Mergers in Network Industries

Chapter · January 2003

1 author:

Sean F Ennis
University of East Anglia

Mergers in Network Industries

Sean F. ENNIS*
OECD, Competition Division, Paris

■ Introduction

In a point-to-point network, a member joins the network of one particular firm and values that membership based on the number of other individuals, or points, the member can reach. Because some individuals belong to other networks, members of a point-to-point network typically value connections between their network and other networks[1]. By connecting to others, a network increases the quality of the product it offers its members and can increase the price it charges for this product. Once connected to other networks, the network serves both as a supplier to all its connected networks, by providing other networks with access to its own members, and as a buyer, or receiver, from all its connected networks, by gaining access to the members of connected networks. Point-to-point networks exist in a variety of industries, including telecommunications, energy, banking and transportation.

Frequently, the terms of connection between individual networks are regulated. The nature of the regulation varies, however, and the reasons for the variation are not always apparent. Most importantly, unless unregulated incentives yield market distortions, there is little economic rationale for the regulation of interconnection prevalent in some network industries. In this paper we seek to understand how mergers may impact interconnection payments in unregulated network industries. Such mergers have occurred,

* The opinions expressed here are those of the author and do not necessarily reflect those of the OECD or its members. I thank Myriam Davidovici, Michael Katz, Angeline Liu, Bob Majure, Alex Raskovich, and seminar participants at the US Department of Justice, the FCC, Leuven University, TPRC and Euro CPR for many helpful comments. I gratefully acknowledge EGIDE, ENST, and Gérard Pogorel for providing support and hosting this research.

[1] There are at least two exceptions to this generalization: (1) when all the people with whom one values communicating are already on one's network, as may be the case with a company employee who only wants to send and receive emails to other people at that company or (2) when other networks generate more negative effects, such as from junk email, than positive effects.

for instance, with respect to automated teller machine networks (as with numerous bank mergers) and with respect to the Internet backbone (as with the MCI-WorldCom and the WorldCom-Sprint mergers).

In order to understand how mergers impact interconnection payments, we need to begin by answering the question: why do firms connect their networks to each other? The benefits of increased aggregate network size to individual members certainly play a role in explaining why networks interconnect. However, the precise incentive mechanism that governs interconnection decisions of firms is relatively poorly understood. This paper develops a model of how incentives operate to examine the implications of that model for mergers. The foundation for the analysis is the derivation of an individual network's incentives from aggregating the representative member's value of network participation over the network's members. Narrowly, our goal is to explain the potential behavior of Internet providers after mergers. More broadly, though, the goal is to explore how the key characteristics of interconnection behavior arise from individual utility functions.

We assume that all potential members are already members of a network, in contrast with the model of CREMER, REY & TIROLE (2000) in which new subscribers are joining networks and the expectations of new subscribers drive the ultimate network structure (KATZ & SHAPIRO, 1985). We thus focus on mature networks as opposed to growing networks. Understanding the behavior of mature networks is important since many networks are relatively mature, including the Internet. When networks have reached a mature stage and there are switching costs, subscribers' expectations are less important to a network's choice since the subscribers already experience lock-in effects. The primary choices faced by mature networks govern interconnection fees.

The Internet is an aggregate network consisting of many individual, unregulated networks. Each Internet provider could exist independently and serve its customers independently[2]. However, most service providers have chosen to connect with each other, either directly or via intermediaries, even in the absence of regulations that require them to do so[3]. As a result of these

[2] In this paper, an internet provider is a backbone provider capable of picking up and delivering internet protocol messages from multiple locations in the USA and world. Internet backbone providers are assumed to have similar costs per member and similar technical capabilities.

[3] Networks that did not provide full web interconnection in the past, such as AOL and Prodigy, now provide full web interconnection. It is worth noting, however, that even now, the Internet

connections, a user of a particular network can generally contact a user of another network without major difficulty. Nonetheless, two networks may value their connection differently even if they send the same quantity of traffic in each direction across their interface. A critical question then becomes what terms of connection will be set.

Interestingly, the carriers of Internet traffic with the largest networks generally do not charge each other to exchange traffic[4]. However, the large networks do charge smaller networks for connectivity[5]. Thus there is an asymmetry in the pricing of interconnection that is related to the size of networks. Our model explains such asymmetric pricing even in the absence of cost differences. Thus, to at least a minimal degree, the model conforms to some important stylized facts about the industry. We then apply this model to assess the impact of mergers between networks.

To understand the incentives for interconnection between networks, we must first understand how a network earns profits. The revenue value of a network is the sum of its members' network values. The primary factor in the calculus of interconnection is therefore the extra value each network derives from connecting to the other, based on each member receiving an incremental increase in the value of belonging to an enhanced network. When one network benefits more from interconnection than the other, a bargaining outcome arises in which the surplus from interconnection is shared. The network that receives the most value from interconnection pays the network that receives less value.

In particular, we find that the benefits of bilateral interconnection for two networks of different sizes vary systematically depending on the marginal value to a user of adding new users to a network. Generally, when consumers experience decreasing marginal value from adding new users to their network, the benefit of interconnection is likely to be greater for the smaller network than for the larger network[6]. In this situation, one might

---

does not provide truly universal interconnection. There are still some networks, typically in developing countries, that cannot be reached from others.

[4] These carriers are frequently called Tier 1 Internet backbone providers, but this paper refrains from using this terminology, instead focusing on more externally identifiable features such as the number of subscribers. This paper shows that the contractual nexus of tier 1 providers and the free exchange of traffic between them may be seen as a consequence of the externally identifiable features.

[5] See § 27 and § 54 of European Commission, 2000.

[6] This intuition has been mentioned by MILGROM *et al* (1999), but has not yet been formalized or systematically analyzed to my knowledge.

expect the small network to pay the large network for interconnection.

Conversely, when consumers experience increasing marginal value from adding new users to their network, the total benefit to a large network of interconnection to a small network is greater than the value to the small network. In such a situation, one might expect the large network to pay the small network for interconnection.

This paper begins by modelling the value of interconnection and then demonstrates how mergers may impact the incentives for bilateral interconnection.

■ Model

The model focuses on the different values of bilateral interconnection between networks and how those values vary with asymmetric network sizes. We assume that two networks send identical quantities of information in each direction across their network interface [7]. Thus any difference in the value of interconnection that we may find is not the result of asymmetric inbound and outbound traffic, but is instead the result of different network sizes.

In this model, no regulations require interconnection or set any terms for interconnection. In particular, there is no requirement that interconnection charges be symmetric. This contrasts with other recent work such as ARMSTRONG (1998) and LAFFONT *et al* (2001) where access charges are set symmetrically. When access charges are symmetric, two networks sending equal amounts of traffic to each other will not make net payments to each other. In general, there is no reason to believe this restriction would apply in the absence of regulation. It is important to relax the symmetry requirement to analyze the asymmetric incentives for interconnection.

[7] This pattern of traffic could arise in the context of email, when sending an email results in a return email, or in video conferencing, when each person is sending a large quantity of audiovisual information while simultaneously receiving that amount of information. Clearly, in these contexts, two networks of very different sizes may have identical traffic flow in each direction.

A network is allowed to charge another network a fee for interconnection. The net result of these charges is the interconnection fee [8].

A user of a network derives a value $v(n)$ from belonging to a network with n users. $v(n)$ is twice continuously differentiable. We say a network effect is present if there are n if, as network size increases, value to the user increases. Stronger network effects are present when the slope of $v(n)$ is closer to 1.That is, $v'(n)>0$. If network i has n_i users, then the non-interconnected network value is the sum of the individual values, or $n_i v(n_i)$. On all τ networks jointly, there are a total of N users, where $N = \sum_{i=1}^{\tau} n_i$.

If all networks connect with each other, then an individual derives benefit $v(N)$. The minimum value of network membership is 0, since a network with just one member yields no network benefits, or $v(1)=0$.

Each user is a member of one and only one network. Members have a switching cost s that is the sum of a network exit cost s_e and a network joining cost s_j [9]. For simplicity's sake, we assume switching costs are such that $s_e+s_j>v(N)$. Users will thus not choose to switch networks. If a member's network ceases operation, the member will necessarily experience the exit cost so s_e will not be a choice variable. The member may then subscribe to another network, by paying just an entry portion of the switching costs s_j. We examine a mature network structure in which all members have already incurred a joining cost in the past. Networks charge existing subscribers the full current value of the network. If the value of the network to a user rises or falls, the charge to the user will rise or fall commensurately.

Physical costs of network operation are c per subscribing member. For analytical ease, there is no cost of interconnection. We assume that $v(n_i)>c$, $\forall i$ unless stated otherwise.

Suppose there are two networks, network i and network j, that are considering interconnecting and that have the technical capability to connect because they have compatible technology. They have n_i members and n_j members respectively. How does each network value the interconnection?

[8] Such a net price could be achieved, for example, by two networks setting fixed charges to each other for interconnecting their two networks or by setting different per unit rates for traffic going in one direction or another.

[9] These switching costs might arise, for instance, from a user's fixed email address that cannot be ported to another network.

The value of interconnection to a network can be represented as the difference between its network value when it connects and its network value when it does not connect. This measures the opportunity cost of not connecting.

When connected, the members of network *i* thus derive a value of interconnection with network *j* of

$$V_i=n_i v(n_i+n_j)-n_i v(n_i).$$

Similarly, network *j* derives a value of interconnection with network *i* of

$$V_j=n_j v(n_j+n_i)-n_j v(n_j).$$

Even though networks *i* and *j* will exchange equivalent quantities of traffic with each other, V_i and V_j need not be equivalent. When there is a difference between the values, the network with the greater value from interconnection will then pay the other network for the interconnection, as a result of negotiation over mutually beneficial gains based on the bilateral NASH bargaining solution (NASH, 1950; LOPOMO & OK, 2001) [10]. The economic opportunity for one network to charge another for interconnection arises since, after interconnection, each network experiences increased revenues from the extraction of increased values from members.

We begin by comparing the values of interconnection between two networks. We consider first identically-sized networks, then the case in which the network value function is linear, and finally the cases in which the network value functions are concave and convex.

The NASH bargaining solution suggests that when there are no differences between the value of interconnection for two networks, as would be the case for identically-sized providers, we might expect no interconnection fee. Such a result would be consistent with contracting practices between internet providers, similar-sized providers typically do not charge each other for interconnection [11].

Now consider the simple case of a linear network value curve where firms are different sizes such that $n_i \leq n_j$ and let that straight line be the line that

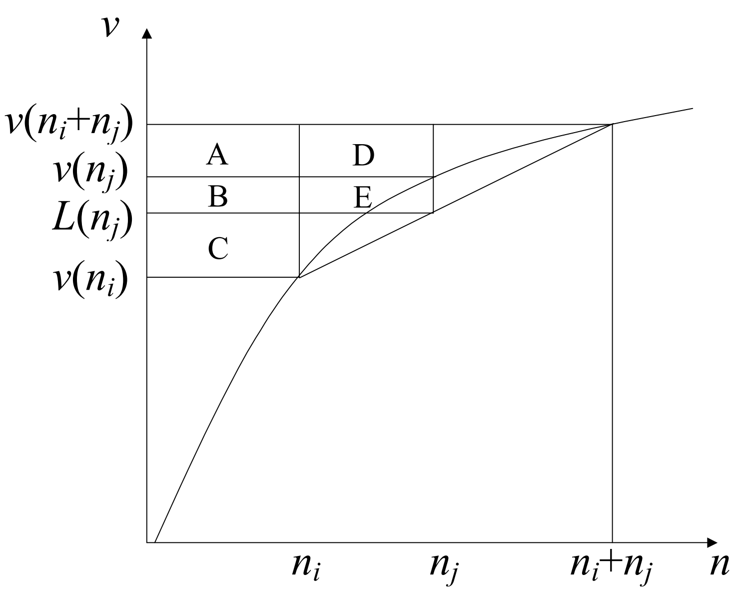
---

[10] Note that networks do behave in ways consistent with a NASH bargaining solution. For example, the physical costs of interconnection are split evenly between large networks. See § 24 of US Department of Justice (2000).

[11] See § 27 of US Department of Justice, 2000.

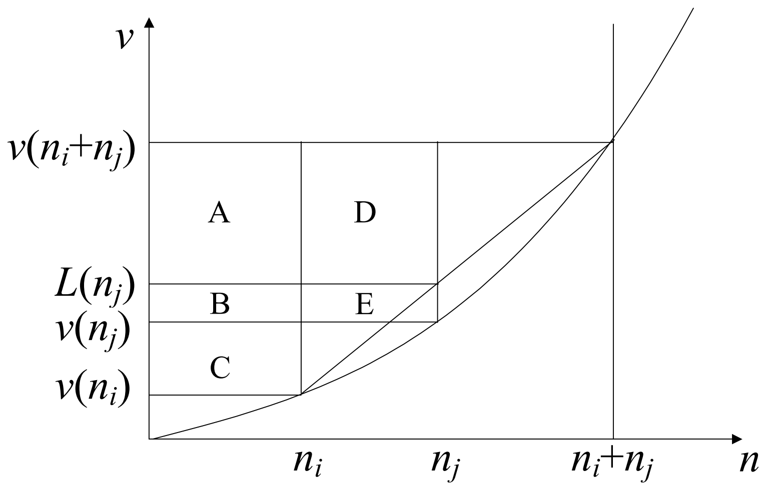
connects points (n_i, $v(n_i)$) and (N, $v(N)$). A user of a small network will value interconnection more than the user of a large network by an amount that is directly proportional to the size of the two networks. However, the difference in values will be precisely counterweighted by the difference in the number of members of each network. As a result, the networks' value of interconnection will be identical. In terms of Figure 1, since the value of interconnection for network *i* is area *A*+*B*+*C*, and the value of interconnection for *j* is the sum of areas *A*+*B*+*D*+*E*, we know that *C*=*D*+*E*.

Figure 1. Decreasing Marginal Returns to Network Size



In contrast, when the member's value function is concave or convex, we find that large and small networks place different values on interconnection. In the case of a concave network value curve of Figure 1, the value of interconnection for *j* is given by *A*+*D*, and the value of interconnection for *i* is the same, as in the linear case, or *A*+*B*+*C*. Since *B*+*C*>*D*, the value of interconnection is larger for network *i* than for network *j*. In the linear case, *C* represented the non-common value of interconnection for *i*, since *A* and *B* were shared in common with *j*, and *D*+*E* represented the non-common value of interconnection for *i*. In short, concavity increases the non-common value of interconnection for the small network *i* and decreases the value for *j* [12].

Figure 2. Increasing Marginal Returns to Network Size



When there are decreasing marginal returns to network size in the member's network value function, the small network will value interconnection more than the larger network. Assuming a bilateral NASH bargaining solution, the large networks will then charge the smaller ones for interconnection. In Figure 1, the amount paid will be (*B*+*C*-*D*)/2.

In contrast, when there are increasing marginal returns to network size, the large network will value interconnection more than the small one. Figure 2 represents increasing marginal returns case. In Figure 2, for a linear network value curve, *D*=*B*+*C*. The value of interconnection for *j* is then *A*+*B*+*D*+*E* and the value of interconnection for *i* is *A*+*B*+*C*. Because *D*+*E*>*C*, network *j* (the large network) experiences a greater gain than network *i* (the smaller network) [13]. As a result, the small network will then charge the large one for interconnection yielding a payment of *(D*+*E*-*C)*/2.

This result extends to environments with more than two networks as long as there is a common expected value of network size assuming interconnection.

[12] For a formal proof, see proposition 1(iii)a of ENNIS (2002).

[13] For a formal proof, see proposition 1(iii)b of ENNIS (2002).

Generally, the concavity or convexity of the consumer's network value function is more critical for outcomes than the strength of the network effect itself. The slope of the value function $v'(n)$ measures the strength of the network effect. We see that the slope per se is not relevant to determining the sign of the net difference in values of interconnection; rather, the changes in slope, or concavity and convexity, are critical to determining the sign of the net differences. Strong network effects can be present without providing any indication of whether small networks will pay large networks for interconnection or not.

When there are decreasing marginal returns to network size, small networks will prefer to band together and achieve their connections with large networks through intermediaries rather than through direct contracting. With decreasing marginal returns, the per member value of interconnection is lower for larger group sizes. Direct interconnections are more costly per member, assuming that the cost of forming an intermediary is moderate. That is, the valuation difference for the group will be less than the sum of the valuation differences of the individual members. As long as the costs of coalition formation are not too high, hierarchical contracting may be preferred to direct contracting with large providers.

This finding is consistent with the hierarchical nature of the internet (see U.S. Department of Justice, 2000). Smaller networks frequently purchase service from medium-sized networks who, in turn, purchase service from large networks. This hierarchy makes sense in an environment of decreasing marginal returns.

Under increasing marginal returns, a hierarchy does not make sense, since small size is then an advantage for bargaining. All else equal, large firms in fact prefer to break themselves up into smaller units to reduce their costs of interconnecting.

Let us move on to consider the role of mergers in affecting the values of interconnection.

■ Merger

Understanding the nature of interconnection value is important for policymakers trying to decide how to treat interconnection. Apart from regulating the nature of interconnection itself, for example, by requiring symmetric access fees [14], there may also be regulatory questions with regard to mergers of interconnecting networks [15]. This section shows that the impact of mergers depends to a great extent on whether the value of interconnection has increasing or decreasing marginal benefits in the relevant range.

Network mergers may impact the actual costs of network provision through economies of scale or scope. A larger network may have lower physical costs per network user, thus increasing the efficiency of the merged networks while placing competing networks at a cost disadvantage. The ultimate dynamic effects of such cost efficiencies can be complex and are not considered here. Because we assume constant costs per subscriber, there are no cost effects of mergers in the model we develop. Rather, merger effects arise from changes in bargaining threat points.

Let there be three networks, *i*, *j*, and *k*, with n_i, n_j, and n_k members respectively. $N=n_i+n_j+n_k$. A merger between networks *j* and *k*, yields a new network of size n_j+n_k. Prior to the merger, each of the three networks must sign two different contracts in order to obtain interconnection, yielding a total of three contracts. After a merger, there is only one contract to sign since there are only two networks.

Let $V_x^y(n)$ represent the value to network *x* of interconnection with network *y* when the expected post-contracting network size of both networks is *n*. We leave out *n* when the expected accessible network size is clear from the context. We refer to the "value difference" for *x* and *y* as the difference between V_x^y and V_y^x. The "aggregate value difference" for *x* is the difference between V_x^y and V_y^x summed over all other networks. That is, when there are τ other networks besides network *x* the aggregate value difference for *x* is given by $\sum_{y=1}^{\tau}\left(V_x^y - V_y^x\right)$.

The aggregate value difference is important because, under NASH bargaining, the amount of network *x*'s payments or revenues from interconnection is one half of the aggregate value difference. In order to examine the impact of a merger between two other networks on *x*, we

[14] The FCC has required symmetric access charges for local access, for instance, while other countries such as New Zealand have chosen to eliminate regulation of access charges (see LAFFONT & TIROLE, 2000).

[15] In the WorldCom-Sprint merger, two of the largest Internet backbone companies proposed to join their backbones which would have resulted in them having 56% of Internet traffic (see US Department of Justice, 2000).

calculate the aggregate value difference for *x* prior to a merger and that after a merger. If the value difference increases after a merger, that means that network *x* benefits more from interconnection after a merger, and thus it will pay more to other networks (or receive less from them) than it did prior to the merger.

Assume NASH bargaining. Because there are always gains from trade, networks believe there will be complete interconnection and this expectation is fulfilled in equilibrium, as in CHIPTY & SNYDER (1999). In the expectations model, networks already have or believe they will have network interconnections with other networks, and thus the key issue in a bilateral negotiation rests on the impact of not having the current contract. Order of contracting does not matter.

In the expectations equilibrium, a network might expect to maintain full interconnection, because there will always be gains from interconnection that could be split between the networks. If there is a merger, the merger will affect the base valuation of the non-merging networks, but will not affect the base valuations of the merging networks.

Proposition 1

Suppose there are three networks, *i*, *j*, and *k*, of arbitrary size, in which each member has a value function such that $v'(n)>0$. Suppose that networks *j* and *k* merge. In equilibrium: (i) if $v''(n)<0$, the merger results in an increase in the value of interconnection to network *i* relative to the merged networks. (ii) If $v''(n)>0$, the merger will result in a decrease in the value of interconnection to network *i* relative to the merged networks.

Proof of (i). Prior to the merger, network *i* will contract separately with network *j* and network *k*. In each negotiation, network *i* assumes that it will be successful in negotiating with the other network. Similarly, *j* and *k* assume they will be successful in negotiating with each other. In the negotiation with network *j*, network *i* will have a value of interconnection $V_i^j - V_j^i$

$$n_i v(N) - n_i v(N - n_j) - [n_j v(N) - n_j v(N - n_i)] \qquad (1)$$

Similarly, in negotiating with *k*, network *i* will have a value of interconnection $V_i^k - V_k^i$

$$n_i v(N) - n_i v(N - n_k) - [n_k v(N) - n_k (N - n_i)]. \qquad (2)$$

The sum of equations (1) and (2) then represents the pre-merger aggregate value difference for network *i*,

$$V_i^j - V_j^i + V_i^k - V_k^i = n_i v(N) - n_i v(N - n_j) - [n_j v(N) - n_j v(N - n_i)] + n_i v(N) - n_i v(N - n_k) - [n_k v(N) - n_k v(N - n_i)] \quad (3)$$

The post-merger aggregate value difference for network *i* is:

$$V_i^{jk} - V_{jk}^i = n_i [v(N) - v(n_i)] - (n_j + n_k)[v(N) - v(n_j + n_k)]. \quad (4)$$

The difference between the post-merger aggregate value difference (4) and the pre-merger aggregate value difference (3) for *i* simplifies to

$$v(n_i + n_j) + v(n_j + n_k) - v(N) - v(n_j). \quad (5)$$

If (5) is greater than zero, then we know that the value difference for *i* increases as a result of a merger between *j* and *k*. Under NASH bargaining, this would imply that network *i* increases its payments to the merging networks as a result of a merger and that the merging networks would improve their bargaining position with respect to network *i* by merging. In contrast, if (5) is less than zero, then we know that the value difference for *i* decreases as a result of a merger. Under NASH bargaining, this would imply that network *i* would decrease its payments to the merging networks as a result of a merger.

We know that $n_i<n_i+n_j<N$ and that $n_i<n_i+n_k<N$. The concavity of the value function indicates that $v(n_i+n_j)$ lies above the linear combination of $(n_i, v(n_i))$ and $(N, v(N))$ at (n_i+n_j) and that $v(n_i+n_k)$ lies above the linear combination of $(n_i, v(n_i))$ and $(N, v(N))$ at (n_i+n_k). Substituting the values of the linear combination at (n_i+n_j) and (n_i+n_k) respectively, both

$$v(n_i + n_j) > \frac{n_k v(n_i) + n_j v(N)}{n_j + n_k} \quad (6)$$

and

$$v(n_i + n_k) > \frac{n_j v(n_i) + n_k v(N)}{n_j + n_k} \quad (7)$$

Summing (6) and (7), we have

$$v(n_i + n_j) + v(n_j + n_k) > v(N) + v(n_j)$$

or: $v(n_i + n_j) + v(n_j + n_k) - v(N) - v(n_j) > 0$

So the post-merger aggregate value difference for network *i* is greater than the pre-merger aggregate value difference.

Proof of (ii). The proof applies the definition of convexity rather than concavity, but follows the same method as for the proof of (i).

These propositions are illustrated for three initially identical networks in Figures 3 and 4, where each network has n_c members. Prior to a merger, no payments are made because the firms are equal in size and thus in benefits. In Figure 3, with decreasing marginal returns, after the merger, the large firm derives a value of interconnection of *A*+*D* and the small firm derives a benefit of A+*B*+*C*. *B*+*C* is larger than *D*, so the small firm pays the larger firm for interconnection after the merger. In Figure 4, the large firm derives a value of interconnection of *A*+*B*+*D*+*E* and the small firm derives a benefit of interconnection of *A*+*B*+*C*. Since *C* is less than *D*+*E*, the larger firm pays the small firm after a merger.

Figure 3. Merger with Decreasing Marginal Returns

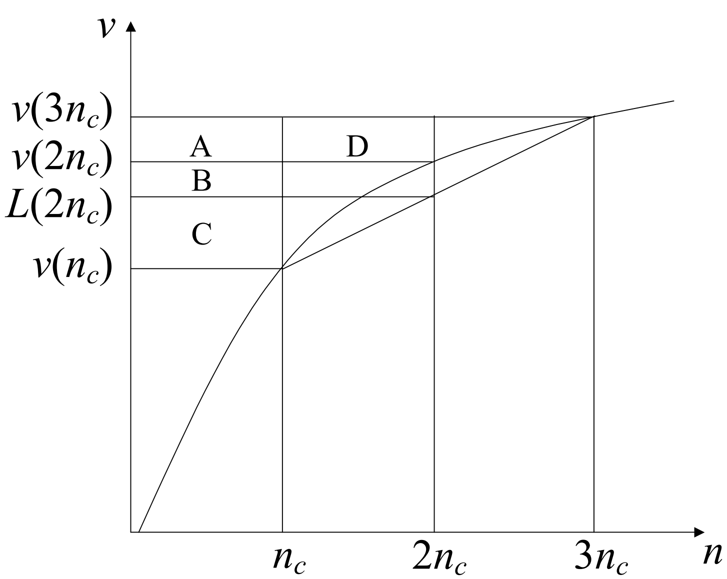
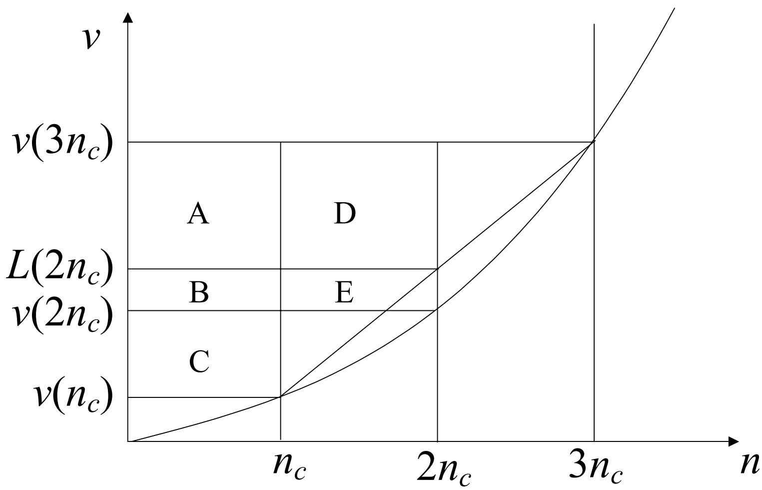


Figure 4. Merger with Increasing Marginal Returns



From the perspective of a non-merging network *i*, the number of users who cannot be reached in absence of the contract with the merged entity is larger than the number of users who cannot be reached in absence of a contract with either of the constituent merging firms. In contrast, from the perspective of the merged network and its constituent original firms, n_i users are unreachable in case no contract is signed with network *i* both before and after a merger. So the change in the net value of interconnection arises from changes in the non-merging network's value of interconnection, not the merging network's value of interconnection.

Proposition 1 is similar to Proposition 2 of CHIPTY & SNYDER (1999) who examine a monopoly seller contracting with multiple independent buyers in a one-way network (ECONOMIDES & WHITE, 1994). In contrast, we examine a situation in which each firm is a supplier to the others and in which the network value arises from the summing of many individual valuations. The difference arises because the Internet is a two-way, point-to-point network. The proof of our proposition is thus quite different. Each network supplies access to its members and receives access to the other networks' members. Assuming decreasing marginal returns, the members of the smaller network clearly experience a larger marginal gain from interconnection than the members of the larger network. At the small network, fewer members receive a larger marginal gain while at the large network, the marginal gain from interconnection is smaller, but a larger number of members receive it.

Note that no assumption is made in proposition 1 about firm size. If two small networks merge and there is a concave value function, they will receive an advantage in their bargaining posture. However, they may still be net payers of fees to a third larger network; they would simply pay less than before.

For tractability, the analysis here focuses on a scenario with three networks. However, the result also applies when there are more networks. What matters for the bilateral contracting decisions is the change in the value difference between the merging network and the other contracting party. Adding other networks to the model is equivalent to raising the size of each side's "base" network, but does not alter the outcome because, in equilibrium, each network expects to maintain or achieve complete contracting, so the base of users a network expects to reach expands from one's own users to all the other users apart from those in the contract under consideration.

An interesting implication of proposition 1 is that when there are increasing marginal returns to network size, the merging networks have a higher valuation difference than prior to the merger. Assuming the change in valuation differences is reflected in prices, a merger would yield higher expenses for the merging networks. In order for such a merger to make sense, either efficiencies must counterbalance the increased network costs or the large network must plan not to interconnect.

■ Conclusion

This paper provides a foundation for evaluating the value of interconnection to networks of different sizes. Both network size and the shape of the representative consumer's network value function are critical to determining an individual network's assessment of the gains from interconnection. The model examines networks of fixed size with simple cost structures in order to focus on the issue of the value of interconnection. The model is most relevant in industries for which the installed base matters more than unaffiliated consumers.

When an individual network value function exhibits *declining* marginal returns to network size, a small network derives more value from interconnection than a large network. If this value difference extends to pricing, small networks may pay larger networks for interconnection. To receive more advantageous terms from larger networks, small networks may join together to form coalitions that lower the per-member fee for interconnection. A merger disadvantages the non-merging networks by increasing the loss in network size from failing to contract. However, mergers need not generate a loss in welfare from within this model, since the model focuses on an installed base of consumers with unit consumption [16].

In contrast, when the individual network value function exhibits *increasing* marginal returns to network size, a large network derives more value from interconnection than a small network. If this value difference extends to pricing, large networks may actually pay smaller networks for the privilege of interconnection. A merger would lead the merging networks to pay even more for interconnection.

The shape of the value function is more important for these results than its slope. That is, the direction of payment for interconnection does not depend on the actual strength of network effects in a given market, given by the steepness of the network value cure, but instead on the shape of the network value function.

A key practical question is whether a consumer's value function can be well-represented and, if it can, whether the function has increasing or decreasing marginal returns in the region of interest. Many features of the Internet are consistent with a declining marginal returns value function and inconsistent with an increasing marginal returns function. Large internet providers often charge smaller providers for interconnection, equal-sized providers do not charge each other for interconnection and small providers often choose to contract with larger providers through a hierarchical structure rather than a direct contract. If we then conclude that internet providers operate in a decreasing marginal returns environment, a merger of large providers is likely to yield a price increase to existing paying customers and may yield a conversion of non-paying customers to paying customers, as the size disparity rises.

The existence of interconnection fees should not necessarily be taken as proof of market power since there are real network complexity costs from interconnecting with a large set of providers. More importantly, to the extent

[16] A more complete dynamic analysis of networks with some switching customers, however, may yield a result in which higher interconnection prices reduce output.

that developing a network requires innovation that would not occur in absence of market power, the market power may be justified in much the same way as patent rights are justified. On the subject of market power, we should note that, if one adopts the view that large networks have excessive market power when there are concave network value functions, then small firms would have excessive market power in the presence of convex network value functions.

Beyond the internet backbone, we find instances both of decreasing marginal returns to network size and of increasing marginal returns. On the one hand, for example, we expect decreasing marginal returns in peer-to-peer file sharing networks, where the objective of users might be to find specific songs stored on other users' computers. New peers add fewer and fewer new songs to the network as the network size increases, because as the network grows larger, most of the songs a peer brings to the network are duplicative. Thus the marginal value of additional users declines as the number of users increases[17].

On the other hand, for example, we expect increasing marginal returns to network size when networks are completed. Once the last unconnected person joins a network, it may be possible to significantly enhance the utility of members. In the case of email, for instance, when the last person a member wants to reach joins the email system, the member may experience a significant enhancement in the value of the network.

In review, the model of this paper is highly stylized. Yet the model does appear to capture many of the basic industry facts related to internet backbone interconnection. Useful additions would include an explicitly dynamic analysis of network size over time, a reduction in switching costs so that the installed base of users is more likely to switch between existing networks and an introduction of heterogeneous consumer types.

[17] See ASVANUND *et al* (2001) for an exploration of the declining marginal benefit of adding new users to OpenNap networks, that operate much like Napster prior to its shutdown.

References

America Online. (2000, September 22): 10-k. SEC EDGAR Archive.

AOL Time Warner. (2001, November 14): 10-q. SEC EDGAR Archive.

ARMSTRONG M. (1998): Network interconnection in telecommunications. *The Economic Journal*, 108, 545-564.

ASVANUND A., CLAY K., KRISHMAN R. & SMITH M. (2001, September 24): Bigger may not be better: An empirical analysis of optimal membership rules in peer-to-peer networks. (TPRC Conference, http://www.arxiv.org/ftp/cs/papers/0109/0109106.pdf).

CHIPTY T. & SNYDER C. (1999): The role of firm size in bilateral bargaining: A study of the cable television industry. *Review of Economics and Statistics*, 81 (2), 326-340.

Commission Decision of 28 June 2000 declaring a concentration incompatible with the Common Market and the EEA agreement. (2000). (Case No. COMP/M. 1741-MCI WorldCom/Sprint)

Complaint for the U.S. Department of Justice, United States of America v. WorldCom, Inc., and Sprint Corporation, Civil Action no. CV 01526. (2000).

CRÉMER J., REY P. & TIROLE J. (2000): Connectivity in the commercial internet. *The Journal of Industrial Economics*, XLVIII (4), 433-472.

ECONOMIDES N. & WHITE L. J. (1994): Networks and compatibility: Implications for antitrust. *European Economic Review*, 38 (3-4), 651-662.

ENNIS S. (2002): *Network connection and disconnection*. Economic Analysis Group Discussion Paper, 02-5, April. Antitrust Division, U.S. Department of Justice.

KATZ M. L. & SHAPIRO C. (1985): Network externalities, competition, and compatibility. *American Economic Review*, 75 (3), 424-440.

LAFFONT J.-J., MARCUS S., REY P. & TIROLE J. (2001): Internet interconnection and the off-net-cost pricing principle. (Mimeo Toulouse, April 23)

LAFFONT J.-J. & TIROLE J. (2000) : *Competition in telecommunications*. Cambridge, MA: MIT Press.

LOPOMO G. & OK E. A. (2001): Bargaining, interdependence, and the rationality of fair division. *RAND Journal of Economics*, 32 (2), 263-283.

MILGROM P., MITCHELL B. & SRINGESH P. (1999, September 25-27): *Competitive effects of internet peering policies*. (Mimeo from Telecommunications Policy Research Conference, 1999).

NASH J. (1950): The bargaining problem. *Econometrica*, 18, 155-162.

SEGAL I. (1999): Contracting with externalities. *Quarterly Journal of Economics*, 114 (2), 337-388.