Determining Optimal Decisions for Investing in Connection Quality and Pricing Internet Services: An Economic Model of Duopoly Competition Between Internet Service Providers

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Abstract

As consumer demand for Internet access and online services continues to grow, so does the competition for market share (i.e., subscriptions) among Internet Service Providers (ISPs). According to recent surveys consumers rate two criteria as most important when deciding to subscribe, or continue a subscription, to an ISP:

- the **connection quality** provided to consumers by the network infrastructure. The connection quality refers to factors such as the accessibility, speed, and reliability of the Internet connection. Connection quality depends on the investments made in the ISPs network infrastructure (e.g., network bandwidth, router switching capacity, and server performance) and the number of subscribers served by that infrastructure. Decisions about connection quality affect the quality of services and, therefore, consumer demand for these services.
- the **price** charged by the ISP for access to its Internet services.

In this paper, we develop an economic model, based on the well-established model of R&D competition used by D'Aspremont and Jacquemin (1998) and Amir and Wooders (1998), to examine the trade-offs between decisions made about investments in connection quality and decisions made about pricing the services that result from these investments for firms competing in a duopoly market for Internet access and services. More specifically, we address the following research questions:

- How should an ISP determine the optimal investment in connection quality (or network infrastructure)?
- How should an ISP price its services and respond to changes in the investment and pricing decisions made by competing firms?
- How will falling technology prices (e.g., for network bandwidth, server capacity and performance, and other infrastructure technologies) affect the optimal investment and pricing decisions by ISPs in this market?

Two key findings in this analysis are that when considering a market for Internet services in which consumers are more sensitive to differences in price than differences in connection quality:

- Prices charged by ISPs should be positively correlated with each other (independent of differences in connection quality)
- Falling technology prices should encourage ISPs to invest more heavily in connection quality which will result in better access and service quality for consumers, but at higher prices.

The results of the analyses will help decision-makers in the Internet services market better understand the implications of their investment and pricing decisions on consumer demand for services and firm profits.

1. Introduction

Recently, growth in consumer demand for Internet access and services (e.g., email, personal web space, newsgroups, message boards, and chat rooms) has been explosive, a trend that is expected to continue over the next decade. In March of 1999, Yankee Group, a market research firm, estimated that about 25% of U.S. households had access to the Internet. However, the firm also predicted that the percent of U.S. households with online access would grow to 33% by the end of 1999 and to 66% by the end of 2003 (Fusco, 1999). In addition, it was estimated that over the next five years the online services market will grow at a compounded annual rate of 21% with households spending more than $56 billion on Internet access and services during this period.

Presently, the market for online services is dominated by America Online (AOL) which accounted for about 57% of the U.S. market as of March of 1999. Three other providers, Microsoft Network (MSN), AT&T WorldNet, and Earthlink (which recently merged with MindSpring) compete for the second position in the U.S. Internet access market, accounting for about 6%, 5%, and 4% of the market respectively.

These Internet service providers (ISPs) are competing aggressively for U.S. market share with a significant focus on targeting and attracting new (or potential) users of Internet services. According to Emily Meehan, analyst in the Yankee Group's Internet Market Strategies practice area, "Any company serious about obtaining double-digit market share must focus on the ***newbie market***; the 75 percent of households who have yet to get online." In fact, AOL Chief Executive Steve Case has said that even AOL is attempting to increase its subscriber base by focusing on the "95% of people out there who are not subscribers." (Richards, 1999) Therefore, many ISPs are attempting to develop services and pricing strategies that will not only attract existing Internet users but also attract new users.

However, for a potential customer of Internet services comparing ISPs is often difficult given all of the different services and pricing strategies available in the market. Several studies have attempted to identify the set of criteria that potential customers consider most important when deciding whether to subscribe, continue a subscription, or discontinue a subscription to an ISP. In particular, PC Magazine surveyed thousands of its subscribers to gauge customer satisfaction with their ISP (Miller, 1999).

Respondents rated ***price*** (40%) as the most important criteria in choosing an ISP. ***Speed of access***(33%)***, available local access numbers***(29%) and ***reputation***(26%), measures related to connection quality, followed price as important factors in choosing an ISP[1]. These findings suggest that while respondents are willing to pay for improvements in network availability and performance.

However, despite the importance of network criteria in customers' decision making, many ISPs rate poorly along these criteria. In fact, "U.S. Internet users are fed up with busy signals, leading to widespread dissatisfaction with Internet service providers and higher rates of users who switch ISPs" (Weil, 1998). Based on these observations, ISPs attempting to grow market share and attract subscribers should focus on developing strategies that carefully consider the trade-offs between the quality of network services provided to their subscribers and the price charged for those services.

In this paper we develop an economic model to examine the trade-offs between investments in connection quality and pricing of services for firms competing in a duopoly market for Internet access and services. Section 2 and 3 further motivate the focus on firm decisions about investments in connection quality and pricing of services. Section 4 presents the key research questions to be examined. Section 5 presents the model assumptions. Section 6 presents the initial model results. Finally, Section 7 concludes the paper and identifies some areas of future research.

2. Investing in Connection-Quality

ISPs may attract more customers by improving the quality of network services provided to subscribers. The connection-quality refers to factors such as the amount of up-time and accessibility, speed of Internet access, the reliability of connection, the amount of delays or packet loss, and the amount of personal web space made available to subscribers[2]. The connection-quality (and, therefore, the quality of network services) depends on the ISPs investments in network infrastructure – that is, the bandwidth of the network media, the switching capacity of routers, and the performance (e.g., disk and CPU capacity) of servers used by the ISP[3]. Investments in these network infrastructure components will generally lead to higher user satisfaction. For example, users desire broader network bandwidth (i.e., broadband network technology currently enabled by digital subscriber lines (DSL), cable-modems, and satellites) to meet their growing needs, including support for more dynamic web page usage, richer on-line multimedia experiences, and faster file downloading and messaging.

These investments in network and server capacity are usually considered fixed, long-term investments because it is technically difficult and expensive to increase or modify capacity in the short-term. Once a network bandwidth type, such as a 56K telephone line based service, has been adopted by an ISP significant investments must be made to change to a higher bandwidth type such as DSL, cable, or satellite. For

[1] Telechoice and Inter@active had over 1000 businesses complete an ISP Customer Satisfaction Survey in 1998. Respondent rated ***connection availability***, ***network performance***, and ***reputation for speed of diagnosis and repair*** as the most important criteria in evaluating an ISP. ***Price*** closely followed in importance with 80% of the respondents citing price as important in choosing an ISP.

[2] The Internet uses a technology called ***packet-switching***. The term ***packets*** (or frames, or cells) refers to the fact that data stream from a computer is broken up into packets of about 200 bytes (on average), which are then sent out onto the network. This technology is connectionless, meaning there is no end-to-end setup for a session; each packet is independently routed to its destination. With current technology, packets are generally accepted onto the network on a first-come/first-served basis. ***Routers*** are devices or softwares in a computer that determines the next network point to which a packet should be forwarded towards its destination. When traffic is heavy, the only way the Internet can handle the congestion is either by delaying traffic or by dropping (or discarding) packets so that some information must be resent by the originating software (Mackie-Mason and Varian, 1994; Nogueira and Cavalcanti, 1998).

[3] According to (Odlyzko, 1998):

"A study carried out in 1997 by Christian Huitema about accessing some popular servers showed that 20% were not reachable. Among the 80% that could be reached, 42% of the delays were caused by network transmission, with DNS [domain name server] accounting for 13% and servers for the remaining 45%."

example, Excite@home had to sign up with 23 cable TV partners in 1999 in order to begin providing cable-based services to its subscribers (Nee, 1999). In response to this and similar investments in bandwidth made by competitors, AOL announced in January 2000 a merger with *Time Warner*, a media company that owns the U.S.'s second largest cable systems; this merger would enable AOL to offer similar cable-based services. Investments such as these would generally be considered long-term investments.

One factor affecting an ISP's decision to invest in network infrastructure is the cost associated with these investments. The costs of broader network bandwidth, disk and CPU capacity of servers, memory, web space, and other infrastructure components have decreased dramatically over recent years. For example, prices for DSL service, a form of high-speed connection, are declining due in part to competition from cable-modem services. The aggressive launch of the cable-modem service, which like DSL offers speeds up to 100 times faster than conventional dialup service, has forced DSL providers to lower prices.

However, there is some debate regarding the impact of the declining costs associated with these infrastructure components on prices charged by ISPs. On one hand, according to David Pine, vice president of cable-modem provider Excite@Home, "With cable and phone companies, not to mention wireless and satellite providers, slugging it out with competing varieties of broadband Internet service, consumers can bet on ***lower prices***, more features and more innovation." (Woo, 1999). Alternatively, declining technology costs may encourage ISPs to invest in more network infrastructure than they would otherwise, leading to improvements in network quality. This, in turn, may lead to an increase in prices as profit-maximizing ISPs attempt to recover their investment costs and to take advantage of the increased demand for their "faster and more reliable" services.

3. Pricing Internet Access and Services

Flat-rate pricing refers to a pricing strategy adopted by many ISPs in recent years in which firms charge customers a fixed fee for unlimited – or limited – access to Internet services. This has been a common pricing strategy among ISPs in the U.S. market since 1996 (Swisher, 1999; Rafter, 1998). The fixed-rate charged by an ISP depends on:

- Investments in network infrastructure – Most of the costs of providing Internet services are the fixed costs associated with the network infrastructure. The incremental cost of sending additional packets (or information) is essentially zero if the network is not saturated. Therefore, the size of investment in network infrastructure will significantly affect the pricing of Internet services.
- Demand for the ISP's services – Customer demand will also drive prices. As discussed earlier, demand partially depends upon the connection-quality and content provided by the ISP (and, of course, the price) and consumers' sensitivity to these factors.

4. Research Questions

Therefore, as ISPs attempt to attract more subscribers, they must decide how to most appropriately invest in connection-quality and how to price the resulting Internet services they are offering; as we will see later, these decisions involve complex trade-offs. In this paper, we will examine the optimal investment and pricing decisions for firms competing in a duopoly market for Internet services in which subscribers gain access to these services through dial-up modem, DSL, or cable modem.

More specifically, we develop an economic model to address the following research questions derived from the discussion above:

1) How should an ISP determine the optimal investment in network infrastructure?

- This raises the question of whether or not an ISP should invest in more bandwidth and better server performance. That is, answering this question should help identify whether or not AOL should invest in relationships with *Time Warner*, *Bell Atlantic Corp.*, and *SBC Communications Inc.* to provide DSL and cable-modem services or just stay with its existing infrastructure of dial-up telephone lines.

2) How should an ISP price its services and respond to changes in the flat-rate prices charged by competing ISPs?

- In 1998, AOL raised its monthly subscription rate by $2, from $19.95 to $21.95 (Quistgaard, 1998). At the time, many observers expected competitors to quickly follow suit, raising the price of Internet access for everyone. However, after the rate hike, most ISPs kept their pricing the same while some even lowered their monthly rates to attract more subscribers (Heid, 1998). We will attempt to examine such dynamic behaviors in our models.

3) How will falling technology prices (e.g., for network bandwidth, server CPU capacity, memory, and other infrastructure technologies) affect ISPs' investment and pricing strategies in this market?

- As suggested earlier, while some believe that declining technology costs should lead to lower prices for Internet access, others believe that declining costs will encourage much larger investments in infrastructure (and, therefore, network quality), leading to price increases to cover the costs and accommodate for changes in demand.

While these questions are important to answer for ISPs, research on optimal investment and pricing decisions for ISPs has received little attention in the information systems and economics literature. In this paper we present an economic model to analyze the relationship between investments in connection-quality and pricing of Internet services.

Model Assumptions

We consider a two-stage model of duopoly competition in a market in which each firm provides consumers with unlimited Internet access and unlimited usage of services at a flat-rate price. We assume that subscribers access these services through dial-up modem, DSL, or cable modem[4]. In the first stage, the firms simultaneously invest in the network infrastructure (e.g., network bandwidth and server capacity) that enables and supports their service offerings. This investment essentially differentiates the connection-quality offered by each firm. In the second stage, each ISP observes the connection quality of its competitor. Then, based on these observations and the demand functions facing each firm, both firms simultaneously determine a flat-rate price to charge for access to their Internet services[5]. The services offered by each firm are somewhat differentiated (e.g., personalized content, personalized interface, special chat rooms, etc.), but can be substituted to some extent.

To analyze this two-stage game of duopoly we will adopt the well-established R&D competition model used by D'Aspremont and Jacquemin (1988) and Amir and Wooders (1998). We assume complete and perfect information in this model; that is, we assume that the payoff function for each firm is common knowledge and that firms can observe their past decisions and those of the competing firm. These assumptions are reasonable since:

- The technology investment options available for providing Internet access are standardized and the costs of technical support and software development are common knowledge. This implies that firms can estimate each other's profit functions.
- ISPs' investment decisions are generally made public to attract investors in the stock market. In addition, market intermediaries typically provide past investment information at a low cost.

The competition between ISPs is analyzed by solving subgame perfect equilibria of the two-stage game. After proving the existence of equilibria, we will use static analysis to analyze the impact of the model parameters on the equilibrium investment and pricing decision made by each firm.

In this two-stage model, Firm 1 faces a demand function for its Internet services, Q_1, which depends on the following:

- Its own price (p_1) and the competing firm's price (p_2) – the demand function implies that a decrease in p_1 or an increase in p_2 will increase consumer demand for Firm 1's services.
- Its investment (k_1) in connection-quality and the competing firm's investment (k_2) in connection-quality – the demand function implies that an increase in k_1 or a decrease in k_2 will increase consumer demand for Firm 1's services

The demand function is symmetric for each firm and is assumed to be linear in price and connection quality. The demand function for Firm 1 is:

$$Q_i = a - p_i + bp_j + k_i - ck_j$$

It is assumed that Internet services (e.g., email, newsgroups, chat rooms, and instant messaging) offered by each firm in the second stage are not perfect substitutes; that is, they are differentiated services to some extent. For example, ISPs may provide access to personalized content. The parameter values b (price sensitivity) and c (connection-quality sensitivity) attempt to capture this dimension. In addition, a represents the size of the market. These parameter values are assumed to be fixed, symmetric across firms, and exogenously given.

The cost function facing Firm 1 exhibits decreasing returns to scale in k_1 (note that the cost function is symmetric for Firm 2). α is a technology cost coefficient characterizing trends in the costs of infrastructure technologies. As the costs to purchase and install broader network bandwidth and better server capacity fall over time, α becomes smaller; if α approaches zero network infrastructure would be free to purchase and install. v is the variable costs per subscription associated with serving additional customers; more subscribers require more technical support which, in turn, requires more technical support assistants and phone numbers. In this model, we will interpret v as the industry standard support level per

[4] The assumption of duopoly competition seems reasonable since a small number of firms serve a large percent of the consumers of Internet access and services.

[5] As suggested earlier, ISPs typically invest in network infrastructure (which is usually considered a fixed cost because it is technically difficult and expensive to modify) and then price services based on these investments (and consumer demand)

subscription and we will take it as fixed, symmetric across firms, and exogenously given.

The total cost function is symmetric for each firm. The total cost function for Firm 1 is:

$$C_i = \alpha \frac{k_i^2}{2} + v_i Q_i$$

Finally, the profit function is symmetric for each firm. The profit function for Firm 1 is:

$$\Pi_i = (p_i - v_i)(a - p_i + bp_j + k_i - ck_j) - \alpha \frac{k_i^2}{2}$$

Parameter Assumptions: (i) a > v, (ii) $0 < b, c < 1$, and (iii) $\alpha > 8/9$

The assumption that a > v is trivial but required to ensure that optimal investments in connection quality are non-negative. The assumption that $0 < b, c < 1$ allows us to focus on a market in which a firm's own investment and pricing decisions have a greater impact on consumer demand for its services than do the decisions made by its competitor. The final assumption, $\alpha > 8/9$, ensures that the costs of technology are sufficiently large to make the firm's profit function exhibit decreasing returns to scale.

In addition, when examining this model we will assume that consumer demand for Internet access and services is more sensitive to changes in price than to changes in connection-quality. We will term this market a ***price-sensitive market***.

Definition: A market is defined as a price-sensitive market if $b > 2c$

We assume a price-sensitive market because, even though network criteria are important, changes in connection-quality are not as salient to consumers of Internet services than are changes in price. That is, consumers are typically are not fully informed about the connection qualities of each ISP. In addition, most consumers must incur some search costs to find this information either from magazines, consumer reports, or friends and family. Without precise information about connection qualities, many dial-up ISPs appear to provide similar content and features (and typically a standard 56K dial-up connection). However, price differences are easier to identify. Therefore, consumers are likely to be more sensitive to changes in price than to changes in connection-quality (but consumer demand is still sensitive to both in absolute terms). This may be especially true for first-time subscribers to Internet services, an important target of many ISPs. In addition to issues of saliency, the analysis of the price-sensitive market is more straightforward analytically that that of the connection-quality sensitive market[6].

5. Model Results

Based on these assumptions, we will now present the subgame perfect equilibrium in the two-stage model of duopoly competition[7]. In the first stage, the firms simultaneously determine levels of connection-quality through investments in network infrastructure. In the second stage, each firm observes each other's connection quality; they then simultaneously set flat-rate prices for unlimited access to their Internet services. We will begin our analysis in the second stage and identify the equilibrium price set by each firm.

Optimal Pricing Decisions (Stage 2)

The optimal pricing decisions, p_1^* and p_2^*, in stage 2 given the investment decisions, k_1 and k_2, made in stage 1 are:

$$p_1^*(k_1, k_2) = \frac{(b+2)(a+v) + (b-2c)k_2 + (2-bc)k_1}{4-b^2}$$

$$p_2^*(k_1, k_2) = \frac{(b+2)(a+v) + (b-2c)k_1 + (2-bc)k_2}{4-b^2}$$

These equations show that in a price-sensitive market Firm 1's Nash equilibrium price, p_1^*, increases not only with k_1 but also with k_2; that is, the coefficients for these two variables, $(b - 2c)$ and $(2 - bc)$ respectively, are both positive given Assumption (ii) and the definition of a price sensitive market presented in Section 5. More specifically, these equilibrium price equations imply that if Firm 2 makes an incremental investment in connection-quality (i.e., increases k_2) it will also increase p_2 to compensate for its incremental investment and to respond to changes in consumer demand for its improved services. However, Firm 1's profit-maximizing response would be to increase its own price, p_1 (without making an incremental investment of its own). However, the increase in p_1 should be less than the increase in p_2. This is because from the equations we see that:

$$\Delta p_2 = (2 - bc)*\Delta k_2 \qquad \text{and} \qquad \Delta p_1 = (b - 2c)*\Delta k_2$$

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[6] When considering a price-sensitive market, each subgame at the second stage of the two-stage model shows a unique, interior, Nash equilibrium. However, when considering a connection-quality sensitive market both interior and boundary Nash equilibria exist. While we have performed the analysis for the connection-quality sensitive market, we are unable to present the results here due to the complexity of the analytics and the space limitations.

[7] Due to space limitations we are unable to present the derivations of these results. However, they can be obtained by contacting the authors.

Given Assumption (ii) we know that $(2 - bc) > (b - 2c)$ which implies that Firm 1 will respond to an increase in k_2 by increasing its price, p_1 (despite making no changes to its own connection quality, k_1), but by an amount less than Firm 2 increases its price. The intuition is that in a price sensitive market Firm 1 has an opportunity to increase its margins (by increasing p_1) while still attracting switchers from Firm 2 (by not increasing p_1 by too much). Again, this result relies on the assumption that these firms compete in a market in which consumer demand is more sensitive to differences in price that to differences in connection quality.

These pricing equations also imply that an increase in v, the industry standard variable costs per subscription, will lead to an in increase in the equilibrium prices charged by both firms, given the investment decisions, k_1 and k_2, made in stage 1. This result is intuitive as the firms would need to increase their flat-rate prices to compensate for (or cover) the higher variable costs associated with providing service and support to consumers.

Optimal Investment Decisions (Stage 1)

The optimal investment decisions, k_1^* and k_2^*, in stage 1 are:

$$k_1^* = k_2^* = \frac{2(2-bc)(a-v(1-b))}{\alpha(b+2)(2-b)^2 - 2(1-c)(2-bc)}$$

That is, in equilibrium both firms will invest equally in connection-quality in stage 1. Of course, this also implies that both firms will charge the same equilibrium price in Stage 2.

These equations also imply that an increase in v will lead to a decrease in the optimal investments decisions, k_1^* and k_2^*, made in Stage 1. This reduction is designed to partially offset the positive correlation between v and equilibrium prices in Stage 2. By making a smaller investment in stage 1, the firms will "cushion" the impact of v on price in stage 2; this result is critical for firms competing in a price sensitive market where consumer demand is more sensitive to changes in price than to changes in connection quality.

The Impact of α, the Technology Cost Coefficient, on Equilibrium Decisions

A decrease in α implies that advances in technology have led to a reduction in computing prices and, therefore, a reduction in the costs of purchasing and installing network infrastructure. According to the equations for k_1 and k_2 such a decrease would encourage firms to increase their investments in connection quality in stage 1 (as implied by the positive α in the denominator of these equations and shown in Figure 1); in fact, firms increase their investments, k_1 and k_2, so much that their total investment costs increase despite the reduction in α. In turn, this will imply an increase in prices charged (see Figure 2), and an increase in profit earned, for both firms in stage 2. The intuition is as follows: as α decreases, an increase in connection quality will now have a smaller affect on pricing decisions made in stage 2 (although the effect is still positive). This will encourage firms to increase their investment in connection quality to increase their profits in stage 2. This result suggests that as investments costs, such as those associated with changing a 56K modem connection to a cable-modem connection, decline that this market will result in better connection quality for consumers, but at higher prices.

Figure 1. Impact of decreasing technology cost on connection quality

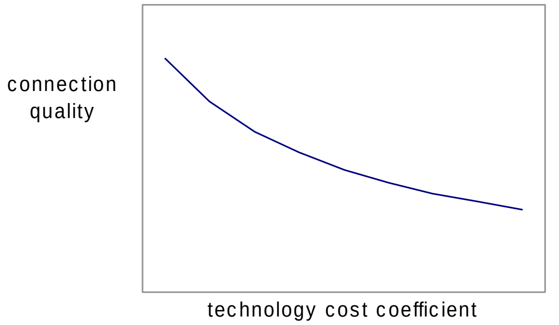
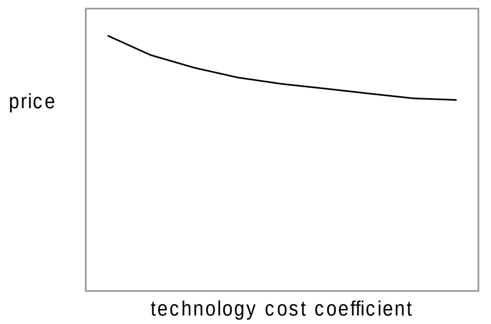


Figure 2. Impact of decreasing technology cost on price



7. Future Research

In this paper we examined a two-stage model of duopoly competition in a market in which each firm provides consumers with unlimited Internet access and unlimited usage of services at a flat-rate price. Two key findings in this analysis are that when considering a market for Internet services in which consumers are more sensitive to differences in price than differences in connection quality:

- Prices charged by ISPs should be positively correlated with each other
- Falling technology prices should encourage ISPs to invest more heavily in connection quality which will result in better access and service quality for consumers, but at higher prices.

The results of the analyses will help decision-makers in the Internet services market better understand the implications of their investment and pricing decisions on consumer demand for services and firm profits.

In future research we plan several model extensions to better account for complexities (e.g., alternative pricing strategies) in the market for Internet services. In addition, we will develop models to address the following research questions:

1) How will the results presented in this paper change if the market is assumed to be a ***connection-quality sensitive market*** (i.e., $b < 2c$) as opposed to a price sensitive market (i.e., $b > 2c$)?

- Changing this assumption will lead to a very different set of results than presented in this paper and, therefore, a very different set of prescribed strategies for profit-maximizing ISPs. We will examine these critical differences in detail in future research.

2) Under what conditions will an ISP decide to offer ***free Internet access and services*** to the market?

- Since 1998, the market for Internet access and services has seen the emergence and growth of free ISPs – that is, firms that offer customers access to Internet services for free (e.g., NetZero, Blulight.com, iFreedom.com, and WorldSpy). Most of these firms earn profits through advertising subsidies – that is, by charging sponsors fees for online advertising space (e.g., advertising banners or windows). We will address the emergence of free ISPs in more detail in future research. More specifically, we will examine the conditions under which offering free Internet access and services will be an equilibrium strategy. More specifically, we will attempt to characterize the advertising subsidy that must be provided to sustain this strategy in equilibrium.

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