react at level 0; then, at each level $k > 0$, consumers form a best response to the belief that other consumers are acting at level $k-1$. An introspective equilibrium is the limit of level-k reasoning as $k \to \infty$.

[11] For a formal proof, see Appendix.

We formally define introspective equilibrium for a market with network externalities as follows.

Definition 1 (Introspective Equilibrium for Network Externalities)**.**
Let $I_0 \in [0, 1]$ *denote the consumers' impulse to consume from firm 1. An introspective equilibrium, denoted* Q_1^**, is constructed as follows:*

1. *Consumption at level k, denoted* I_k*, is obtained by letting each consumer best-respond to the relative price p and to the belief that other consumers are acting at level* $k - 1$*:*
$$I_k := D(p, I_{k-1}).$$

2. *An introspective equilibrium is the limit as* $k \to \infty$*:*
$$Q_1^* := \lim_{k\to\infty} I_k.$$

In our setting the impulse may be understood to arise from a combination of factors, not explicitly modeled, such as:

- Advertising.
- The use of nudges, such as a specific search engine being the default one on a smartphone.
- A firm's past sales (even past success in related markets) and, more generally, its reputation.[12]
- The actions of "influencers" – broadly defined as economic agents with the power to change expectations.[13]

Proposition 1 derives the introspective equilibrium as a function of the impulse.

[12]Even though our model is static, it has implications for the steady state of a dynamic environment in which the dominant firm does not change over time.

[13]Large consumers (or blocks of small consumers) who happen to move first, as for instance in Akerlof and Holden (2019) and Markovich and Yehezkel (2021), may have a similar impact. See also Corsetti et al. (2004) for an analysis of the impact of large players in coordination games within a global-games environment.

Proposition 1. *Suppose demand is In/Out. When $p_{\min} \leq p \leq p_{\max}$, the introspective equilibrium depends upon the impulse I_0 as follows:*

$$Q_1^*(p) = \begin{cases} Q^{in}(p), & \text{if } I_0 > Q^{mid}(p). \\ Q^{mid}(p), & \text{if } I_0 = Q^{mid}(p). \\ Q^{out}(p), & \text{if } I_0 < Q^{mid}(p). \end{cases}$$

When instead $p > p_{\max}$ or $p < p_{\min}$, the introspective equilibrium corresponds to the unique Nash equilibrium regardless of impulse.

To establish this result, we begin with the case where p takes an intermediate value ($p_{\min} \leq p \leq p_{\max}$). Figure 1(b) shows level-k consumption $I_k := D(p, I_{k-1})$ as a function of I_{k-1} given p, together with the evolution of I_k for any given impulse I_0. To see why $D(p, I_{k-1})$ has the shape shown in the figure, observe that $I_{k-1} = D(P(I_{k-1}), I_{k-1})$ (per the definition of the demand curve $P(\cdot)$). Therefore, whenever $P(I_{k-1}) = p$, which occurs at the three Nash equilibria $Q^{out}(p)$, $Q^{mid}(p)$, and $Q^{in}(p)$ in the first panel, $D(p, I_{k-1})$ is equal to I_{k-1}, i.e. it intersects the 45° line. Moreover, since $D(\cdot, I_{k-1})$ is a decreasing function, whenever $P(I_{k-1})$ is above p, which occurs between $Q^{mid}(p)$ and $Q^{in}(p)$, $D(p, I_{k-1})$ is greater than I_{k-1}, i.e. is above the 45° line. Finally, whenever $P(I_{k-1})$ is below p, $D(p, I_{k-1})$ is lower than I_{k-1}.[14]

Observe that whenever I_0 is strictly greater (respectively smaller) than $Q^{mid}(p)$, I_k converges to $Q^{in}(p)$ (respectively $Q^{out}(p)$) as k goes to infinity; moreover, if $I_0 = Q^{mid}(p)$, $I_k = I_0$ for all k and hence I_k converges to $Q^{mid}(p)$, as desired.

Now, suppose $p > p_{\max}$ or $p < p_{\min}$. In this case, I_k intersects the 45° line only once (as $P(I_{k-1})$ intersects p only once); this point of intersection corresponds to the unique Nash equilibrium. It is easy to see that, regardless of whether I_0 is above or below the point of intersection, I_k converges to the point of intersection in the limit. Hence, the introspective equilibrium is the same as the Nash equilibrium. **Q.E.D.**

For a simple intuition, observe that for any given relative price p, so long as $P(Q_1)$ exceeds that price (i.e. relative willingness to pay firm 1 exceeds relative price) additional consumers join firm 1; the opposite happens when $P(Q_1)$ is below

[14] Since $D(p, I_{k-1})$ is continuous in I_{k-1}, so is I_k.

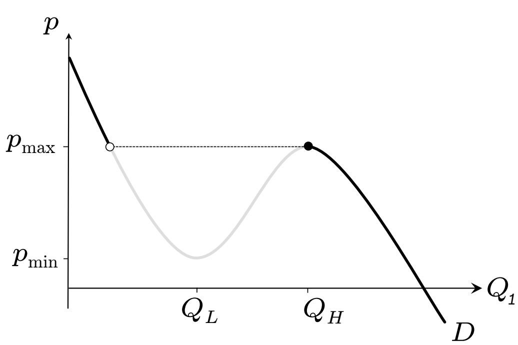
the relative price.

Corollary 1. *Suppose demand is In/Out. Upon applying the introspective equilibrium refinement, firm 1 faces one of three demand curves:*

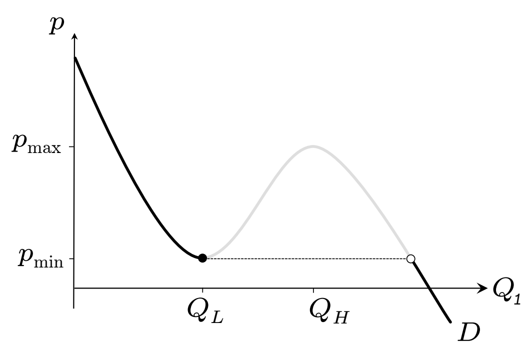
1. *"In Demand Curve" when* $I_0 \geq Q_H$ *(Figure 2a).*
2. *"Out Demand Curve" when* $I_0 \leq Q_L$ *(Figure 2b).*
3. *"Between Demand Curve" otherwise (Figure 2c).*

Each of these curves has a weakly negative slope.

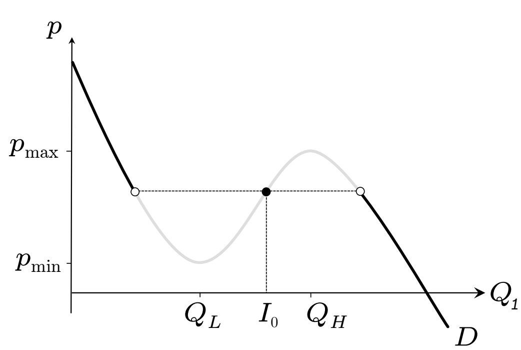
Figure 2



(a) "In" Demand Curve ($I_0 \geq Q_H$)



(b) "Out" Demand Curve ($I_0 \leq Q_L$)



(c) "Between" Demand Curve ($Q_L < I_0 < Q_H$)

That this result follows from Proposition 1 can be seen from the fact that, in the event of three equilibria (i.e. $p_{min} < p < p_{max}$), an impulse of at least Q_H guarantees that the impulse exceeds $Q^{mid}(p)$, and hence firm 1 ends "in"; similarly, an impulse no greater than Q_L guarantees that the impulse is below $Q^{mid}(p)$, and therefore firm 1 ends "out." In the event of two equilibria ($p = p_{min}$ or $p = p_{max}$), a similar reasoning applies.

When the impulse is such that firm 1 faces an in (resp. out) demand curve we shall say it is "in" (resp. "out"). Otherwise, we shall say that firm 1 is "between." Notice that, when there are two firms, firm 2 faces an out demand curve when firm 1 faces an in demand curve (and vice-versa).[15]

3 Monopoly

Before turning to duopoly, let us briefly consider the monopoly case, which serves as a simple benchmark for understanding the role of the impulse. We will discuss in turn how the impulse affects the monopolist's profits, quantity, and price.

Profits. As illustrated in Figure 2, demand is weakly increasing in the impulse. It immediately follows that the monopolist's profits are also weakly increasing in I_0.

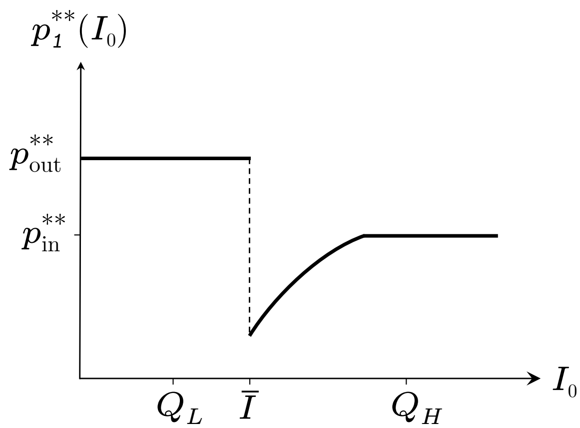
Quantity. At the optimal price, the monopolist either sells a "low" quantity ($Q_1 \leq Q_L$) or a "high" quantity ($Q_1 \geq Q_H$). To see why, note that a monopolist with a "between" demand curve can in principle sell an intermediate quantity at a positive price (see Figure 2(c)) but will never choose to do so because a slight reduction in price leads to higher profits. As the impulse increases, the monopolist is increasingly inclined to sell the high quantity. This follows from the observation that an increase in the impulse extends the "high" portion of the demand curve and truncates the "low" portion.

There are two cases to consider:

1. The monopolist sells a low quantity regardless of the impulse or a high quantity regardless of the impulse.

[15] Observe that the discontinuities in the "out" and "mid" demand curves may imply that an optimal price within the high quantity region (above Q_H) does not exist. To overcome this problem one may assume that prices lie on a finite, but very fine, grid.

Figure 3: Price and Impulse



The figure depicts optimal price as a function of the impulse for case (2). $p_1^{**}(I_0)$ denotes the optimal price when the impulse is I_0; p_{in}^{**} denotes the optimal price of an in firm ($I_0 \geq Q_H$); p_{out}^{**} denotes the optimal price of an out firm ($I_0 \leq Q_L$). Note that p_{out}^{**} may be greater than or less than p_{in}^{**}.

2. The monopolist sells a low quantity when the impulse is below a threshold $\bar{I}$ and a high quantity when the impulse is above the threshold.[16]

Case (2) is more likely when network externalities are large and the demand curve has a significant upward-sloping portion.

Price. The impulse has an ambiguous effect on price. Figure 3 illustrates how the optimal price changes with the impulse in case (2).[17] At $\bar{I}$, the firm drops its price discontinuously to overcome consumer hesitancy and achieve high sales.

Above $\bar{I}$, the price is weakly increasing in the impulse. To see why, observe that the firm must set its price below a threshold to sell a high quantity, and as the impulse increases, this threshold rises. Hence, the firm can raise its price while maintaining

[16]Note that quantity may not be monotonic in the impulse in case (2). In fact, quantity is weakly decreasing above $\bar{I}$ and price is weakly increasing above $\bar{I}$. See the discussion of price for elaboration.

[17]The equivalent figure for case (1) looks either like the part of Figure 3 to the left of $\bar{I}$ (if the monopolist sells a low quantity) or to the right of $\bar{I}$ (if the monopolist sells a high quantity).

high sales.[18,19]

4 Duopoly

We now bring a competitor into the model. For ease of exposition, we assume that $Q_H = 1 - Q_L$, which ensures that both firms' demand curves are upward-sloping between Q_L and Q_H. This assumption holds under both micro-foundations when the type distribution f is symmetric.

To ensure that a pure strategy equilibrium exists, we assume a "Bertrand-Stackelberg" timing where firm 1 is the price leader and firm 2 is the follower.[20] We focus on outcomes where the price leader obtains the larger market share for reasons that we will discuss below.

The presence of network externalities in our model means that firms may end up competing "over the market" (i.e., over a large block of consumers) rather than over a marginal consumer alone. When this occurs, the model gives rise to a novel form of limit pricing—from within rather than from outside the market—where the losing firm captures a positive market share (a "consolation prize") even when it does not supplant its rival and where competition is modulated by consumer beliefs.

The following lemma describes the limit-pricing aspect of the model.

Lemma 1. *There exist a threshold, which we call p^{win}, such that firm 1 wins the market (i.e. serves at least Q_H consumers) if $p_1 \leq p^{win}$; otherwise, firm 2 wins the*

[18]Below $\overline{I}$, the firm's price is unchanging in the impulse. To see why, observe first that the firm must set a price above a threshold in order to locate on the low portion of the demand curve rather than the high portion. Let $p_1^L(I_0)$ denote the optimal price conditional on locating on the low portion. $p_1^L(I_0)$ will be fixed so long as pricing above the threshold is not a binding constraint. If pricing above the threshold is a binding constraint at impulse I_0', the firm is clearly better off locating on the high portion. Hence, $I_0' \geq \overline{I}$.

[19]Notice that an increase in the impulse may cause consumer surplus to rise or fall. On the one hand, the firm may raise its price and lower the quantity sold, leading to a fall in consumer surplus. On the other hand, the firm may lower its price and raise the quantity sold (i.e. at impulse $\overline{I}$), leading to a rise in consumer surplus. Intuitively, while an increase in the impulse gives market power to the monopolist, it also coordinates consumers and may thereby generate network externalities.

[20]If instead pricing was simultaneous, competition for the dominant market position would generate a type of "all-pay contest" that may not admit pure strategy outcomes.

market.

To derive this result, fix p_1 and let $\Pi_2^L(p_1)$ denote firm 2's maximum profit conditional on selling less than Q_L; similarly, let $\Pi_2^H(p_1)$ denote firm 2's maximum profit conditional on selling more than Q_H.[21]

Since $\Pi_2^H(p_1)$ exceeds $\Pi_2^L(p_1)$ when p_1 is very high, and vice versa when p_1 is very low, it suffices to show that as p_1 grows, $\Pi_2^L(p_1)$ grows less than $\Pi_2^H(p_1)$. To this end, observe that as p_1 grows, $\Pi_2^H(p_1)$ increases at a rate no less than Q_H (as an in firm serves at least Q_H consumers and firm 1 can choose to raise its in price one-to-one in response to a higher p_1 while keeping its sales unchanged), and $\Pi_2^L(p_1)$ increases at a rate no greater than Q_L (as firm 2 can at most capture the added marginal willingness to pay of all Q_L consumers). **Q.E.D.**

We shall call the inequality $p_1 \leq p^{win}$ the *win-the-market constraint* (or WIN constraint for short). A simple intuition for this result is that a higher p_1 shifts firm 2's demand vertically, which means firm 2 is more likely to expand; moreover, constant marginal costs imply that firm 2 will never choose to sell an intermediate quantity between Q_L and Q_H (as would be possible if it faced a "between" demand curve as in Figure 2(c)).

Observe that, when firm 1 wins the market with a slack WIN constraint (p_1 strictly less than than p^{win}), competition between the firms is over a marginal consumer. By contrast, when firm 1 wins the market with a binding WIN constraint ($p_1 = p^{win}$), competition is "over the market": rather than fighting for the marginal consumer, firms are fighting for the "in" position.

To obtain further results, we impose a regularity condition on the "low" portion of the demand curve (i.e. the portion to the left of Q_L).[22]

Assumption 1. *The optimal price and quantity for firm 2 conditional on selling no more than Q_L are both increasing in p_1.*

The following result gives conditions under which firm 1 wins the market while charging exactly p^{win}. (For a formal proof, see the Appendix.)

[21] Because marginal costs are constant, firm 2 will never select the "mid" position.

[22] This assumption holds, for instance, if the relevant portion of the demand curve is sufficiently close to linear.

Proposition 2. *Suppose Assumption 1 holds and firms face an In/Out demand curve that admits the first micro-foundation. Then:*

A. *For any given impulse, firm 1 wins the market (i.e. sells at least Q_H) if and only if the difference in the firms' intrinsic quality $\mu_1 - \mu_2$ is above a threshold, which itself is weakly decreasing in the impulse I_0.*

B. *Provided firm 1 wins the market, $p_1 = p^{win}$ whenever the type distribution f has sufficient mass concentrated around its peak.*

A simple intuition for part 1 is that having higher quality $(\mu_1 - \mu_2)$ makes it easier for firm 1 to win the market because it raises the minimum price differential needed to do so; a higher impulse helps firm 1 for a similar reason. For part 2, observe that when the mass of f is highly concentrated around its peak—i.e. there is little taste differentiation amongst the bulk of consumers—the vast majority of them will end up with firm 1 when it wins. Hence, if this firm were to lower its price below p^{win}, the minimum needed to win, it would face a large infra-marginal loss (over at least Q_H consumers) while attracting very few additional consumers, as there are very few left.

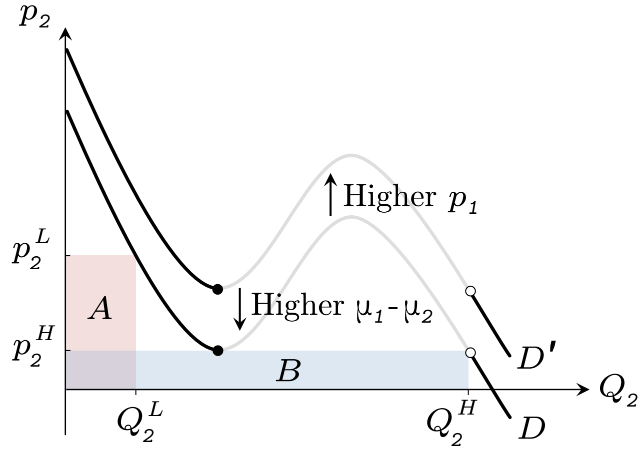
While our model is static, firms in reality may interact repeatedly and not set prices once-and-for-all. A more realistic price-setting game may therefore be one with many pricing periods where, in any given period, the firm with higher past sales – by virtue of its success – is the price leader and holds the "in" position (i.e. has a high impulse). Proposition 2, as well as our comparative statics in the next section, apply equally to the steady state of an infinite-horizon model of this type.[23] This provides a rationale for focusing on the Bertrand-Stackelberg environment in which the price leader wins the market, as we do.

We now derive some comparative statics that will be the backbone of our policy discussion. Our focus is on the case where firm 1 (the price leader) wins the market, which matches the steady state noted above.[24]

[23] What changes in such a model relative to the static model is that firms obtain a continuation payoff that may depend on who wins the market today. This potentially lowers the value of p_{win} needed to keep firm 2 out, but otherwise leaves our results unaffected.

[24] Also of interest is understanding the conditions under which firm 2 displaces firm 1, and the

Figure 4: The WIN Constraint



The WIN Constraint is satisfied when area A is weakly greater than area B. The figure is drawn for the case where firms have zero marginal costs.

4.1 Comparative Statics

Our first result concerns the impact of the firms' intrinsic quality on equilibrium quantities and payoffs.

Proposition 3. *Suppose firms face an In/Out demand curve that admits micro-foundation #1. Suppose further that firm 1 wins the market and the WIN constraint binds. Then:*

1. *Consumer surplus is independent of μ_1 and increasing in μ_2.*
2. *Firm 1's profits are increasing in $\mu_1 - \mu_2$; firm 2's profits are independent of $\mu_1 - \mu_2$.*
3. *The equilibrium levels of Q_1 and Q_2 are unchanging in $\mu_1 - \mu_2$.*

Figure 4, which display's firm 2's demand curve for a given p_1, helps provide intuition. A binding WIN constraint means that firm 1 sets p_1 such that area A (firm 2's "low-demand" profits) and area B (its "high-demand" profits) are equated. A

dynamics that result from it. To be tractable, however, such analysis is likely to require a more specialized model, which is beyond the scope of this paper.

greater $\mu_1 - \mu_2$ shifts the demand curve vertically; hence, to keep the WIN constraint binding, firm 1 raises its price one-to-one, which leaves both p_2 and the equilibrium quantities unaffected. Consequently, an increase in μ_1 has the sole effect of raising firm 1's profits, whereas an increase in μ_2 raises the surplus of all consumers one-to-one, with firm 1 consumers benefiting from a reduction in p_1 and firm 2 consumers directly benefiting from the higher μ_2.

This result has the paradoxical implication that only μ_2 benefits consumers, and yet, conditional on not winning the market, firm 2 has no reason to invest in a higher μ_2. We shall return to this observation in Section 5.

Changes in the firms' marginal costs have a similar impact, but with all signs reversed; that is, an increase in the marginal cost of firm i is analogous to a reduction in μ_i.[25] It follows that only firm 2's marginal costs impact consumers (with lower costs helping all consumers one-to-one, like an increase in μ_2), and yet only firm 1 gains from reducing its costs.

Next, we consider the impact of the impulse I_0.

Proposition 4. *Suppose firms face an In/Out demand curve that admits micro-foundation #1. Suppose further that firm 1 wins the market and the WIN constraint binds. Then, an increase in I_0:*

1. *Weakly lowers consumer surplus and total surplus.*

2. *Weakly raises the prices and profits of both firms.*

3. *Weakly lowers Q_1.*

Moreover, whenever the WIN constraint binds and $I_0 < Q_H$ (so that firm 1 faces a demand curve worse than the "in" curve), all of the above changes are strict.

To understand this result, note that when the impulse is sufficiently high (at least equal to Q_H), firm 1 enjoys an "in" demand curve (the best possible one) and so a

[25] To see why, let MC_i denote firm i's marginal cost and redefine variables so that $\tilde{p}_i := p_i - MC_i$ takes the place of p_i and $\tilde{\mu}_i := \mu_i - MC_i$ takes the place of μ_i and, upon this change of variables firms have zero marginal costs. It follows that an increase in MC_1 shrinks $\tilde{p}_1$ one-to-one and has no impact on p_1 or p_2, and thus merely lowers the profits of firm 1; whereas an increase in MC_2 raises p_1 one-to-one and has no impact on $\tilde{p}_2$, and thus hurts all consumers.

further increase in impulse has no effect. When instead the impulse is lower than Q_H (and WIN binds), an increase in impulse lowers, for any given p_1, the threshold price p_2 needed for firm 2 to go in. This extends the "out" portion of firm 2's demand curve and shrinks its "in" portion, and hence firm 1 is able to raise p_1 while still winning the market; firm 2 reacts by raising both p_2 and it own sales. While both firms benefit from this change, the larger of the two networks (that of firm 1) falls, which damages overall surplus. Because prices rise and network externalities fall, consumer surplus falls as well.

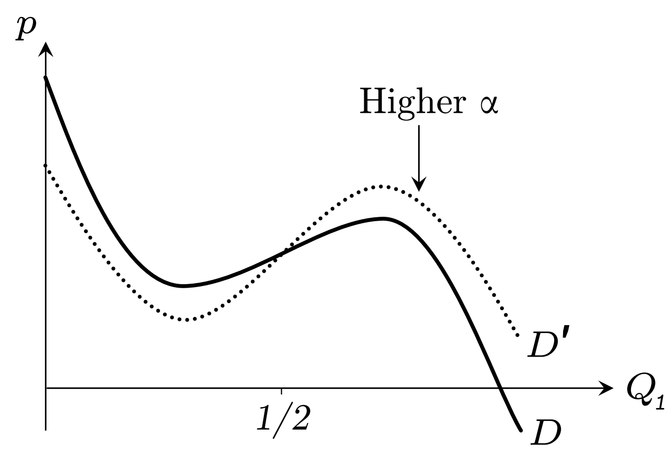
Our final comparative static concerns the impact of α. A natural conjecture is that a higher externality allows the winning firm to set a higher price, which leads the losing firm to raise its price too. It turns out, however, that a higher α has an ambiguous effect on prices.

Proposition 5. *Suppose firms face an In/Out demand curve that admits micro-foundation #1. Suppose further that firm 1 wins the market and the WIN constraint binds. Then, an increase in* α*:*

1. *Reduces prices when the impulse is in firm 2's favor (*$I_0 \leq 1/2$*).*
2. *Has an ambiguous effect on prices when the impulse is in firm 1's favor (*$I_0 > 1/2$*).*

To understand this result, consider Figure 5. An increase in α rotates demand counter-clockwise, which has the effect of increasing demand on the high portion of both firms' demand curves ($Q \geq Q_H$) and decreasing demand on the low portion ($Q \leq Q_H$). Other things equal, this makes it harder for firm 1 to satisfy WIN since firm 2 is more inclined to go for high demand (a pro-competitive force). However, depending on the impulse, the shift in demand may also lower the threshold price for firm 2 to achieve high demand, making it *easier* for firm 1 to satisfy WIN (an anti-competitive effect). When the impulse is in firm 1's favor ($I_0 > 1/2$), either effect can dominate. When the impulse is in firm 2's favor ($I_0 \leq 1/2$), an increase in α *raises* the threshold price for firm 2 to achieve high demand, and hence a higher α is guaranteed to lower prices.

Figure 5: An Increase in Network Externalities (α)



5 Policy Implications

Our model has a number of implications for policy debates concerning "new-economy" companies and it highlights why thinking about such debates through an "old-economy" anti-trust lens can be misleading.

It is useful to start by asking what the goals of policy might be? These include:

- Reducing market power to reduce the quality-adjusted prices faced by consumers.
- Increasing or maintaining the size of networks, since network size affects social surplus. (This consideration is unique to markets with network externalities.)
- Fostering innovation.

Notice that the standard prescription for reducing market power—limiting the size of firms and breaking up large firms if necessary—is in direct conflict with the benefits that flow from network externalities. Thus, new-economy markets call for a different approach.

One might also ask how network externalities affect the degree and extent of competition. Proposition 5 suggests that they are not bad for competition per se—in fact, they may even strengthen it. However, it is possible for large firms to become entrenched and acquire market power over time. Our theory points to the reduction of entrenchment as a particularly important policy goal.

Entrenchment might come about through two channels. First, impulses might become unequal. One reason is that the winning firm's high sales today relative to the losing firm's might lead to unequal impulses tomorrow. In addition, as shown in Proposition 4, the winning firm has an incentive to invest in its impulse—for example, through advertising—while the losing firm does not.[26]

Second, winning the market may, over time, lead to a technological advantage.[27] To see why, recall from Proposition 3 that the winning firm gets all of the surplus from quality improvements while the losing firm gets none of the surplus. Hence, the winning firm has a strong incentive to increase quality—either through acquisition or in-house development of new technology—while the losing firm has no incentive.

5.1 Breakups, Mergers, and Acquisitions

Numerous politicians on both sides of the aisle—as well as legal scholars such as Scott Hemphill and Tim Wu, and commentators such as Kara Swisher—have suggested that large, dominant firms like Facebook and Amazon should be broken up. What exactly they mean by "breakup" is not entirely clear. Presumably they do not mean breakup in the traditional anti-trust sense into a number of small, regional businesses—along the lines of AT&T or Standard Oil—since such breakups can be extremely damaging when there are network externalities. For example, to the extent a firm like Facebook has value, it derives from its ability to connect users widely.

So what could reasonably be meant by "breakup" of new-economy firms? To make progress on this question consider, on the flip side, three reasons why firms might merge or make acquisitions: cost synergies, technological improvements, and "impulse synergies."

[26] According to Proposition 4, the winning firm's profits are increasing in its impulse while those of the losing firm are decreasing in its impulse.

[27] This technological advantage could either take the form of a quality advantage ($\mu_1 - \mu_2$) or a marginal cost advantage ($MC_1 - MC_2$).

Cost synergies

Cost synergies are a well-known motive for mergers between firms in related industries. For instance, they appear to have been one of the reasons why Facebook acquired Instagram and WhatsApp. From a consumer perspective, there has been relatively little integration of these apps; but there has been significant integration of the systems required to run them.[28]

In terms of the model, we might think of such acquisitions as ones that reduce a firm's marginal cost. Proposition 3 says that reducing a firm's marginal cost is surplus-enhancing—although only beneficial to the firm if the firm has a dominant position. Our theory therefore takes a somewhat benign view of these acquisitions.

It is noteworthy that many advocates of tech breakups point to Facebook's acquisitions of Instagram and WhatsApp as canonical examples of anti-competitive behavior. Our theory suggests that, if these acquisitions were anti-competitive, it was for other reasons besides cost synergies.

Technological improvements

A second class of acquisitions are those motivated by the desire to buy better technologies. Consider some of the startups acquired by Apple: PA Semi (purchased in 2008) has been instrumental to the development of Apple's low-power processors; Siri (purchased in 2010) was used to create Apple's virtual personal assistant; C3 Technologies (purchased in 2011) is one of several startups acquired to improve mapping features; and PrimeSense (purchased in 2013) powers the facial recognition features of the iPhone and iPad. Apple is far from the only large Silicon Valley firm to make such acquisitions. In the decade between 2008 and 2017, Google/Alphabet made 166 acquisitions, Amazon 51, Facebook 63, Ebay 31, Twitter 54, and Apple 66.

In our theory, if a dominant firm acquires a new, superior technology—one that raises quality or lowers marginal cost—its profits increase. On the other hand, if its

[28] While there is currently relatively little integration on the consumer side, Facebook started a project in 2019 to integrate Facebook Messenger, Instagram DMs, and WhatsApp with the goal of allowing cross-platform messaging. Facebook claims that such integration will be optional for users. See Mehta, Ivan, "Facebook won't force WhatsApp and Messenger cross-app chat on you, VP Claims," *The Next Web,* 28 September 2021, Retrieved from `https://thenextweb.com`.

smaller rival acquires a superior technology, its profits do not change so long as it does not supplant the dominant firm. This result suggests that a dominant firm may be able to acquire new technologies at very low prices and, in doing so, entrench its dominant position.

According to Proposition 3, consumers are not hurt when a dominant firm acquires a startup with a new technology—but they do not benefit either (all of the surplus goes to the firm). If, on the other hand, the non-dominant firm acquires the startup, consumers are made better off. In fact, consumers obtain all of the surplus in that case. Consequently, dominant firms' acquisitions are harmful to the extent that they prevent technology-improving acquisitions by non-dominant firms. Our theory therefore suggests that regulators should look at them with a critical eye.

Regulators might also consider forcing firms to share technologies. For example, one could imagine a regulatory regime where a search engine was required to share its algorithm with competitors. The normal concern with forced technology sharing is that it can deter innovation. This concern is somewhat mitigated in the present case since only the dominant firm has a significant incentive to innovate and consumers do not benefit from the dominant firm's innovations unless they are shared with the non-dominant firm.

Impulse synergies

A third class of acquisitions are driven by a consideration unique to markets with network externalities: impulse synergies, which arise when business in market 1 creates impulse in market 2. Take Amazon, for instance, which started out in the book business. Once consumers were familiar with Amazon from buying books, presumably they had an impulse to buy other goods as well—such as shoes. Notice that business in the shoe market may further create impulse in the book market, making the overall synergies even larger. Impulse synergies may partly explain why Amazon entered the shoe market and acquired online shoe retailer Zappos.

Per Proposition 4, an increase in a dominant firm's impulse leads to higher prices, and lower consumer and total surplus. This suggests that regulators should take a critical view of mergers or expansions that may have such effect.

5.2 Interoperability

A common recommendation for promoting competition is to require greater interoperability of products and systems. For instance, the Chicago Booth Stigler Center's Committee on Digital Platforms argues that interoperability should be mandated in social media, just as it was in the phone industry:

> Mandating not only an open but also a common Application Program Interface (API) would allow different messaging systems to connect to one another. In so doing, a common API guarantees interoperability and eliminates the network externalities that drive the winner-take-all nature of the social media market.[29]

For modeling purposes, one can think of interoperability as generating cross-good network externalities. For instance, a consumer of good i receives $\alpha(Q_i + Q_j)$ when there is perfect interoperability rather than αQ_i. Interoperability has both a direct and an indirect effect. The direct one is that, holding prices fixed, consumer surplus is greater due to the additional externalities; the indirect one is that it changes consumer demand and, with it, price competition between firms.

From a demand point of view, interoperability is equivalent to lowering α.[30] Intuitively, when products are interoperable, consumers do not need to worry about which firm has the greater market share. Proposition 5 therefore suggests that, when there is a dominant firm with a higher impulse, greater interoperability may cause prices and firm profits to fall.

In other words, interoperability is likely to make consumers better off—through both the direct and indirect effects—but be resisted by firms.[31] Facebook's stance

[29]Stigler Committee on Digital Platforms, Final Report, September 2019, p. 16, available at `https://research.chicagobooth.edu/stigler/media/news/committee-on-digital-platforms-final-report`.

[30]Recall from equation (4) that, when there is no interoperability, good 1 is preferred to good 2 when $\mu_1 - \mu_2 + z + (\alpha Q_1 - \alpha Q_2) \geq p_1 - p_2$. By contrast, when there is perfect interoperability, good 1 is preferred when $\mu_1 - \mu_2 + z + (\alpha(Q_1 + Q_2) - \alpha(Q_1 + Q_2)) \geq p_1 - p_2$. Observe that α drops out completely. Thus, perfect interoperability is equivalent from a demand point of view to dropping α to zero.

[31]See Genakos et al. (2018) for a related argument concerning interoperability and second-degree price discrimination for a monopolist who can foreclose competition in a complementary market by reducing interoperability.

provides a striking example. As the Stigler Center's report notes:

> [Facebook] used all its power to kill potential interoperability solutions in order to gain market power. In 2008, it even used Federal Criminal Law to successfully attack a young startup called Power Ventures that was trying to connect different social media platforms.

A legitimate concern with interoperability, of course, is that it may raise marginal costs or (isomorphically in terms of our model) lower quality. In principle, this effect could offset its benefits.

5.3 Investing in Impulses

Our discussion in Section 2.1 suggests a variety of ways in which firms can invest to increase their impulse. These include the use of advertising, nudges, and loyalty programs. Consider two concrete examples:

- To compete with Netscape Navigator, Microsoft paid Dell to pre-install Internet Explorer on newly-shipped computers. We might view this as a nudge that increased the impulse for Internet Explorer.[32]

- Amazon's loyalty program, Prime, gives subscribers a variety of benefits including extremely fast shipping. We might view this costly program as not only raising quality but also changing the default for consumers—and thereby raising Amazon's impulse.

Recall that, per Proposition 4, an increase in the dominant firm's impulse raises prices and lowers consumer and total surplus. Our model therefore suggests that regulators should be instinctively skeptical of arrangements that look like impulse investments by dominant firms. In principle, impulse investments by a non-dominant

[32] A related example concerns Apple's iPhone. Apple's ability to set the default search engine on the Safari browser gives it considerable control over impulses in the search market. Google invests in its impulse by paying a hefty sum to Apple ($15 billion in 2021) to remain the default search engine. See Miller, Chance, "Analysts: Google to pay Apple $15 billion to remain default Safari search engine in 2021," *9to5Mac*, 25 August 2021, Retrieved from `https://www.9to5mac.com`.

firm could help to address impulse imbalances; but Proposition 4 suggests that the non-dominant firm has poor incentives to invest since the profits of both firms are increasing in the dominant firm's impulse.[33]

5.4 Regulating Firms as Utilities

Given how easily firms can become entrenched in these markets, it may not be sufficient to simply promote competition using the above approaches. It may be worthwhile to directly regulate firm behavior, as is frequently done for utilities.

Uber's drivers, for instance, have called attention to its troublingly high "take rates"—the share of the fare that it claims. These high take rates may reflect the company's market power.[34] Much like Uber, Amazon reportedly squeezes its suppliers on price and other terms—even establishing the Gazelle Project to "approach small [book] publishers the way a cheetah would pursue a sickly gazelle."[35] Arguably, Uber and Amazon have impulse advantages that are hard to dislodge; as an alternative to promoting competition, there could be direct regulation of Uber's and Amazon's take rates.[36,37]

6 Conclusion

We analyzed a novel model of competition in markets with network externalities. We focused on the case where consumers are heterogeneous, leading to demand with an

[33] On its face, it does not appear as though Amazon Prime has caused Amazon to raise prices. It is important to remember, though, that Amazon is a two-sided market with both buyers and sellers. While beyond the scope of our model, it is quite possible that Amazon has used market power derived from Prime in its relationship with sellers.

[34] See Rapier, Graham, "Uber and Lyft drivers are planning to strike this week, and it highlights the challenge the 2 ride-hailing giants face as public companies," *Business Insider*, 6 May 2019, Retrieved from `https://www.businessinsider.com`.

[35] Stone (2013), p. 553.

[36] Uber and Amazon are two-sided markets and so differ slightly from the one-sided market in our model. Nonetheless, the lessons from our model may apply.

[37] There are other practices that might be addressed through direct regulation. For instance, there is concern about companies' use of consumers' data to direct unwanted advertising at them (e.g., advertising that exploits behavioral weaknesses). In terms of our model, we might think of such advertising as raising a good's effective price—its price net of quality. Directly limiting companies' use of data might be an option.

In/Out Shape. To deal with equilibrium multiplicity, we introduced a new focality concept based upon "introspective equilibrium." Competition, rather than being for the marginal consumer, may instead be *for the market,* leading to a new form of limit pricing where the losing firm captures a positive market share even when it does not supplant its rival.

We characterized how competition changes with firms' technologies, consumers' impulses, and the strength of network externalities. We showed that improvements in the dominant firm's technology benefit the firm (not consumers), while improvements in the non-dominant firm's technology benefit consumers (not the firm). A change in consumers' impulses in favor of the dominant firm benefits the firm but leads to higher prices, and lower consumer and total surplus. Perhaps counter-intuitively, prices may rise or fall when network externalities become stronger. We also used these results to derive a variety of policy implications.

One limitation of our model is that it is essentially a static one. Firms, in reality, may interact repeatedly and have many opportunities to adjust their prices. One direction for future work would be to make the model more dynamic. Another direction would be to enrich the present framework so as to encompass more complex multi-sided markets.

7 Appendix

7.1 Micro-foundation #2

To see why demand is In/Out under the second micro-foundation, observe that when $Q_1 \geq Q_2$, consumers above the cutoff $\hat{z} = \frac{1}{Q_1 - Q_2}(-(\mu_1 - \mu_2) + (p_1 - p_2))$ consume from firm 1; when $Q_1 < Q_2$, consumers below that cutoff consume from firm 1. Hence, $Q_1 = 1 - F(\hat{z})$ when $Q_1 \geq Q_2$ and $Q_1 = F(\hat{z})$ when $Q_1 < Q_2$, from which it follows that $P(Q_1) = (\mu_1 - \mu_2) + (2Q_1 - 1)F^{-1}(\min(Q_1, 1 - Q_1))$ when $N = 2$. Differentiating, we find that the slope of demand is $2F^{-1}(\min(Q_1, 1 - Q_1)) - |2Q_1 - 1|\frac{1}{f(F^{-1}(\min(Q_1, 1 - Q_1)))}$. Since both the first and second terms of this expression have an upside-down U-shape with peak at $Q_1 = 1/2$, the slope also has an upside-down

U-shape with peak at $Q_1 = 1/2$. At the peak ($Q_1 = 1/2$), the slope is positive since the first term is positive at $Q_1 = 1/2$ and the second term is equal to zero. Provided the distribution's mass is sufficiently concentrated, the slope is negative at high and low values of Q_1 since the second term is highly negative. It immediately follow that demand has an In/Out shape.

7.2 Proof of Proposition 2

Part A. Observe first that because both firms have positive intrinsic quality, if firm 1's intrinsic quality advantage (resp. disadvantage) is arbitrarily high, it will serve 100% (resp. 0%) of the market, as in the case the firm's 1 (resp. firm 2's) marginal revenue is guaranteed to be uniformly positive. It therefore suffices to show that firm 1's gain from going in relative to letting firm 2 take over the market is strictly increasing in $\mu_1 - \mu_2$. But this follows from the fact that as $\mu_1 - \mu_2$ grows by some amount d, firm 1's additional gain from going in is no less dQ_H (as it can opt to raise p_1 by exactly d, leaving its equilibrium quantity unchanged) and its additional gain when letting firm 2 take over the market is at most dQ_L (as when going out, firm 1 can at most capture the additional willingness to pay of Q_L consumers).

Part B. Suppose toward a contradiction that firm 1 ends in and yet $p_1 < p^{WIN}$. Note that if firm 1 raises its price by epsilon, per Lemma 1 it still ends in. This causes firm 1 to gain at least $q_H\epsilon$ and to lose at most $\epsilon|Q_1'(p_1 - p_2)|p_1 + O(\epsilon^2) = \epsilon/(-\alpha + 1/f(z'))p_1 + O(\epsilon^2) < \epsilon/(-\alpha + 1/f(z'))(\overline{z} + \mu_1 + \alpha) + O(\epsilon^2)$ (where z' is the marginal type). Provided the mass of f is sufficiently concentrated close to zero— which means $f(z')$ approaches zero and Q_H remains high— and ϵ is small, the gain exceeds the loss. **Q.E.D.**

7.3 Proof of Proposition 3

We first claim that a change in $\mu_1 - \mu_2$ translates one-to-one to an increase in p_1 and has no impact on p_2. Figure 4 shows the demand for good 2 for a particular value of p_1. Firm 2's best response to p_1 is either to choose the profit-maximizing price conditional on staying "out" (p_2^{out} in the figure), or the profit-maximizing price conditional on going "in" (p_2^{in} in the figure).[38]

Region A in Figure 4 represents the profits to firm 2 from choosing p_2^{out}; Region B represents the profits from choosing p_2^{in}. Observe that the WIN constraint is satisfied when Region A is weakly larger than Region B; WIN binds when the regions are of equal size.

An increase in p_1 shifts firm 2's demand curve vertically up, which increases the size of Region B relative to Region A.[39] This explains why firm 1 must price below a threshold, p^{win}, in order to meet the WIN constraint.

Now suppose WIN is a binding constraint and suppose demand curve D in Figure 4 depicts a binding WIN constraint. Observe that the demand curve firm 2 faces depends upon the "effective price" of good 1: $p_1 - (\mu_1 - \mu_2)$. Hence, if $\mu_1 - \mu_2$ decreases by an amount d, firm 1 must decrease p_1 by d to stay on demand curve D. This explains why, in the region where WIN binds, a change in $\mu_1 - \mu_2$ changes p_1 by an equivalent amount. This establishes the claim.

Part 1 follows from the fact that an increase in μ_1 has zero impact on both firm 1 consumers (since p_1 grows one-to-one with μ_1) and firm 2 consumers (since it does not affect p_2); moreover an increase in μ_2 benefits firm 1 consumers (as p_1 falls one-to-one with μ_2) and firm 2 consumers (as p_2 does not change and μ_2 increases).

Part 3 follows from the fact that firm 2 always faces the same demand curve D in the region where WIN binds, it always charges the same price (p_2^{out}) and sells the same quantity (Q_2^{out}).

Part 2 follows the fact that Q_1 and Q_2 are unchanging in $\mu_1 - \mu_2$, together with the above claim regarding the impact of $\mu_1 - \mu_2$ on prices. QED.

7.4 Proof of Proposition 4

Observe that, for a fixed price p_1, a decline in firm 1's impulse changes firm 2's demand curve in the following manner: it (weakly) raises the threshold price p_2 at

[38] In the figure, p_2^{in} is depicted as being right at the threshold for firm 2 to go "in" but p_2^{in} may also be lower than that threshold.

[39] This observation follows from the Envelope Theorem and the fact that $Q_2^{in} > Q_2^{out}$.

which firm 2 goes in. This change in threshold (weakly) truncates the "out" portion of firm 2's demand curve which (weakly) reduces the profits firm 2 can obtain while staying on the out portion. Thus, Region A in Figure 4 weakly decreases in size. The change in threshold likewise (weakly) extends the "in" portion of firm 2's demand curve and so (weakly) increases the size of Region B.

If the change in impulse has no effect on the size of either region, the outcome does not change. On the other hand, when the change in impulse changes the size of either region (which necessarily increases the size of Region B relative to Region A, and which occurs whenever WIN binds and $I_0 < Q_H$), firm 1 must lower p_1 to satisfy WIN.[40] Assumption 1 implies that firm 2 responds to the decline in p_1 by decreasing p_2 and Q_2.

In this case, aggregate network externalities increase because there is an increase in consumption of the more consumed good (good 1). Consumer surplus increases for the following reason: prices fall, consumers are free to switch firms, and aggregate network externalities increase. Total surplus also weakly increases because the change in total surplus is equal to the change in aggregate network externalities. Profits of firm 1 fall because firm 1 faces a more severe WIN constraint; profits of firm 2 fall because firm 2 maximizes subject to a lower firm 1 price (and hence a demand curve that is worse along the "out" portion). QED.

7.5 Proof of Proposition 5

Under micro-foundation #1, $P(Q_1) = (\mu_1 - \mu_2) + \alpha(Q_1 - Q_2) + F^{-1}(1 - Q_1)$. Rearranging terms, and substituting $1 - Q_2$ for Q_1, we obtain the following inverse demand curve for firm 2: $p_2(Q_2) = p_1 + (\mu_2 - \mu_1) + \alpha(2Q_2 - 1) - F^{-1}(Q_2)$. Observe that an increase in α raises the curve for $Q_2 > 1/2$, lowers the curve for $Q_2 < 1/2$, and leaves it unchanged at $Q_2 = 1/2$. Since $Q_L < 1/2 < Q_H$, an increase in α causes demand to fall on the low portion of firm 2's demand curve ($Q_2 \leq Q_L$) and rise on the high portion ($Q_2 \geq Q_H$), as shown in Figure 5. Notice also that the slope of the inverse demand curve is: $2\alpha - \frac{1}{f(F^{-1}(Q_2))}$. Therefore, an increase in α increases the

[40] This is because, as noted in the proof of Lemma 1, lowering p_1 decreases the size of Region B more than it decreases the size of Region A.

slope everywhere.

An increase in α has two effects on firm 1's WIN constraint. First, demand falls on the low portion of firm 2's demand curve and rises on the high portion. Other things equal, this makes firm 2 more inclined to go for high demand, and so makes it harder for firm 1 to satisfy WIN. Second, depending upon the impulse, an increase in α may raise or lower the threshold price for firm 2 to achieve high demand. This second effect makes WIN harder to satisfy if the threshold rises and easier to satisfy if the threshold falls. The threshold price is $p_2(1 - I_0)$, which is rising in α when $I_0 < 1/2$, falling in α when $I_0 > 1/2$, and unchanging in α when $I_0 = 1/2$.

If $I_0 \leq 1/2$, both effects go in the same direction. So, an increase in α makes the WIN constraint harder to meet, and hence causes p_1 to fall. If, on the other hand, $I_0 > 1/2$, the effects go in opposite directions so a change in α may cause p_1 to rise or fall.

Let us now consider what happens to p_2 in the case where p_1 falls. Firm 2's optimal price is on the low portion of its demand curve given that WIN holds. The rise in α and fall in p_1 cause the low portion of firm 2's demand curve to shift in two ways: (1) there is a downward shift in the level of demand (due both to the rise in α and the fall in p_1), (2) the slope rises (due to the rise in α). By Assumption 1, we know that the level effect causes p_2 to fall. The slope effect means that marginal revenue is greater at any quantity and hence quantity rises and price p_2 falls. So, both the level and slope effects cause a drop in p_2. Therefore, when $I_0 \leq 1/2$, both p_1 and p_2 fall when α rises. Q.E.D.

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