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consumers' expectations and firms' pricing policies

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# Entry into a network industry:
# consumers' expectations and firms' pricing policies

Angelo Baglioni (*)

*Abstract.* This paper presents a model of entry into a network industry. The entrant tries to attract the customer base of the incumbent service provider. While the entrant is more efficient, the incumbent enjoys an advantage thanks to a bias in consumers' expectations. Buyers enter the game with heterogenous beliefs as to which of the two firms is going to win competition. Then expectations converge - through higher order beliefs - and select one winner, who ends up being the single supplier. The path of expectations convergence crucially depends on the pricing policy followed by firms: so equilibrium beliefs are endogenous. Depending on parameter values, one of two outcomes obtains: (i) the incumbent is able to exclude the entrant, by lowering his price below the monopoly level; (ii) the entrant is successful, by undercutting the incumbent price. Productive efficiency and consumers' welfare are hurt by exclusion; the entry threat is beneficial to consumers anyway. Imposing compatibility among networks is welfare improving, as it removes the exclusionary potential enjoyed by the incumbent.

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# 1 Introduction

This paper deals with entry into a network industry. The traditional literature in this area[1] assumes that the incumbent enjoys an installed base of "old" consumers, so that the entrant may try to attract only a "new generation" of buyers. This is equivalent to assuming that the switching costs faced by old consumers are infinite: as a consequence they are locked-in, giving the incumbent a competitive advantage over the entrant. While this extreme assumptiom seems useful to focus the attention on issues like technology adoption, it is an evident over-simplification: in the real world consumers face finite switching costs, so an entrant may try to attract *all* consumers, old and new ones; in other words, the incumbent's "installed base" of customers is more fragile than it is usually assumed[2]. Therefore, I present a model where an entrant challenges the dominant position of an incumbent, trying to attract the customer base of the latter. In particular, the model focusses on the competition between two service providers, where all consumers have to decide whether to continue buying the service provided by the incumbent or to switch and buy the service offered by the entrant.

The main source of competitive advantage for the incumbent comes from expectations. In a network industry consumers' utility is increasing in the number of people buying from the same supplier. So a consumer buys from a supplier, at a given price, only if he expects that the number of other buyers doing so is sufficiently large to be worth paying that price: suppliers then face a typical "critical mass problem". Now, an incumbent has already reached the critical mass; to the contrary, a new entrant has to convince consumers that he will be able to attract a critical mass of buyers, starting from zero.

In a rational expectations model, the problem at hand typically originates a multiplicity of equilibria. In particular, only two extremes are possible, since in equilibrium (exogenous) beliefs have to be homogenous across consumers: either all of them believe that the incumbent is going to win over the entrant, or the opposite holds. In the first case the incumbent retains the whole market and continues to apply the monopolist price. In the alterna-

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[1] See the references in the next Section.

[2] Of course, switching costs are typically higher for durable goods (e.g. CD players, video-game consoles, PC hardware) than in other sectors, like payments cards, telecommunications, stock exchanges, media: in the former case "old" consumers have bought a physical good, and the replacement cost might be substantial; in the latter case the cost of switching to a new service provider is presumably lower.

tive scenario the entrant attracts all buyers, again applying the monopolist price. These findings are at odds with reality, where one observes incumbents reacting to entry threats - by lowering prices - and entrants applying "penetrating" (undercutting) prices.

While maintaining the rational expectations assumption, I try to deepen the analysis of expectations formation. I assume that consumers enter the game with heterogenous beliefs: they assign a probability ranging from zero to one to the incumbent being the winner over the entrant. Then expectations converge towards one of the two extremes, where all consumers share the same belief (probability one or zero). Understanding this convergence process requires specifying consumers' higher order beliefs (i.e. their expectations on others' expectations)[3]. Firms are able to influence this process through prices: the price difference between incumbent and entrant turns out to be crucial in determining the path of expectations convergence. For example, by observing an aggressive pricing policy of the entrant, consumers may be induced to believe that the entrant is going to be successful and replace the incumbent; then they will switch to the entrant and join the new network. Therefore equilibrium expectations are endogenized, as they depend on the pricing choice of firms.

In addition, I will assume that the entrant is more efficient, as he has a lower cost of production - equivalently, he is able to produce a better service at the same cost. However, consumers may face (finite) switching costs and - more importantly - their expectations may favor the incumbent: more precisely, the aggregate distribution of initial beliefs is possibly biased, giving the incumbent a competitive advantage (technically: the critical mass condition allows him to set a higher price than the entrant).

The outcome of the game is the following. If the advantage enjoyed by the incumbent - in terms of consumers' expectations - is large enough to compensate his cost disadvantage, he is able to implement an exclusionary price: by lowering his price below the monopoly level, he is able to avoid entry. If the expectations bias favoring the incumbent is not large enough, the entrant is able to attract all buyers, provided he undercuts the incumbent

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[3]This might seem too demanding, as it requires a high level of rational reasoning by consumers themselves. However, other approaches are at least as demanding, e.g.: imposing no coordination failure, so that consumers are able to select a Pareto superior equilibrium (as in Economides (1996) and Shy (2001)); assuming rational expectations (or even perfect foresight) with infinite horizon, so that consumers are able to compute their payoffs for infinitely many periods ahead (as in Katz - Shapiro (1992)).

price by a sufficient amount.

The plan of the paper is the following. In the next section I provide a brief overview of the literature related to my work. Section 3 contains the model: after showing the set-up, I derive the multiple equilibria result (Lemma 1), which serves as a starting point to analyze the equilibrium selection through higher order beliefs (Proposition 1 and Corollary 1); then the incumbent's advantage in terms of expectations is specified (Proposition 2 and Corollary 2), leading to an equilibrium either with exclusion or with entry (Proposition 3). The entry decision is discussed in Section 4. Some policy implications are derived is Section 5. Section 6 summarizes the main results.

# 2   Related literature

The analysis of network externalities in consumption dates back to the pioneering work by Rohlfs (1974), where he studies interdependent demands in the communications service sector. In particular, he analyzes the start-up issue, pointing to the central role of the critical mass and finding that a low pricing strategy is crucial for the successful marketing of a new service. However, his model is not framed in a rational expectations context: consumers react to observed - not to expected - quantities.

The literature on product innovations in network industries has shown that the rational expectations approach typically lead to multiple equilibria. Consumers may find themselves stuck in an inefficient equilibrium, if this is supported by expectations: the outcome of the interaction among consumers may be biased for or against innovation, showing "insufficient friction" or "excess inertia" (see Farrell - Saloner (1986) and Katz - Shapiro (1986, 1992)[4]). The multiplicity of equilibria emerges also in other contributions, where competition and compatibility decisions are analyzed in the context of oligopolystic markets with network externalities (see Katz - Shapiro (1985)). More recently, competition in markets with two-sided networks have been studied (see Rochet - Tirole (2003))[5].

The papers closest to mine are those by Fudenberg - Tirole (2000) and

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[4]In particular, Farrell - Saloner (1986) analyze predatory pricing by a monopolist incumbent, enjoying an installed base of consumers. Katz- Shapiro (1986) study the penetrating pricing strategy of a supplier having proprietary rights to a new technology.

[5]Overviews of the issues and the literature related to network industries are provided by Shy (2001), Economides (1996), Katz - Shapiro (1994), Shapiro - Varian (1999).

by Karlinger - Motta (2006). They show that an incumbent in a network industry may implement exclusionary pricing. In particular, in F-T a monopolist sells only to consumers having a high valuation of the network good, while under the threat of entry it sells also to lower-type consumers, in order to enlarge his own installed base; I will instead assume homogenous consumers, all of them attaching the same value to the network good. In K-M the incumbent has to implement some kind of non-linear pricing - two-part tariffs or rebates - in order to avoid entry; to the contrary, in my model the exclusionary equilibrium may be obtained with linear pricing. In line with the above-mentioned literature, both F-T and K-M assume that the incumbent enjoys an installed base of consumers who have bought his product and are locked-in: only new consumers may choose to buy the entrant's product; to the contrary, in my approach the incumbent's advantage (if any) is due only to expectations. In addition, F-T assume no coordination failure among consumers, while coordination of expectations is the crucial issue in my analysis.

Some works on (financial) markets and liquidity take an approach similar to the one taken here, as they do not rely on an installed base of locked-in consumers who have purchased the incumbent's good. Traders concentrate in a single trading venue to enhance liquidity; equilibria where more than one market exist are possible but very fragile, as a slight change in expectations makes traders shift and all go to the market with higher liquidity (see Pagano (1989)). The incumbent's advantage comes from the fact that, given an equilibrium, nobody wants to trade in a new market with low liquidity, so entry may become impossible (see Economides - Siow (1988)).

The other stream of literature linked to this paper is that focussing on the equilibrium selection in games with multiple equilibria. The classic work by Harsanyi - Selten (1988) introduces the assumption that, given two equilibrium points, a player enters the game with a prior probability that one of them will eventually be the equilibrium, and such prior is uniformly distributed over the unit interval. Carlsson and van Damne (1993) have introduced global games, where each player observes a noisy signal, relative to an unobservable state: given that the noise technology is common knowledge, players are able to select an equilibrium through higher order beliefs. In their comprehensive treatment of global games, Morris - Shin (2001) also adopt a neutral prior: each player assumes that the proportion of other players taking a particular action is a random variable uniformly distributed over the unit interval. As we shall see below, I assume that each player enters

the game with a prior probability (first order belief), relative to which out of two equilibria is going to prevail; given that the aggregate distribution of such beliefs - not necessarily uniform - is common knowledge, they are able to figure out higher order beliefs and select one equilibrium.

Finally, there is a wide literature on strategic complementarity and coordination failures (see Cooper - John (1988) and Cooper (1999)): in a context where the incentive of each player to take a specific action is increasing in the number of people taking such action, multiple equilibria may emerge and players may find themselves stuck in a Pareto-inferior equilibrium, as they lack a coordination device. This is the case in network industries, where consumers' demands exhibit positive externalities. We shall see a case of coordination failure below, where consumers do not switch from the incumbent to a more efficient entrant, able to apply a lower price.

# 3   The model

## 3.1   Set-up

The model presented here is focused on a service industry, where network externalities in consumption are present. Consumers have to decide whether to continue buying the service provided by the incumbent or to switch and buy the service offered by the entrant.

More specifically, let us consider a one-period model. There are two firms, indexed by $i = I, E$: the incumbent ($I$) and the entrant ($E$). $I$ has been a monopolist until yesterday; $E$ is trying to enter the market in the current period. The services offered by the two competing networks are not compatible[6]. Both $I$ and $E$ have already paid any sunk costs of entry, so these are irrelevant for their current decisions. The entrant is more efficient than the incumbent: in particular, the unit cost of production is zero for $E$ and $c \in (0, 1]$ for $I$[7].

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[6]The issue of compatibility is not explicitly addressed in this paper. However the reader may check that, given the model structure, the incumbent would never agree to compatibility, as this would drive him out of the market: so incompatibility is the equilibrium market outcome (in other words, it is not imposed by assumption). This feature makes the model not directly applicable to the analysis of competition among compatible networks (e.g. telecommunications). However some implications, as far as the imposition of compatibility by a regulator is concerned, are derived below (see Section 5).

[7]Equivalently, $E$ could be assumed to be able to provide a better service at the same

Each consumer periodically buys one unit of the service. All of them did buy from $I$ until yesterday. Now, they can choose whether to stay with the incumbent or shift to the entrant in the current period: the decision space of a buyer is given by $d \in \{I, E\}$. Depending on his choice, his surplus is going to be $S_d \equiv q_d - p_d$, where $q_d \in [0, 1]$ is the total number of people buying from the same provider he buys from, at price $p_d$. The total size of the market is normalized to 1, so that $q_I + q_E = 1$. Any switching cost is captured by the term $c$: this is actually the cost differential between the two firms, net of the cost (if any) a consumer has to bear for switching from $I$ to $E$[8].

At the start of the period, each supplier makes a binding announcement: a price $p_i$ ($i = I, E$), with $p_E \in [0, 1]$ and $p_I \in [c, 1]$[9]. Given such prices, consumers simultaneously make their decisions and buy: we label this stage (consumers' decisions) as the "game among buyers". The behavior of each buyer is determined by the comparison between the expected surplus from staying with the incumbent and from shifting to the entrant: $S_i^e = q_i^e - p_i$, for $i = I, E$ (where $q_i^e$ is the expected quantity sold by supplier $i$). Then the optimal decision of a buyer (denoted by $d^*$) is determined by the following rule: $d^* = I$ if and only if $S_I^e \geq S_E^e$ (where we assume that a buyer stays with the incumbent if he is indifferent).

For the game among buyers, a Nash equilibrium with fulfilled expectations (hereafter: "equilibrium") is described by a quantity $q_I^*$, such that: given $q_I^e = q_I^*$ for all buyers, $d^* = I$ for a number of buyers equal to $q_I^*$.[10] Let's define $p \equiv p_I - p_E$; given the above assumptions, the only feasible values of $p$ are in the interval $[c - 1, 1]$.

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production cost as $I$.

[8] Of course, any switching cost for consumers may be seen as an additional cost for the entrant - equivalently as a cost advantage for the incumbent - as $E$ has to compensate buyers to attract them.

[9] On one hand, a price lower than cost makes a firm earn a negative profit. In a multi-period context this might be a feasible option: a firm might be willing to incur a short period loss, in order to retain or gain a monopoly rent in the future. However, this issue cannot be addressed in a one period model.

On the other hand, a price larger than one makes buyers get a negative surplus, even in the most favorable case where all of them buy from the same provider.

[10] Of course, the (expected) quantity sold by the incumbent is enough to describe an equilibrium, since the (expected) quantity sold by the entrant is its complement to one.

## 3.2 The game among buyers: self-fulfilling expectations and multiple equilibria

The first step in finding the outcome of the interaction among buyers is given by the following Lemma: this highlights the multiple equilibria resulting from self-fulfilling exogenous expectations, and it will be the starting point for the main contribution of this paper, namely the analysis of the game among buyers where equilibrium expectations are endogenoulsy determined through higher order beliefs (Section 3.3).

**Lemma 1** *For any feasible value of p, there exist two equilibria of the game among buyers, where $q_I^* = 1$ and $q_I^* = 0$ respectively.*

**Proof.** Let $q_I = 1$ and $q_I^e = 1$ for all buyers. Condition $S_I^e \geq S_E^e$ boils down to $p \leq 1$, which is met. Then $d^* = I$ for all buyers and $q_I^* = 1$ is the equilibrium.

Let $q_I = 0$ and $q_I^e = 0$ for all buyers. Then condition $S_I^e < S_E^e$ boils down to $p > -1$, which is met. Then $d^* = E$ for all buyers and $q_I^* = 0$ is the equilibrium.

Let $q_I \in (0, 1)$ and $q_I^e = q_I$ for all buyers. Either $q_I \geq \frac{1+p}{2}$ or $q_I < \frac{1+p}{2}$. In the first case, $S_I^e \geq S_E^e \to d^* = I$ for all buyers: $q_I = 1$. In the second case, $S_I^e < S_E^e \to d^* = E$ for all buyers: $q_I = 0$. Both cases lead to a contradiction with $q_I \in (0, 1)$: so this cannot be an equilibrium. ∎

The intuition behind Lemma 1 is simple. Since all buyers share the same preferences and, in equilibrium, the same expectations, all of them must behave the same way. Therefore, the only candidate equilibrium points are the extremes: either $q_I^* = 1$ or $q_I^* = 0$. They are indeed equilibria: one where the incumbent retains the whole market, and the other one where the entrant is able to attract all buyers.

Self-fulfilling expectations are crucial in determining which of the two equilibria prevails: if all buyers believe that all of them are going to stay with the incumbent, then the optimal individual strategy is to do so; if the opposite expectation is shared among consumers, all of them will shift to the entrant. Coordination failures are possible. Take, for example, the case where $p > 0$ and $q_I^* = 1$ is the equilibrium: the alternative equilibrium ($q_I^* = 0$) is clearly Pareto superior, but it is not supported by expectations.

Lemma 1 tells us that, for *all* possible levels of the price difference $p$, *both* equilibria exist. At this level of analysis, the prices announced by the

two firms are irrelevant in determining which equilibrium prevails; in other words, "only expectations matter". Therefore, if the incumbent is supported by expectations ($q_I^e = 1$), he is able to retain his dominant position in the market, even by setting his price at the monopoly level: $p_I = 1$ (which is also the equilibrium price absent any entry threat). On the other hand, if the entrant is supported by expectations ($q_I^e = 0$), he is able to enter the market even with $p_E = 1$. These results do not seem to be realistic; in particular, the commonly observed strategies of entrants involve some sort of "penetrating pricing", while defensive strategies may lead incumbents to cut their prices below the monopoly level.

## 3.3  The game among buyers: higher order beliefs

I introduce the following assumption relative to first order beliefs. Each buyer enters the game attaching a probability $\alpha$ to the equilibrium where $q_I^* = 1$ (and $(1 - \alpha)$ to the alternative equilibrium). The cross-sectional density of first order beliefs is exogenous: $f(\alpha)$, with support $\alpha \in [0, 1]$ and c.d.f. $F(\alpha)$, where $F(1) = 1$. We might think of $\alpha$ as the belief each buyer holds, based on his own information about the features of the network services - offered by $I$ and $E$ - different from price (for example: quality, marketing ability of suppliers). What really matters is that first order beliefs are not equilibrium beliefs (in general). Like any other assumptions so far, this aggregate distribution of first order beliefs is common knowledge (although a buyer does not observe the individual beliefs of others).

Higher order beliefs are formed by combining this information with the announcements made by the two suppliers, i.e. prices $p_I$ and $p_E$. In particular, each buyer forms his second order belief by considering the expectations of other buyers relative to which equilibrium is going to prevail; his third order belief is then formed by considering the beliefs of other buyers relative to the expectations of other buyers. Formally, the sequence of events is the following:

    - stage 1: buyers form their first order beliefs,

    - stage 2: firms (simultaneously) announce prices,

    - stage 3: buyers form their higher order beliefs and one equilibrium is selected.

This sequence is not chronological, but rather logical. In particular, the assumption that prices are announced *after* the formation of first order beliefs captures the fact that firms are somewhat flexible in setting prices: the

entrant may adjust his price during the start-up stage, upon observation of consumers' attitudes; similarly, the incumbent is able to react to the ability of his competitor to attract his customers. On the other hand, prices are set *before* higher order beliefs are formed, so that consumers are able to exploit this information to form their expectations. This framework enables us to analyze the interaction between expectations and prices: firms are able to react to consumers' attitudes, and prices contribute to determine the path of expectations formation. Expectations are then partially endogenized, as they are driven (among other things) by prices, which are optimally chosen by firms.

Let's continue to focus on the game among buyers, namely stage 3 above, taking prices as given. In the next sub-section, we will proceed backward and solve the firms decision problem, namely stage 2 above, thus determining the equilibrium for the complete game.

**Proposition 1** *For any c.d.f.* $F(\alpha)$ *of first order beliefs, the unique equilibrium of the game among buyers is* $q_I^* = 1$ *iff* $p \leq 1 - 2F\left(\frac{1+p}{2}\right)$*; otherwise the unique equilibrium is* $q_I^* = 0$.

**Proof.** From Lemma 1, we have only two candidate equilibrium points: $q_I^* = 1$ and $q_I^* = 0$.

Let $p \leq 1 - 2F\left(\frac{1+p}{2}\right)$.

*First order beliefs.* Each buyer has $q_I^e = \alpha$, where $\alpha$ is drawn from $f(\alpha)$.

*Second order beliefs.* The number of buyers with first order beliefs such that $S_I^e \geq S_E^e$ is equal to $1 - F\left(\frac{1+p}{2}\right)$, because $S_I^e \geq S_E^e \iff \alpha \geq \frac{1+p}{2}$. This is common knowledge, so $q_I^e = 1 - F\left(\frac{1+p}{2}\right)$ for all buyers.

*Third order beliefs.* For all buyers, second order beliefs are such that $S_I^e \geq S_E^e \iff p \leq 1 - 2F\left(\frac{1+p}{2}\right)$, which is met. This is common knowledge, so $q_I^e = 1$ for all buyers. Therefore $q_I^* = 1$ is the equilibrium.

Let $p > 1 - 2F\left(\frac{1+p}{2}\right)$.

*First and second order beliefs*: as above.

*Third order beliefs.* For all buyers, second order beliefs are such that $S_I^e < S_E^e \iff p > 1 - 2F\left(\frac{1+p}{2}\right)$, which is met. This is common knowledge, so $q_I^e = 0$ for all buyers. Therefore $q_I^* = 0$ is the equilibrium. ∎

**Corollary 1** *For any c.d.f.* $F(\alpha)$ *of first order beliefs, there is a unique* $\overline{p} \in (-1, 1)$*, defined by equation (1), such that: the unique equilibrium of the*

*game among buyers is $q_I^* = 1$ iff $p \leq \overline{p}$; otherwise the unique equilibrium is $q_I^* = 0$.*

$$\overline{p} = 1 - 2F\left(\frac{1+\overline{p}}{2}\right) \tag{1}$$

**Proof.** *For $p = -1$, it is $p < 1 - 2F\left(\frac{1+p}{2}\right)$, as this inequality boils down to $-1 < 1$. For $p = 1$, the opposite is true. Both sides of equation (1) are continuous and strictly monotone in $p$: the LHS is increasing and the RHS is decreasing. Therefore, there exists a unique $\overline{p} \in (-1, 1)$ satisfying equation (1) and such that: $p \leq 1 - 2F\left(\frac{1+p}{2}\right)$ iff $p \leq \overline{p}$. This, together with Proposition 1, proves Corollary 1.* ∎

Proposition 1 shows that, for given aggregate distribution of first order beliefs, the price difference $p$ is crucial to determine which equilibrium prevails. Intuitively, the process of expectations formation is as follows. Each buyer enters the game with an expectation given by his own first order belief: $q_I^e = \alpha$. Then he computes a (second order) expectation, by considering the (first order) expectations of other consumers: he finds that consumers buying from $I$ are those for which $\alpha \geq \frac{1+p}{2}$, their number being $1 - F\left(\frac{1+p}{2}\right)$; this computation is made by everybody, so at this stage expectations converge to $q_I^e = 1 - F\left(\frac{1+p}{2}\right)$. Then each buyer computes his (third order) expectation, by considering the second order expectations of others: now he finds that, if $p \leq 1 - 2F\left(\frac{1+p}{2}\right)$, buying from the incumbent gives all consumers a higher surplus than buying from the entrant; this is known by everybody, so expectations further converge to $q_I^e = 1$, supporting the equilibrium where $q_I^* = 1$. If the opposite inequality holds, expectations converge to $q_I^e = 0$, supporting the equilibrium where $q_I^e = 0$.

The critical mass concept may be applied to understand what drives the above result. Let us define the *critical mass for the incumbent* $(cm_I)$ as the minimum (expected) level of his sales, such that his customers get a surplus (weakly) higher by staying with him rather than by shifting to the entrant; formally, the lowest value of $q_I^e$ such that $S_I^e \geq S_E^e$. This inequality may be written as $q_I^e - p_I \geq (1 - q_I^e) - p_E$, from which $cm_I = \frac{1+p}{2}$. The critical mass for the entrant may be derived in a similar way: $cm_E = \frac{1-p}{2}$. Therefore, we have two mutually exclusive critical mass conditions: one for the incumbent $(q_I^e \geq cm_I)$ and one for the entrant $(q_E^e > cm_E)$[11]. Note how the critical

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[11] The strict inequality must hold for the entrant, due to the assumption that consumers stay with the incumbent in case of indifference.

masses depend on prices: for example, by lowering his price the incumbent is able to lower his own critical mass and to increase the critical mass of the entrant, thus making entry more difficult. Now, consumers enter the game with heterogenous beliefs; then expectations converge as they try to figure out which firm will achieve its critical mass; as prices affect critical masses, they act as a coordination device among buyers. For example, by observing an aggressive pricing policy of the entrant, each consumer may be induced to believe that the entrant is going to be successful and replace the incumbent; then he will switch to the entrant and join the new network[12].

Corollary 1 shows that there is a maximum level $\overline{p}$ of the price difference between incumbent and entrant, such that the former (the latter) is going to be the "winner" of the game among buyers - servicing the whole market - if $p \leq \overline{p}$ $(p > \overline{p})$. The threshold level $\overline{p}$ depends on the distribution of first order beliefs in the following way.

**Proposition 2** *Let $F(\alpha)$ and $G(\alpha)$ be two c.d.f. of first order beliefs, such that $F(\alpha) \leq G(\alpha)$ for any $\alpha \in [0,1]$ . Let $\overline{p}$ be defined by equation (1) and $\widehat{p}$ be defined by equation (2). Then it is $\overline{p} \geq \widehat{p}$.*

$$\widehat{p} = 1 - 2G\left(\frac{1+\widehat{p}}{2}\right) \tag{2}$$

**Proof.** Let $\overline{p} < \widehat{p}$. This implies, through equations (1) and (2), that $G\left(\frac{1+\widehat{p}}{2}\right) < F\left(\frac{1+\overline{p}}{2}\right)$. But it also implies that $G\left(\frac{1+\widehat{p}}{2}\right) > G\left(\frac{1+\overline{p}}{2}\right) \geq F\left(\frac{1+\overline{p}}{2}\right)$ $\rightarrow G\left(\frac{1+\widehat{p}}{2}\right) > F\left(\frac{1+\overline{p}}{2}\right)$, which is a contradiction. ■

**Example 1** *Let $f(\alpha) = 2\alpha$ and $g(\alpha) = 1$. Then we have: $F(\alpha) = \alpha^2$ and $G(\alpha) = \alpha$, so $F(\alpha) \leq G(\alpha)$. By using equations (1) and (2), you may easily check that $\overline{p} \approx 0.24$ and $\widehat{p} = 0$.*

Example 1 highlights an important point. If the distribution of first order beliefs is uniform, than the threshold level for the price difference between incumbent and entrant is zero. The uniform distribution is "neutral": the

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[12]The model is able to account for the particular case where consumers enter the game with homogenous beliefs, i.e. they all have the same value of $\alpha$. In this case expectations converge to $q_I^e = 1$ or $q_I^e = 0$ at the level of second order beliefs (depending on whether $\alpha \geq cm_I$ or $\alpha < cm_I$). Of course, if $\alpha = 1$ (or $\alpha = 0$) for all buyers, then first order beliefs themselves are equilibrium beliefs.

heterogenous beliefs of consumers - as to which firm is going to win competition - do not create a competitive advantage for one of them[13]. If this is the case, the supplier announcing the lower price is able to attract the critical mass of buyers and consequently to cover the whole market. In the end, the game among suppliers would turn out to be much like a competition *à la* Bertrand[14].

This result provides a natural way to model the competitive advantage typically enjoyed by the incumbent in a network industry. Remember that $I$ was the only supplier before the current period - i.e. before $E$ would try to enter the market. In other words, the entrant is trying to challenge the dominant position of a supplier who has already reached his critical mass. It is then reasonable to assume that consumers' expectations are not neutral; to the contrary, they are biased in favor of the incumbent. If this is the case, then $\overline{p} > 0$: the incumbent retains his position even with $p_I > p_E$, provided the difference is not too large. This point is formalized in the following Corollary, where the aggregate distribution of first order beliefs is supposed to be biased in favor of the incumbent.

**Corollary 2** *Let $F(\alpha)$ be the c.d.f. of first order beliefs, such that $F(\alpha) \leq \alpha$ for any $\alpha \in [0, 1]$. Then $\overline{p} \geq 0$, where $\overline{p}$ is defined by equation (1).*

**Proof.** Trivial, by application of Proposition 2 with $G(\alpha) = \alpha$. ∎

Proposition 2 and Corollary 2 show that the incumbent can enjoy a competitive advantage, due *only* to the favorable beliefs of consumers: the population of buyers is - at the aggregate level - more inclined to think that the incumbent, rather than the entrant, will be able to achieve his critical mass. This attitude is justified by the fact that the incumbent is already there, so actually all he has to do is to keep with him a sufficient number of customers as to satisfy its critical mass condition; to the contrary, the entrant has to build up its critical mass of customers, starting from zero. The advantage enjoyed by the incumbent is larger, the more biased are customers' beliefs.

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[13]Note that we are not saying that each *individual* consumer has the same evaluation of the two suppliers, which would require $\alpha = 0.5$ for all buyers. We are instead saying that the *aggregate* distribution of (first order) beliefs is such that neither of the two suppliers is favoured over the other.

[14]With the specificity that $I$ would retain the whole market in case of equal prices.

## 3.4 The complete game: exclusion or entry

So far, we have focussed our attention on the game among buyers. Now we turn to the decision problem of the two producers, namely which price to announce. Actually, in Proposition 3 the optimal strategies for both firms and consumers are specified, thus describing the Nash equilibrium of the complete game (stages 2 and 3 above). Remember that $p_I \in [c, 1]$ and $p_E \in [0, 1]$, so $p \in [c - 1, 1]$. Moreover, for the reason outlined above, we restrict to the region where $\overline{p} \in [0, 1)$[15].

**Proposition 3** *The Nash equilibrium of the complete game is the following:*
- *if $\overline{p} \geq c$: $p_I = \overline{p}$, $p_E = 0$, $q_I^* = 1$ ("exclusion");*
- *if $\overline{p} < c$: $p_I = c$, $p_E = c - \overline{p}$ (minus a small $\epsilon$), $q_I^* = 0$ ("entry").*

**Proof.** *Exclusion.* $I$ does not deviate, as lowering $p_I$ would lower his profit and increasing $p_I$ would make his sales and profit drop to zero. $E$ does not deviate, as increasing $p_E$ would not alter his payoff. Then $p = \overline{p} \rightarrow q_I^* = 1$ (by Corollary 1).

*Entry.* $I$ does not deviate, as increasing $p_I$ would not alter his payoff. $E$ does not deviate, as lowering $p_E$ would lower his profit and increasing $p_E$ would make his sales and profit drop to zero. Then $p > \overline{p} \rightarrow q_I^* = 0$ (by Corollary 1). ∎

Proposition 3 shows that the outcome of the complete game depends on the value of $\overline{p}$: it is crucial whether this threshold level for the price difference lies above or below the cost difference between incumbent and entrant ($c$). Suppose $\overline{p} \geq c$: by setting $p_I = \overline{p}$, the incumbent is able to avoid entry - even if the entrant announces the lowest possible price (zero) - and to enjoy a non-negative profit ($\pi_I = \overline{p} - c$). In doing so, he exploits his advantage in terms of consumers' expectations, which is so large as to overcome his cost disadvantage. This case points to a possible coordination failure among consumers, as the more efficient producer is prevented from entering the market, although he commits to charge a lower price than the incumbent. To the contrary, if $\overline{p} < c$ the entrant is able to successfully challenge the position of the incumbent and actually enter the market: even if $I$ announces a price as low as he can ($p_I = c$), $E$ can undercut by setting a price a bit lower

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[15]The case where $\overline{p}$ takes negative values looks unlikely, as it needs first order beliefs be biased in favor of the entrant, so that he can be successful even though applying a higher price than the incumbent. This presumably requires the entrant being very strong, as far as product quality and marketing ability are concerned.

than $p_I - \overline{p}$, thus covering the whole market and earning a positive profit $(\pi_E = c - \overline{p})$.

# 4   The entry decision

In the above model, I did not formally include the decision problem of the entrant as to whether (try to) enter the market in the first place. However, this issue can be easily addressed through an informal discussion.

If a potential entrant does not even try to enter, his payoff is zero. Then he decides to try only if he expects a positive payoff from entering, large enough to compensate any sunk cost of entry. Of course, he has to take his decision before entry (if any) occurs, so before consumers' beliefs are formed. Thus, it is realistic to assume that such decision is based on an estimate of $\overline{p}$ (say a noisy signal $\widetilde{p} = \overline{p} + \widetilde{\varepsilon}$, where $\widetilde{\varepsilon}$ is a white noise error term), while the true value $\overline{p}$ would be observed only in case $E$ were actually trying to enter and marketing his product. So he might under-(over-)estimate the competitive advantage of the incumbent due to consumers' expectations, although on average his forecast is correct.

Therefore, if $E$'s forecast is such that he does not expect a sufficient profit from entering, $I$ continues to be a monopolist. If instead $E$ expects a positive profit from entering (larger than sunk costs), he tries to enter and the game analyzed in the above model takes place, leading to one of the two equilibria described in Proposition 3 (entry or exclusion).

A (potential) entrant might make two kinds of mistakes. He might under-estimate the incumbent's advantage (due to consumers' expectations), so that he takes the wrong decision to enter ($\widetilde{p} < c \le \overline{p}$): if this is the case, he faces a stronger incumbent than expected, and he ends up with a failure. On the other hand, he might over-estimate the incumbent's advantage and not even try to enter the market, although entry were a profitable business ($\overline{p} < c \le \widetilde{p}$).

This argument is able to explain an apparent paradox, possibly observed in a network industry: empirical evidence may show repeated entry tries (by different firms), all of them ending up in a failure[16]. This does not imply an irrational behavior of entrants (systematic forecast error). It may rather be

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[16]This seems to be the case in the stock exchange industry. See the evidence provided by the UK Competition Commission (2005 - Appendix H), showing seven cases of failed entry into the European stock exchange sector during the last decade.

explained by the fact that only the first type of mistake (under-estimation of $\overline{p}$) is actually observable, while the second type is not, as it does not induce potential entrants to take any action.

# 5   Welfare analysis and policy implications

Proposition 3 identifies two equilibria: one with exclusion and the other one with entry. The comparison between them shows that entry is preferable, whatever welfare criterion is adopted: either total surplus (consumers' plus producers') or consumers' surplus only.

Total surplus is equal to 1 in the entry equilibrium, as $S_E = 1 - p_E$ and $\pi_E = p_E$. It is equal to $1 - c$ in the exclusionary equilibrium, as $S_I = 1 - p_I$ and $\pi_I = p_I - c$. Thus the exclusion of the more efficient entrant entails a productive inefficiency, which reduces total welfare by $c$.

Consumers' surplus is at *least* as large as $(1 - c)$ in case of entry: if $\overline{p} = 0$, then $E$ is able to enter by setting $p_E = c$ (actually, a bit lower than that); as $\overline{p}$ gets higher, $E$ has to lower his price, until $p_E = 0$ when $\overline{p}$ is (almost) equal to $c$; thus $S_E \in [1 - c, 1]$. To the contrary, consumers' surplus is at *most* as large as $(1 - c)$ with exclusion: $p_I = \overline{p}$, where $\overline{p} \in [c, 1)$, so $S_I \in (0, 1 - c]$. Therefore $S_E \geq S_I$: consumers are better off with entry than without.

The exclusionary behavior of the incumbent is detrimental both for productive efficiency and for consumers' welfare. On the other hand, it might be interesting to ask whether the entry threat, even when unsuccessful, is able to bring some welfare improvement. The answer is negative, if we look at total surplus: this is equal to $1 - c$ in the exclusionary equilibrium and in the monopoly equilibrium as well (absent any entry threat). But the answer gets positive if we focus on consumers: the incumbent monopolist - absent any threat of entry - charges a price equal to 1, extracting the whole consumers' surplus; to the contrary, in order to exclude an entrant he has to lower his price below such level, to the benefit of consumers. So, from consumers' perspective, the equilibrium with exclusion is worse than that with entry, but it is better than a monopoly without any threat of entry.

The last result may be relevant for merger policy. In the context analyzed here, the merger between the incumbent and another firm - currently operating in a different geographic/product market - should be carefully considered by the anti-trust authorities: in particular, a condition for authorization should be that the merger does not eliminate all significant threats of entry

into the incumbent's market, even if entry is not likely to be successful.

An example, where the above criterion has been applied, is provided by the Report of the UK Competition Commission (2005), relative to the proposed mergers between the London Stock Exchange and either Euronext or the Deutsche Borse. The horizontal mergers have not been seen as able to lessen competition in the market for trading services on UK shares, as other potential entrants remain. However, the authorization has been subordinated to the implementation of (structural and behavioral) remedies, aimed at removing the vertical control of both Euronext and DB over their post-trading infrastructures: such vertical control has been judged able to jeopardize competition in the trading sector (through foreclosure). This position of the UK CC relies on the assumption that, despite the observation of several failed entries, the entry threat is a valuable source of competitive pressure in the trading services industry. Indeed, in some cases the incumbents have dramatically reduced their fees to defend their dominant positions[17].

Finally, the model provides an argument supporting the imposition of compatibility among networks. As noted above, in the framework of this paper compatibility is not a market outcome, as the incumbent would never sign a compatibility agreement. By imposing compatibility, the regulator would make the networks of the two competitors be of equal size, so this variable would become irrelevant in the competitive game among them. Then competition would be only in prices; given the higher cost of production, the incumbent would be unable to exclude the entrant, to the benefit of consumers and of efficiency.

# 6   Concluding remarks

Summing up, the model presented here is able to show that firms make a substantial contribution, through their pricing policies, in determining which equilibrium prevails, following the decision of an entrant firm to challenge the dominant position of an incumbent in a network service industry. The final outcome of the entry game does not only depend on exogenous consumers' expectations, but also on the optimal choices of producers. More specifically:

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[17]Euronext lowered its fees by up to 50% following the DTS-LSE initiative aimed at attracting trades on Dutch shares; LSE slashed its fees by more than 60% to face competition with the new entrant Tradepoint/Virt-x. See Competition Commission (2005) and Di Noia (1999).

starting from an initial (out-of-equilibrium) set of exogenous heterogeneous expectations, prices act as a coordination device in the process of expectations convergence, where consumers try to forecast which firm will eventually reach its critical mass; thus equilibrium (homogenous) expectations are endogenous, as they depend on prices. While expectations may be driven by a number of factors (e.g. quality, advertising), this work has focussed on prices: for example an incumbent, by reacting aggressively to an entry threat, might be able to convince his own customers that he will be able to retain his customer base, and this belief becomes self-fulfilling.

The incumbent possibly enjoys an advantage, in terms of consumers' initial expectations, but this does not necessarily allow him to retain his dominant position: his ability to exclude the entrant crucially depends on the magnitude of such advantage, relative to its cost disadvantage.

On one hand, exclusion requires the incumbent to lower his price below the monopoly level - the one he would select absent any entry threat. On the other hand, the entrant may be successful only by undercutting the incumbent's price by a sufficiently large amount. So the model is able to account for aggressive pricing policies, commonly observed when an incumbent and an entrant compete for the market.

Welfare analysis shows that both productive efficiency and consumers' welfare are hurt by exclusion. However, consumers benefit from the threat of entry, even when entry is not successful. Imposing compatibility among networks is welfare improving, as it removes the exclusionary potential enjoyed by the incumbent.

These insights are made possible by an explicit analysis of the impact of prices on expectations, where the latter are (partially) endogenized. Absent this type of analysis, one of the two extremes would obtain: exogenous equilibrium expectations would completely support either the incumbent or the entrant, with the "winner" firm setting his price at the monopoly level.

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