INFORMATION GAMES IN THE QUEST FOR MINDSHARE

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December 22, 1999

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Abstract: The rapid growth and great popularity of Internet sites that specialize in providing intangible services in the form of information and community services gives rise to new forms of competition. Information Web sites such as www.how2.com and community sites such as www.iVillage.com provide free "content" and rely on advertising and hosting revenues to generate income. The competition between content sites in the same market niche is intense and only a few companies are likely to survive. In this paper, we examine a number of competitive models or "information games" that provide insights into the nature of this competition. The models capture differences between the type and maturity of the markets and differences in the behavioral assumptions about the nature of consumer demand for content. While these markets often have a "winner-takes-all" nature, we find a number of situations in which more than one player can survive at equilibrium.

Keywords: *Electronic markets; information goods; competitive equilibria*

1. INTRODUCTION

Advances in information technology, and in particular, the rise of the World Wide Web (WWW) accentuate the differences between information goods and other goods (Varian & Shapiro 1998, p.3). While information goods are often costly to produce, they have (almost) zero costs of reproduction. Only a few years ago, Encyclopaedia Britannica, was sold at retail for $1,600 per 31-volume hard-copy set. The same information on a CD can be reproduced for almost $1 per copy. Faced with competition from Microsoft's Encarta and other CD-based encyclopaedias, Britannica entered the CD-based market and was forced to continually reduce its price until it matched Microsoft Encarta's price of $89.95 per CD. The online version of Britannica suffered even more price attrition. At first, annual subscriptions to the Web-based version of Britannica cost $120 per year but attracted very few customers. In September 1999, Britannica decided to make its content free on the Internet. One day after the announcement, users swamped Britannica's Web site, (Headlam 1999). On the Web, price elasticity, for at least some information goods, is high only in the vicinity of zero!

In fact, it is often hard for a Web site to charge subscription fees or to price its content on a per use basis (Reuters 1999). Notable exceptions are AOL and other well-established online information and community sites that have always charged a subscription and have built a huge base of users. The Wall Street Journal successfully introduced a subscription fee on its Web site in 1998. However, the New York Times still distributes its content free online along with a majority of other sites on the Web. To survive, companies that are solely Web-based – content Web sites such as Yahoo and community Web sites such as GeoCities.com and IVillage.com - rely on advertising and online commerce revenue. Advertising revenues depend on attracting a very large number of users. For example, a major advertising network such as Flycast will not accept Web sites that have fewer than 100,000 page views per month (www.flycast.com). The same is true, although possibly to a lesser extent, with e-commerce revenues. Portal sites, like Yahoo, that are the first entry point to the Web for millions of users, have the scale to attract significant advertising and e-commerce revenue. Information Systems Providers (ISPs), who provide local access to the Web, are attempting to become portals by providing search capabilities and content such as access to news items. In turn, portals are busy trying to turn themselves into "hubs" like AOL, where users stay for extended periods of time to communicate with other users, enjoy rich content, click on banner advertisements, and shop.

While our analysis in this paper applies to some extent to portals and hubs, their operations are becoming increasingly complex as e-commerce and physical distribution of goods becomes relatively more important. Our research is more applicable to "information" sites and "community" sites. Both depend for their success on capturing the attention and loyalty of a specific community of users. In the former, the community is united through a common interest in the content offered by the site. In the latter, the community is based on the attraction of interacting with people of similar interests, occupations, hobbies, or ethnic background. Information sites and community sites both compete in "niche" markets and aim to be one of the top players in their niches. Motley Fool, which provides financial advice (an information site), has just completed a $25 million round of financing with the intent of increasing activity on its Web site (Anders 1999). Community Connect Inc., which runs AsianAvenue.com, the largest ethnic community site, recently launched another ethnic community site - BlackPlanet.com. The market for digital content is predicted to reach $275 billion by 2003 (Robinson 1999.) Community sites are currently one of the fastest growing areas of the Web (Sun 1999.)

For the most part, we drop the distinction between "information" and "community" sites. For our purposes, they both provide "content" – either information in the conventional sense or information based on community interactions. The sites that we can include in our analysis obtain revenues from advertising and/or by hosting "third party" commerce sites. By "third party commerce" we mean that physical distribution of products is not part of the service offered by the Web site. Thus, in addition to the pure information and community sites defined above, our analysis is applicable to sites that host online shopping malls and to auction sites such as Onsale.com, that rely on the buyers and sellers to perform the exchange of goods. Our analysis does not extend to Web sites such as LandsEnd.com and Amazon.com that involve physical distribution systems. Analysis of such sites requires more complex cost functions and different forms of analysis involving variables such as service quality, order-to-ship times, and so on.

We define "mindshare" as a composite variable that captures a number of desirable relationships between a Web site and its users. These include the number of individuals that identify with the Web site as their primary source of content and the strength of their identification with the site. Capturing the mindshare of a community implies capturing the lion's share of visitors to the Web site. Within a given population mindshare is a fixed commodity. This means that Web sites that focus on a community are playing a market game of trying to grab share from the other players. Typically, a few Web sites have a dominant position within a community.

2. LITERATURE REVIEW

A small but growing literature examines industrial organization in the world of electronic commerce. An early hypothesis was that the decrease in transaction costs enabled by information technology (IT) would lead to a larger number of small, highly networked "virtual" organizations Malone & Laubacher (1998). On the other hand, as pointed out by Kambil et al (1999a,b) among others, IT also decreases the agency and other internal costs of hierarchical operations, increasing economies of scale and enabling much larger firms to operate efficiently. More germane to the current discussion, Internet sites often have positive network externalities (positive returns) associated with user participation. In essence, the value to a consumer of belonging to a network (using a Web site) often grows with the number of other consumers that use the site. Chat-rooms provide a good example where the value of a Web site grows with the number of users. A chat room with only one or two users is a pretty forlorn place! As pointed out by Arthur (1996) many of the assumptions of classical economics do not hold when network effects lead to increasing returns to scale. In particular, nothing prevents a firm from growing without bound and eventually dominating its market.

An analysis by Dewan et al (1998) addresses issues similar to those in this paper. They analyzed a game that included ISPs and content providers. Their analysis led to the conclusion that "content is king." In the long run, the content providers, rather than the access providers, have the advantage. To some extent, their analysis adds support for our concentration in this paper on content as a key competitive element.

Much of the literature in electronic commerce has focused on issues of pricing in electronic markets. For example, Bakos and Brynjollfsson (1999) find that it is often preferable to "bundle" information goods together for sale rather than to price each item individually at a very low price as envisaged by proponents of micro payment systems. Aron (1999) investigates the impact of information search engine characteristics such as "recall" and "precision" on prices and product information. Among other things, he shows that it might often be optimal for Web merchants to trade-off accuracy in providing price information in favor of greater accuracy in portraying product characteristics.

In contrast to this stream of literature that focuses on pricing issues, we investigate the very common situation (on the Web) where information goods are provided free of any explicit price. The cost to the users comes in the form of their expenditure of time and tolerance for advertising banners.

3. MODEL FOUNDATIONS

In this paper, we study the economics of competing for mindshare among a small number of Web sites. We focus on the competitive dimension of content in attracting visitors and members. This means that we ignore the influence of marketing and Web site design as a means for consumers to differentiate among sites. Our approach is to look at each community as a market with dominant providers who compete to maximize profits by providing content that attracts mindshare. We model the providers as oligopolistic players in a Cournot duopoly game.

Classical oligopoly theory with standard supply and demand curves includes results on how one player reacts to changes in supply from another and whether or not one player can completely dominate a market. We examine these issues here under the different market structure of the Internet. The market for mindshare is different from the market for a standard commodity. In a traditional market the consumer pays for the product and considers price an important component when making a purchasing decision. In a game for mindshare the consumer does not necessarily pay for the product. Instead, advertisers and sales of ancillary products or services through an attached cyber mall pay for the free portion of the Web site. In this context, price is not a significant element in the competition for mindshare.

We therefore assume a market in which Web sites offer their content for free but gain revenues from advertising and/or renting space to third parties in a shopping mall. Attractive content is required to gain and maintain visitors to the Web site and thereby generate advertising and e-commerce revenues. The Web sites can develop new, unique content, acquire exclusive rights to material developed by other organizations, duplicate material from other Web sites without copying it, or acquire nonexclusive rights to other material.

We define a measure of the content in a Web site i, x_i. This content can be a function of the number of messages posted to a bulletin board or chat room on a subject, the depth and breadth of information on diseases and conditions covered on a medical Web site, or the number of articles on a company posted to a finance Web site. We assume that the desirability of a site is an increasing function of the amount of content that it contains.

Let the amortized cost of acquiring and maintaining content be $C_i(x_i)$ per time period. The cost functions can have a variety of shapes. If the content is provided in part by the members, then the cost of providing an additional unit of content decreases as content increases, since more content attracts more members and therefore more content. We see this phenomenon of positive returns to scale on community sites such as AsiaAvenue.com and BlackPlanet.com (Sun 1999.) In other cases, content costs may increase as the content space is exhausted and it becomes harder and harder to add something new. This is likely to be the case with lifestyle sites where the permutations of human behavior are limited by our physical characteristics. This could become the case with pornography sites, as they have to appeal to more-and-more extreme tastes. Finally, costs can be proportional to content. An example may be news sites since the material regenerates continuously and the audience does not have to be subdivided further and further when adding new material.

We keep x_i an abstract concept. It can be measured in bits, for example. Alternatively, the units can be utiles captured by a utility function $U(y)$. These two measures translate from one to the other using $C_i(x_i) = \hat{C}_i(U^{-1}(x_i))$ where $U^{-1}(x_i)$ is the inverse of the utility function. For news sites, x_i can be considered to be a measure of the quantity of the flow of information in the relevant domain rather than a stock.

We examine four distinct cases of information Web site competition along two dimensions. The first dimension is whether or not the domain of information relevant to a community is exhausted and the second is whether or not the Web sites have exclusive rights to the information. Some examples may clarify this classification scheme. Dun & Bradstreet's credit valuations are both exclusive and exhaustive. Game sites have exclusive (proprietary) information, but there are other sites with rival games. Humor sites may have jokes in common and certainly have not exhausted the available jokes. Although the Patent Office is the original source of patent information, since information produced by the Federal government is copyright free, it does not have exclusive ownership of the information. In fact, IBM has built a patent Web site. A similar situation pertains to the Security and Exchange Commission's EDGAR database of company financial filings. Finally, Yahoo pays for nonexclusive rights to Reuters' news articles, which do not exhaust all possible news items. Table 1 summarizes these examples and also identifies the models that we develop during the course of the paper.

Table 1: Classification of Competitive Situations

		Information Domain	
		Not Exhaustive	**Exhaustive**
Ownership	**Exclusive**	<u>Model 1</u> Game sites	<u>Model 1'</u> Dun & Bradstreet
	Not Exclusive	<u>Models 2 and 3</u> Humor sites Reuters on Yahoo	<u>Models 2' and 3'</u> EDGAR Database U.S. Patent Office

4. MODEL 1: EXCLUSIVE, NON-EXHAUSTIVE CONTENT

The market for free Web sites is comparable to the market for television services in that the programming is provided at no cost and the revenues come from advertisers. However, the differences in technologies lead to major differences in market structure. The most critical competitive dimension in television is the timing of the shows and what the competition has in the same time slots. Also, given the limited number of channels and their high fixed cost, television communities are so broadly defined that it is impossible to monopolize their time. On the Internet, content is available on demand. Consequently, the attractiveness of a Web site's content is the key element in establishing its competitive position.

Hits to a Web site depend on the amount of content in the Web site and the amount of content in competing Web sites. Since people have more than one interest, we also need to factor in the effects of other Web sites and media in drawing people away from the community. Since viewers have a fixed amount of recreation time, we look at the proportion of this time that can be captured by a Web site. We posit a behavior of viewers where the share of recreation time spent at the site is positively related to the site's share of content. We use the following functional form for shares among Web sites competing for a community's interest.

$$s_i = \frac{x_i^a}{\sum_i x_i^a} \qquad (1)$$

Here, x_i is the amount of content in site, *i*. Alternatively, x_i can be interpreted as the aggregate utility of the content on the Web site. The exponent *a* is a shape parameter that captures alternative community responses to the quantity and share of information. With $a \leq 1$, (1) is a concave function that is asymptotic to 1. With $a>1$, (1) becomes s-shaped and asymptotic to 1.

This functional form has had a long history in modeling economic phenomena. Mills (1961) used it to model market share as a function of promotional effort. Luce (1959) used it to model market share as a function of utility. McFadden (1974) extended this model by using exponentials instead of powers for the individual terms in (1) and showed that this form can be derived from probability distributions of utility. For a survey of these models see Meyer and Kahn (1991) and Cooper and Nakanishi (1988). This share model has a variety of uses. For example, Boyd, Phillips and Regulinski (1982) used (1) in models of technology choice.

As the content grows in the Web sites serving a community, members will devote more of their time to this community at the expense of other communities. Yet, members will still participate in other communities. To analyze a market, we partition the sites into those that react to each other and those that do not view themselves as part of the community and do not react to changes in activity by the Web sites within the community. We can aggregate the other attractors of mindshare that are outside our community of interest into a constant. Let *b* be the total content of

Web sites outside the community that is of interest to members within the community. For example, members of a flower-gardening community also can track stocks in their 401 K's through Yahoo Finance, which does not react to changes in gardening websites. The content of Yahoo Finance is incorporated in b. The share formula (1) becomes

$$s_i = \frac{x_i^a}{\sum_i x_i^a + b}. \tag{2}$$

We assume that the number of visitors to the site is a function of its market share as given by (2). For sites establishing a new community of interest, b is relatively large and s_i will be small or even tiny. We assume a fixed total amount of mindshare, M, that is possessed by all the potential users of the content or community sites that we are analyzing. Let M, be measured in minutes per month, for example. M is the amount of these users' time that they are prepared/able to spend on the Internet. While M is growing quite rapidly as more and more people spend more and more time on the Internet, we assume that this growth is independent of the content offered by sites in the market we are studying. Then $s_i \times M$ is the total number of minutes spent on site i in a month.

We assume that the revenues received by the site are proportional to the number of minutes spent by visitors to the site in any time period. This is approximately true for ad revenues that are based on contractual rates per impression or clickthrough. It will also be approximately true for "third party" electronic commerce revenues if we can assume that the average new visitor spends approximately the same amount per time period as existing users. Our revenue model is then

$$R_i(x) = v_i \times M \times \frac{x_i^a}{\sum_i x_i^a + b}. \tag{3}$$

where, v_i, represents the average value per minute of a visitor to the site, and x is a vector of all x_i.

We assume each firm optimizes given its cost and revenue stream. We have the following optimization model for firm i

$$\max_{x_i \geq 0} P_i(x) = d_i \times \frac{x_i^a}{\sum_j x_j^a + b} - C_i(x_i). \tag{4}$$

where, to simplify the notation, we defined $d_i = v_i \times M$. Here, d_i is the marginal revenue given that the total mindshare equals M.

The standard approach for representing competition in an oligopoly is to assume that each player maximizes its revenue function taking the other players' investments as given. We take this approach here as well. The content levels where neither player can improve, given the other players' positions is the Nash-Cournot equilibrium. Mills (1961) used this approach and it has become standard in the marketing literature. See, for example, Urban and Hauser (1993).

The nature of the solution depends on the assumptions about the parameters. For example, when $a \leq 1$ and $C_i(x_i)$ is convex, then $P_i(x)$ is concave and has a unique optimum and a local optimum is global. When $a>1$ and/or $C_i(x_i)$ is strictly concave, $P_i(x)$ is not necessarily concave and (4) can have local optima that are not global. That the optimum to (4) is unique does not mean that the solution of the game is unique. We examine the character of the game under different cost structures.

When Game 1 is Convex

In this section of the paper we examine the simplest form of the game – a duopoly where each player has the following concave optimization problem

$$\max_{x_i \geq 0} P_i(x) = d_i \times \frac{x_i}{\sum_i x_i + b} - C_i \times x_i . \tag{5}$$

We find the solution to (5) for player i, given the content level x_j for the other players, by taking the derivative of (5), setting it equal to 0, and solving for x_i

$$x_i = \max\left\{ \left(\frac{d_i}{C_i}\right)^{1/2} (x_j + b)^{1/2} - (x_j + b), 0 \right\}. \tag{6}$$

Equation (6) describes how x_i changes as a function of x_j. This is known as the reaction function. The derivative of (6) gives the slope of the reaction function, which is

$$\frac{dx_i}{dx_j} = \frac{1}{2}\left(\frac{d_i}{C_i}\right)^{1/2} \frac{1}{(x_j + b)^{1/2}} - 1. \quad (7)$$

Note that for $x_j = 0$, when b and/or C_i are small or the marginal revenue, d_i is large, (7) is positive. That is, we can say

Theorem 1: When the competitor's site content is low and only a small portion of consumers' mindshare is outside the community, each player reacts to increases in content of the other player by increasing its content.

This result is the opposite of what happens in traditional market games. In the standard oligopoly game with a demand curve that decreases with increasing prices, when player j increases its production, player i reduces its production. This result for the mindshare game is a partial explanation of the aggressive moves that competing firms engage in to establish their initial positions within a community.

Note that as x_j increases, (7) is monotonically decreasing to –1 in the limit. This means that the reaction functions are concave, and if even if they increase, they eventually decrease. The reaction functions and the equilibrium are illustrated in Figure 1. The structure of the reaction functions implies that they intersect once and only once and we can say the following.

[Insert Figure 1 about here]

Theorem 2: With the cost structure defined in (5), a solution to the game exists and is unique.

Proof: From (6), for player i to enter the game, we must have $\frac{d_i}{c_i} > b$. With both players in the game, by (7), the reaction functions are continuous, and after any increase, they decrease to 0. Consequently, the reaction functions intersect once and only once.

The key feature that leads to these results is the concavity of P_i. Whenever $a \leq 1$ and $C_i(x_i)$ is convex, these results will hold.

When the Player Optimization Problems in Game 1 are Non-convex

For a>1 the revenue function is monotonically increasing. However, it has an s shape and is not concave. When the cost function is concave, (4) is not unimodular and can have multiple local optima. Consequently, solving the individual-player optimizations becomes complex and the Cournot equilibrium may not exist. This issue has been raised in the context of the multinomial logit model of McFadden (1980). Gruca and Sudharshan (1991,1992) show that that model implies the optimal solution is to spend the maximum possible amount on advertising by any firm with less than a 50% market share. To provide a more reasonable solution, Mesak and Means (1998) introduce decreasing returns to advertising. Hanson and Martin (1996) address the computational issues in solving the non-convex model and conclude that each setting of model parameters requires individual treatment. We take this approach in the context of information games.

In our context, the cost function can be either convex or concave. As discussed above, it is concave for communities where the participants create the content and the existing content leads the members to generate new content. When the optimization problem for a player is nonconvex, the solution is harder to find since a local optimum is not necessarily global. With two players, the problem remains tractable because the combinatorial possibilities that must be considered remain small.

The general reaction function is the solution to the following equation

$$[da(x_j^a+b)]^{1/2}x_i^{\frac{a-1}{2}}-[C_i'(x_i)]^{\frac{1}{2}}x_i^a-[C_i'(x_i)]^{\frac{1}{2}}(x_j^a+b)=0 \qquad (8)$$

Since this equation does not solve readily in general, we illustrate some of the consequences of having a non-convex game with a profit function that is not unimodular by means of an example. The numbers provided here can be reproduced using Solver in Excel.

Figure 2 shows the objective function for player 1 when x_2=0, 4, 6.1 and 7 and a=2. The other parameters are b=.5 and d=4 and the cost function is $C_1(x_1)=.6x^{.7}$. The cost function is concave. From Figure 2, we see that the profit function is not unimodular.

[Figure 2 about here]

As shown below, the game with both players having these parameters does not have an equilibrium under the standard Cournot assumptions. This is all the more striking since the game is symmetric and each player has the same cost structure and demand response. Using Figure 3 we can understand why.

[Figure 3 about here]

The profit line is the profit each player would have if both invested in the same amount of content. The derivative of the profit function of player 1 (also, player 2) given the level of player 2 (also, player 1) shows in what direction player 1 should move given that both players start out at the same level on the horizontal axis. Note that whenever the profit line is positive (when both players have identical quantities of content), it is always profitable for player 1 to increase its content, and vice versa. By the same token, whenever player 2 can make a profit by matching player 1, it can do better by exceeding the content of player 1. That is, the model does not have an equal-share equilibrium with these parameters.

Looking at the game as a tatonnement process in search of the Cournot equilibrium, this last property implies an escalation in content until one player drops out. The situation becomes more complicated in that once one of the players drops out, the profit-maximizing player that survives cuts its content to increase its profits. Say player 2 drops out and offers no content. Solving player 1's optimization problem with player 2 at 0, we see from Figure 2, that the optimal solution for player 1 is 2.1 with a profit of 2.58. This leads player 2 to reenter at a level beyond 2.1. The increases continue until one player cannot make a profit and reduces its content to 0, at which point the other player drops its content to 2.1 and the cycle begins again.

The only equilibrium that can occur is if the first player to move sets the content at a level where it is profitable and the other player can never make a profit. The first player solves the original optimization problem with the added constraint that the other player cannot make a profit. With the parameters used here, the level is 6.1 (see Figure 3 and reverse the roles of the players). If player 1 sets its content level to 6.1, player 2 does not enter the game and player 1 makes a profit of 1.82. To keep the other player out, the first player sacrifices .76 in immediate profit.

The optimization by player 1 is equivalent to limit pricing in Cournot games. With limit pricing, player 1 sets its price at a level that denies player 2 the opportunity to make a profit. This strategy works only when player 2 has higher costs or, more importantly, economies of scale in production or customer relationships are present. Given a value of $a>1$, economies of scale exist, and this limit-quantity strategy to keep out other entrants is likely to be the best one to undertake by a site pioneering in a community.

Discussion of Model 1

When competing Web sites have exclusive rights to information, we have shown that a unique equilibrium exists in the simplest case when the profit function is concave. In other cases, the equilibrium may not exist. However, when no standard equilibrium exists, a company can make a preemptive investment in content and block other entrants.

We have analyzed the effects on the solution of different values for a. The effect of different levels of b is more straightforward. The larger the value of b, the shallower the revenue function. That is, the marginal revenue function is lower. When $a>1$, as b increases, it takes a smaller value of x_i to reach the point where the revenue function turns concave. Lastly, because the marginal revenue is lower with a larger b, the total content provided in the market of interest to the community is lower at the equilibrium.

5. MODELS 2 AND 3: NON-EXHAUSTIVE, NON-EXCLUSIVE INFORMATION

McFadden (1980) points out that the model in (1) suffers from the problem that the market shares are affected by irrelevant alternatives. He uses the example of consumer choice among transportation modes. Say one uses a share model such as equation (2) for an individual's choice of transportation to another city by car, train or bus, and then adds a blue bus to the red bus that already operates on this line. Then the market share of buses increases despite the blue bus not being a truly new alternative. The probability that the traveler will take a bus (either red or blue) should not increase as would be implied by the use of the share formula.

The analog to this situation in information markets occurs when sites carry duplicate information. However, an information market has a different structure. If all companies have the same information, given all else equal (e.g., identical access times), a new entrant takes away market share from the others, even if the content is not different. In model 1, we assumed that each Web site had unique information. We now examine the issues associated with content overlap among the websites.

We present two different models of market share that depend on the consumer response to the overlapping content. Content overlap occurs when the information is identical, such as when two sites carry articles from Reuters, or when the information is very close, such as articles on the same subject appearing in Encyclopaedia Britannica and in Encarta. We assume that consumers are indifferent between the sites on issues other than their information content. To keep the discussion clear, we examine these models in the context of a duopoly and we leave out the coefficient, b, representing the non-competing marketing and set the exponent, a=1. If consumers are equally likely to access either Web site when looking for specific content that is duplicated, the market-share equation is as follows.

$$\frac{x_{iu} + \frac{1}{2}x_s}{x_{1u} + x_{2u} + x_s} \qquad (9)$$

where x_{iu} = the quantity of unique content in Web site i

x_s = the quantity of shared content in both Web sites.

We refer to this as model 2.

When the consumers go to Web sites based on their share of *unique* information, the share equation is as follows

$$\frac{x_i - x_s}{x_1 + x_2 - 2x_s} \quad . \qquad (10)$$

We refer to this as model 3.

These models represent two polar-opposite responses by consumers. Model 2 is most appropriate when each time consumers go to the Web sites for single items of information, the site that they visit is independent of the site they last visited.

Model 3 is the information-equivalent of choosing between two cars that are effectively identical, except that one has a cup holder and the other does not. In this case, the cup holder is the tiebreaker and the car without the cup holder does not sell despite millions invested in all of the other aspects of the car. In the information case, this is equivalent to the consumer seeking out the site containing the unique information desired and then using that site for the common information desired in the current round of searches. That is, model 3 captures the situation where consumers combine their information-acquisition needs into extended searches or look for common information in the site last visited.

In the following theorem we provide formal proofs that the behavioral assumptions for models 2 and 3 lead to equations (9) and (10), respectively.

Theorem 3: (a) Model 2, equation (9), represents the market shares of each site if consumers are indifferent among the information sources for common information and their choice of site is independent of the most recently visited site. (b) If the first location examined for the current piece of information is the most recently used Web site then model 3, equation (10), obtains.

Proof:

As stated above, we assume that consumers are indifferent between the sites on issues other than their information content. We also assume that access to each piece of content is equally likely and that the probability of a consumer accessing any piece of content is independent of the piece of content previously accessed.

(a) In model 2, consumers are equally likely to access either Web site when looking for content that is duplicated. Clearly, for the unique information, access to each site is proportional to its share of unique information. Given the indifference assumption and no retention effects by a site, the site chosen by a consumer for common information is random and equally likely. This implies a 50% share of visits for common content as in equation (9).

(b) In Model 3, we assume that users stay with the information provider that they last used as long as the next item that they desire is available on that provider's site. They change sites only when the next item is unique to the other site. The probability of staying in Web site i given the consumer is already in i is its fraction of all content that is available to the community including shared information. The probability of transitioning to j from i is the fraction of unique content in Web site j. The following Markov matrix represents the movements between Web sites.

$$\begin{bmatrix} \frac{x_1}{x_1 + x_2 - x_s} & \frac{x_2 - x_s}{x_1 + x_2 - x_s} \\ \frac{x_1 - x_s}{x_1 + x_2 - x_s} & \frac{x_2}{x_1 + x_2 - x_s} \end{bmatrix} \quad (11)$$

In this case, the market shares of the sites are the steady-state probabilities (π_1, π_2), which can be found by solving the two simultaneous equations

$$\pi_1 \frac{x_1}{x_1 + x_2 - x_s} + \pi_2 \frac{x_1 - x_s}{x_1 + x_2 - x_s} = \pi_1$$

$$\pi_1 + \pi_2 = 1 \tag{12}$$

which leads to

$$\pi_i = \frac{x_i - x_s}{x_1 + x_2 - 2x_s} \tag{13}$$

and the result holds.

The above Markov model generalizes readily to calculate market shares for markets with more than two players.

Analysis of Model 2

The different models have very different implications for the nature of the market equilibrium. We begin by analyzing the optimization problem of player *i* using model 2 and general acquisition costs as a function of total content.

$$\max_{x_{iu}, x_s \geq 0} P_i(x_{iu}, x_s) = d_i \times \frac{x_{iu} + \frac{1}{2} x_s}{x_{1u} + x_{2u} + x_s} - C_i(x_{iu} + x_s)\,. \tag{14}$$

Taking the derivatives with respect to x_{iu} and x_s, we can compare the value of acquiring content that the other player has versus continuing to acquire new content. The derivative with respect to x_{iu} is

$$\frac{\partial P_i(x_{iu}, x_s)}{\partial x_{iu}} = d_i \times \frac{x_{ju} + \frac{1}{2} x_s}{(x_{1u} + x_{2u} + x_s)} - C_i'(x_{iu} + x_s)\,. \tag{15}$$

The derivative with respect to x_s is

$$\frac{\partial P_i(x_{iu},x_s)}{\partial x_s} = d_i \times \left[\frac{1}{2} \frac{x_{ju} - x_{iu}}{x_{1u} + x_{2u} + x_s} \right] - C_i'(x_{iu} + x_s) \quad (16)$$

The first term in (15) is greater than the corresponding term in (16). Hence, as long as new content can be acquired, the better margin is to acquire new content instead of duplicating the content of others. Note that this inequality always holds. We now have the following theorem.

Theorem 4: Neither Web site will duplicate the content of the other as long as new material can be added up to the point where the marginal profit of doing so is zero.

If there is no initial shared information, the implication of this theorem is that case 2 reduces to case 1.

Analysis of Model 3

We now treat model 3. The optimization problem for player *i* is as follows.

$$\max_{x_i, x_s \geq 0} P_i(x_i,x_s) = d_i \times \frac{x_i - x_s}{x_1 + x_2 - 2x_s} - C_i(x_i + x_s)$$
$$\text{subject to} \quad (17)$$
$$x_s \leq x_j.$$

At the optimal solution, the derivatives with respect to x_i and x_s are as follows

$$\frac{\partial P_i(x_i,x_s)}{\partial x_i} = d_i \times \frac{x_j - x_s}{(x_1 + x_2 - 2x_s)^2} - C_i'(x_i + x_s) \leq 0, \quad (18)$$

and

$$\frac{\partial P_i(x_i,x_s)}{\partial x_s} = d_i \times \frac{x_i - x_j}{(x_1 + x_2 - 2x_s)^2} - C_i'(x_i + x_s) \leq 0. \quad (19)$$

Note that when x_i is positive, (18) is an equality and when x_s is positive, (19) is an equality.

We see from (19) that the smaller player never tries to duplicate content since the derivative (19) in this case is negative. Note that when $x_i > x_j$, the marginal revenue term in (19) is positive and increasing in x_s. Thus the revenue term is convex with respect to x_s. The nature of the equilibrium then depends on the shape of $C_i(x_i + x_s)$. If $C_i(x_i + x_s)$ is concave, the profit function is convex with respect to x_s and the optimal solution lies at one of the two extremes, x_s=0 or x_s=x_j. If

$C_i(x_i + x_s)$ is convex, the profit function need not be either convex or concave. In this case, we can say only that a solution satisfies the fundamental condition that marginal cost equals marginal revenue for interior solutions and that marginal cost can be below marginal revenue when the solution is on the boundary. We summarize this in the following theorem.

Theorem 5: In model 3, when $C_i(x_i + x_s)$ is concave, there are two potential equilibria for the larger player. Either it does not duplicate anything or it duplicates all of the content of the smaller player. The smaller player never adds duplicate content. When $C_i(x_i + x_s)$ is convex, the larger player duplicates content until marginal revenue equals marginal cost or until the smaller player is eliminated. In all cases, since the smaller player never duplicates information, $x_s = 0$ at equilibrium.

The last sentence in the theorem follows since model 3 assumes that only unique content is valuable in attracting customers. The smaller player therefore surrenders any content duplicated by the larger player.

In the concave cost case, we can give a sufficient (but not necessary) condition for the larger player to duplicate the content of the smaller player. Initially, let $x_s = 0$ and find the equilibrium for x_1 and x_2 in problem (17). Setting the partial derivative (18) equal to zero and using this equation to eliminate the cost term in (19), we find that

$$\frac{\partial P_i(x_i, x_s)}{\partial x_s} = d_i \times (x_i - 2x_j) \qquad (20)$$

If $x_i > 2x_j$, then (20) is positive and x_s should be increased. Concavity ensures that increasing x_s lowers marginal cost in (18) and (19) and the result holds.

Corollary: If (20) is true for $x_s = 0$, the larger player, *i,* should acquire all of the content owned by the smaller player, *j*.

The situation is more complex than stated above because the smaller player must recognize the potential for the larger player to duplicate its content. Consequently, the smaller player faces an optimization problem that is more complex than (17) in that it must choose a minimum content level so that it is not optimal for the larger player to duplicate its content. That is, player j must first iteratively solve player i's optimization problem for x_s with x_i fixed until it finds the minimum level of x_j for which $x_s = 0$. Then it must solve its optimization problem with this as a lower bound. If the profit at this lower bound is negative, then player *j* does not enter or it exits the market. In a sense, the decision to duplicate or not has all of the features of a two-stage game with a closed-loop equilibrium.

Discussion of Models 2 and 3

We have analyzed two different duopoly games for the case where Web sites may have unique, as well as duplicate, content and it is possible to add new content. In Model 2 consumers make independent choices of which site they will use when they need an item of content offered by both sites. In this case, up to a certain point, neither Web site duplicates the content in the other Web site.

In Model 3, each consumer is attracted to the site that has (for him or her) the most unique information. The result for Model 3 states that, with concave costs there are two potential choices for an equilibrium. In the first case, the larger Web site duplicates all the content in the smaller Web site, forcing it out of business. In the second case, the larger Web site duplicates no content and the smaller site stays in business. The solution, once found, is unique. When costs are convex, the increasing cost of duplication can lead the larger player to not completely duplicate the content of the smaller player. Consequently, the smaller player can survive despite the size of the larger player.

The larger player has a limit-pricing game, similar to the one described in the context of Model 1. Say player i eliminates player j. The larger player's profit in (17) is maximized by having minimal content. However, to maintain its market dominance, it must acquire sufficient content to block the re-entry of player j. That is, the larger player may have to make a strategic investment, where price is below marginal cost.

6. WHEN COMPETING WEB SITES EXHAUST ALL RELEVANT CONTENT

In this section, we reexamine models 1, 2 and 3 for the situation where all possible content of interest to the relevant community is already available on one or the other of the Web sites.

Model 1': Exclusive Content, Market Exhausted

As in model 1, we assume that all content is exclusive to one or the other of the sites and that, therefore, no duplication (common content) is possible. In the simplest case, where $a \leq 1$ and the cost function is convex, we showed earlier that a unique equilibrium exists – if content is not exhausted. When content is exhausted, the largest player can add content up to the point where marginal cost equals marginal revenue. To find this point, we modify (5) to reflect that the content is exhausted so that player *i's* problem becomes

$$\max_{x_i \geq 0} P_i(x) = d_i \times \frac{x_i}{X} - C_i \times x_i \quad (21)$$

where *X* represents the totality of content of interest to the community. Taking the derivative of (21) player *i's* maximum potential content is at the point where either $x_i = X$ or

$$\frac{d_i}{X} = C_i'(x_i)\,. \quad (22)$$

Let $\hat{x}_i$ solve (22). Now, any solution $x_1 + x_2 = X$ that satisfies $x_1 \in [X - \hat{x}_2, \hat{x}_1]$ and $x_2 \in [X - \hat{x}_1, \hat{x}_2]$ is a potential equilibrium. For the non-convex version of model 1, a similar argument applies. Consequently, the equilibrium is path dependent and each player will race the other to capture content (as long as marginal revenue exceeds the marginal cost of the new content) until all that can be added has been added.

Models 2' and 3': Non-exclusive Content, Market Exhausted

From the previous analysis of models 2 and 3 with concave costs, when it is possible to add new information, either duplication does not occur or the larger player duplicates everything owned by the smaller player. In this section, we cover the situation where it is not possible to add new information. We take the initial positions in content as given and examine what happens when the players compete by duplicating the content of the other sites.

Model 2'

Let X represent the totality of content of interest to the community and assume that all the relevant content is covered by the Web sites. Given the initial captures of unique content of x_{iu} and x_{ju}, optimization model 2 (equation (11)) becomes

$$\max_{x_s \geq 0} P_i(x_{iu}, x_s) = d_i \times \frac{x_{iu} + \frac{1}{2} x_s}{X} - C_i(x_{iu} + x_s) \tag{23}$$

where x_{iu} is fixed at X-x_{ju}-x_s. Now x_{iu} is constant when player i moves to change x_s since any change in x_s by i reduces x_{ju} instead.

The derivative of (23) with respect to x_s is

$$\frac{\partial P_i(x_{iu}, x_s)}{\partial x_s} = \frac{d_i}{2X} - C_i'(x_{iu} + x_s). \tag{24}$$

That is, if any content is duplicated by the larger player, it is duplicated until the marginal cost reaches the constant $\frac{d_i}{2X}$ or until x_j is exhausted. This implies the following result.

Theorem 6: Assume that both players have the same marginal revenue, d, and the same cost function and that this cost function is convex. In model 2' if the players duplicate any information, then both players have equal shares even if one player can get an initial advantage before the content is completely covered. Furthermore, the equilibrium is unique.

Proof: Let x_s>0. If $x_s = X$, the result follows immediately. Otherwise, from (24), at an optimum point for each player, , we have

$$C'(x_{iu} + x_s) = C'(x_{ju} + x_s) = \frac{d}{2X} \tag{25}$$

If (22) holds and $x_s < X$, then

$$x_{iu} + x_s = x_{ju} + x_s. \tag{26}$$

This implies

$$x_{iu} = x_{ju}. \tag{27}$$

Given this, it is clear that the solution is unique, which completes the proof.

From (24) we can also conclude the following.

Theorem 7: In model 2', if $C_i(x)$ is concave and all content relevant to the community is covered, then either all or no content is shared.

Proof: If $C_i(x)$ is concave, (23) is convex. Since the maximum of a convex function lies at an extreme point, the result holds.

Model 3'

We now examine model 3 (equation (17)) for the case when all available content has been exhausted. The results follow the same pattern as in model 3. The optimization problem for player *i* is as follows

$$\max_{x_s \geq 0} P_i(x_i, x_s) = d_i \times \frac{x_i - x_s}{X - 2x_s} - C_i(x_i + x_s). \quad (29)$$

Taking the derivative with respect to x_s, we get

$$\frac{\partial P_i}{\partial x_s} = d_i \times \frac{-X + 2x_i}{(X - 2x_s)^2} - C_i'(x_i + x_s). \quad (26)$$

When player *i* has less than half of the market, (29) is necessarily negative. This means that player *i* never wants to acquire shared information. When player *i* has half of the market or more, the revenue term is convex and we can say the following.

Theorem 8: In model 3', if $C_i(x)$ is concave, then the dominant player duplicates either all of the content of the other player or duplicates none of the other player's information.

Proof: Again, the maximum of a convex function lies at one of its extreme points and (29) is convex in this case.

We can also say:

Corollary: If the cost functions are identical and any content is duplicated, either both players duplicate everything or the larger player eliminates the smaller player by completely duplicating its content.

If $C_i(x)$ is convex instead of concave, then it is difficult to characterize the equilibrium.

7. DISCUSSION OF RESULTS

Table 2 summarizes the major qualitative results from this analysis across all models. Note that we assume away differences between the firms in terms of marketing and Web site design. Furthermore, some of the results assume that the two firms have identical cost functions. Under these circumstances, only the value of the content on each site as perceived by users comes into play in the analysis.

The duopoly games analyzed in the previous sections have different solutions. In some cases, e.g. the convex version of model 1 and certain cases of models 2 and 3, a unique equilibrium point is assured. In other cases, the result of the game is uncertain.

Our analysis sheds light on two sets of questions. The first set of questions has to do with the strategies of the various players and the second set with the likely end state in the market. We discuss each in turn.

In model 1, when both players have exclusive information, the nature of the competition depends on the parameter a and whether or not the relevant content space can be exhausted. When $a \leq 1$, a functioning market with multiple competitors evolves. When $a > 1$, the players engage in a race for content and a natural monopoly can result. Nothing certain can be said about the outcome. This situation is indicated in Figure 4(a).

When content is not exclusive to either site (i.e., the same content may be displayed on both sites) the optimal strategies depend on the assumptions about user behavior.

Model 2 assumes that consumers visit sites randomly depending on their content needs at the time. In model 2 each player optimizes by differentiating itself through adding unique content up to the point where marginal revenue equals marginal cost, as long as new content is available. Once all the available content has been exhausted, the only avenue for growth for a player is to duplicate on its own site the content of the other player. In this case, with concave costs, either no content is duplicated or all of the content is duplicated. If no content is duplicated, the players end up with a share of the market based on their starting positions plus the unique content they

Table 2: Summary of Major Results

Model	Content Assumption	a	Demand Assumption	Cost Function	Interaction Between Players	Equilibrium
1 Thms 1, 2	Exclusive, Non-exhaustive	1	Share of market Equation (2)	Linear	Player 1 may initially *increase* content in response to an increase by player 2.	Unique equilibrium with multiple participants.
		>1	(As above)	Concave	Uncertain. Both players race for market share. Winner can take all. First mover advantage.	Not necessarily have an equilibrium. Can have a monopoly. Preemptive investment possible.
1'	Exclusive, Exhaustive	1	(As above)	Concave	(Same as above)	(Same as above)
				Convex	(Same as 1). Continuum of multiple equilibria. First mover advantage.	(Same as above)
2 Thm 4	Non-exclusive, Non-exhaustive	1	Equally likely to visit either site for shared info. Equation (9)	Concave	Neither website will duplicate content of the other as long as new material can be added. First mover advantage.	Can have a monopoly.
				Convex	(Same as above)	Unique equilibrium with both players positive
2' Thms 6 & 7	Non-exclusive, Exhaustive	1	(As above)	Concave	Either all or no content is shared. First mover advantage.	Two possibilities, either all or no content is shared.
				Convex	If any content is duplicated, both players will end up with equal shares.	Unique equilibrium
3 Thm 5	Non-exclusive, Non-exhaustive	1	Share of unique information Equation (10)	Concave	Smaller website never duplicates content of larger. Larger may duplicate all of smaller. First mover advantage.	Two equilibria; either largest player eliminates smaller player or no content is duplicated.
				Convex	Smaller website never duplicates content of larger . Larger may duplicate some or all of smaller. First mover advantage.	Multiple possibilities for equilibria
3' Thm 8	Non-exclusive, Exhaustive	1	(As above)	Concave	(Same as 3)	Two equilibria; either largest player eliminates smaller player or no content is duplicated.
				Convex	(Same as 3)	Indeterminant

obtain through new acquisitions. If all of the content is duplicated then, by definition, both players end up with equal shares of the market. The possible paths are indicated in Figure 4(b).

Model 3 assumes that consumers are attracted to a site based on its share of unique content. In this case, it never pays for the smaller Web site to duplicate content displayed on the larger site. However, it should continue to add its own unique content while it is available and while the marginal revenue of the unique content exceeds its marginal cost. If it does this quickly enough, it may end up becoming the larger player. The larger player may find it optimal to not duplicate any content from the smaller site. In this case, both sites will co-exist with whatever share of the market they are able to obtain with unique information. If it is optimal for the larger firm to duplicate content available on the smaller firm's site, then, with concave costs, it is optimal to duplicate all of the content and the smaller firm will be forced out of business. These results are summarized in Figure 4(c).

The above three models are driven by different assumptions about customer demand. It is therefore interesting to consider their implications for marketing strategies designed to shape customer opinions regarding content and community Web sites. In general, the advertising of large firms should emphasize their unique content and community features, since large firms have more to gain from a market characterized by model 3. On the other hand, smaller firms should emphasize the total size of their content and community offerings, since market model 2, offers more chance for survival for the smaller firm.We now turn to the second set of questions – those concerning the equilibrium state in the information game. The most important question is whether or not one firm can capture a market niche. From the above analysis, it is obvious that the larger Web site has a competitive advantage ceteris paribus. However, this does not always mean that the smaller Web site will be eliminated. Based on the market-demand assumptions, and arguing purely from the point of view of the attractiveness of the content to consumers, we have demonstrated a number of cases of competitive equilibria in which two firms coexist with positive market shares. If the smaller firm is in one of these situations, and especially if it employs good marketing techniques and efficient operations, it should be able to survive in the long term. In the cases where a player can completely capture a niche, typically, non-convexities create scale economies. If the content of an area can be exhausted, being first, and becoming the largest player is enough to lead to market control, as in model 3'.

As pointed out in Section 2 of the paper, x_i, the amount of content, is a proxy measure for the attractiveness of the site, which in many cases grows with the number of users of the site (through their additions to chat rooms, news groups, etc.). Positive returns in the cost of providing content can enter through the presence of a concave cost function as also discussed in Section 2. The economies of scale from operating in more than one community are not included in our models. When these economies occur, larger firms have an even greater advantage than indicated by our analysis.

8. CONCLUSIONS AND FUTURE RESEARCH

The different information games presented here provide some insights into the nature of the competition for "mindshare" among information and community sites. At present, we believe that the explosion of activity on the Internet best matches the class of games without duplicate content that we analyzed under Model 1. While many competing sites look very similar, most of the action appears to be in developing whole new areas of content. For example, sites such as how2.com and justwheels.com have identified unique and very plausible content areas.

In the near future, sites will expend more effort to duplicate the material on other sites and the second set of games (Models 2 and 3) will become more relevant as various market segments begin to consolidate.

In this paper, we have analyzed only a few of the many possible information games. For example, instead of assuming a homogeneous set of content items, we could define classes of content with a separate cost equation for acquiring content in each class. If we interpret x_i as the utility of the content (rather than as a measure of the quantity of information), having different cost equations can be regarded as having different values for different kinds of information. The above theorems would hold for each individual class of information. Then, in models 2 and 3, duplication could occur before the entire universe of relevant content is covered. Nevertheless, duplication within a class would not occur until the Web sites fully cover that class of information.

We have focused on equilibrium solutions and have not addressed the dynamics of the games. For example, our cost function does not differentiate between acquisition and maintenance of information. In understanding the evolution of the play in the game we need to see how the market evolves with content treated as either stocks or flows. If content is a stock, then it is cheap to maintain and path dependence is important. If it is a flow, it is expensive to maintain the flow of information. With content a flow, if a player duplicates another's information, then the smaller player may have to abandon the flow and the attacking player acquires a unique stream. If maintaining content is far cheaper than acquiring information, then once the content space for the community is exhausted, the larger site has a harder time dislodging the smaller site, since the smaller site pays the lower maintenance costs.

Another game is to determine if subscriptions should be charged for access to either specific classes of "premium" material within the site or to all material on the site. If it is optimal to charge a subscription price, the next issue is to determine its value. This brings in the traditional elements of oligopoly theory. As illustrated by the encyclopaedia example, an important aspect of this problem is the psychological discontinuity between allowing free access versus charging anything, no matter how small.

In all of these games we have presumed that the material can be acquired at cost. However, much of the content is provided by third parties. For example, Reuters is a major provider of financial information to Yahoo. This leads to situations where suppliers can play off Web sites against each other. Suppliers have to consider the costs and benefits of offering exclusives on the content they develop. To some extent, suppliers can play a monopoly game. Yet, they have to make sure that by favoring a supplier they do not create a dominant Web site and face a monopsony game.

Much of the run up in Internet stocks has come from people looking for the next Microsoft and Intel. Our analysis shows the potential for monopoly power. However, we do not see the potential for natural monopoly power over a correspondingly large a segment of the Internet market, or total mindshare, as these two companies have over the key valued-added segments of the personal computer market. Currently, Web communities are fragmented and there are few barriers to new communities forming. We have not investigated the possibilities of communities linking across providers or abandoning one provider for another. Furthermore, we have not looked into the value of acquiring one's competitors or companies that operate in adjacent communities.

Clearly, as the market becomes more complex, the positioning strategies of the various players become more elaborate and more features of the market must be considered.

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$$\max_{x_i \geq 0} P_i(x) = d \times \frac{x_i}{\sum_i x_i + b} - C_i \times x_i$$

where: d = 6, b = 0.5, C_i = 0.6

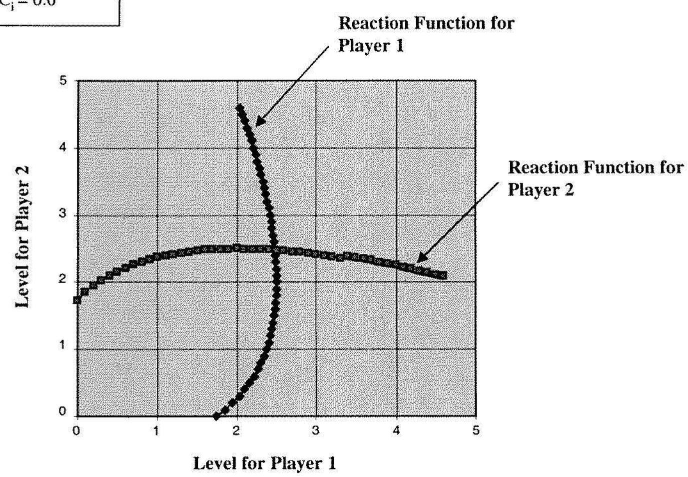


Figure 1
Reaction Functions & Equilibrium for Convex Version of Game 1

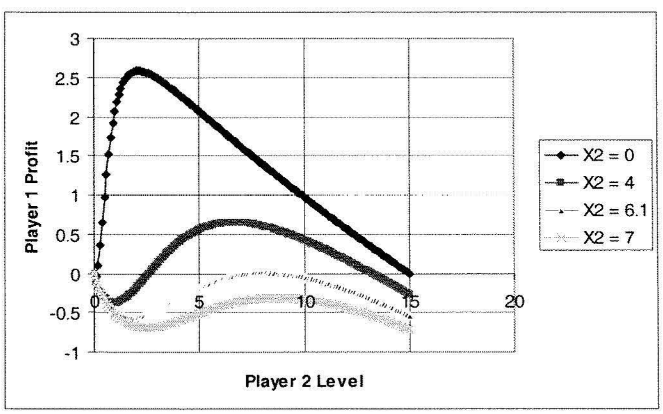


Figure 2
Player 1 Profit for Fixed Levels of Player 2 Content

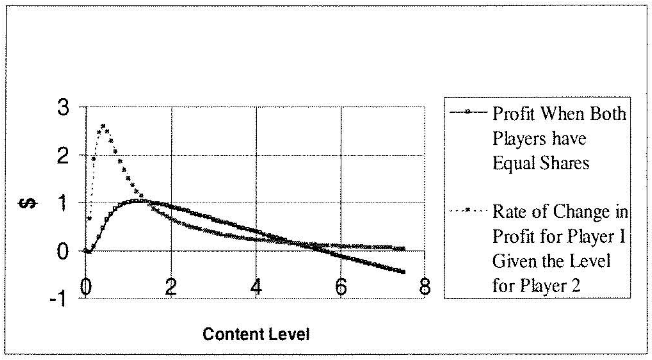
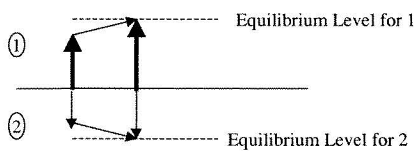


Figure 3
Relationship Between Profit and the Reaction Function

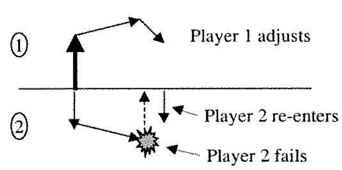
Model 1- Exclusive Content - Convex Case



Shares not necessarily equal - unless cost functions are the same

Players 1 and 2 could end up either higher or lower than their starting points

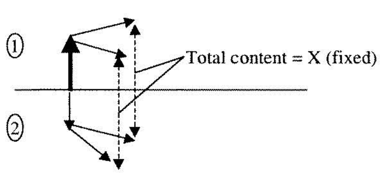
Model 1- Exclusive Content - Non-Convex Case



There is no equilibrium. Content increases on both sites until one drops out because its costs are too high.

The winning player adjusts downward creating an opportunity for reentry.

Model 1' - Exclusive Content, Non-Convex, Market Exhausted



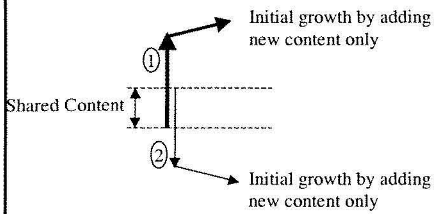
There is no determinant equilibrium.

Final state depends on actions in an indeterminant way

Figure 4(a)

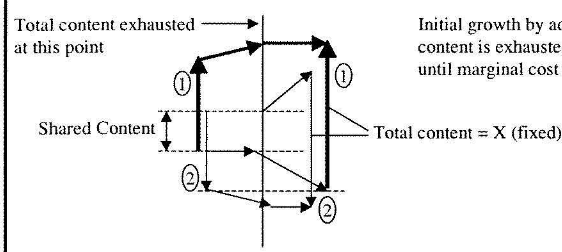
Duopoly Competing on Exclusive Content

Model 2 - Non-Exclusive Content



Final market shares not necessarily equal - unless cost functions are the same

Model 2' - Non-Exclusive Content, Market Exhausted



Initial growth by adding new content only. When the total content is exhausted, content is duplicated from the other's site until marginal cost = D/2X.

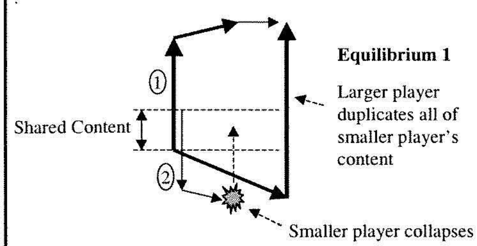
Final market shares are equal - if cost functions are the same

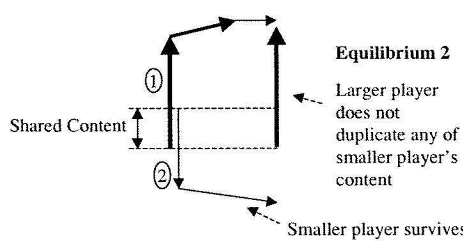
Figure 4(b)

Duopoly Competing on Non-Exclusive Content
Case of Independent Visits

Model 3 - Non-Exclusive Content

Smaller player never tries to duplicate information of larger player
If $2x_2 < x_1$, the smaller player (2) collapses
If $2x_2 > x_1$, there are 2 potential equilibria as illustrated.





Model 3' - Non-Exclusive Content, Market Exhausted

The results mirror those for the case when all the content is not exhausted.

If C(x) is concave, either the dominant player duplicates all of the content of the smaller player and the smaller player collapses or it duplicates no content - in which case the smaller player survives.

If C(x) is convex, the results are indeterminant.

Figure 4(c)

Duopoly Competing on Non-Exclusive Content
Case of Unique Shares