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Firm value in emerging network industries

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ABSTRACT

This paper examines emerging industries that exhibit positive network effects. We put forward a dynamic model in which two technologies compete to be the standard. The model provides a quantitative method for the valuation of firms. We use the model to examine the relationship between network effects, consumer heterogeneity, and prices. We show that the firm value depends strongly on the particular choice of the network strength function. We compare three types of such functions, identify shortcomings of traditionally used ones, and propose a more realistic one.

1. Introduction

In the late 1990s, prior to the burst of the dot-com bubble, and then again in the following decade, a large number of relatively young companies in emerging network industries reached extremely high valuations. This phenomenon seems puzzling considering that, in most cases, the financial statements did not reflect the cash flows or profits necessary to justify such high firm values.

Both *Facebook* and *Groupon* serve as recent prominent examples: a simple analysis based on nonlinear demographic dynamics reveals a huge gap between fundamentals on the one hand and actual valuations on the other hand, at virtually any time in these firms' histories (Cauwels and Sornette, 2012). In both cases, the driving force behind the extensive growth in firm value appears to be investors' expectations that the companies can build up a dominant position and "win" their respective markets in the long run.

In general, a technology often becomes more attractive to a potential user if many other users are already employing it. It is clear that the strength of these network effects will have a significant impact on the valuation of such a company. Where network effects are weak, and the company is likely to share the market with one or more other companies, valuations will certainly be different from the case in which network effects are strong and one of the companies is likely to take over the market and drive out the others (for example, the case of *MySpace* ceding to *Facebook*).

For an innovator launching a new technology, there are two other important factors that will have an impact on its potential value: the overall size of the available market to be captured, and consumer heterogeneity. With respect to the market size, Cauwels and Sornette (2012) write for example that "the future growth of users will be regarded as the key to the future valuation of the company". And regarding consumer heterogeneity, there are well-known examples where strongly pronounced preferences can counteract even significant network effects, as in the case of *Skype* vs other Voice over Internet Protocols (VOIP) such

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as Apple's *FaceTime*, which integrates seamlessly into an Apple user's already existing platform.

We provide a quantitative method for valuing a particular firm. This is done by constructing a dynamic model in which two price-setting firms compete by promoting their own technology for establishing a standard. More specifically, by examining the relationship between network effects, consumer heterogeneity, and prices, we find that:

1. Unique Nash equilibrium prices exist at all times, and these prices are always strictly higher than the unit production cost (Proposition 1).
2. For a given difference of the strengths of the two networks, firms will set prices more closely to each other if consumer heterogeneity is higher (Proposition 2).
3. There is an important lower boundary for the price difference, which holds for arbitrarily high consumer heterogeneity (Proposition 3).

Then we evaluate a firm by considering the sum of all discounted profits made during the market growth period, plus the sum of all discounted further profits in the period when the market is saturated. This allows us to compare three specifications for the network effects. We find that traditional specifications such as linear network strength functions lead to price explosions in the model and therefore unrealistically high firm values. We introduce and compare two other network strength functions, an exponential and a logarithmic one, and conclude that the latter one leads to a more realistic and robust model.

2. A model of a network market with price setting

We propose a simple model of an emerging network market in which two companies compete for customers.

2.1. Consumers

Two companies, company 1 and company 2, sell two competing "sponsored" products (technologies) in an emerging network market at prices p_1 and p_2, which they are allowed to change over time.[1] We consider positive network effects, which furthermore work in the same way for both companies. We assume these effects are given by a *network strength function* f that depends both on the number N of previous adopters and a *network strength parameter* α.[2]

At time $t_0 = 0$, both networks have size zero. Customers then arrive in groups of size $s(t_i) \geqslant 0$ at times $t_i, i = 1, \dots, m$. Every customer comes with his own stand-alone valuations v_1 and v_2 for the two products, which are independent of prices and network strengths. The numbers of previous adopters of products 1 and 2 are given by $N_1(t_{i-1})$ and $N_2(t_{i-1})$, respectively. At time t_i, each customer bases his choice of product 1 or 2, independently of the other customers concurrently arriving, on his utility for product j, which is given by

$$u_j(t_i) = v_j + f(N_j(t_{i-1}), \alpha) - p_j(t_i), \quad j = 1, 2. \tag{1}$$

As the customer will be comparing these two utilities, we introduce the difference $d_u := u_1 - u_2$ in utilities, along with the differences $d_v := v_1 - v_2$ in valuations, $d_n := f(N_1, \alpha) - f(N_2, \alpha)$ in network strengths, and $d_p := p_1 - p_2$ in prices.[3] It then follows from (1) that the difference d_u in utilities is given by

$$d_u(t_i) = d_v + d_n(t_{i-1}) - d_p(t_i). \tag{2}$$

so that the customer will choose product 1 if $d_u(t_i) > 0$, which occurs if the customer's difference in valuations d_v satisfies

$$d_v > d_p(t_i) - d_n(t_{i-1}). \tag{3}$$

This difference is assumed to be normally distributed with mean 0 and variance σ^2, i.e.

$$d_v \sim \Phi(0, \sigma^2) = \Phi_\sigma, \tag{4}$$

which reflects the heterogeneity of customers' valuations. From Eqs. (3) and (4) it follows that the probability ρ_1 of a given customer choosing product 1 will depend on d_p and d_n, and be given by

$$\begin{aligned} \rho_1(d_p, d_n) &:= \mathbb{P}\big(d_v > d_p(t_i) - d_n(t_{i-1})\big) \\ &= \Phi_\sigma\big(-d_p(t_i) + d_n(t_{i-1})\big). \end{aligned} \tag{5}$$

Similarly, the probability $\rho_2 = 1 - \rho_1$ of the customer choosing product 2 will be given by

$$\begin{aligned} \rho_2(d_p, d_n) &:= \mathbb{P}\big(d_v \leqslant d_p(t_i) - d_n(t_{i-1})\big) \\ &= \Phi_\sigma\big(d_p(t_i) - d_n(t_{i-1})\big). \end{aligned} \tag{6}$$

2.2. Firms

If firm j sells $n_j(t_i)$ products at time t_i, it will make a profit π_j given by

$$\pi_j(t_i) = \big(p_j(t_i) - c\big) n_j(t_i), \quad j = 1, 2, \tag{7}$$

where c is the production cost per unit of each product, which we assume to be equal for both companies. If the prevailing network sizes $N_1(t_{i-1})$ and $N_2(t_{i-1})$ are known, the expected profit at time t_i is given by

$$\mathbb{E}_{t_{i-1}}\big[\pi_j(t_i)\big] = \mathbb{E}\big[\pi_j(t_i) | N_1(t_{i-1}), N_2(t_{i-1})\big]. \tag{8}$$

We assume that each firm $j = 1, 2$ sets its price $p_j(t_i)$ based on the knowledge of prevailing network sizes $N_j(t_{i-1})$, such that it maximises its expected profit for t_i as given by (8). Companies are therefore *myopic* (i.e. not forward-looking). In this competition à *la Bertrand*, the equilibrium prices are those for which both firms simultaneously and non-cooperatively maximise their expected individual profits at t_i.

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[1] According to Arthur (1989), "*sponsored* technologies are proprietary and capable of being priced and strategically manipulated; *unsponsored* technologies are generic and not open to manipulation or pricing."

[2] This specification encompasses Arthur's model when the strengths are of the same size α for both networks: his network strength function f then measures the return by $f(N, \alpha) = \alpha N$. Note that Arthur also treats the case of different strengths $\alpha_1 \neq \alpha_2$, which we do not consider here.

[3] For the reader's convenience, the parameters used to describe the market evolution and the network model are given in Tables A.4 and A.5 of the appendix.