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The Nature of the Externality
in Systems Compatibility Decisions

by

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ABSTRACT

Katz and Shapiro (AER forthcoming) have analyzed the impact of competition on compatibility in the context of network externalities. This note presents an alternative approach which utilizes a technological externality. Marginal valuation does not rise when sales increase. Rather, the existence of incompatibilities directly dampens demand. The approach is applied to three areas: equilibrium outcomes under cooperation and rivalry, strategic consideration related to insulating a product from a rival's actions, and vertical aspects of compatibility.

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In many markets, physical linkages between products are required for proper system performance. Incompatibilities are present when products from one producer cannot be used with products from another. How one models these incompatibilities depends on the nature of product demands and on the technological decisions made by managers. Given the growing importance of compatibility problems in areas like computers and telecommunications, it is important that economic models capture the essential features of those markets.

Katz and Shapiro (AER forthcoming) have analyzed the impact of competition on compatibility in the context of network externalities. While their framework allows a number of interesting issues to be addressed, the network formulation has some limitations. After exploring the strengths and limitations of the network paradigm, this note suggests that direct inclusion of a technological externality has some useful analytical features. This alternative approach is applied to three areas: equilibrium outcomes under cooperation and rivalry, strategic considerations related to insulating a product from a rival's actions, and vertical integration aspects of compatibility. The technological externality approach provides some insights into key market interactions via compatibility decisions.

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1. Katz and Shapiro: Network Externalities

In their formulation, Katz and Shapiro (hereafter K-S) view consumers as forming expectations regarding sales of compatible products, with firms playing an output game. The externality arises since consumer valuations depend on the expected network size, where the network is defined in terms of compatible products. K-S examine incentives for firms to choose compatibility; since externalities are involved, private incentives deviate from socially optimal incentives.

Their characterization is adopted from models of communications markets, where total output (serving as a proxy for number of subscribers) affects an individual's valuation of access to that network. The network externalities approach allows the derivation of equilibrium outcomes and yields some real insights into firm's decisions regarding compatibility. In particular, K-S underscore (1) the importance of consumer expectations (and producer reputations) in these markets; (2) the distinction between unilateral versus collective actions which contribute to compatibility; (3) the differential impacts of compatibility-induced changes in variable vs. fixed costs; and (4) the feasibility and nature of side payments as permitted in copyright and patent laws (per unit charges induce contractions which facilitate cartel-like outcomes). However, their particular model is built on a conception of consumer preferences that defines away an important part of the problem.

One of the K-S conclusions illustrates a weakness of the model. They find that it is possible for a monopoly to benefit from entry (even with complete incompatibility), since consumers are aware that the monopolist would have a higher price and lower output than a Cournot

duopolist. The awareness is reflected in the consumer's valuation of the product--causing a reduced consumption externality under monopoly. However, in some situations, the introduction of an incompatible product could affect consumer valuations directly.

Take the following example. There are two firms and I expect each to sell 100 units. The products are compatible, so K-S would place them in the same network. In their single period model, my valuation depends on the expectation that 200 units will be sold, with high total output serving as a proxy for the future availability of complementary components or inputs (eg. videocassettes with a particular format). Consider another market with two firms, where I expect each to sell 200 units this period. However, these products are incompatible, so each product comprises its own network. The network characterization views the two situations as comparable. In both instances, there is a duopoly which I consider when calculating the expected price and sales. At issue is whether network size is in my utility function, or whether the mere existence of an incompatibility reduces my marginal valuation of the product. Either way, incompatibilities can result in externalities, but the distinction needs to be recognized.

For some markets, like telephone access, we may have a network (consumption) externality. For others, such as videocassette recorders, a product standard (technological) externality may best reflect consumer preferences. Under the latter conception, incompatibilities matter directly, not through sales or size of groups. Thus, when firms adhere to compatibility standards, market demand this period is expanded due to a reduction in uncertainty regarding the availability of related products in later periods.

Furthermore, as a rational consumer, my sense of market size will be far less precise than, say, my awareness of technical incompatibilities. For K-S, consumers are not only able to group products by compatibility, but are able to correctly predict sales. Basing policy conclusions on such assumptions may be inappropriate for some markets--especially when alternative formulations offer more realistic characterizations of the valuation process and of the interrelationships among firms.

2. Technological Externalities and Market Augmentation

A formulation which incorporates technical standards directly into the utility function is presented elsewhere (Berg 1984), but the outlines are presented here to see how a different characterization of the compatibility problem yields additional perspectives on managerial incentives and public policy. First, technical standards (engineering protocols for physical linkages) can be viewed as one of the inputs in the production function. Costs are functions of outputs (y^i) and standards (T_i):

$$C^i = C^i(y^i; T_i); \quad \partial C^i / \partial y^i > 0 \quad (1)$$

For the duopoly case, let each firm have a cost-minimizing standard, T_i^* . The firms are ordered so that $T_1^* < T_2^*$, and deviations from T_i^* raises costs:

$$\partial C^1 / \partial T_1 > 0 \quad \text{for } T_1 > T_1^* \quad (2a)$$

$$\partial C^2 / \partial T_2 < 0 \quad \text{for } T_2 < T_2^* \quad (2b)$$

Note that T_i^* can be dependent on the level of output and that marginal production costs can be dependent on the deviation from T_i^* . As K-S

stressed, separability of the cost function affects the equilibria that arise under alternative behavioral assumptions.

Marginal valuations depend on outputs (the products are substitutes) and standards, so revenue is characterized by

$$R^i(y^1, y^2; T_1, T_2) \quad , \text{ where} \quad (3)$$

$$R_j^i < 0 ; \quad R_{ij}^i < 0 \quad (4)$$

As T_1 and T_2 come closer together, the degree of compatibility between the products increases--causing the demand for each product to increase

$$\partial R^1 / \partial T_1 > 0 ; \quad \partial R^2 / \partial T_2 < 0 ; \quad T_1^* < T_1 < T_2 < T_2^* \quad (5)$$

In this formulation, the externality does not occur via expected output and consumption decisions, but through the choice of standards, where profits depend on outputs and standards of both firms;

$$\Pi^i(y^1, y^2; T_1, T_2) = R^i(y^1, y^2; T_1, T_2) - C^i(y^i; T_i) \quad (6)$$

The basic results for sequential and simultaneous decision-making are presented elsewhere (Berg, 1984), using a two-step equilibrium for duopoly. Drawing upon the concept of subgame perfect equilibria, producers are viewed as calculating accurately the effects of their first stage decisions on the second-stage outcomes. The work built upon a model developed by Brander and Spencer (1983) who used R&D outlays and output as the two choices.

In this model, choosing a technical standard closer to my rival's standard increases compatibility, expanding demand. The trade-off enters via higher production costs and possible changes in cross-price elasticities which affect the Cournot equilibrium. The equilibrium conditions for four models are presented in Table 1 to illustrate how the outcomes are affected by both market structure and the decision sequence. Equilibrium outputs (q^i) are functions of the chosen standards:

$$y_e^i = q^i(T_1, T_2) \quad (7)$$

Table 1
First Order Conditions for Four Models

<u>Equilibrium Conditions</u>			
<u>Output</u>		<u>Standards</u>	
Simultaneous Rivalry			
$\frac{\partial \pi^i}{\partial y^i} = \partial R^i / \partial q^i$	$-\partial C^i / \partial q^i = 0$	$\frac{\partial \pi^i}{\partial T_i} = R_i^i q_i^i$	$+\partial R^i / \partial T_i - (\partial C^i / \partial q^i) q_i^i - \partial C^i / \partial T_i = 0$
Sequential Rivalry			
$\frac{\partial g^i}{\partial q^i} = \partial R^i / \partial q^i$	$-\partial C^i / \partial q^i = 0$	$\frac{\partial g^i}{\partial T_i} = R_i^i q_i^i + R_j^i q_i^j + \partial R^i / \partial T_i - (\partial C^i / \partial q^i) q_i^i - \partial C^i / \partial T_i = 0$	
Welfare Maximization			
$\frac{\partial W}{\partial y^i} = U_i$	$+ U_j \partial q^j / \partial q^i - \partial C^i / \partial q^i = 0$	$\frac{\partial W}{\partial T_i} = U_i q_i^i + U_j q_i^j$	$-(\partial C^i / \partial q^i) q_i^i - \partial C^i / \partial T_i$ $-(\partial C^j / \partial q^i) q_i^j = 0$
Monopoly			
$\frac{\partial \pi^M}{\partial q^i} = \partial R^i / \partial q^i + \partial R^j / \partial q^i \cdot \partial q^j / \partial q^i - \partial C^i / \partial q^i = 0$		$\frac{\partial \pi^M}{\partial T_i} = R_i^i q_i^i + R_j^i q_i^j + \partial R^i / \partial T_i - (\partial C^i / \partial q^i) q_i^i - \partial C^i / \partial T_i$ $+ R_i^j q_i^i + R_j^j q_i^j + \partial R^j / \partial T_i - (\partial C^j / \partial q^j) q_i^j = 0$	

Under simultaneous rivalry, firms select T_i and y^i assuming that T_j and y^j from the previous period remain unchanged. Marginal revenue equals marginal production cost, and the additional revenue from changing T (marginal revenue times the additional output, plus the shift in the revenue function) equals the additional costs from changing T (marginal production cost times the additional output, plus the change in costs due to the change in T , $\partial C^i / \partial T_i$). With proper bounds on the cost and revenue functions, a unique, stable equilibrium exists. Since firms do not take into account the impact of T_i on y^j , output tends to be greater under simultaneous decision-making.

If instead, firms independently choose T_1 and T_2 , observe the rival's T , and independently pick output levels, such a sequential choice of design standards allows each firm to take into account the impact of changes in T_i and T_j on y^j (due to demand augmentation). However, firm i is aware that some of the private benefit from changing T_i is lost since the rival takes T_i into account when choosing its output.

Comparing outcomes under both types of rivalry with the equilibrium conditions for social optimality requires that a welfare function be specified. Let Z be the numeraire (priced at marginal cost) and the marginal utility of income be constant:

$$W(T_1, T_2) = Z + U(q^1(T_1, T_2), q^2(T_1, T_2)) - C^1(q^1, T_1) - C^2(q^2, T_2) \quad (8)$$

Outputs and the standards are adjusted to equate marginal benefits with marginal costs. Like a multi-product monopoly, welfare maximization takes into account the cross-effects when determining output levels, however the former considers marginal revenue rather than marginal benefits. By restricting output, the monopoly outcome may be far from

welfare maximization, particularly if there are output scale economies and standards economies (as variety reduction associated with compatibility allows input suppliers to achieve scale economies). Note that welfare maximizing compatibility standards need not be closer than those emerging under rivalry: specific cost functions and demand interdependencies determine the appropriate relationships.

A strength of the technological externality framework is that it permits exploration of the public goods nature of compatibility, as stressed by Kindleberger, (1983). If market demand is augmented only when products are completely compatible ($T_1=T_2$), then the particular standard chosen is like a public good--whose production costs depend on costs of related research and negotiation. Furthermore, the framework permits the analysis of partial cooperation (on standards or output) and Stackelberg leadership. One interesting result derived in Berg (1984) is that sequential cooperation on standards specification can yield outcomes that involve less compatibility (and lower welfare) than full rivalry. Antitrust authorities take note! Similarly, under standards leadership, firm 1 takes advantage of its rival's reaction function to its standards (and output responses to closer standards). In theory, both firms could be better off under leadership than sequential rivalry, given the externality associated with standards. Whether society is better off depends on cost and demand parameters.

The framework has its own limitations: the unidimensional nature of "standards" is simplistic and the required concept of subgame perfect equilibria has its own detractors. One direction for future research is towards more detailed characterizations of strategic considerations.

3. Brander and Eaton: Product Line Rivalry

Although the technological externality approach to compatibility does permit the exploration of a number of issues, the model just described is essentially one of substitute products; it does not directly incorporate the complementary products into the analysis. Brander and Eaton (1984) offer a point of departure for incorporating such factors. Although they focused on the decision to produce close vs. distant substitutes, their formulation can be modified to handle strategic compatibility considerations. Furthermore, in contrast to the previous model where different degrees of compatibility were possible, the product line approach developed here is an all-or-nothing characterization.

B-E examined the incentives of two firms to produce from among a set of four products. Decisions are made at three stages: scope of production (number of products), product line, and output. They were interested in the conditions determining whether competing multiproduct firms produced close or distant substitutes. The compatibility decision corresponds to the B-E characterization of product line choice. Besides choosing the degree of substitutability, firms influence the market demand they face.

Consider the demands for a set of four related products, where p^i is the price of good i :

$$p^i = p^i(x^1, x^2, x^3, x^4) = p^i(X)$$

Like B-E, we assume symmetry but products 1 and 2 are complements, as are products 3 and 4:

$$p_2^1 = p_4^3 > 0$$

Products 1 and 3, and 2 and 4 are substitutes:

$$p_3^1 < 0 \text{ and } p_4^2 < 0$$

This adaptation of B-E incorporates the technological externality directly into the demand function: product groups 1,2 and 3,4 are incompatible, so product demand is dampened if both types of products are produced.

Begin with a monopoly, assuming the simple cost structure used by B-E: constant marginal production cost (c) and a fixed cost (K) per product. If the scope choice is two products for firm A, the firm maximizes profits by producing compatible complementary products, where

$$\pi_A = p^1 x^1 + p^2 x^2 - c(x^1 + x^2) - 2K$$

If it produced substitutes (1,3) or weak complements (1,4), profits would be lower.

Once entry is possible, the question is whether a different product line commitment would raise post-entry profits or prevent entry, yielding higher profits over time. B-E analyzed the possibilities with a different demand structure, where products 1 and 2 were closer substitutes than 1 and 3. B-E compared segmentation (choosing 1 and 2) versus interlacing (1 and 3) for sequential entry by duopolists. They concluded that segmentation by the first firm (pre-empting the market for the close substitute) could insulate a firm from the actions of the rival, and yield higher profits. However, if products 1 and 2 are very close substitutes but virtually unrelated to products 3 and 4, interlacing (1 and 3) is more profitable--since otherwise the firm B would choose to overlap firm A's product set. Also, they find that interlacing can result in higher profits for two firms if there is the threat of further entry.

Returning to the modified framework, a different set of results obtain for the sequential entry case when we have complementary products and tack on a demand penalty for the existence of incompatibilities. For example, the odd numbered products might be home computers, and the even numbered products could be printers. The incentives facing the second firm involve balancing the market augmentation effect of compatibility with the increased vulnerability that arises from the adoption of common technical standards. Here, we make the extreme assumption that if firm B also chooses to produce products 1 and 2, that consumers see the two firm's outputs as homogeneous. Hence, B's profits will depend on that firm's evaluation of the equilibrium outcome if it chooses to produce compatible products 1 and 2 ($B_{\Pi C}$) or products 3 and 4 ($B_{\Pi I}$).¹

Under compatibility, we have the following profit functions for A and B.

$$A_{\Pi} = x^{1A} \cdot p^1(x^{1A}, x^{1B}, x^{2A}, x^{2B}) + x^{2A} \cdot p^2(x^{2A}, x^{2B}, x^{1A}, x^{1B}) - c(x^{1A} + x^{2A}) - 2K$$

$$B_{\Pi C} = x^{1B} \cdot p^1(x^{1B}, x^{1A}, x^{2B}, x^{2A}) + x^{2B} \cdot p^2(x^{2B}, x^{2A}, x^{1B}, x^{1A}) - c(x^{1B} + x^{2B}) - 2K$$

The first order conditions yield four equations in four unknowns. If demand is regular, a unique, symmetric equilibrium is obtained, where

$$x^{1A} = x^{1B} = x^{2A} = x^{2B}, \quad p^1 = p^2$$

Different output and price levels arise if firm B chooses incompatibility, since the Nash-Cournot outcome reflects a different

¹Given the demand interdependencies and relative costs, the second firm might only choose to produce one product. We did not analyze that possibility here.

pair of profit functions:

$$A_{II}^I = x^{1A} \cdot p^1(x^{1A}, x^{2A}; x^{3B}, x^{4B}) + x^{2A} \cdot p^2(x^{2A}, x^{1A}; x^{4B}, x^{3B}) \\ - c(x^{1A} + x^{2A}) - 2K$$

$$B_{II}^I = x^{3B} \cdot p^3(x^{3B}, x^{4B}; x^{1A}, x^{2A}) + x^{4B} \cdot p^4(x^{4B}, x^{3B}; x^{2A}, x^{1A}) \\ - c(x^{3B} + x^{4B}) - 2K$$

Using again the concept of subgame perfect equilibrium, firm B sees through to the end of each duopoly game, calculates the profits under each strategy, and makes its choice. It is reasonable to assume simultaneous determination of both outputs by each firm--otherwise, both firms pick an output level, say for product 1, observe their rival's output, and then choose the amount of product 2 (for compatible products). Under the sequential pattern, decisions take into account the extent that a complementary product raises the demand for the second.

In general, demand augmentation supports compatibility. That is, ceteris paribus, the marginal valuation consumers place on the 200th unit of product 1 is greater if output is composed of 100 units per firm than if firm 1 produces 200 units of product 1 and firm 2 produces 200 units of product 3. The difference arises not because the products are substitutes (although changes in p^3 would certainly affect x^1 since the products are substitutes). Rather, it arises because there is a demand penalty for incompatibility.

Running counter to this force is the increased vulnerability to price competition when products are compatible:

$$p_1^1 < p_3^1 < 0$$

Cournot outcomes are dependent on cross-elasticities between products. In this extreme case, compatibility implies homogeneous products and greater sensitivity of profits to output changes of rivals. Clearly, the parameters (elasticities and penalties) determine which outcome is most profitable for firm B.

Detailed elaboration on the modified B-E model would take us far afield. Yet the outlines presented here show how complementary products and an all-or-nothing approach to compatibility can be introduced into a model of product line rivalry. This characterization opens many directions for research. For example, the cost side warrants consideration: economies of scope for multiproduct firms raise interesting issues. In addition, firm A may have a first mover advantage if firm B incurs greater costs to achieve compatibility. The key point is that analysis which utilizes a technological externality will yield results which differ from one which adopts a network externality approach.

4. Braunstein and White: Vertical Integration and Standards

The technological externality approach is also utilized by Braunstein and White (forthcoming) in a relatively nontechnical, but very insightful article. They analyze compatibility standards in the context of vertical integration and address a number of important

issues. For example, they note that if a firm has an enclave with some market power, incompatibility can allow it to remain insulated from rivals. Consequently, a complementary product can involve a tie-in sale. Vertical linkages can also be used to meter demand--serving as a second best technique for price discrimination. In addition, incentives to integrate can arise from efficiency considerations, such as the prevention of uneconomic downstream substitution.

B-W are particularly concerned with predation (via premature scrapping of standards by a dominant firm) and other strategic motivations affecting product compatibility (also see Ordoover and Willig, 1981). By focusing on product linkages which derive from the vertical structure of industries, B-W underscore the importance of the product line decision in affecting the structure of industry and incentives to coalesce around particular standards (and associated technologies). For example, if a dominant firm integrates forward and provides a "package" in the marketplace (color TV broadcasts and color TV receivers), nonintegrated producers may be forced to do the same to ensure the availability of the downstream products compatible with their broadcasts. Alternatively, nonintegrated producers might be compelled to adopt the standards of the dominant, integrated firm, incurring substantial costs. Such strategic choices regarding standards raises entry barriers in the upstream industry, and reduces the likelihood that potential entrants will gain toeholds in either industry.

B-W also consider new issues not addressed by the other articles discussed here. Specifically, they ask whether the source of a technological advance makes a difference in terms of subsequent decisions to produce compatible or incompatible products. The framework

they introduce is relevant for current debate surrounding the FCC's decision not to establish a standard for AM stereo. Here, we have two markets: broadcasting and radio manufacturers. B-W describe a situation in which stations have different shares of the total viewing market: 30% station A, 20% station B, etc. The shares can arise out of consumer preferences via three processes: (I) portfolio listening (each consumer listens to the stations in this proportion); (II) specialized tastes (whereby listeners focus on only one station each--with their number determining the market shares); or (III) mixtures of the other two cases.

B-W assert that under Case I, if the stations develop incompatible AM stereo technologies, the manufacturers of receivers will conclude that consumers will want to maximize the stereo AM programming that can be heard. Since consumers spend 30% of their listening time with station A, that will be the standard that all manufacturers will adopt--without coordinated action. The other stations will realize this, and also adopt the technical standards associated with that technology. Of course, if market shares are similar (with no dominant firm), the coalescence may take longer to achieve. In such cases, industry associations may become key vehicles for overcoming resistance to compatibility standards.

In Case II, tastes are specialized, with listeners being loyal to individual stations. Now the source of the new technology does make a difference. Absent substantial scale economies, manufacturers produce sets compatible with particular technologies. Here, not only is compatibility unnecessary, but B-W argue that technological diversity

mights contribute to further advances.²

If the new technology is being initiated by receiver manufacturers, then stations will tend to adopt the technology of the manufacturer with the largest market share. B-W note that this tendency occurs in all three cases. Furthermore, "...if viewers are 'specialized' vis-a-vis stations, and the stations perceive their [listeners] as coming from 'specialized' manufacturers, compatibility may not occur."

Finally, B-W argue that if stations and manufacturers are vertically integrated, "...the importance of the different source of the technology disappears." However, coalitions may have a hard time forming if the dominant firms in the two markets differ. Throughout their analysis, the externality arises due to standards, not network size.

In terms of public policy, B-W conclude that while market processes may not yield the "best" technology (and associated technical standards) due to dominant firm considerations, it is not clear that regulators can do a better job. They characterize the basic choice as between imperfect markets and imperfect regulators. Thus, Braunstein and White direct our attention to the vast literature on vertical integration, while suggesting a number of directions for future research on compatibility.

²In the mixture case (III), pockets of specialized listeners might keep a standard which differs from A's viable for a while, but the forces tend to lead to the adoption of the technology with the greatest number of potential listeners.

5. Conclusions

The purpose of this note has been to distinguish between two characterizations of the compatibility externality. Katz and Shapiro use a network externality approach to analyze the implications of different market structures and to explore the incentives for selecting common standards or incompatibility. An alternative approach incorporates the externality directly into the utility function, so someone else's decision to buy more of brand X does not influence my own valuation of X or Y. Rather, my concern is with the availability of future complements--which is threatened by present incompatibilities.

The problem is not merely academic, given the importance of compatibility in a number of industries. Ultimately, the evaluation of managerial decisions will hinge on the gains and costs compatibility, which in turn, depend on the valuations potential customers place on compatibility (compared with foregone alternatives) and on the costs borne by firms in selecting technical standards and utilizing them in the production process.

Compatibility is not a characteristic completely analogous to product quality because one firm's expenditures to achieve compatibility with another firm can expand the demand for the other firm's product. This externality is central to the analysis, since it introduces the possibility of a market failure: the underproduction of compatibility. Furthermore, strategic considerations can arise which complicate the story, as when a firm wishes to insulate a product line from price changes and the introduction of substitute products. The evaluation of such behavior depends on several considerations: Is some feature which

necessitates incompatibility especially valued by a portion of the market-place? Are the additional costs incurred (or avoided) commensurate with the gains to the firm--assuming that rivals remain in business (or is the economic viability of the new product dependent on the exit of rivals)? A single model may not capture all the dimensions of corporate behavior or all the relevant market interactions without becoming cumbersome. So there is room for several approaches when addressing compatibility issues.

In summary, the evolution of many markets--ranging from microcomputers to videocassettes and photography systems--is affected by decisions of firms to standardize components or to introduce incompatibilities into the market. The latter will tend to directly reduce market demand, as consumers fear that premature purchases will leave them stuck with a system that is incompatible with those dominating the market in the future. Balancing the demand augmentation effects are the cross-elasticity impacts of rival's price changes and the inward shifts caused by the entry of compatible substitutes. Different models can capture aspects of the opportunity sets and conjectural variations that influence managerial decisions in this area.

On the cost side, the production function for any individual component will depend on inputs used for compatibility. They might be fixed or variable, and they might depend on the output level, so separability (or lack of it) affects the equilibrium costs and output levels of rival producers.

In addition, there may be asymmetries in consumer perceptions. Particular firms may be viewed as technological leaders whose choice of

compatibility standards has special significance for the market. The existence of such a firm (which may or may not be the pioneer) leads to a premium for compatibility with that firm's products. The positioning of new products also can be considered in this general set of economic issues. For example, Epson begins with a successful printer, moves into portable personal computers, and finally upgrades into stand-alone microcomputers for business. Compaq starts with a portable and later introduces a desk-size version. Finding market niches and expanding into full product lines depends on the compatibility decisions made early in the corporate business plan.

Clearly, potential interchangeability is a significant decision variable for firms, as it affects costs and demand. The overall performance of some high technology industries is highly dependent on how technical standards evolve. We do know that monopoly and rivalry are unlikely to yield the same degree of compatibility. In the author's view, the simple duopoly models reviewed here provide some insights into likely developments under alternative market structures. They offer perspectives on the implications of technological externalities for three areas: (1) partial cooperation and standards leadership, (2) strategic decisions when product complementarities are explicitly modeled (especially under sequential entry), and (3) market power at various stages of production (to analyze compatibility under vertical integration).

The analysis depends on whether the externality is simply a network size externality or a direct incompatibility externality. For example, the addition to the market of new demanders who buy product 1 affects my valuation for that brand in the network characterization, but not in

the technological externality formulation. In the technological/standards approach, the mere existence of incompatibilities reduces my valuation of the product. Such a formulation seems particularly appropriate for the analysis of the early stages of a product life cycle.

REFERENCES

- Berg, Sanford V., "Duopoly Compatibility Standards with Partial Cooperation and Stackleberg Leadership," mimeo, University of Florida 1984.
- Brander, J.A. and Spencer, B.J., "Strategic Commitment with R&D: the Symmetric Case," Bell Journal of Economics, Spring 1983, 225-235.
- _____, and Eaton, Jonathan, "Product Line Rivalry," American Economic Review, June 1984, 323-334.
- Braunstein, Yale M., and White, Lawrence J., "Setting Technical Compatibility Standards: An Economic Analysis," Antitrust Bulletin, forthcoming.
- Katz, Michael L., and Shapiro, Carl, "Network Externalities, Competition, and Compatibility," American Economic Review, forthcoming.
- Kindleberger, Charles, "Standards as Public, Collective, and Private Goods," Kyklos Vol. 36, 1983, 393-401.
- Ordover, Janusz A., and Willig, Robert D., "An Economic Definition of Predation: Pricing and Product Innovation" Yale Law Journal, November 1981, 8-53.