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**Working Paper**

## Network Externalities and Interconnection Incentives

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and Interconnection Incentives**

Margit A. Vanberg

**ZEW**

Zentrum für Europäische  
Wirtschaftsforschung GmbH

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## **Non-Technical Summary**

The majority of industrial organizations literature on network externalities treats network externalities in an oligopoly context. The focus in this literature is to understand firm behavior under given market characteristics. The present paper, instead, analyses whether network externalities can, in fact, change market characteristics. Can network externalities lend network specific market power to market players and thereby allow one or more firms to dominate the market? What does this imply for interconnection incentives between competing network operators in a market characterized by network externalities?

The paper comes to the conclusion that only when a network operator previously has network specific market power due to the ownership of a monopolistic bottleneck network area, can network externalities increase the market power of the network owner by helping him to transfer dominance to related markets. In this case network externalities increase the need for regulation. Besides network access regulation to the monopolistic bottleneck there is a need for the regulation of open standards between the bottleneck area and related markets, such that competitors on these markets can benefit equally from indirect network effects which emanate from the monopolistic bottleneck network area.

In competitive markets or in contestable natural monopolies, however, network externalities will not lend network specific market power to the largest competitor. The market process can be expected to find many innovative ways of solving the trade-off between ensuring compatibility between competing networks when network externalities are important and safeguarding variety of service. The paper concludes that government imposed compatibility requirements will not be able to outperform the market.

# Network Externalities and Interconnection Incentives

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## Abstract

The majority of industrial organizations literature on network externalities looks at firm behavior under given market characteristics. The present paper instead asks the question whether the presence of network externalities can change market characteristics, specifically, whether an initially large market player can decline cooperation (interconnection) with competing network operators and thereby gain a dominant position when network externalities are significant. The paper comes to the conclusion that only when a network operator already has network specific market power due to the ownership of a monopolistic bottleneck network area, will network externalities enable the operator to increase his market dominance. In competitive markets or in contestable natural monopolies, however, network externalities will not lend network specific market power to an initially large operator. In these markets, the market process can be expected to solve the trade-off between ensuring cooperation between competing operators and at the same time safeguarding competition in product characteristics and quality of service.

**Keywords:** network externalities, interconnection, regulation

**JEL classification:** L15; L43

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## 1 Introduction

The majority of industrial organizations literature on network externalities treats network externalities in an oligopoly context. The focus in this literature is to understand firm behavior under given market characteristics. The present paper, instead, analyses whether network externalities can, in fact, change market characteristics. What is the effect of network externalities on competition and cooperation in network industries? Can network externalities lend network specific market power to market players and thereby allow one or more firms to dominate the market?

The paper uses the disaggregated regulatory approach (see Knieps, 2000) to isolate the effects that network externalities have on market structure and the competitive process. The analysis comes to the conclusion that only when a network operator already has network specific market power due to the ownership of a monopolistic bottleneck network area, will network externalities enable the operator to increase his market dominance. In this case network externalities increase the need for regulation. Besides network access regulation to the monopolistic bottleneck, open standards need to be enforced between the monopolistic network area and markets related to this area by indirect network effects. In competitive markets or in contestable natural monopolies, however, network externalities will not lend network specific market power to an initially large operator. Market intervention is counterproductive in these cases.

The paper is organized as follows. Section 2 discusses the characteristics of network externalities. Section 3 introduces the disaggregated regulatory approach and discusses relevant parts of the literature on network externalities with a view to the question of how the presence of network externalities influences market processes. Conclusions are presented in section 4.

## 2 Defining Network Externalities

Network externalities are a special kind of external effect. External effects are present whenever the production or consumption of a good or service results in costs or benefits experienced by third parties without these parties receiving compensation for the costs incurred respectively paying for the benefits received. The lack of a price attached to the external effect prevents market processes from leading to an efficient production or consumption level of these goods.

When the benefit received from consuming a good or service is positively related to the number of other purchasers of the good, then this good exhibits positive network externalities. Formally,

when the utility  $U_{i,j}$  that individual  $i$  receives from consuming a particular network technology  $j$  is dependent not only on the product characteristics of product  $j$ ,  $T$ , but also on the number of other users of this technology,  $S$ , then this utility function reflects network externalities:

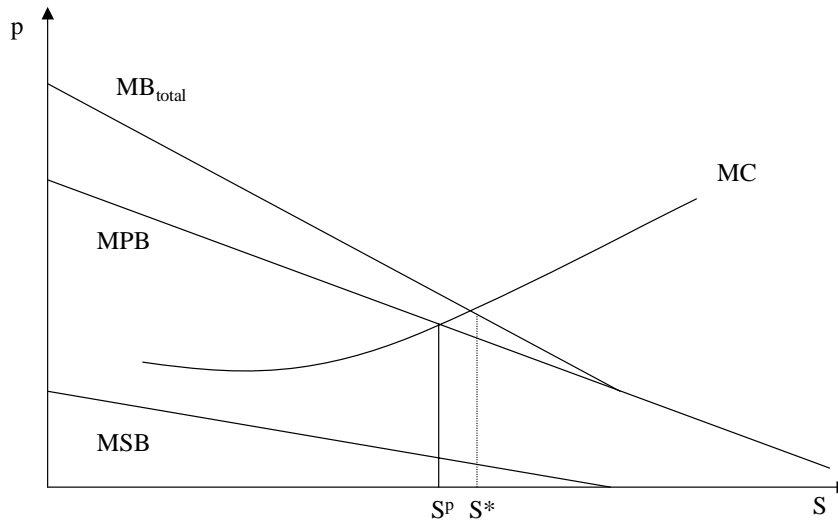
$$U_{i,j}(S, T) < U_{i,j}(S', T); \quad \text{for } S < S'$$

The utility derived from the consumption of a network good can be decomposed into two components (Blankart and Knieps, 1992: 80) the “technology effect”, measuring the utility derived from the product characteristics of the network good and the “network effect” measuring the utility derived from the number of other purchasers of the same good. When the network effect is of high importance, as for instance in communication networks, (think, for instance, of fax machines), then the utility of being the only person to consume this communications technology may correspond to  $U_{i,j}(1, T) = 0$ . On the other hand, when the technology effect is of particular importance, then a consumer can derive a higher utility from consuming the most preferred technology (with characteristics  $T_1$ ), even when there are less users of this technology compared to the second placed technology (with characteristics  $T_2$ ):  $U_{i,1}(S, T_1) > U_{i,2}(S', T_2)$ , for  $S < S'$ .

The term externality is applied for utility functions exhibiting these properties because the demand effect which results from an increase in  $S$  is not internalized through the price system of the market. Existing users do not reveal the extra benefit they obtain from additional users by, for instance, compensating newcomers for the benefit they bring to the installed base. Rather, new consumers base their decision for or against purchasing the technology only on their own preferences for the product characteristics and on their knowledge of the existing and perhaps the expected size of the user base.



**Figure 2.1: Unexploited gains from further network participation**



While a static analysis is inappropriate to study external effects in the context of dynamic industries the simple diagram depicted in Figure 2.1 serves well for the purpose of illustrating that in the presence of network externalities the equilibrium network size will generally be smaller than the socially optimal network size such that the competitive equilibrium is likely to reflect an inefficient welfare loss. Figure 2.1 shows the marginal cost function (MC), the marginal private benefit (MPB) and the marginal social benefit (MSB) functions for a network good. The total benefit function (MB<sub>total</sub>) exceeds the private benefit function because it includes the benefits which accrue to other users of the technology when an additional user joins the network. In the social optimum, the level of network participation would be  $S^*$ , in which the sum of the private and social benefits from further network participation (MB<sub>total</sub>) are equal to the marginal cost incurred by the marginal consumer. The private equilibrium  $S^p$  is smaller than  $S^*$ , however, because a user will purchase the technology only when the private benefits received exceed the private marginal costs. The private consumption decision leads to too little network participation compared to the social optimum. Only coordination between the users of the technology can internalize the external benefits and increase network participation to  $S^*$ . Existing consumers would, for instance, have to agree to subsidize the marginal consumer. The question of how and when users will coordinate their consumption decisions in the presence of network externalities will be taken up again in sections 3.3 and 3.4.

## 2.1 Direct and indirect network externalities

Before analyzing the consequence for the functioning of market mechanisms from the presence of network externalities, it is worthwhile to introduce a few more definitions. In the basic definition of network externalities given above, it was assumed that the network effect is a function only of the number of purchasers of the same good. The literature on network externalities distinguishes more precisely between direct network externalities and indirect network externalities (Katz and Shapiro, 1985: 424). The term direct network externalities refers to the immediate effect the size of a network has on the utility received from participation in that same network. This is the effect introduced above. The term indirect network externalities refers to the effect the size of a network can have on markets for complementary goods or services. When the number of subscribers of a network increases, this can positively affect the variety of complementary goods and services offered on complementary markets. A common illustration of indirect network externalities is the interrelationship between the diffusion of compact disc players and the variety of CDs offered. Early adopters of compact disc players experienced a utility increase from the later broader diffusion of CD players, because only then did the variety of CDs offered reflect the full spectrum of music styles. In general, it can be said that indirect network externalities often occur on markets interrelated by a so-called hardware/software relationship.

## 2.2 Pecuniary network externalities

A further distinction made in the literature on externalities is the one between pecuniary network externalities and technological network externalities. As will be shown below, pecuniary network externalities are demand effects that are transmitted through the price system, whereas technological network externalities impose benefits (or costs) outside of market mechanisms. Since pecuniary externalities are common in network industries, it is worthwhile to consider this point at length.

Pecuniary network externalities can, for instance, result from an outward shift in demand in a decreasing costs industry. When the demand shift allows the producer to reach a lower level of production costs both new consumers and existing consumers benefit from a lower price level. Formally the utility increase to existing consumers could, of course, also be illustrated by the utility function  $U_{i,j}(S,T)$  introduced at the beginning of this chapter. However, the difference to “real” external effects is that in the case of pecuniary externalities the utility increase is only indirectly related to the number of network participants. The direct relationship is between the fall

in prices, induced by increased participation, and the resulting increase in consumers' surplus. Existing consumers appropriate the increase in consumer rents as a result of a functioning price system. So, in fact, with pecuniary externalities there is no external social benefit when an additional user joins the network. Obviously, it is inappropriate to use the term 'externality' in the context of pecuniary effects, since they are transmitted through the price mechanism of the market.

Liebowitz and Margolis (1994: 137) find that the traditional differentiation between technological and pecuniary externalities is not consistently applied in more recent work on network effects. The large fixed costs associated with setting up a network infrastructure make economies of scale common in network industries. Networks therefore regularly feature pecuniary effects. Because communications networks are also prominent examples of markets characterized by technological network externalities, the distinction between these effects is not always evident.<sup>1</sup> In a policy context it is however important to distinguish the two effects. Pecuniary externalities should not attract policy intervention because they are a part of a functioning price mechanism. Technological externalities may, however, justify policy directed at internalizing the externality. Section 3 will go deeper into the analysis of when policy intervention is called for and when the market can be expected to generate alternative institutions to internalize external effects, such as, for instance, private standardization committees (see Blankart and Knieps, 1993 and Knieps, 1994).

### **2.3 Pareto-relevance of network externalities**

It is important to realize that not all correctly identified technological network externalities result in too little network participation, even when no deliberate internalization of the external effect is given. External effects that are inframarginal, in the sense that they would not change the equilibrium outcome even if internalized into the market mechanism, do not lead to a pareto-inferior equilibrium (Liebowitz and Margolis [1994: 140]). The scenario of inframarginal externalities is a realistic one because it is reasonable to assume that while many networks profit from increasing membership up to a critical size, further growth beyond that point would yield no further external benefit. Rather, when the critical size of the network is small relative to the

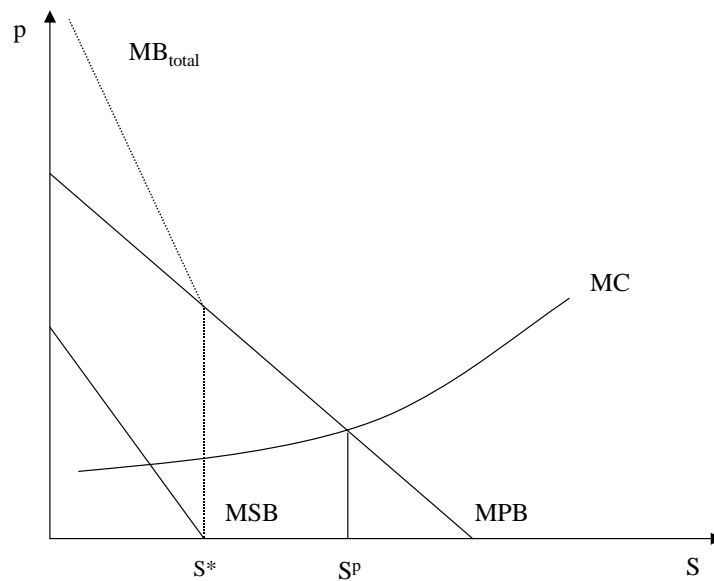
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<sup>1</sup> It may be that the confusion Liebowitz and Margolis (1994) identify in the context of network industries with respect to the differentiation of pecuniary and technological externalities is explained by the following: Network industries, at least in part, are often characterized by economies of scale in the relevant output region. These network areas, as natural monopolies, lend market power to the incumbent firm, such that the market process cannot be relied upon to bring about the socially optimal outcome. The close relationship between economies of scale and pecuniary effects may explain why pecuniary externalities are sometimes classified as cases in which market mechanisms lead to unwanted outcomes.

number of potential members, several networks can coexist and compete for membership. Therefore, whenever network effects are inframarginal, policy interventions in the market would be misguided.

Figure 2.2 is a graphic illustration of inframarginal network externalities in a static environment. The marginal social benefit from further network participation is zero once network size has reached  $S^*$ . Because the private equilibrium  $S^P$ , where marginal private benefits equal marginal private costs, is to the right of  $S^*$ , the socially optimal equilibrium coincides with the private equilibrium.

**Figure 2.2: Inframarginal network externalities**



If one considers policy intervention a viable means of correcting market outcomes which are thought to be inefficient due to externalities, then they can only be justified when the external effects to be corrected are pareto-relevant in equilibrium. If the external effects are inframarginal, intervention will create deviations from the efficient outcome, rather than help to eliminate them. Of course, determining the pareto-relevance of network externalities presupposes that the cost and benefit schedules are known. Because such knowledge is generally not available to policy makers, there is always a great risk of false positives (and false negatives) in these policy decisions.

## 2.4 Network externalities, product variety and innovation<sup>2</sup>

As was shown in Figure 2.1, internalizing pareto-relevant network externalities requires that consumers gather on one uniform technology as long as the marginal social benefit from further network participation continues to be positive. However, when consumers derive utility not only from network size but also from the product characteristics (the technology effect), internalizing network externalities in this way may not correspond to the socially optimal solution. When consumers' tastes for product characteristics differ, there may be a conflict between internalizing network externalities and catering to individual preferences. Consumers with heterogeneous tastes will not be able to agree on a single preferred set of product characteristics. They may prefer to consume a variety of products offering less network benefits to compromising on product characteristics in order to maximize the utility received from belonging to one network.

This problem is similar to the trade-off between optimal firm size and product variety in the context of production economies of scale. With falling average costs over the relevant output region, exhausting production economies of scale is possible only at the expense of less product diversity. When consumers have heterogeneous tastes, it is however not necessarily in society's interest to decrease product diversity in order to decrease production costs. There is an extensive body of literature devoted to finding the socially optimal solution to this conflict [See for instance Lancaster (1975), Spence (1976), Dixit and Stiglitz (1977)]. A general result of this literature is that when consumers prefer product variety, then higher costs of producing more variety do not necessarily reflect an inefficiency in the market. Rather, the increase in utility from consuming a product close to the individual preferences can compensate for the additional resources devoted to production in this market. Transferring this result to the trade-off between network externalities and product variety indicates that not to reach the optimal network size in a market featuring pareto-relevant network externalities may not indicate an inefficiency when this is a result of more product variety in the market.

There is a further reason not to prefer the exhaustion of network externalities by requiring all consumers to choose one network. Only an environment which offers diversity will bring about product innovations. Such innovations are important in dynamic markets with continual technological progress. Consumers participate in the search for better technologies by trying out

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<sup>2</sup> See Blankart and Knieps (1994) for a more elaborate discussion of the trade-off between externalities, variety and innovation.

new products. Markets featuring network externalities are at a disadvantage with respect to this competition of new ideas because new entrants offering newer technologies have no established customer base and can therefore not offer the same benefits from the network effect as established firms. Consumers may be reluctant to try out the new products which have a disadvantage in the network effect and offer only uncertain benefits with respect to their new product characteristics.

It is not likely that decentralized decision-making by consumers will solve the trade-off between externalities, variety and innovation. A single consumer cannot choose the technology he or she would prefer in equilibrium without knowing how the other consumers in the market will decide in different constellations. Because this information is impossible to come by, a consumer can always take a wrong decision. Because of this, the question arises whether policy intervention can help resolve the conflict between network size, variety and innovation. However, also policy makers would need to know the individual consumers' preferences and would have to aggregate them in order to approximate a socially optimal policy. Strictly speaking, policy makers would furthermore have to take into account the development of future technologies to solve not only the conflict between network size and variety but also take into account new innovations. Given that this information cannot be obtained, it is impossible that policy intervention can bring about a socially optimal outcome (Blankart and Knieps, 1994: 458). Therefore, neither free market mechanisms nor public policy is optimal. This discussion is taken up again in section 3.4.

## **2.5 Summary**

The purpose of this section was to draw up the deviations from perfect competition to be expected in markets exhibiting network externalities but to also heighten the awareness for the pitfalls of calling for market intervention whenever externalities are suspected. For one thing, it is possible that the externalities are not technological or even if they are, that they are not relevant in market equilibrium. Furthermore, it was argued that even when network externalities are pareto-relevant in equilibrium, there is a trade-off between network size, variety and search for new technologies, such that internalizing the externalities is not always the optimal solution. Resolving the trade-off between these three goals is far from a simple task. Both non-intervention market outcomes and policy-induced outcomes will not be able to solve the trade-off optimally. Section 3 is devoted to analyzing the functioning of market processes in the presence of network externalities. Based on the findings of this analysis an evaluation of the market outcomes and the possibilities for policy measures is possible.

### 3 Market processes in the presence of network externalities

The implementation of policy measures geared to internalizing external effects, for example the implementation of a Pigouvian tax, was traditionally considered a viable means of restoring efficient production in the presence of external effects.<sup>3</sup> It was already argued above that such intervention is difficult, particularly in dynamic markets, in which the trade-off between externalities, variety and innovation plays a role. Taking the limitations to policy intervention into account, it is obvious that market outcomes cannot and should not be measured against a hypothetical standard of a social optimum which is not realizable.<sup>4</sup> Rather, the standard should be an outcome which can realistically be expected to emerge from the political process.<sup>5</sup> Given such alternatives, Hayek (1945), for instance, emphasizes that the competitive process is the most efficient means of using the individual knowledge dispersed among the members of society.<sup>6</sup> In his view, the market spontaneously generates institutions in which decentralized choices of consumers can be directed to pursue a common goal and it is much better at doing this than any centralized planning committee. The following sections will analyze whether such a belief in the ability of the market to coordinate decentralized decision-makers is warranted also in the presence of network externalities or whether it is rather to be expected that market processes are inhibited to such a significant degree that even given all its limitations, public policy can be expected to improve on the market outcome.

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<sup>3</sup> See Baumol and Oates (1988) for an overview of the policy instruments which are applied to internalize external effects in the context of environmental management.

<sup>4</sup> See also Demsetz' argumentation that policy considerations should not be based on a nirvana approach (Demsetz, 1969).

<sup>5</sup> Besides the fact that optimal policy intervention is hindered by missing information, research in political economy further warns that policy makers also lack the necessary knowledge to predict correctly the consequences of their actions [notion of "division of knowledge", Hayek (1945)] and are not oriented on maximizing public welfare [public choice theory, Buchanan (1987)].

<sup>6</sup> Austrian economics in general rejects the concept of "social welfare" as a criterion against which market outcomes can be measured. From the point of view of Austrian economics "coordination efficiency", by which is meant the ability of the market process to coordinate the actions of the individual members of society, is an appropriate measure by which the functioning of the market can be evaluated. This concept reveals the relative importance of dynamic processes in Austrian economics as compared to the evaluation of transient equilibria. (See Schmidchen, 1990, especially at 136-7.)

### 3.1 A disaggregated regulatory approach to market structure and network externalities

There is a fairly broad body of theoretical economics literature on network externalities and their effect on market equilibrium.<sup>7</sup> Typical research questions in this literature are: What influences consumers' decision on which network to join? How do firms decide whether to cooperate or not? How do the private and the social incentives for compatibility between competing technologies compare?<sup>8</sup> Under what circumstances can a market tip in favor of inferior products or services and become "locked-in"?<sup>9</sup> How should standards be set, i.e. is it optimal to leave standardization to market forces, should industry groups cooperate, or is it optimal to mandate standards?<sup>10</sup>

The following discussion of the literature is structured along the assumptions made therein about market structure. The categories of "monopolistic bottleneck market", "contestable market" and "competitive market" used below are taken from the disaggregated approach to market power regulation (see Knieps, 2000). This approach specializes in the localization of market power in network industries. It uses the concept of network-specific market power to characterize network areas which justify regulatory intervention. A firm has network-specific market power when there is no active competition and when no potential competitor can enter the market such that the incumbent firm can realize supra-competitive profits over an extended time period.

In order to prove the existence of network-specific market power it is therefore essential to understand the entry-conditions in a particular market. The disaggregated regulatory approach uses Stigler's definition of barriers to entry to narrow down the entry conditions which hinder the dissipation of supra-competitive profits even over a longer time period. Stigler defines: "A barrier to entry [...] as a cost of producing (at some or every rate of output) which must be borne by a firm which seeks to enter an industry but is not borne by firms already in the industry" (Stigler, 1968: 67). This definition interprets only real asymmetric cost advantages of incumbent firms as barriers to entry, but not, for instance, the capital requirements which entrants face in any industry. This is so because the capital requirements are the same for incumbents as for entrants. From the point of view of the disaggregated regulatory approach, wider definitions of entry-barriers than Stigler's

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<sup>7</sup> Surveys of the literature on network externalities are for instance given in Farrell and Saloner (1987), Gilbert (1992) and Holler (1996).

<sup>8</sup> For the first three questions see the seminal papers on network externalities in an oligopoly context by Farrell and Saloner (1985, 1986) and Katz and Shapiro (1985, 1986).

<sup>9</sup> See, for instance, David (1985) and Arthur (1989).



definition are not suited to localizing network-specific market power. Definitions which treat mere hindrances to immediate market entry, as entry barriers, will not localize stable network specific power. For instance, the classical work on entry barriers by Bain includes product differentiation advantages of incumbents, such as advertising expenditures, among the barriers to entry. It can be argued, however, that as long as the costs of differentiating one's service or product are the same for both incumbents and newcomers, product differentiation activities can be undertaken by either firm, such that incumbents have no strategic advantage. Advertising outlays will not deter market entry in the long run, when supra-competitive profits continue to be made in the industry over a substantial time period. Along the same lines, even economies of scale and scope in the relevant region of market demand cannot be considered barriers to entry in the long run, as long as both the incumbent and the entrant have access to the same production technologies and therefore to the same cost functions. This is why not even an incumbent in a contestable natural monopoly is seen as having network specific market power.

This paper uses the market segmentation of the disaggregated regulatory approach as a backdrop for the discussion of the effect network externalities have on market outcomes. This allows us to disregard the influence of cost characteristics on market structure as these are already accounted for in the market segmentation of the disaggregated approach. The focus can therefore turn to identifying the influence that network effects have on market structure and on the competitive process.

The disaggregated regulatory approach differentiates between network areas which are characterized as monopolistic bottlenecks, network areas which are considered contestable natural monopolies, and network areas in which active competition is possible. The combinations of these cases with network externalities, as they are analyzed in the following subsections, are illustrated in Table 3.1.<sup>11</sup>

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<sup>10</sup> See, for instance, Farrell and Saloner (1988) and Gandal (2002).

<sup>11</sup> Blankart and Knieps (1995) organize their analysis of the need for ONP (open network provision) regulation in networks exhibiting both network externalities and economies of scale in a very similar way. They differentiate the three different forms of the cost function mentioned above on both sides of the market (supply-side and demand-side). Their analysis therefore covers nine different scenarios. The analysis here presupposes competitive conditions on the demand-side of the market and therefore differentiates only a subset of three of the scenarios treated by Blankart and Knieps.

**Table 3.1: Combinations of Cost and Demand Characteristics in Network Industries**

<b>De- mand side</b> \ <b>Cost-side</b>	Monopolistic bottleneck	Contestable natural monopoly	Active competition
network externalities	Case 1	Case 2	Case 3

The majority of industrial organizations literature on network externalities is embedded in an oligopoly context.<sup>12</sup> The focus of this literature is to understand firm behavior under given market conditions. This chapter, in contrast, seeks to answer the question whether network externalities can be the source of market power, i.e. change market structure. The disaggregated regulatory approach places the entry conditions of a market at the basis of every analysis of market power. Since the following discussion of the literature is based on this theory, there is no need to treat the oligopoly case separately.<sup>13</sup> A market either features entry barriers which lend market power to active firms (Case 1) or a market is characterized by free entry such that active firms have no market power (Cases 2 and 3). The disaggregated theory predicts that an oligopoly market of few active firms with significant barriers to entry will lead to market outcomes comparable to those of a monopolistic bottleneck (Case 1), whereas a market with few active firms but no barriers to entry will lead to market outcomes comparable to competition (Case 3).<sup>14</sup>

A major drawback of the literature on network externalities in an oligopoly context is that the standard oligopoly assumption of a fixed number of active firms enters into the analysis elements of market power which can later not be differentiated from market imperfections resulting from network externalities. The approach of this chapter will therefore be to differentiate clearly between Case 1 which contains pre-defined market power due to the cost-characteristics of the market and the cases 2 and 3 which are not characterized by any entry restrictions resulting from

<sup>12</sup> See, for instance, the seminal articles in this branch of literature by Katz and Shapiro (1985) and Farrell and Saloner (1985).

<sup>13</sup> See also Blankart and Knieps (1995: Footnote 2).

<sup>14</sup> A competitive market with few active firms but no barriers to entry is, for instance, described in the theory of monopolistic competition (Chamberlin, 1950). This theory provides a broader understanding of competition than, for instance, the theory of perfect competition. Most importantly, it is compatible with more realistic assumptions on market characteristics allowing, for instance, fixed costs of production, product differentiation, advertising and some degree of price setting liberties on the part of the firms. Due to the assumption of free market entry, any profits “above those necessary to maintain capital and business ability in the field” (Chamberlin, 1950: 169), will attract market entry until no extra profits are being earned. The demand curve shifts inward as new firms enter the market until it is tangent

production costs. In these two cases suppliers are disciplined either by potential or by actual competition. The number of firms in these cases is endogenously determined through the interplay of supply and demand conditions. If market power can be located in these markets once network externalities are added, then this is a stronger indication that network externalities cause market power, than when market power is ascertained in one of the oligopoly models mentioned above.

## 3.2 Case 1: Network externalities in a monopolistic bottleneck

The first case to be considered here is a monopolistic bottleneck with network externalities. Non-contestable natural monopolies are characterized by cost subadditivity in the relevant output region paired with sunk costs of production.<sup>15</sup> The disaggregated regulatory approach argues that monopolistic bottlenecks, i.e. network areas showing both of these characteristics, lend network-specific market power to the owner of the monopolistic bottleneck and therefore justify sector-specific regulation.

### 3.2.1 Direct network externalities in a monopolistic bottleneck area

When network externalities are added to a monopolistic bottleneck network area, the monopolists' profit maximization behavior will generally lead to a market outcome that is not compatible with exhausting the direct network externalities present in the market. Farrell and Saloner (1992:13), for instance, argue that when the monopolist cannot price discriminate, he will not be able to appropriate the utility increase existing consumers experience with a higher subscription rate. Rather, a monopolist constricted to linear prices will continue to maximize profits by maximizing the willingness to pay of the marginal consumer. The monopolist's price will take into account the marginal consumers' valuation of the network externalities, but not the valuation of the increased network size by all inframarginal users. Compared to a competitive market outcome, the monopoly price (above marginal cost) will aggravate the problem of too little network participation (Katz and Shapiro, 1994: 101).<sup>16</sup> The market equilibrium in a monopoly will be to the left even of the private equilibrium  $S^p$  in Figure 2.1.

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to the average cost curve. The number of firms active in the industry is determined by the condition that profits are equal to zero. There is no market power in equilibrium.

<sup>15</sup> On the concept of cost subadditivity see Sharkey (1982: Chapter 4). In the single product case economies of scale over the relevant output region are a sufficient condition for subadditivity. In the multi-product case subadditivity requires both economies of scale for every single output separately as well as "economies of joint production" for all outputs over the relevant output region.

<sup>16</sup> In a slightly different partial equilibrium oligopoly model Katz and Shapiro (1985) argue that under the assumption that consumer expectations on network size be fulfilled in equilibrium, a monopoly context will lead to consumers expecting the network size to be smaller compared to a competitive market. Automatically consumers therefore adjust their willingness to pay for the network service downward in

### **3.2.2 Indirect network externalities in a monopolistic bottleneck area**

Monopolists have an incentive to transfer market power from the monopolized market to vertically and horizontally related markets. Indirect network externalities, which affect markets complementary to the monopolistic bottleneck area, can provide the monopolist with the necessary prerequisites to pursue such strategies. For instance, when complementary markets are dependent on a common standard with the monopolistic bottleneck, the owner of the monopolistic bottleneck could refuse non-discriminatory open standards to competitors. As an example consider markets characterized by a hardware/software relationship. If the hardware market were a monopolistic bottleneck, producers of related software would depend on open standards, which the monopolist could refuse in favor of an integrated or a cooperating software producer.

### **3.2.3 Public policy for monopolistic bottleneck areas featuring network externalities**

This discussion shows that the presence of network externalities in a non-contestable natural monopoly will not reverse the fact that the owner of a monopolistic bottleneck has network-specific market power. Rather, network externalities offer the potential for further strategic actions to an uncontested monopolist. Therefore, network externalities increase the need for regulation in the monopolistic bottleneck area. In addition to open access regulation of the network elements, there is a need to pay attention to complementary markets and compatibility issues. Open standards need to be enforced such that competitors on vertically related markets benefit equally from indirect network externalities that emanate from the monopolized market. For example, product compatibility between the monopolist's products and the products of the competition should be ensured, such that an increase in the monopolist's output initiates demand effects not only for the monopolist's complementary products but also for the products of independent competitors.

The question remains which standards are to be used by the bottleneck owner. Allowing the monopolist to decide on standards may already be discriminating towards competitors. Blankart and Knieps (1995: 289ff.) discuss the practical design of the regulation of standards. They suggest that, when it is possible, a contest for best standard can be held before monopoly is awarded. This is, however, feasible only prior to product introduction. Very often the need for a new standard evolves in markets of established products when a new application is introduced. In these cases the regulation of open standards must be designed carefully. First of all, both the monopolist and its

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a monopoly context. This decreases the willingness to pay and ultimately reduces even further the equilibrium network size.

competitors will have legitimate interest in influencing the standard because they have the best knowledge of the technical and qualitative requirements of their applications. Secondly, governments may be prone to promote standards which serve their own interests rather than societies interests. The standard-setting process has to take these aspects into consideration. This discussion is taken up again in section 4.

### **3.3 Case 2: Network externalities in a contestable natural monopoly**

Natural monopolies with no significant irreversible costs of production, are contestable natural monopolies. A contestable natural monopoly can support only one active firm. However, the monopolist does not possess network specific market power because in a contestable market potential competitors have access to the same cost function as the active firm and market entry does not require investing into irreversible assets. Under these conditions, a potential competitor will enter the market and undersell the monopolist should he be charging super-competitive rates.<sup>17</sup> Therefore it was argued that the possibility of market entry by potential competitors disciplines the monopoly supplier.

The effectiveness of potential competition hinges on the readiness of consumers to switch to the new entrant should he supply a superior product. The question now becomes whether the presence of network externalities in a market can change the fact that a superior product can establish itself in competition with a contestable monopolist. Can network externalities prohibit consumers from switching to a new entrants' product even when the cost characteristics of the market allow free entry and exit? Can network externalities introduce barriers to entry as defined by Stigler (1968: 67)?

Some economists have argued that network externalities can hinder new entrants from establishing themselves in a market even when they have an objectively superior product to sell. This assumption of so-called "inefficient lock-in" is seen to result from the fact that a product featuring network externalities has to gain a critical mass of users in order to become viable. When network externalities are strong, a new product will fail to be of any noteworthy use to consumers until a required minimum of other users (the critical mass) is given. An obvious example is a telephone network. In a world without interconnection, a user will not switch to a new telephone network

featuring better technology at lower prices as long as there are no subscribers on that network to communicate with. The theory predicts, that if all consumers postpone purchase of a product with network externalities until the critical mass is reached, then new entrants will not be able to establish themselves. A cheaper product or a product of better quality would not be sufficient to gain a user base in the face of strong network externalities which guide users to previously established networks.

It is important to understand that the problem of reaching a critical mass does not compare to ordinary switching costs. Switching costs are a factor in many markets that do not feature network externalities. The difference between switching costs and the problem of critical mass is that in the case of ordinary switching costs a consumer can weigh her private costs and benefits from switching to a new product and make an informed choice. For instance, a consumer may consider it costly to learn to use a new mobile telephone of an unknown manufacturer, because of an unfamiliar menu navigation. She can compare these costs to the benefit received from the new phone in terms of new features, better design, lower price etc. Liebowitz would argue that such switching costs “are real costs, and if the new product is not sufficiently better to outweigh those costs, then it is efficient for society to stick with the old” (Liebowitz, 2002: 36). Ordinary switching costs do not cause market failure. Rather, they deliver important information in the market process. Sufficiently superior products will overcome switching costs of this kind and there are plenty of examples in real markets as proof of this.

What is different for consumers deliberating to switch products in a market exhibiting network externalities is the fact that the individual consumer does not have all the information needed to compare the relevant costs and benefits of switching. The individuals’ costs and benefits from switching to the new product always depend on the product choice made by other consumers. For a single consumer to make an informed product choice all consumers would need to communicate their interests ahead of time.

Given these difficulties, the economics profession has produced different viewpoints on the question whether network externalities can substantially reduce the threat of potential competition and therefore lend market power to an otherwise contestable monopolist. While, for instance,

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<sup>17</sup> When the entrant has not reached the scale economies of the incumbent, his actual production costs will exceed the incumbent’s costs. However, because the entrant expects to replace the incumbent, he is willing to sell at prices equivalent to the long run minimum average costs.

Arthur (1989) and David (1985) argue that market equilibrium will be influenced to a significant degree by chance events, Katz and Shapiro (1994: 112) argue that “the market efficiency is unclear, once recognition is given to the many private institutions that arise to achieve coordination and internalize externalities. [...] there are many possible responses of systems markets to these problems that involve no government intervention whatsoever.” The following three sections illustrate the aspects which have been shown to be important for achieving market coordination in the presence of network externalities.

### 3.3.1 The role of information in overcoming the critical mass problem

In a contestable natural monopoly the choice between technologies can be reduced to a two-dimensional choice between staying with the incumbent’s technology or switching to a new entrant. Farrell and Saloner (1985) model a very similar market. Here  $n$  firms decide between a status quo standard  $T_1$  and a new standard  $T_2$ . By assumption, all firms agree that the new standard is superior, but because of network externalities, switching is only beneficial if all other firms switch. In equilibrium, when all firms have complete information on the other firms’ preferences, then all firms will switch to the new standard.<sup>18</sup> Only when the preferences of the other firms are not common knowledge, then only those firms with a very high preference for the new product will switch early and it is not clear, whether all other firms will follow, even when the new standard is preferred by all consumers. Farrell and Saloner call this phenomenon “excess inertia”. When consumers have different preferences with respect to the two products it is also possible that “excess momentum” occurs. Those that favor the newer product switch early and then may regret this when they are not followed by the users preferring the older product.

The Farrell and Saloner model focuses on the importance of information. In their model consumers need to be able to communicate their preferences in order to co-ordinate a switch that leads to a superior market outcome. Otherwise either excess inertia or excess momentum can leave some users stranded with a less-preferred technology. Central to the question whether network externalities impede the efficient market process is therefore the likelihood of consumers succeeding in reducing the information problem by communicating their preferences.

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<sup>18</sup> This outcome results from the fact that each individual  $i \in (1,2,\dots,n)$  prefers to switch to the new technology when all individuals  $1, \dots, i-1$  have already switched and when he believes the rest will switch when he switches. The individual believes that  $i+1, \dots, n$  will switch when he switches because he knows that they have the same preferences as he does. Therefore individual  $i$  will switch and all others will follow (see Farrell and Saloner, 1985: 73).

### 3.3.2 The role of consumer expectations in overcoming the critical mass problem

The likelihood that consumers can spontaneously organize to systematically reveal to each other their product preferences depends to a large degree on the extent of the market. A small user group is more likely to achieve coordination than a market with many anonymous buyers. The later case is modeled by Arthur (1989), who assumes a situation in which consumers have no further information on the prospects of a product except for the number of previous customers of the product. They decide which technology to use based only on the technological characteristics and on the number of existing users. The process of technology adoption is then stochastically determined by a chance sequence in which consumers make their technology choice. Arthur uses this model to show how historical events, even if insignificant at the time, play a significant role in the long-run adoption of products and technologies.<sup>19</sup> Early events that, by chance, favor one technology will grant this technology a significant installed base such that when a superior product arrives on the scene at a later time, even those consumers that would prefer this newer product will buy the inferior existing product as it offers the larger network benefit. Thus, according to this model, society can experience inefficient lock-in<sup>20</sup>.

Two assumptions are critical for Arthur to arrive at his prediction. First, consumers' preferences for product characteristics (the technology effect) are exogenous to the model. They cannot be altered by making available newer information or by changing product characteristics. Second, the consumers' utility is endogenously determined only by the number of existing users of a product (the network effect). Expectations of future consumption levels are not considered. As a result, only historical chance events influence the consumer decision which network to join.

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<sup>19</sup> David (1985: 332) even speaks of "historical accidents" in this context.

<sup>20</sup> The best-known exponents of the theory of inefficient lock-in are David (1985) and Arthur (1989). See also Cowan (1991). Liebowitz and Margolis (1995) offer a very interesting critique of the literature on path-dependency and lock-in by differentiating three different forms of path dependency of which only one leads to market failure in the sense that policy interventions can be shown to improve on the market outcome. This case presupposes that "there exists or existed some feasible arrangement for recognizing and achieving a preferred outcome, but that outcome is not obtained" (pg. 207). The authors argue that this third case is based on restrictive and implausible assumptions, especially because it is assumed that at least one person must know of the better solution, but this person does not turn this knowledge into profit by coordinating buyers to the superior outcome (pg. 217). Nevertheless, in academic discussions the policy implications of this case are applied to the two other more realistic cases of path-dependency which assume that "the existence or superiority of alternative paths are not known at the time that initial decisions are made" (pg. 211). Liebowitz and Margolis argue that in these cases, there is not real inefficiency in the market outcome as there is no knowledge of the superior outcome in the economy.



These random events can, however, be dominated by the influence of strategic actions taken by market participants, once consumer expectations regarding future network size and changes in technology are taken into account. While it is true, that consumers will often lack the organization necessary to reveal their preferences to each other, a new entrant, with a possibly superior product, has opportunities to disclose relevant information on his products' chances and to influence consumer buying decisions. And when he believes in the superiority of his product he has an incentive to do so. As Liebowitz and Margolis (1990: 4) suggest: "An owner with the prospect of appropriating substantial benefits from a new standard would have an incentive to share some of the costs of switching to a new standard. This incentive gives rise to a variety of internalizing tactics." These tactics are discussed in the following section.

### **3.3.3 The role of sponsorship in overcoming the critical mass problem**

There are several papers in the literature which focus on these abilities of firms to "sponsor" their products in order to overcome the critical mass problem. Katz and Shapiro (1986), for instance, analyze technology adoption given that a new entrant is willing to incur short-run losses in order to establish his technology. This model is interesting in the context of the contestable monopoly case discussed here, because it considers two competing technologies available in two time periods. Period one consumers take into account the probable consumption decision of period two consumers when making their technology choice. Period two consumers make their technology choice dependent on the technology chosen in period one. Preferences of consumers are assumed to be homogeneous and consumers are assumed to have rational expectations. In the first period, consumers unanimously choose the technology yielding the highest consumer surplus at that time. In the second period, consumers compare the benefit from the combined technology and network effects of both products. The second period is thus comparable to the contestable monopoly case in which a newer technology competes with an incumbent technology.

The model assumes that the newer technology will win the market in the second period only when the extent of the price/quality superiority over the previous technology is worth more to consumers than the installed base advantage the existing technology offers. The paper thus emphasizes the possibilities an entrant has to influence the price/quality superiority of his product. It is argued that the entrant can differentiate his product so as to offer more benefits from the technology effect of

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Then, however, these more common cases lack the strong policy implications of the case in which a superior outcome is known to be feasible.

his product. When consumers' expectations of future network size factor into their benefit function, the new entrant also has the possibility to convince consumers that his product will offer more benefits from the network effect in the future: early product announcement and a penetration price strategy can, for instance, induce some first period consumers to wait until the second period to make their purchase decision, thereby decreasing the installed base advantage of the first technology. Furthermore, this may convince new users that the entrant will pull sufficient demand to be able to offer similar network benefits as the incumbent.<sup>21</sup>

Katz and Shapiro (1986: 832) show that when neither of the two technologies is sponsored then there is a tendency in the market to standardize on the initially superior network, even when this is not the socially optimal outcome in later periods. This confirms Arthur's (1989) result. However, when both technologies are sponsored there is a tendency that the market will standardize on the technology which has lower costs in the second period (Katz and Shapiro, 1986: 838). Interpreting lower costs as a signal for a more advanced technology, this model shows that sponsoring can be an efficient means for a new entrant with a superior product to overcome critical mass restrictions.

There are multiple strategies an entrant can follow to sponsor his product.<sup>22</sup> Whenever consumer expectations of future market shares play a role, advertising can, for instance, increase a product's reputation and influence the expected sales of a product. This will in turn increase the realized demand share in the present. The entrant can also make the price of his service dependent on network size. As long as the network is small, consumers pay a lower price. This pricing scheme acts as insurance for consumers. Only when network size increases will membership become more expensive. The risk of being stranded on the "wrong network" is thereby reduced. A further pricing strategy is to subsidize a basic service and thereby bind more consumers to a technology, while adding mark-ups to advanced services and applications in order to cover the losses obtained on the basic service. The entrant can also use subscription in order to build a customer base before actually introducing his product. Consumers that subscribe in advance commit to switching to the new product once an appointed number of subscribers is reached.

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<sup>21</sup> In a related paper Farrell and Saloner (1986) analyze the welfare effects of product pre-announcement and strategic pricing in dynamic markets with network externalities.

<sup>22</sup> See also Katz and Shapiro (1994: 102).

### 3.3.4 Public Policy for contestable markets featuring network externalities

The discussion of the various ways in which information dissemination, consumer expectations and sponsorship can influence the markets abilities to achieve coordination even in the presence of network externalities shows, that the theory of inefficient lock-in may throw an overly pessimistic view on the problem of network externalities in contestable markets. For the purposes of taking policy measures in such markets it would be dangerous to conclude that a firm which has been able to dominate a market has market power. It may well be that no superior product has as yet been offered by potential market entrants. From their studies of real-world examples Liebowitz and Margolis conclude that the dominance of a particular product can often be explained by superior quality and/or price advantages offered to consumers.<sup>23</sup> Using Stigler's definition of entry barriers they conclude: "...it is unclear how network effects, economies of scale, or any of the other factors at work favor the incumbent relative to the challenger. The incumbent had to coordinate consumers to adopt his product, whether it was first in the market or replaced a previous incumbent. In either case, getting consumers to come on board is a cost imposed on all market entrants, late or early, and does not necessarily favor early firms" (Liebowitz and Margolis, 2001: 164-165). Therefore, network externalities alone do not lend market power to a contestable natural monopolist which would justify policy interventions into the market process. Rather, market institutions are creative in finding ways by which consumer preferences are revealed such that network externalities can be internalized within regular market operations. Policy makers would have difficulty improving on market outcomes.

With respect to the allocative efficiency of the market outcome to be expected in an unregulated contestable market featuring network externalities, it can be said that since the cost conditions of the market favor only one active firm, there is no threat of network islands developing.

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<sup>23</sup> Liebowitz and Margolis have put the hypothesis of inefficient lock-in to an empirical test by analyzing real-world markets commonly associated with this phenomenon. In "The Fable of the Keys" (Liebowitz and Margolis, 1990) investigate the history of the Qwerty keyboard, which has long served as the standard example for an inefficient lock-in, because it is argued to be inferior in terms of typing efficiency when compared to keyboards developed subsequently. In Liebowitz and Margolis (2001) they analyze the hypothesis of inefficient lock-in in a competitive context. They examine the claim that network effects in the software market are responsible for Microsoft's success in particular product groups. In the antitrust case against Microsoft it was argued that Microsoft dominates particular software markets only because the software is part of the Microsoft operating system and not because of product quality and price advantages. Liebowitz and Margolis use software reviews from leading computer magazines to compare the product rankings according to expert opinions with measures of market share. They find that the market success of, for instance, the spreadsheet program Excel and Microsoft's Internet browser Explorer can also be explained by a quality lead over the competing product as well as competitive price setting.

Furthermore, should the operator try to enforce a price above the competitive level this would invite market entry. Only the competitive price protects the operator from replacement by a potential competitor. This competitive price level leads to a network size which internalizes the network externalities to a large degree (comparable to equilibrium  $S^p$  in Figure 2.1.).

### **3.4 Case 3: Network externalities in a competitive market**

The last case to be discussed here is the competitive case.<sup>24</sup> In a competitive market featuring substantial network externalities, firms will compete not only in price and product characteristics, but also in the dimension of network size. The stronger the network externalities, the more important will be the “network effect” a product offers compared to its “technology effect” (see section 2 above).

The important difference to case 2, in which network externalities are analyzed in the context of a contestable natural monopoly, is that in a competitive market users will have a choice between several operating networks. The trade-off between standardization and variety, mentioned in section 2.4, takes on its full meaning only in this context. An increased variety of technologies available for consumption makes it more difficult for consumers to resolve the trade-off between choosing the technology with the most preferred product characteristics and benefiting from being a part of a network with a large number of users. Consumers can be expected to have different preferences with respect to their preferred technological and qualitative product characteristics and also different valuations of the network effect. It is likely that in this scenario consumers will be better off when a variety of network islands caters to particular consumer tastes, rather than when one large network offers a compromise between the demanded product characteristics (see for instance a model by Shy, 2001: 27-35). However, the more important the network effect, the more willingly will consumers give up specialized technologies and concentrate on the network offering the largest user base. The aim of this section is to understand how the competitive market process will solve the trade-off between taking advantage of network externalities (implicating a small number of active firms) and offering product variety and competition in the market (implicating a larger number of active firms).

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<sup>24</sup> The reference scenario of competition in this case is not the textbook model of a perfectly competitive market but rather an understanding of competition which allows product differentiation and therefore concedes a degree of price setting competencies on the part of the firm. See also footnote 14.

As was discussed in section 2.4, a trade-off between scale and variety is also a common problem in markets featuring supply-side economies of scale. Here the trade-off between scale and variety results from the fact that the cost efficiencies of larger scale production can be exhausted only at the expense of a decrease in product variety. Multi-firm production (when operating below minimum efficient scale) entails a duplication of fixed costs, such that variety comes at the price of higher average production costs. With network externalities in a market, the requirements on size are on the demand-side rather than on the supply-side of the market. This leads to an important difference in the inefficiencies which can result from multi-firm production. The problem with network externalities is not that multi-firm production increases average costs, but rather that users will not be able to benefit from the positive network externalities when split on different network islands. Unlike in the case of economies of scale, there is a solution to this problem of the type “you can have your cake and eat it too”, i.e. which allows the consumer to profit both from product variety and the positive network externalities. This solution presupposes that rival firms will cooperate by making their networks compatible. Compatibility between self-contained network islands allows users to communicate and share network benefits while competition is preserved in product dimensions not affected by the cooperation.<sup>25</sup> With full compatibility the consumer will base his product choice on technological characteristics and price. Network reach will be the same for all products. The main question therefore is what incentives firms in a competitive market have to make their networks compatible.

### **3.4.1 Firm incentives for compatibility**

When network externalities are strong and the consumer valuation of compatibility accordingly high, the question is whether firms are likely to voluntarily engage in cooperation but salvage competition in product characteristics or whether larger firms will have an incentive to decline cooperation in the hopes of collecting supra-competitive profits from offering the largest network. To answer this question it is useful to consider the costs and benefits of cooperation from the perspective of the firm. Most substantial on the cost side is that, by making its network compatible, a firm gives up network size as a differentiating product characteristic in its competition with rival firms. This aspect is especially costly to firms with initially large networks. Furthermore, cooperating firms have to invest more in product differentiation with respect to remaining

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<sup>25</sup> Put differently, supply-side scale economies determine the cost-efficient physical network size, while user externalities determine the efficient number of compatible network users. Since physical network size cannot be shared between independent network owners, supply-side economies of scale lead to higher firm concentration in a market. User externalities do not have this inevitable effect, since the “user size” of a network can be shared through cooperation.

differentiating characteristics. Lastly, there are transaction costs involved in coordinating the cooperation of firms with conflicting interests.

On the other hand, there are positive aspects to compatibility which may outweigh these costs. The most substantial benefit derived from cooperation from the point of view of the firm is the possibility to benefit from a significant demand shift generated by the increase in overall network size. When total demand for network services rises due to several networks becoming compatible, then even initially large networks can experience a demand increase for their network services. Economides (1996), for instance, shows that even a monopolist, can profit from inviting entrants, even subsidizing their market entry, and making his services compatible to theirs. This counterintuitive result is explained by the fact that when consumer demand is a function of the expected network size and when network externalities are sufficiently strong, then the demand effect from a larger network pushes the demand curve outwards to such an extent that the higher market wide sales allow the monopolist to sell so much more of his product compared to the monopoly output that even at a lower competitive price he can increase his profit.<sup>26</sup> The monopolist can realize this output level and this price only in a competitive setting. A monopolist cannot credibly commit to producing a competitive output/price combination because, given a level of demand, it is always in the monopolists' interest to restrict output and raise prices. Since consumers expect the monopolist to offer network services only at higher prices, they expect a smaller network in a monopoly and their demand at any given price will be correspondingly lower in a monopoly than in a competitive market.

A further benefit to cooperation is that it eliminates competition to establish the largest network and therefore frees resources which can be put to other uses. These can, for instance, be invested into competing in other product characteristics. The more important technological differentiation is to consumers, the more important it will be to invest into product innovations. This is likely to be of greater significance in dynamic markets.

### **3.4.2 A model of network externalities in Cournot competition**

To my knowledge there exists no model of network externalities in a competitive market. The literature on compatibility choice mostly uses Cournot or Bertrand competition, assuming a fixed

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number of firms in the market. The section discusses why the results of these models cannot be transferred to a free-entry market environment. It looks at the assumptions of the common oligopoly models in the literature on network externalities and on their influence on the results derived therein.

The seminal paper on network externalities in oligopolistic competition is Katz and Shapiro (1985). The authors analyze equilibrium outcomes and firm incentives for compatibility. The model defines a consumers' utility as:

$$U_{i,j}(S,T) = r_i + v(S_j^e) \text{ for consumers } i = 1, 2, \dots, m \text{ and technologies } j = 1, 2, \dots, n.$$

Parameter  $r_i$  stands for the basic willingness to pay for network services (this is the willingness to pay which results from the "technology effect"). As technologies are assumed to be homogeneous in all characteristics but network size,  $r$  does not differ across technologies  $j$ , but only across consumers  $i$ , assumed to have different basic valuations of network services. The parameter  $r$  is assumed to be uniformly distributed between minus infinity and  $A$  with density one and  $A$  is assumed to be a positive value.<sup>27</sup>

The consumers' valuation of the network externality is expressed in the externality function  $v(S_j^e)$ , where  $S_j^e$  is the sum of the network users expected to be compatible with technology  $j$ . All consumers have the same valuation of the network effect. The model assumes  $v'(S_j^e) > 0$ ,  $v''(S_j^e) < 0$  and  $\lim v'(S_j^e) = 0$  as  $S_j^e \rightarrow \infty$ . Users counted among  $S_j^e$  are either subscribers of technology  $j$  or subscribers of networks compatible with technology  $j$ . When  $x_k^e$  stands for the expected network size of technology  $k$ ,  $S_j^e$  can be expressed as:

$$S_j^e = \sum_{k=1}^m x_k^e, \text{ where } k = 1, 2, \dots, m \text{ are the networks compatible with } j.$$

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<sup>26</sup> The elasticity of demand obviously plays an important role in this context. The more elastic the demand, the more pronounced will be the demand expansion induced by more rivalry in the market.

The static, one-period model is solved in three steps. In a first step, consumers build expectations about the future network size associated with each technology. In a second step, firms choose their output given the consumer expectations of network size and assuming the output of rival firms as given (Cournot competition).<sup>28</sup> This output game determines the prices that firms charge in equilibrium. In a third step, consumers make their purchase decision by maximizing their utility. When the price of a technology is given by  $p_j$ , a consumer chooses the technology for which utility is maximized (and is equal to or greater than the utility realized with the next best alternative resource utilization). Formally, the consumer's decision function is:

$$\max_j [U_{i,j}(S, T) - p_j] \geq U_{\min}$$

Assuming that  $U_{\min}$  is equal to zero, the consumer maximizes

$$U_{i,j}(S, T) - p_j = r_i + v(S_j^e) - p_j. \quad (1)$$

If this expression is negative for all available technologies  $j$  the consumer will join none of the available networks.

Since the consumer's basic willingness to pay  $r_i$  is the same for every available technology  $j$ , the consumer will choose that technology for which the difference,  $[v(S_j^e) - p_j]$ , is maximized, respectively that technology for which the price adjusted for the network effect offered by a particular technology,  $[p_j - v(S_j^e)]$ , is minimized. Katz and Shapiro call this price the "hedonic price" of technology  $j$  (Katz and Shapiro, 1985: 427).

Since all consumers are assumed to have the same evaluation of the network externality, all consumers will choose that technology which is available at the lowest hedonic price. Therefore, the equilibrium will only feature more than one firm with positive output, if these firms offer their technology at the same hedonic price.

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<sup>27</sup> These assumptions on the distribution of  $r$  ensure a linear demand curve for technology  $j$ .

<sup>28</sup> The model assumes constant marginal costs.



The equilibrium concept employed in the model is that of fulfilled expectations Cournot equilibrium (FECE). This concept assumes that all firms maximize their profits by choosing their output. Consumer expectations and the output level of rival firms are given. Production costs are assumed to be the same for all firms; all costs are non-variable. In equilibrium expected sales must be equal to actual sales.

Assuming that fixed costs are zero and redefining  $r_j$  as the willingness to pay which exceeds marginal costs, allows the authors to set up a profit function, which, differentiated with respect to output, yields output equations for all firms. Solved simultaneously, these equations yield the following equilibrium output:

$$x_j^* = [A + n \cdot v(S_j^e) - \sum_{k \neq j} S_k^e] / (n + 1)$$

Since the number of active firms  $n$  is exogenous to the model, the model leads to the conclusion that those networks which consumers expect to be dominant (high value of  $v(S_j^e)$ ), for instance because of their initial network size or because of their reputation, will in fact be dominant in equilibrium (high  $x_j^*$ ). Therefore, within their framework, the authors conclude that network externalities lend market-power to initially large firms.

This equilibrium outcome is a result of the specifications of the model. Particularly, the model does not include a positive value to product variety. For consumers to value variety, the parameter  $r$ , reflecting the willingness to pay for the technological characteristics, would have to vary in technologies  $j$ . If this were the case, then not all consumers would prefer the same network, even if their valuation of the network externality were the same. In this case, consumer expectations of network size would not dominate the consumer's choice of network. Furthermore, the assumption that all consumers have the same valuation of the network effect is also unrealistic but very restrictive with respect to the results of the model. Lifting these assumptions would allow different combinations of price, technological characteristics and network size to exist simultaneously in the market. The result that networks which have an initially large user-base will come to dominate a market would no longer hold. More realistic market conditions (heterogeneous consumers, product differentiation and free market entry) are likely to lead to more firms in equilibrium.

Within their model Katz and Shapiro do analyze how their result would change if they lifted the assumption of a fixed number of firms and assumed instead that the number of firms increases indefinitely. The equilibrium output then converges on:

$$\lim_{n \rightarrow \infty} x_j^* = v(S_j^e) - \lim_{n \rightarrow \infty} \left[ \sum_{k \neq j} v(S_k^e) / (n + 1) \right]$$

In words, as the number of firms grows, firm j's equilibrium output will be the larger, the larger the expected network size of firm j as compared to the network sizes of its competitors. When firms are expected to have the same network size in equilibrium, either because of full compatibility in the market or because firms are grouped in network islands of equal size, then the equilibrium output of each single firm will tend towards zero (because the second term of the above equation,  $\lim_{n \rightarrow \infty} \left[ \sum_{k \neq j} v(S_k^e) / (n + 1) \right]$ , will tend towards  $v(S_k^e)$  and  $v(S_k^e)$  is equal to  $v(S_j^e)$  when networks are symmetric). Using this result, Katz and Shapiro (1985: 429) show that when there is full compatibility between all active firms then there is a unique symmetric equilibrium which converges on the perfectly competitive equilibrium when the number of firms becomes increasingly large.

This competitive case analyzed by Katz and Shapiro is trivial. Since the model does not allow competition by product differentiation the firms are homogeneous whenever there is full compatibility, since compatibility takes away the last differentiating aspect, namely network size. Naturally a market with an infinite number of homogeneous firms will converge on the perfectly competitive equilibrium. A realistic model of competition which allows for consumer valuation of product differentiation in technological characteristics as well as in network size will necessarily not predict perfect competition in a competitive market featuring network externalities. This is, as was already stated above, not the criterion against which market performance should be measured.

Katz and Shapiro (1985) also analyze the firms' choice to make their technologies compatible by comparing the difference in realized profit from the non-compatibility case to the compatibility case. They argue that only when the expected profit with compatibility is larger than the profit in the incompatibility case, will an individual firm have an incentive to cooperate. The authors show

that within their framework not all suppliers necessarily benefit from increased compatibility. Even when overall output rises, initially large networks may have a lower output in a compatible equilibrium. Therefore, when firm size is highly asymmetric, firms may not voluntarily agree on a common standard. Rather, initially larger firms will tend to favor incompatibility.

When the authors enter the possibility that firms make side-payments among one another, it becomes sufficient that average profits increase through cooperation for firms to voluntarily agree on compatibility. Those firms which gain disproportionately from compatibility can compensate the losses of those firms that would otherwise prefer not to cooperate. Because the condition that average profits rise for compatibility to be a viable outcome is less restrictive than the condition that profits increase individually, side payments increase the likelihood that firms reach a mutually beneficial compatibility agreement, even when they are of substantially different initial size.<sup>29</sup>

### **3.4.3 Public policy for competitive markets featuring network externalities**

The above discussion shows that cooperation is likely in a competitive market with substantial network externalities, especially when consumer tastes vary and firms have the possibility to differentiate their services not only in network size, but also along technological and qualitative characteristics. A larger firm can hope to benefit from an overall demand increase resulting from increased network benefits and hold on to its previous customers by offering superior product characteristics. Product differentiation can therefore strengthen the incentives to cooperate on compatibility issues. And as was argued by Katz and Shapiro, allowing for side-payments further increases the opportunity for market participants to internalize the network externalities. There are even cases in which side-payments may flow from the initially larger network to smaller competitors. These analysis show that payments made to induce competitors to become compatible can be interpreted as compensating a firm for a kind of property right it has to the positive network externalities associated with its network size.<sup>30</sup> Such payment should not be interpreted as

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<sup>29</sup> Compensation here refers strictly to payments made in order to induce the other party to agree on a common standard. These payments have to be differentiated clearly from payments which are compensation for costs incurred by the other party as a consequence of the compatibility. For example, if one network offers another network free licenses for its software products in order to induce it to agree to interconnect this can be considered a side-payment. When, however, payments flow in direct relation to the costs of achieving compatibility, such as transportation compensation for the costs incurred in terminating one another's traffic, then these payments do not reflect side-payments.

<sup>30</sup> There are strong parallels here to the Coase Theorem, which postulates that as long as property rights are well-defined, private negotiations can lead to efficient market outcomes. See also Katz and Shapiro (1986: 825).

reflecting market power. Rather, they redistribute the gains from network compatibility in a way that all firms are better off.

Up until this point we have regarded the problem of compatibility only from the point of view of the firms. It is possible, however, that the social incentives for compatibility are not congruent to the firm incentives for compatibility. First, there can be too little cooperation among firms when cooperation is in the interest of society but firms cannot appropriate enough of the benefits from cooperation to exceed their costs. Second, there can be too much cooperation when firms cooperate even though society's costs to cooperation (see the following section) exceed the benefits. Is this a reason to assume that there is, after all, a responsibility to bring about the correct level of compatibility through government intervention? Whether the move to compatibility is efficient from a social welfare point of view depends on how the costs of compatibility relate to the benefits derived from the internalized network externalities (see Katz and Shapiro, 1985: 438). Because both the benefits and the costs are impossible to measure, there is no reason to assume that policy makers can bring about a closer congruence between the private and social incentives for compatibility than will emerge from an unaided market process. The information requirements for determining the socially optimal level of compatibility are impossible to fulfill. Therefore, the need for government intervention into competitive markets featuring network externalities is not substantiated by the present discussion of market processes in the presence of network externalities.

#### **4 Standards as a prerequisite for cooperation**

So far we have discussed the compatibility decision in the abstract. Taking a more practical view, technological requirements will have to be fulfilled before network services become compatible across network boundaries. How do firms decide on a standard to which all compatible networks have to conform?

One can differentiate between three general mechanisms by which agreement between firms is reached. The first is standardization by multilateral agreement. For this the firms convene in standardization committees charged with reaching a consensus on a particular product standard. The second mechanism is a unilateral predetermination of a particular standard by a leading firm in the industry. The remaining firms either adopt this standard or employ adapters or gateway

technologies in order to make their products compatible to the standard set by the industry leader. Lastly, an industry standard can be imposed by governmental decree.

#### **4.1 Voluntary standardization**

When governmental intervention is not deemed appropriate (as was the case in the above discussed contestable markets and competitive markets), then either the first or the second of these mechanisms will be used to fix the industry standard. What are the relative advantages of either multilateral or unilateral standardization?

Multilateral standardization aspires to a consensual decision by all affected parties. This makes a multilateral standardization process very political and drawn-out. The advantage of such multilateral agreements, on the other hand, is that they are more likely to come to a sustainable solution. Unilateral choice of a standard, in comparison, is most likely quicker. The standard may however not be adopted readily, should conflicts arise between several players wanting to take on the role of market leader. In the end, incompatible standards may prevail.

Farrell and Saloner (1988) compare coordination by explicit communication in standardization committees and standardization by unilateral predetermination of a standard. They assume that everyone prefers standardization over incompatibility, regardless of the standard that is finally agreed upon. In finitely repeated games committees are shown to dominate unilateral standardization because they are more likely to achieve coordination.<sup>31</sup> Only a hybrid system, in which both standardization by committees and standardization by unilateral action are possible, is more efficient than standardization by multilateral agreement alone. This is so because the threat of pre-emptive action by the industry leader entices committees to work more effectively such that agreement is reached sooner.

In conclusion, the above discussion showed that when markets are considered competitive, then private solutions to the standardization problem can be expected. In these cases standardization committees often take on the important task of information dissemination in the market. Public policy should therefore allow and even encourage standardization committees. This is in contrast to traditional competition policy, which is skeptical towards joint decisions taken by members of the same industry, suspecting collusive and anti-competitive behavior. In markets featuring

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<sup>31</sup> There is no difference in infinitely repeated games.

network externalities competition policy must, however, respect the difference between welfare-enhancing standardization and anti-competitive collusion.

## **4.2 Standardization by governmental decree**

In section 3.2 it was argued that government intervention is deemed appropriate when standardization of vertically related product markets is desired, and when one of these markets is a monopolistic bottleneck. The first alternative for government control of market power is to impose government designed standards. What can be said about the efficiency of standardization by governmental decree?

A fundamental problem with standardization by government is the fact that the politicians charged with the standardization do not necessarily have the best interest of consumers and producers in the market in mind. Governments generally delegate standardization tasks to bureaucracies that are closer to individual industries. As Blankart and Knieps (1993: 46) put it, there is no “...democratic link between those who define and enforce standards and those who are subject to standards.” Bureaucrats, other than members of government, do not depend on being re-elected every term. Rather, they can pursue goals such as maximizing their influence and budget, which may not be related to optimally serving the interests of the general electorate. Rather, bureaucrats are likely to be especially susceptible to rent-seeking such that the firm willing and able to invest into rent-seeking behavior, i.e. the firm with market power, can use the bureaucrats to pursue its own agenda. Furthermore, for reasons of self-legitimation, the bureaucrats have an interest to extend their realm of action beyond the market areas affected by market power.

Because of these problems with governmental standard-setting it is important that rules are defined which limit the realm in which public standard setters are allowed to become active. If governmental standards are deemed necessary, there should be limitations concerning how deep standardization by bureaucrats may go. Blankart and Knieps (1993:40-44) suggest that network services are technological systems of many interrelated components which form a technological hierarchy. Standardization can be applied to any subset of these components. Since standards built on one another in the same way that technological components are part of a logical structure, one can speak of various degrees of standardization where the standardization of basic technological functions is a prerequisite for a “deeper standardization”, involving also the specialized functions higher up in the technological hierarchy. With this view, standardization becomes a gradual

process. From the point of view of affected firms there is a diminishing marginal return to standardization. Adopting a basic standard offers higher marginal benefits than joining a higher-level standard because basic standards have a wider dissemination. Using a compatible basic standard is a prerequisite for many interactions with horizontally/vertically related firms whereas compatible higher-level standards, specialized to specific applications, are required only seldomly and only in interactions with specific partners.

Because the positive network effects of adopting a uniform basic standard are clearly more important than the network effects of a uniform standard for advanced applications, Blankart and Knieps (1992:84) argue that government regulation should be confined to basic standards. To counteract the tendency of bureaucracies to tend to interfere too much rather than too little, the standardization of advanced applications should, however, not be allowed. Of course, the practical implementation of this rule hinges on the assumption that basic functions can be identified. Blankart and Knieps (1994: 459) argue that with regard to network services, basic functions are often tied to the infrastructure facilities of the network services whereas applied functions are tied to the applications offered on the network. A further indication as to whether a function can be counted among the basic functions is the expected dissemination of the standard within the industry. A standard with a wide dissemination regulates basic functions applied by many market participants. Standards with limited dissemination are or particular functions not used widely.<sup>32</sup>

## 5 Conclusions

This review of the literature on network externalities was by far not comprehensive. It disregards, for instance, the related branch of literature which focuses on network interconnection charges and competition in the telecommunications industry. Seminal articles in this tradition are Armstrong (1998 and 2002), as well as Laffont, Rey and Tirole (1998a and 1998b).<sup>33</sup> These papers focus on interconnection charges in the telecommunications industry and the question whether the regulation of these charges needs to prevent network operators from utilizing the interconnection charge as an instrument of collusion. Although the general results presented in these papers have

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<sup>32</sup> In a later paper Knieps (1995: 294) suggests an even more restrictive alternative. Here he argues that governmental activities can be limited to the regulation of access to monopolistic bottlenecks alone. In his view, reducing the market power of the bottleneck owner by price and quality control should suffice to eliminate the monopolists' incentive to prevent coordinated standardization activities in multilateral committees.

important implications for the question discussed in the present analysis, it is beyond the realms of the present paper to go into their specific focus.

The papers which were evaluated for the present analysis are part of a tradition which takes a more general and abstract view on network externalities. The chosen papers show the representative themes which play a role in the analysis of how market processes are affected by network externalities. It was shown that the models presented in this chapter arrived at their specific results using restrictive assumptions. Based on these models it is not possible to reach universal conclusions on the changes to be expected in the competitive process when network externalities are present. Already early on in the academic discourse of compatibility choice in free market processes Besen and Johnson (1986: 18) concluded that the applicability of the theoretical models on network externalities to real world markets is limited. This evaluation is still appropriate today, even when the models have since been refined. Nevertheless, the analysis presented in this paper provide useful insights into the mechanisms that influence the ability of market processes to solve the trade-off between user externalities, product variety and search for new technologies. Farrell and Saloner (1985), for instance, emphasize the role of access to information on consumer preferences. Katz and Shapiro (1994) emphasize what firms can do to motivate consumers to reveal their preferences. The preparedness to sponsor a product (Katz and Shapiro, 1986) as well as to make side-payments (Katz and Shapiro, 1985) was also shown to have substantial influence on the market outcome.

The theories indicate that market processes very often generate novel ways for coordinating users and firms – especially in markets with heterogeneous consumers and product differentiation. Keeping in mind the various impediments to governmental institutions imposing efficient policy (i.e. Buchanan, 1987 or Blankart and Knieps, 1993: 46) the discussion suggests that in many realistic market environments the spontaneous market order has a comparative advantage in internalizing network externalities as compared to administered policy. To support regulation as a means of internalizing network externalities requires strong evidence that the many ways by which market participants can solve the information problem are not functional under particular circumstances, as for instance in the case of an uncontestable natural monopoly. In the remaining cases, government imposed standards cannot outperform standardization committees because a

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<sup>33</sup> These models in their most basic form assume that interconnection is given and that network externalities do not play a role. Only when price-discrimination between on-net and off-net calls are analysed do network size and network externalities play a role.



regulator does not have nearly enough information on the preferences of consumers and firms and also cannot foresee the technological developments in the market. Furthermore, even if the regulator had as much information as the sum of the members of a standardization committee, the regulator does not have the instruments at hand which allow a market-oriented aggregation of the preferences (such as side-payments resorted to by firms). Instead, the regulator is likely to be the target of rent-seeking behavior by firms with high stakes in the standardization decision. Therefore, the only role for government is to apply general competition policy in a way that allows beneficial standardization committees in which the members of one industry convene.

## 6 References

- Armstrong, M. (2002)**, The Theory of Access Pricing and Interconnection, in: Cave, M., S. Majumdar and I. Vogelsang (Eds.), *Handbook of Telecommunications Economics: Vol. I*, Amsterdam.
- Armstrong, M. (1998)**, Network Interconnection in Telecommunications, *The Economic Journal*, 108, 545-564.
- Arthur, W. B. (1989)**, Competing Technologies, Increasing Returns, and Lock-In by Historical Events, *The Economic Journal* 99, 116-131.
- Baumol, W. J. and W. E. Oates (1988)**, *The Theory of Environmental Policy*, Cambridge.
- Besen, M. S. and L.L. Johnson (1986)**, *Compatibility Standards, Competition, and Innovation in the Broadcasting Industry*, Santa Monica, CA.
- Blankart, Ch. and G. Knieps (1992)**, Netzökonomik, *Jahrbücher für neue politische Ökonomie*, 73-87.
- Blankart, Ch. and G. Knieps (1993)**, State and Standards, *Public Choice* 77, 39-52.
- Blankart, Ch. and G. Knieps (1994)**, Kommunikationsgüter ökonomisch betrachtet, *Homo oeconomicus* 11, 449-463.
- Blankart, Ch. and G. Knieps (1995)**, Market-oriented Open Network Provision, *Information Economics and Policy* 7, 283-296.
- Buchanan, J. M. (1987)**, The Constitution of Economic Policy, *American Economic Review* 77, 243-250.
- Chamberlin, E. H. (1950)**, *The Theory of Monopolistic Competition*, 7<sup>th</sup> ed., Cambridge, MA.
- Cowan, R. (1991)**, Tortoises and Hares: Choice Among Technologies of Unknown Merit, *The Economic Journal* 101, 801-814.
- David, P. A. (1985)**, Clio and the Economics of QWERTY, *American Economic Association Papers and Proceedings* 75, 332-337.
- Demsetz, H. (1969)**, Information and Efficiency: Another Viewpoint, *Journal of Law and Economics* 12, 1-22.
- Dixit, A. K. and J. E. Stiglitz (1977)**, Monopolistic Competition and Optimum Product Diversity, *American Economic Review* 67, 297-308.
- Economides, N. (1996)**, Network externalities, complementarities, and invitations

to enter, *European Journal of Political Economy* 12, 211-233.

**Farrell, J. and G. Saloner (1985)**, Standardization, Compatibility, and Innovation, *Rand Journal of Economics* 16, 70-83.

**Farrell, J. and G. Saloner (1986)**, Installed Base and Compatibility: Innovation, Product Preannouncements, and Predation, *American Economic Review* 76, 940-955.

**Farrell, J. and G. Saloner (1987)**, Competition, Compatibility and Standards: The Economics of Horses, Penguins and Lemmings, in: Gabel, L. (Ed.), *Product Standardization and Competitive Strategy*, Fontainebleau.

**Farrell, J. and G. Saloner (1988)**, Coordination Through Committees and Markets, *RAND Journal of Economics* 19, 235-252.

**Farrell, J. and G. Saloner (1992)**, Converters, Compatibility, and the Control of Interfaces, *Journal of Industrial Economics* 40, 9-35.

**Gandal, N. (2002)**, Compatibility, Standardization, and Network Effects: Some Policy Implications, *Oxford Review of Economic Policy* 18, 80-91.

**Gilbert, R. J. (1992)**, Symposium on Compatibility, *Journal of Industrial Economics* 40, 1-8.

**Hayek, F. A. (1945)**, The Use of Knowledge in Society, *American Economic Review* 35, 519-530.

**Holler, M. (1996)**, Die Modellierung von Netzeffekten und Ansätze industriepolitischer Steuerung, in: Boettcher, E.; Herder-Donereich; Schenk, K.-E.; Schmidtchen, D. (Eds.), *Jahrbuch für Neue Politische Ökonomie*, Tübingen.

**Katz, M. and C. Shapiro (1985)**, Network Externalities, Competition, and Compatibility, *American Economic Review* 75, 424-440.

**Katz, M. and C. Shapiro (1986)**, Technology Adoption in the Presence of Network Externalities, *Journal of Political Economy* 94, 822-841.

**Katz, M. and C. Shapiro (1994)**, Systems Competition and Network Effects, *Journal of Economic Perspectives* 8, 93-115.

**Knieps, G. (1994)**, Standards und die Grenzen der unsichtbaren Hand, *ORDO* 45, 51-62.

**Knieps, G. (1995)**, Standardization: The Evolution of Institutions versus Government Intervention, in Gerken, L. (Ed.), *Competition Among Institutions*, Houndmills.

**Laffont, J.-J., P. Rey and J. Tirole (1998a)**, Network Competition: I. Overview and Nondiscriminatory Pricing, *Rand Journal of Economics* 29, 1-37.

- Laffont, J.-J., P. Rey and J. Tirole (1998b)**, Network Competition: II. Price Discrimination, *Rand Journal of Economics* 29, 38-56.
- Lancaster, K. (1975)**, Socially Optimal Product Differentiation, *American Economic Review* 65, 567-585.
- Liebowitz, S. (2002)**, *Re-Thinking the Network Economy: The True Forces That Drive the Digital Marketplace*, New York.
- Liebowitz, S. and S. Margolis (1990)**, The Fable of the Keys, *Journal of Law & Economics* 33, 1-25.
- Liebowitz, S. and S. Margolis (1994)**, Network Externality: An Uncommon Tragedy, *Journal of Economic Perspectives* 8, 133-150.
- Liebowitz, S. and S. Margolis (1995)**, Path Dependence, Lock-In, and History, *Journal of Law, Economics, & Organization* 11, 205-226.
- Liebowitz, S. and S. Margolis (2001)**, Network Effects and the Microsoft Case, in: Ellig, J. (Ed.), *Dynamic Competition and Public Policy: Technology, Innovation, and Antitrust Issues*, Cambridge.
- Schmidtchen, D. (1990)**, Neoclassical and Austrian Theory of Economic Policy: Differences Constitutional Policies, in: Bosch, A., P. Koslowski and R. Veit (Eds.), *General Equilibrium or Market Process*, Tübingen.
- Sharkey, W. (1982)**, *The Theory of Natural Monopoly*, Cambridge.
- Shy, O. (2001)**, *The Economics of Network Industries*, Cambridge.
- Spence, M. (1976)**, Product Differentiation and Welfare, *American Economic Review* 66, 407-414.
- Stigler, G. (1968)**, *The Organization of Industry*, Homewood, Ill.