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Economics of Network Industries

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Part A: Network Economics

1. Introduction

In traditional industries the economic model conventionally used to estimate the market function is perfect competition. Perfect competition theory assumes that individual economic agents have no market power . The agents in the economy are price takers. It is generally believed that competition will drive the market price down to the competitive level (equal to the marginal costs) and consumer welfare is improved through allocative and production efficiencies. The perfect competition or nearly perfect market is remised on the assumption in a market containing many equally efficient firms, each firm in the market faces a perfectly horizontal demand curve for a homogeneous product, and that firms freely enter or exit the industry.
It is against this benchmark that network industries are a world apart. In their markets products are heterogeneous, differentiation in products is common, the life cycles of products are short, sunk cost is significant, innovation is essential and sometimes 'only the paranoid survive' (A. Grove). In some industries only a handful of participants are in the market and the dominant firms may easily raise the barriers of market entry to exclude competitors. In other words, in network industries, markets usually involve enormous capital and highly risky investment, economies of scale, intensive and interdependent technologies owned by different market players, network externalities of products, and tendency of product standardization. In view of this, market failures in those industries appear significant.
In this chapter I give a fairly extensive characterization of network industries and discuss some of the policy conclusions

2. Networks and Network Industries

In conventional terms empirical examples of network industries embrace electricity supply, telecommunications and railroads. Network industries can be defined as those where the firm or its product consists of many interconnected nodes, where a node is a unit of the firm or its product, and where the connections among the nodes define the character of commerce in the industry. Railroads, for example, are a network industry. The nodes of a railroad (its tracks, rolling stock, switches, depots) are scattered across a geographic area, and the configuration of the nodes determines where, when, to whom, how much, and how quickly goods can be transported. Like the railroads, the entire transportation sector can be analysed as a network industry. Be it airlines, trucks, or ships, each mode of transport has its network of nodes. Other network industries include utilities, telecommunications, computers, and information and financial services. The nodes of these industries are units like electricity lines, phone sets, personal computers, and information platforms. The number of nodes and connected consumers may grow in tandem, but a distinction exists between an additional node on the network and an additional consumer. A node is a capital addition. This distinction is of some importance for the analysis of positive, negative, or negligible externalities in a later section.

Star Networks: a star network has a collection of nodes clustered around some central resource. Movement of resources or products from one node to another must always pass through this central node. A simple example of a star network is a local telephone exchange, a call from any node (phone) must be transmitted through the central switch. [Figure: Star Network] The figure illustrates the central resource CR with N denoting network nodes.
Tree Networks: In a tree network, the purpose of the infrastructure is movement between the central resource and the nodes. Flow among the nodes is not part of the system design. Examples of systems like this include the

distribution of public utilities like water, electricity, and natural gas. In each of these systems, resources flow from a central area to many outlying points [Figure: Tree Network]

Tree-structured networks can be considered one-way networks because resources flow in only one direction. On the other hand, if the system is defined broadly enough, tree-structured networks can also move resources in both directions. Consider, for example, a combined water and sewage system. Water flows out from the central resource to the nodes along a tree structure, and sewage returns from the nodes to the central receiving area through the same structure.

Crystal Networks: A crystal network occurs when the central resources are distributed among connected star networks. Like a star network, movement can occur from any point on the network to any other point. Unlike the star network, that movement will not always traverse a single central point. Movement from one star to the next will involve both central connections, while movement within a star will require only one. An example of a crystal network is the long-distance telephone network which is really the connection of many local networks through medium and long-distance lines [Figure: Crystal Network]

Web Networks: In a web network, each node is connected to many other nodes. Paths between the points on the network multiply as the interconnections increase, and the network assumes a distributed character, no network center can be identified. There are two salient features to a network with a web structure. First, the resources distributed via a network with a web structure are located in the nodes. This means that as the number of nodes increases, the resources to be distributed throughout the network also increase. Second, the distributed nature of a web network makes the system less vulnerable to the failure of any part. This feature was a key attraction of networked computing projects evolving into today's Internet [Figure: Web Structure]

Here each node is connected to four nodes around it, and a lattice or grid emerges. That is, if you pick any two points between which data should travel, the failure of any one point in the lattice (as long as it is not the origin or destination of the data) will not interrupt communication. This is not the case with the other structures presented here. In a star network, for example, failure of the central node disables the rest of the system.

Network Characteristics: Beyond the various structures of networks, there are also a few characteristics of networks that can influence their economics. Two of the most common characteristics made about networks concern their directionality and spatial character. Most networks carry their loads to and from all the nodes on the network, traffic is reciprocal. Transportation networks and the telephone system are like this, and reciprocal networks are probably what most people imagine if they think about networks. One-way networks, however, also exist. Most of the tree structured networks, electricity, water, natural gas, deliver from a central resource to homes, but not vice-versa. A communications example of a one-way network is the cellular paging system, though the introduction of two way pagers and cellular phones shows that a transformation of that network is already underway. A spatial network is one that is fixed geographically , a railroad network is a typical example. As a spatial network, the existing track layout determines, for example, who can be served by the railroad and where goods can be delivered. A non-spatial network like the Internet, is free of these geographic constraints.

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3. High Risk Investments and Sunk Costs

A network industry company survives in the market only by maintaining rapid innovation, relying on intensive, large scale research and development projects to develop new products or processes .

On the other hand, sizeable financial commitments receive no guarantee of profits or success, as a recent survey on the New Economy (Economist, 2000) appears to substantiate. Accordingly, these tremendous sunk costs make entry and exit to market relatively difficult. Such a company , therefore, inevitably requires large, irreversible investment. Further, rapid innovation shortens the product's life cycle and leads to non-price competition. The costs of new products, hence, usually increase rather than decrease. Today's semiconductor industry illustrates this dilemma. The cost of staying at the cutting edge of semiconductor technology is horrendous. In addition to the large investment on the supply-side, customer's investment can also be enormous and irreversible. Because today's technologies are complicated, sophisticated and complementary as well as compatible, customers must commit to a generation of equipment, where personal training, ancillary facilities, applications software, or other ongoing expenses are tied to the particular technologies. This means the investments of customer and their switching costs are very high (Choi, 1994).

4. Economies of Scale

In network industries, the fixed costs are tremendous in proportion to its total costs of the products. The returns to size of the firms are not constant. The average total cost lowers as the total output increases.
The effect of economies of scale is commonly seen in every stage. The most important assets of network industries are knowledge or information. The costs of research and development of new products or new processes are prohibitively high. Nevertheless, once it has been developed, a product (book, software) can be produced with almost zero marginal costs. This is illustrated in the computer software industry where virtually all of the costs of production are in the design of the program of software. Once it is developed, the incremental costs of reproducing software, that means , the costs of copying a disk, are negligible. In other words, the production costs of software are almost totally independent of the quantity sold and consequently, the marginal cost of production is almost zero. At the same time , unlike in other industries, the increasing returns may be of no ending . One of the characteristics of computer software industries is that there is no natural point of exhaustion at which marginal costs begin to exceed marginal revenues and at which it becomes uneconomical to increase production. That is to say, in this industry there is always the case that the more products produced the lower the costs per product. Large scale production is generally required in order to achieve minimum per unit cost rapidly when the descending learning curve, termed 'learning by doing' effects, are significant. The increasing returns to scale arise because increasing experiences foster the improvement of production technologies , and allows the managers and workers to specialize in their tasks . As a result, the unit cost fell as workers and operators learn by doing. This is particularly evident in the semiconductor industry or computer assembly industry. In those industries, very often than not, shadow costs lie below current-period costs because the presence of a learning curve allows firms to lower their unit costs tomorrow by acquiring production experiences today (**wafer production**)
Moreover, in some industries where price discrimination is possible, the learning curve effect leads to a dynamic process whereby differential pricing increases the volume of output and expanded output results in declining costs, thereby allowing new customers being served. The presence of learning curve economies is particularly important from a public policy perspective. If there are increasing returns, then it is more economically advantageous to have one large firm producing than have many small firms.
On the other hand, the increasing returns, at the same time, handicap small-scale entry.
For example, the introduction of competition into the telecommunications market generally has two phases. The first phase allows new suppliers in the areas of value-added services. The next phase introduces competition into core areas of local, trunk (long-distance), and international services. However, in practice, high capital costs and economies of scale limit the development of competition in local services.
So far we have observed economies of scale effects from the supply side, those are reinforced by equally strong effects from the demand side which are facilitated through ‘network externalities’. Also those reinforcing effects could easily lead to overwhelming market dominance and winner-take-all situations (Shapiro and Varian, 1999).

5. Network Externalities

One of the most striking economic aspects of networks is how they create externalities. Network externalities occur in both the demand and supply of the network. The textbook externality is a supply externality. For example, as a negative byproduct of a factory's production, pollution spews into the air or water. Demand externalities, on the other hand, may exist for non-network goods, but they are not usually considered important enough to merit attention. For example, economists typically do not factor demand externalities into consumers' demand functions. Many models of consumer behaviour assume that the average consumer's demand for potatoes, lettuce, corn, etc., for example, are formed without any reference to how many other people are purchasing these products. Certainly the number of consumers in a given market affects demand and therefore price, but an individual's demand is independent -- it does not depend directly on a product's popularity in most models. Such effects are assumed away as insignificant.
Besides the supply-side economies of scale the demand-side economies of scale are commonly seen in the communications and computer industries among others. For some goods and services, a person's demand depends on the demands of other people, or the number of other people who have purchased the same good may affect a person's demand. For example, the buyer of a telephone or fax machine would have not bought it if there were no one else who had purchased or would have purchased it. When more people have purchased it the more value of a telephone or fax machine the buyer would have obtained. This is a positive network externality based on an 'actual' or 'physical' network. Moreover, for some goods , such as Microsoft Office, the individual demand for that good inherently exists but enormously increases when other people buy the same good. In an actual ù network, products have very little or no value when alone, they generate value or more value when combined with others (example: fax machine). In a virtual network, hardware/software network products have value even if they exist alone, however, they are more valuable when there are more complementary goods, and also there will be more complementary goods when more people use the products. Application software developers are likely to write for the platform of the operating system that most people favour. Conversely, the operating system that

more application software writes on are favoured by more people. The operating system with a larger market share will provide a bigger market for the application programs. At the same time, the availability of a broader array of application programs will reinforce the popularity of an operating system which in turn will make investment in application programs compatible with that operating system more desirable than investment in application programs compatible with other less popular systems. As a result, the operating system with a larger installed base attracts more buyers whereas the small and later entrant with a smaller installed base with equal or even superior quality finds it difficult to compete. As more users are attracted to a network , the size of the network grows and confers greater value to the network users. Network effects directly challenge an important principle of classical economic theory , which posits decreasing (and eventually negative) returns to scale in most markets. Also this theory basically deals with increasing returns problems in case of supply side economies of scale but ignores cases of demand side economies of scale brought about by increasing value of existing users through increased demand, i.e. through network externalities. That is, network markets offer increasing returns over a large portion of the demand curve or even the entire demand curve. Markets with increasing returns imply that bigger is better and consumers deriving more value as the number of users grows. The flip side of this situation in terms of market structure is that the strong grow stronger and the weak become weaker.
Hence, network markets provide potentially fruitful returns to firms that can make their own products as standards in markets or in aftermarkets for complementary goods. . This presents the possibility of substantial first-mover advantages: being the first seller in a market may confer an important strategic advantage over later entrants because a first mover's technology may become locked in as a standard (Arthur, 1989, Katz and Shapiro, 1986)That is to say, the first technology that is introduced into the market may gain excess momentum when many early users join in anticipation of other users hopping on the bandwagon at a later date. This strong expectation is critical to network expansion (Choi, 1997). In the end consumers already belonging to an existing network will not likely switch to a new technology, even if it is better (Economides, 1996)
The switching costs associated with transferring to an incompatible but superior technology create 'excess inertia' to consumers. That means consumers will not adopt a new superior technology not only because of the sunk costs they have already put in but also because values from network externalities may be lost if they switch. Network effects, therefore, could stifle innovation.
In a traditional market, where network effects are negligible or non-existent, competition turns primarily upon price, quality and service considerations. In contrast, in those markets in which network effects are significant, competition plays out in other dimensions as well: particularly in strategies to establish, maintain, and control standards for the industry. The computer industry hence suggests that network effects have played an important role in shaping the market structure and the margins on which competition occurs.
Also, increasing returns raise the possibility of leveraging a monopoly power from one market to another. Because users may be reluctant to commit to any given system unless they believe it will be adopted by many others, the 'network owner' may engage in a variety of strategies to discourage potential buyers from buying a smaller network regardless whether or not it is superior. Strategies include expanding the system to include complementary products offering a wide variety of complementary products at very attractive prices or through bundling. At the same time , leveraging is able to raise rivals' economic costs of competing in the marketplace. For example, in its effort to be adopted as the next generation standard, the owner of one element of a system may enter complementary markets by engaging in alliances as part of a strategy of attracting users to its network . Consequently, rival operating systems need to ensure the provision of substantial complementary products in the market, otherwise very few buyers will try its system. As a result, the follow-on improved or complementary products markets become very difficult.
Strong network effects are therefore themselves barriers to entry, even though it is sometimes unclear whether entry into the market ought to be encouraged. Since the increasing return deters the incentive of new entrants and increases the costs of new entrants. Such a blunting of incentives can occur if the leveraging practice is undertaken, not primarily as part of a vigorous competitive strategy, but in part to decrease the likelihood of competitor entry, so that the dominant firm will continue to be dominant in competition for the next market. This has clearly be shown for the Japanese telecommunications market (Gottinger and Takashima, 2000) The unlikelihood of success for new entrants will reduce the incentives of other competitors to innovate to the extent that these competitors perceive that the opportunities to profit from their innovations are hindered. All of this is particularly significant because markets in which there is rapid technological progress are often markets in which switching costs are high, in which users find it costly to switch to a new technology that is not fully compatible with the older technology. The result is an increase in entry barriers.
From what follows the definition of a network externality is given by the value of a network created by the number of its nodes. Also, network externalities can exist both for the supply and demand side of the economic equation. And networks can generate negative, positive or no externalities. Network externality networks are those that decrease in value when the number of nodes increases. More 'traditional' network industries fit into this category.

6. Complementarity, Compatibility and Standardization

In network industries, many products have very little or no individual value, but produce value only when combined with other products. Since a product involves lots of technologies, or is made of different components, or a product system combines several goods and services, the demand of those technologies or intermediate goods or services are thus often interrelated. That is to say, they are strongly complementary, although they need not be consumed in fixed proportions. Those complementary products are usually described as forming systems, which refer to a collection of two or more components together with an interface that allows these components to work together. Nevertheless those components, products, or services are usually provided by different manufacturers, in fact. The products, components or services need to be compatible with each other in order to combine the components into operable systems. By the same token, other manufacturers can market their individual products only when the products are compatible with other products. This is easily illustrated in computer assembly, software industries and elsewhere. In many cases, these strongly complementary components purchased for a single system are spread over time. If the components or products of different brands are incompatible, the customers need to make their purchase decision on the total system. Besides the complementary components, a system may include the future stream of ancillary products and services over the life of a primary product. In other words, rational buyers should take into consideration availability, price and quality of the components that they would be buying in the future. As a result, customers' costs in purchasing network products are not limited to the price of the product but more importantly, also include the customer's large investment in complementary equipment or training for employees when they use the product. Likewise, whenever consumers become accustomed to the products of particular manufacturers, they do not shift to other products quickly not only because they are unfamiliar with the new products to operate with but also because the complementary equipment or system is sometimes incompatible. In short, the incumbent users switching to a new technology would lose existing network benefits and would have to replace not only the durable goods themselves, but also any sunk investment in complementary assets. It thus provides opportunities for the existing system to exploit the customers and deter competition from the rivals. Compatibility is crucial to gain the benefits in network industries. Network effects will be workable in products of different manufacturers only when their products have the same protocol or bridging technologies allowing them to communicate with each other . Even in the computer software industry, although the product will allow even a single user to perform a variety of functions , whether or not others own the software, the value of a given software program grows considerably as the number of additional purchasers increase. This means that network effects will be unavailable in the software of different manufacturers, which are not compatible, unless converters exist in the interface, if the technology allows (Farrell and Saloner, 1992). Standards, especially interface standards, therefore play an important role in network industries. Without standardization networks would be confined to those users who purchased the products made by the same manufacturer if products made by different manufacturers are incompatible. The standardization of computer software hence facilitates the formation and operation of computer networks, the transfer of files among users and across applications, and savings in training costs. When standards are established, entry, competition , and innovation may be easier to handle if a competitor needs only produce a single better product , which can then hook up to the market range of complementary products, than if each innovator must develop an entire 'system'. Compatibility standards thus allow networks to grow, providing pre-competitive benefits by creating 'networks' of compatible products

Further, because of the standard, economies of scale drives prices down, and the network becomes more attractive and grows. The benefits to society as a whole are greater when standardization allows for product compatibility among all users.(Besen and Farrell, 1994). On the other hand, standardization may carry costs of their own. First , there may be a loss of variety , reducing the flow of services generated by the product. Second, the costs of each technology may vary between and among consumers , so that if only one technology is offered, some consumers are forced to purchase what is for them the more expensive technology. Third, and most important, is that despite their advantages for innovation, networks can also retard innovation

Some economists argue , once standardization is achieved, it can be hard to break out of that standard and move to another, even if the original is no longer the most suitable (Farrell and Saloner, 1992) . I t can be hard for users or vendors to coordinate a switch from an old standard to a new one, even if all would like to do so. Moreover, some users may have invested a considerable amount in training themselves to use the existing standard. They will be reluctant to abandon that investment even if new technology is better and a switch would be desirable for the sake of efficiency. New users must choose between the benefits of compatibility and the benefits of the new technology, and often compatibility wins the game because of the effects of 'excess inertia', even if it should not. This is a socially undesirable failure to adopt an improved technology or facilitate improved innovation.

7. The Rationale of Strategic Alliances

To do business in an international or globalized context more and more network companies decide to form strategic alliances instead of other interfirm transactions such as acquisitions or transactional arrangements. Strategic alliances of that sort rely on sharing the risks, synthesizing complementary skills or assets, and attaining economies of scale and scope. More importantly, this quasi-integration arrangement can provide participants closer long-term relationships that arms length market transactions and short-term contracts can not offer. In network industries , strategic alliances are formed to share the costs of research and development, to complement technologies when producing new products, or to combine resources when entering new markets. Strategic alliances coordinate divergent strengths of research capacities to facilitate an efficient exchange of knowledge or a pooling of skills. More often than not the introduction of a new product, process or improving the quality of the product is possible only when these insights combine together , insights which would have been otherwise closely held as trade secrets by individuals while acting alone. Diverse skills can be brought together in a manner that creates economies of scale in product or process innovation. In addition, when the minimum efficient scale of research and development is too large relative to production and marketing, sometimes it can be performed economically only if two or more firms join together.

8. Setting Standards

Standardization is a natural tendency in network markets, particularly in system markets where strong positive feedback enables one system to pull away the popularity from its rivals once it has gained an initial edge. This de facto standardization generated through market competition in network industries confers on the winner the full value of the standard and not just the value of his contribution. This result is inefficient in social benefits, however. Network effects , which posit incremental benefits to existing users from network growth, suggest that network goods should be optimally priced as low as possible to allow widespread adoption of the standard. Nevertheless, just as a monopolist maximizes its revenue by raising prices above a competitive level, a single company winning and owning a propriety standard can set whatever price it wants. This is not the best way to benefit consumer welfare. A proprietary standard also seems unnecessary as it is used to encourage the production of future works of intellectual property. While the intellectual property regime posits incentives of innovation, the winner of the standards competition may receive a windfall that is far greater than what an intellectual property regime normally provides. Of course, in order to resolve the problem of de facto standardization, a central government authority may simply decree a standard. This strategy is likely not to be effective. The government organization is not market-oriented, and is very likely technologically less efficient. If they choose an inefficient standard, it will be hard to surpass. Private standard setting organizations are more efficient. If they choose the wrong standard it may be leapfrogged by a new standard. At the same time the innovating firm may believe that it can be advantageous from allowing, indeed encouraging, other firms to attach to its new product. In this case, strategic alliances including licensing and joint ventures provide a direct and explicit way to make its product standard. At the same time, if people can switch back and forth between competing systems of what essentially is the same standard, perhaps society can seize the benefits of competition without wasteful duplication of efforts and without stranding consumers who make the wrong choice. A possible solution is to make competing standards interoperable. One approach to achieving interoperable standards is for a private industry organization open to all members to adopt a single standard.

If the members of such a group collectively have a significant market share, their adoption of a standard may produce a 'tipping' effect, bringing the rest of the industry into line. That is to say , the group standard setting may trade off first-round competition (to set the de facto standard) for competition within the standard in later periods. Cooperation is therefore extremely attractive in the setting of standards in the network industry because compatible systems are almost unavoidable in this field. Private group standard-setting through strategic alliances or joint ventures will be more efficient than both by government organization and de facto standardization. Since having multiple companies participating in a standard means that those companies can compete to offer products incorporating the standard after it is selected , thus expanding output and lowering prices. Group standard setting may also promote competition in the development of improvements to the standard, since each of the competitors may seek an advantage over the others by improving the design in ways compatible with the basic interface specifications. Such group standard-setting is common in the computer and telecommunications hardware

industry. It has especially been known as the computer industry reaches maturity that the open system plays an essential role. An illustrative example is the market for digital videodiscs (DVD) where two major industry groups, such as Sony-Philips and Toshiba-Matsushita, competed offering incompatible standards for several years snd once agreed to use a single compatible format incorporating elements from both products. The agreement is splinted at last not because advantages of compatibility are underestimated but gross profits and possibilities of controlling next generation technology by the winning system are dominant.
Some difficulties are usually found in forming the alliances to set up a standard. The first obstacle is that, since a standard must be chosen for the long term, participants want to get it right. Thus even if all interested parties had indentical interests, there would be some delays. The second obstacle is vested interest. Unless discussions are in advance of the market, different vendors have different installed bases neither of them wants to agree on the other's standard. This bargaining problem can cause serious delay. For example, many of the tree-structures public utility networks like water and electricity distribution display negative network externalities. The key to the negative externality is that in many tree-structures networks, resources are concentrated in a central location. For the electricity grid, that location is the main power plant, for the water system, the central resource is usually a reservoir. The utility network exists to connect consumers to the central resource. When new nodes are added to the network, the number of consumers with access to the resource increases but the potential resource to be distributed remains the same. Thus adding nodes to the network divides a fixed resource among more consumers, meaning less of the resource for each user on average. One can see examples of this in developing countries when, for example, new electricity consumer demand is not met with increased power generating ability and brown out results. One can then clearly see the negative network externalities of an electrical grid. In contrast, networks may also exhibit no significant demand externalities. One may consider, for example, the many large and important broadcast networks (i.e. television, radio) that exist in the world today. Adding nodes (television sets, radio receivers) to these networks creates little or no demand externalities: the average considering purchasing a television or radio does not care what percentage of other consumers own these products. Value in these networks is created centrally, and the nature of television and radio broadcasts is such that reception by one instrument has no impact on others' reception. Finally, many of the high technology networks flourishing today embody positive externalities. Networks like these increase in value for the consumer as nodes are added and the system expands. One of the best examples of these kinds of networks is the telephone system. What makes the difference between negative or no-externality networks and positive externality systems? The key resides in the location of resources . Where the electricity grid or the water pipelines or the radio broadcasts are built around a valuable central resource, the telephone network is used to bring highly distributed resources together. When a new phone is added to the network it makes demands on the central resources of the network (switching, for example) but it also adds the resources of the newly connected people to the network. Even more striking is the example of the world wide web. New servers (nodes) on the world wide web bring with them new web users who bring new information with them. The attraction of the world wide web only grows as more people make more information available.

Part B: Network Size and Value

1. Introduction

We examine competing assumptions about the relationship between network size and network value which are key to models involving network externalities. Network externalities have been the modeling basis for studies ranging from industrial location decisions (Arthur,1987), to urban residential patterns (Schelling,1978), to riot behaviour (Granovetter,1978) and political revolutions (Kuran, 1995).
In industrial organization, economists like Economides (1993, 1996) have begun to apply the lessons of networks to industries characterized by vertical relations.
Despite the variety of economic work on networks and network externalities that has occurred in the past few years little empirical work on those topics exist. Almost all of the published work is of a theoretical nature, few papers have attempted to quantify network externalities in some meaningful way.
First we discuss the motivation behind the work on network externalities relating to the academic and business worlds. Then we outline some key hypotheses on network size and economic value that should be subject to empirical testing. Further on we establish a relationship to the macroeconomic debate on increasing returns industries, forming the 'new' vs. the 'old' economy.

2. Perspectives on Network Externalities

We start with a useful distinction suggested by Economides (1996) in his survey of the literature, he divides the work on network externalities into what he calls macro and micro approaches. Macro investigations assume that externalities exist and then attempt to model their consequences. Micro investigations start with market and industry structures in an attempt to derive (theoretically) the source of network externalities. The later category is largely founded on case studies. Three of those are symptomatic. David's(1985) QWERTY study, Arthur's (1989) model , and the domination of VHS in the videotape recorder market combined , spurred theoretical and empirical interest in network externalities. The gist of David's QWERTY study is that inferior technologies through network externalities may be subject to 'lock-ins'. This might apply to the keyboard QWERTY as well as to the adoption of the VHS against the Betamax standard though with specific technological advantages of Betamax over VHS. In empirical support of network externalities , Gandel (1994) finds that consumers pay a premium for spreadsheets which are compatible with Lotus 1-2-3 (an industry standard for spreadsheets). In other words, consumers are willing to pay for the ability to share spreadsheet information and analysis easily with other computer users. Thus he concludes that there is strong empirical support for the existence of network externalities in the computer spreadsheet market. In another aper, Saloner and Shepard (1990) test for the existence of network externalities in the network of Automated Teller Machines (ATMs), their results support existence.

3. Hypotheses on Network Externalities

Perhaps it is not surprising that little quantitative work on network externalities has been done. Many examples of network industries embody cutting-edge technologies, given that theoretical work on network externalities is still relatively new, data collection is fragmentary and common data sets upon which to test theories are severely limited. One particular important question emerging on network externalities is the functional relationship between the size of a network (its number of nodes) and the network's value.

Three key assumptions about the relationship between network size and network value underlie most analyses of network externalities and their effects. They relate to linear, logarithmic and exponential assumptions.

The linear assumption postulates that, as networks grow, the marginal value of new nodes is constant. The logarithmic assumption postulates that, as a network grows, the marginal value of new nodes diminishes. Network externalities at the limit in this formulation must be either negative, zero or of inconsequential magnitude in comparison to quantity effects on prices. In contrast, Katz and Shapiro (1985) make their assumptions explicit: network externalities are positive but diminish with development, at the limit they are zero.In any case, network effects diminish in importance in these models as a network grows. The third key assumption about the relationship between network size and value is the exponential assumption which in the popular business and technology press has been named 'Metcalfe's Law'. It embodies the idea of positive network externalities whose marginal value increases with network size. Robert Metcalfe (1995) states the 'law' in this way: "In a network of N users, each sees a value proportional to the N-1 others, so the total value of the network grows as N(N-1), or as N squared for large N" . The validity of Metcalfe's Law is crucial to the 'increasing returns' debate on the New Economy , facilitated by the aggregation of positive network externalities in high tech industries. One could also consider a mixture of hypotheses such as a combination of Metcalfe's Law and the logarithmic assumption, that is early additions to the network add exponentially to the value of a network, yet later additions diminish in their marginal value. The result looks like an S curve, as illustrated. It is based on the idea that early additions to a network are extremely valuable, but at some point 'network saturation' should take place and marginal value should fall.

In summary, the industry and hence aggregate (growth) benefits can be classified as follows:

(i) industries that show an exponential growth (through strong complementarity)
(ii) industries that show linear growth (additive benefits)
(iii) industries that show a log relationship (stable benefits)

The mixtures of those economies create the features of the new economy. Such an economy is not immune to economic cycles, but to the extent that the network economy snowballs in an upswing period, by the same token it might also contract faster in a downswing period but with a better chance to stabilize quicker.

4. Technology Adoption , Network Industries and Hypotheses on Network Effects

We look at the main hypotheses as how they are likely to affect the adoption process of particular network industries. The linear hypothesis is the assumption of Arthur's (1989) model subject to simulation. Given a very large number of trials , technology adoption leads (almost surely) to lock-ins. Given two technologies , A and B, further R and S agents that make adoption decisions , respectively, in Arthur's model each trial represents a random walk of an ever increasing number of R and S agent decisions. As the number of trials increases, with symmetries in both technologies A and B, the split between A and B adoptions approach fifty-fifty. That is, either one of them will be adopted , and non-adoption will be most unlikely. In Arthur's analytical model, as the number of iteration goes to infinity, the possibility of non-adoption disappears.
Correspondingly, the average adoption time until lock-in will increase with decreasing probability (of non-adoption), in conformity with the linear hypothesis, in other words, more agents become (linearly) more convinced to adopt either way. This suggests that the network effect leaves only a neutral impact on the innovation process. Against this bench mark, when the value of network size grows logarithmically in relation to its size, the average time until lock-in occurs is extended. What appears surprising is how much the logarithmic assumption delays lock-in. That is , the logarithmic specification creates less growth prospects and greater instability by delaying (or preventing) adoption from occurring. In contrast to the logarithmic hypothesis, the exponential assumption shortens the average time until adoption occurs. The average adoption is affected just as drastically by the exponential assumption as by the logarithmic one. With the exponential assumption, however, the average adoption occurs much earlier than in the baseline case. No wonder, that on an aggregate scale across network industries, it is this network effect that lends support to 'increasing returns' by the proponents of the New Economy. It can even be reinforced by speed of transactions, for example, enabled through large scale broadband internet technologies. This would support a scenario of a sustained realization of an exponential assumption as even more likely. If it can be established that the Internet triggers a technology adoption process in the form of a large and broad wave ('tsunami') across key industries, sectors, regions and countries , then increasing returns will generate exceptional growth rates for many years to come. For this to happen there should be a critical mass of network industries being established in an economy. Then an innovation driven network economy feeds on itself with endogeneous growth . It remains to be determined , empirically, which mix of sectors, with network effects with exponential, linear and logarithmic relationships will have a sustained endogeneous growth cycle.
From a slightly different perspective, it is interesting to note that the logarithmic assumption creates instability in the models. Metcalfe's law, on the other hand, which leads to immediate adoption, creating a dynamics of its own, would prevent many contemporary models from reaching equilibrium.

Part C: Technology Adoption in Networks

1. Introduction

Technology adoption in networks suggests that individually rational decisions regarding technologies can, in the presence of network externalities, generate collectively inefficient results (Arthur, 1989). Such a statement would be subject to qualifications if one incorporates adapter (converter) technologies into the adoption problem. Adapters allow previously unattainable network externalities to be captured, in some cases, adapters preclude 'lock-in' from ever occurring, in others, previously unpredictable technology adoptions can be predicted with high confidence . These issues dominated historically the late nineteenth century rift between electric power standards and today governs the evolution of Internet standards .

2. Examples: Present and Past

Example 1. Consider two competing technologies that exhibit network externalities of some sort, such as WINTEL and Macintosh computers.. In the framework of the Arthur(1989) and David (1985) models, these technologies battle for market share across several dimensions, including network size. If consumers value the size of the network (positive externalities), decisions to adopt one technology increase its subsequent attractiveness. In the classic case, market share builds on market share, and once a technology has been established a solid lead it becomes 'locked-in'. The consumer decision is plausible enough. Few people use computers just for their own sake. Most value the ability to share data electronically among co-workers, clients, friends and family. The more data one shares, the more important network compatibility becomes. In aggregate, positive network externalities drive a market toward a single standard. Now consider how the consumer decision would change if an inexpensive translating disk drive were invented that allowed PC disc and data to be read for Macintoshes and vice versa, and nothing were lost in the process. A Mac user could then completely capture the benefits of the PC network, and network size would become a trivial component of the buying decision. Assuming price and quality of the technologies remained comparable, the market would no longer drive toward one technology. Finally, consider the asymmetric situation, in which a different disk drive allows Mac users to access the PC network but did not allow PC users to access the Mac network . Given comparable prices and qualities , the attractiveness of the PC declines. The Mac would gain strength in the market. Those knowledgeable in computers will note that translating software and drives that read both Mac and PC-formatted discs have existed for a number of years, though none provides a seamless transition from one system to another. That these kinds of devices --- adapters, converters, gateways--- exist is not a situation unique to the Mac and PC rivalry. Gateways exist to bridge incompatible systems as diverse as railway gauges, electrical current, and computer networks. It is thus likely that the existence of gateways substantially alters the dynamics of technology adoption where positive network externalities are present.

Example 2. Another example has been noted by David(1987) . It centers around the question why support for direct current (DC) power (including the one of the inventor: Thomas Edison) collapsed around the end of the nineteenth century. Until then competition between alternating current (AC) and DC systems had been fierce throughout the 1880s and neither was clearly superior at that time. DC systems, although inferior to AC in terms of transmission, led in the ability to translate electricity to mechanical power via motors. They also enjoyed an installed base of generating systems and infrastructure in the most advanced, electrified, urban areas. Moreover, DC's installed base meant that line engineers and electricians were familiar and comfortable with the system, the system was reliable and the flaws known. Support for DC power, however, dissipated as Edison withdrew from the management of Edison General Electric and the company (after merging into General Electric) began selling AC systems in the 1890s. Although DC systems continued in use over the next thirty years, they were enclipsed by the expansion of AC systems. Why after such fierce competition, did support for DC systems so suddenly evaporate?

David and Bunn (1988) find a reasonable explanation for the quick collapse of the DC system. They identify the invention of the rotary converter --- a gateway that allowed AC substitutions to be attached to DC main lines - as a turning point in the competition between the standards. It appears that the rotary converter's invention is the turning report.

3. The simple mathematics of technology adoption

We consider Arthur's (1989) basic model with two agents **,** R and S, and two technologies A and B. Each agent makes a buying decision based upon an initial preference for the technologies and from the network externalities associated with each technology. These payoff rules can be summarized in Table 1 where A_R is the R-agent's initial preference for technology A, N_a is the size of the network using technology A, and r is the parameter for network valuation.

Table 1

	Technology A	Technology B
R-agent	$A_R + rN_a$	$B_R + rN_b$
S-agent	$A_S + rN_a$	$B_S + rN_b$

The increasing returns to scale case is under consideration here, so r is always positive. The R-agent initially prefers technology A and the S-agent initially prefers technology B, therefore $A_R > B_R$ and $A_S < B_S$.

Arthur's simple model can be envisioned as a universal sales counter where all agents interested in technologies A and B must go for their purchases. The R and S agents queue, and one agent makes a purchase in each time period. In modeling terms, agent i comes to the market at time t_i , at which point he makes his decision based upon his payoff rule. Whether the i-th agent is of R or S type constitutes the stochastic element in the model. Arthur stipulates a fifty percent probability that agent i will be of the R type. Thus the technology choice of the i-th agent is determined by a combination of three things: agent i's identity as an R or S type (determined stochastically), agent's i's initial technology preference (determined by the agent's type), and the number of previous adopters of each technology

Arthur shows that, under these parameters, one of the two technologies will 'lock-in'. This result is easily derived from the payoffs in Table 1. R agents will initially prefer technology A given his preferences and no network benefits. R agents will switch to technology B, however, when

$$B_R + rN_b > A_R + rN_a \qquad (1)$$

Equation (1) can easily be rearranged into the following 'switching equation'

$$(A_R - B_R)/r < N_b - N_a \qquad (2)$$

Equation (2) and a similar one for the S agent establish 'absorbing barriers'. When the size of technology B's network exceeds A's network by some arbitrary amount, as determined by initial preferences and the r value, technology B will lock-in as the de facto standard. Intuitively, the R agent will abandon technology A when the size differential of technology B's network is so large that the benefits of B's outweigh the R's agent's initial technology preferences. Because at that point both R and S agents will purchase only technology B, the network for technology A will not grow further.

This analysis can be captured by a simple graphic (see Fig. 1). The horizontal axis represents the progression of time and the subsequent agent technology adoptions. The horizontal axis represents the right-hand side of equation (2), that is, the difference between the sizes of technology A's network and technology B's network.

4. Compatibility through Bridging Technology

Adding converter technology to achieve compatibility produces some interesting changes to Arthur's model. Consider the addition of parameters k and c , assuming values from zero to one, which represent the compatibility of technology A with technology B and the reciprocal compatibility of B with A, respectively.

A parameter equal to 1 denotes a converter that is perfectly compatible and a zero value would indicate complete incompatibility.

The payoffs for this model appear in Table 2. Note that the model can be collapsed by to Arthur's formulation by the assumption that k=c=0 which is the absence of the need of any converter.

Table 2

	Technology A	Technology B
R-agent	$A_R + rN_a + krN_b$	$B_R + rN_b + crN_a$
S-agent	$A_S + rN_a + krN_b$	$B_S + rN_b + crN_a$

(a) partial, reciprocal converter

As a derivation of the model we can state: the introduction of a partial, two-way gateway will, ceteris paribus, prolong the time required for technological lock-in to occur. Assume the introduction of a bridging technology that is compatible in both directions, i.e. k=c. The R-agent will switch preference to technology B when

$$(A_R - B_R)/r < (1 - k) (N_b - N_a) \qquad (3)$$

At the introduction of a gateway, the distance between network parity and the absorbing barriers will be multiplied by 1/(1-k) . If the bridging technology were fifty percent campatible, the difference between N_b and N_a would have to be twice as large to persuade the R-agent to switch to technology B. This proposition is illustrated in Fig. 2. Note that the stochastic nature of the modeling process does not guarantee that introducing a converter will prolong the adoption process. On average, however, adoption will take longer in systems with partial, reciprocal converters.

(b) perfect, reciprocal converter

The presence of a perfect, two-way gateway will prevent any technology from emerging as the standard. In the case where k=1 (which technically makes no sense but is nevertheless instructive) , equation (3) reduces to stating that R-agents will switch to technology B when $A_R < B_R$. Because initial preferences assume that $A_R > B_R$, the existence of a perfectly compatible gateway will assure agents abide by their initial preferences. This is logically consistent, because network externalities have effectively been eliminated from the situation. It is illustrated in Fig.3.

(c) partial, one-way converter

The introduction of a partial, one-way converter will likely bias technological lock-in toward the favoured technology. The favoured technology is the one which has access to its counterpart network (in this case, technology A). The unfavoured technology has no such benefit. In a Mac/PC analogy, a partial, one-way converter might allow PC users to access the Mac network while Mac users had no such advantage in the PC realm. To create this scenario within the model, assume that c=0 and 0< k < 1. Users of technology A now have a partial compatibility with technology B's network, but users of technology B find the A network perfectly compatible. In this scenario, the R-agent with initial preference for technology A will switch to technology B when

$$(A_R - B_R)/r < (1 - k)N_b - N_a \quad (4)$$

Moreover, the introduction of this partial, one-way technology will cause S-agents to switch to technology A when

$$(B_S - A_S)/s < N_a - (1 - k) N_b \quad (5)$$

Not only does the absorbing barrier for technology B become 1/ (1 – k) times as far away from network parity, the absorbing barrier for technology A becomes even closer. Fig. 4 illustrates this result.

(d) perfect, one-way converter

If a perfect one-way converter is introduced, the standard will inevitably converge to the favoured technology. To model the case where A is perfectly compatible with B, but technology B is perfectly incompatible with A, set k = 1 and c = 0. The R-agent will then convert to technology B when

$$(A_R - B_R)/r < - N_a \quad (6)$$

Because the left-hand side of equation (6) is always positive, the R-agent will never adopt technology B. The S-agent will stay with technology B as long as

$$(B_S - A_S)/s > N_a \qquad (7)$$

As the number of adopters increases $n \rightarrow \infty$, however, equation (7) will no longer hold, and the S-agent will switch to technology A. Technology A will become the standard. This is reflected in Fig.5

5. Resolving empirical puzzles

As referred to in Sect. 2, the empirical puzzle of technology adoption relates to the question: why was it logical for Thomas Edison and Edison General Electric suddenly to stop their active support of DC power after such intense competition in the 1880s? At that time , the Westinghouse company and other AC supporters, though becoming strong competitors, were far from demonstrating clear technological superiority of the AC system. The AC system then faced substantial engineering problems related to the higher voltages it used: greater insulation and better grounding were required to protect against the higher risks of electrical shock inherent to the AC system. Because of the reasoning behind using bridging technologies to reconcile different standards a logical reason to abandon DC power could be seen in the invention of a gateway between AC and DC power systems emerging in the late 1880s. In 1888, C..S. Bradley invented the 'rotary converter', a device which allowed AC power to be converted to DC power. With this device, local DC substations could be attached to high voltage AC transmission lines from regional generators. The reverse was not true. The rotary converter was a one-way gateway favouring AC power systems. As we derived in the previous section, a one-way gateway will bias lock-in toward the favoured technology. The favoured technology gains (on average) because ist users can appropriate the network externalities of its competitor technology while the reverse is not true. This scenario played itseld out in the 'battle of the systems'. To visualize the transition from a contested market to AC dominance (and the role of the gateway), imagine the buying decision of an electric station owner. Stations bought equipment and/or electricity from Edison and Westinghouse and delivered service to local customers. As new stations were built, owners faced this choice: gamble on the DC system, or choose a system that could operate regardless of which standard prevailed.

6. Discussion and Related Work

The various models suggested in Sect. 3 build upon and extend previous work on the economics of technology adoption, standards, and compatibility in network industries.
The topic on using bridging technologies in extending network externalities has been formalized only rarely. Braunstein and White(1985), in their analysis of standards and compatibility recognize that the introduction of high or low cost gateways will have varying effects. Similarly, Farrell and Saloner (1985) close their article on standards, compatibility , and innovation with a list of interesting future research topics-- one being firms' strategic manipulation of network externalities through the creation of one-way gateways .
Katz and Shapiro (1985) considered the significance of 'adapters'. Their work analyzes the private and social incentives leading to the construction of a gateway. Similarly, Farrell and Saloner (1992) investigate primarily the provision of 'converters' under different regimes of market power. Choi's research (1994,1996,1997) is similar to that presented here in that he focuses on the effects of gateways. Choi, however, has directed his attention primarily to the role of gateways in the transition from one wave of technology to the next.
The model suggested contextualizes Arthur's (1989) seminal work on technology adoption. Arthur's two most surprising conclusions are: 1) that, given two competing technologies that exhibit positive network externalities, it is impossible to predict which one will be adopted by the market, and 2) that it is therefore possible for an inferior technology to be 'locked-in' by historical accident. The range of applicability for both of these results is restricted when gateways are introduced to the analysis.

7. Procurement Policies

Gateways produce a similarly complex lesson for government policies. Government procurement has been seen by some as a means for establishing an 'installed base' of users. Once this presumably large base has been installed, many assume that lock-in to the standard of the installed base will follow. In the context of Arthur's model a government procurement policy is equivalent to shift in network advantage toward the procured technology. Not only is the procured technology closer to ist absorbing barrier, it has also garnered increased network externalities so that future purchasers may also be influenced. Th more effective the gateway, the less likely a procurement policy will be able to set a de facto standard.

8. Conclusions

There are five main conclusions from this chapter:

- Introduction of a partial, two-way gateway will, on average, delay technology adoption
- Introduction of a perfect, two way converter will preclude technology adoption
- Introduction of a partial, one-way gateway will bias lock-in toward the favoured technology
- Introduction of a perfect, one way converter will cause the favoured technology to be adopted
- Analysis of converters can be applied to historical examples to provide plausible explanations of outstanding empirical puzzles.

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Part D   Technological Races in Network Industries

1. Introduction

a.Motivation

The striking pattern that emerges in firms' innovative activities is that the firms rival for a technological leadership position in situations best described as 'races'. A 'race' is an interactive pattern characterized by firms constantly trying to get ahead of their rivals, or trying not to fall too far behind. In network industries, where customers are willing to pay a premium for advanced technology, leadership translates into increasing returns in the market. Each race involves only a subset of the firms in the industry, and the activity within each race appears to strongly influence the behaviour of the firms within that race. Surprisingly, the races share broad similarities. In particular, firms that fall behind in their race display a robust tendency to accelerate innovative effort in order to catch up.

Existing theory focuses on the impact of a single innovation at the firm level, or on the effect of a single 'dominant design' on an industry's evolution. Like the dominant design literature, racing behaviour is also a dynamic story of how technology unfolds in an industry. In contrast to any existing way of looking at the evolution of technology, racing behaviour recognizes the fundamental importance of strategic interactions between competing firms. Thus firms take their rivals' actions into account when formulating their own decisions. The importance of this characterization is at least two fold. At one level, racing behaviour has implications for understanding technology strategy at the level of the individual firm and for understanding the impact of policies that aim to spur technological innovation. At another level, racing behaviour embodies both traditions that previous writings have attempted to synthesize: the 'demand-pull' side emphasized by economic theorists and the 'technology-push' side emphasized by the autonomous technical evolution school. It remains an open problem how technological races can be induced endogenously, e.g. by changes in economic variables (such as costs, prices and profitability).

Our stochastic model of a race embraces several features that resemble moving objects towards a stochastic final destination. By exploring 'hypercompetitive' patterns of racing behaviour, in respective industries, we look into racing patterns of individual firms in view of their strategic responses to their racing environment. Among those features we identify is the **speed race problem**, the selection of an **optimal decision point** (t*), to optimize a gradient trajectory (of technological evolution) and to determine the '**stopping line and the waiting region'**. Such a model would be conducive to observations on innovation races in high technology industries, in particular, with race-type behaviours such as leapfrogging and catching-up, striking a balance between moving ahead , waiting and repositioning themselves.. The model can be improved by incorporating constraints . For example, constraints on an innovation path could be given by road blocks such as a bankruptcy constraint or an R&D uncertain payoff constraint. Some of these constraints may be conceptually easy to introduce, others may be tougher such as an investment constraint if the total innovation effort en route to t* plus the worst case would violate it. In such a case one may want to weigh the distant finishing line unproportionately.
Beyond the micro-meso level of explaining changes in industry structures the model also addresses comparable issues on the macro level of global industry change. Aggregation of racing behaviour may result in catchup behaviour among countries that are the second subject level of our exploration.

Simple catchup hypotheses put emphasis on the great potential of adopting unexploited technology in the early stage and the increase in the self-limiting power in the later stage. However, an actual growth path of technological trajectory of specific economy may overwhelmingly be constrained by social capability. And the capability endogenously changes as states of the economy and technology evolve. The success of economic growth due to diffusion of advanced technology or the possibility of leapfrogging is mainly attributable to how the social capability evolves, i.e., which effects become more influential, growing responsiveness to competition or growing obstacles to it on account of vested interests and established positions.

b. Objectives

(a) A key objective is to explore and explain which type of 'racing behaviour' is prevalent in network industries, as exemplified by information technology (computer and telecommunications) industries. The pattern evolving from such racing behaviour would be benchmarked against the frontier racing type of the global technological leaders.
(b)Another objective is to draw policy inferences on market structure, entre-preneurship, innovation activity, industrial policy and regulatory frameworks in promoting and hindering industry frontier races in a global industrial context.
(c) Given the statistical profile of technological evolution and innovation for respective global industries as it relates to competitive racing and rivalry among the leading firms. Among the performance criteria to be assessed

are frequency of frontier pushing, technological domination period, innovations vs. imitations in the race, innovation frequency when behind or ahead, nature of jumps, leapfrogging or frontier sticking, inter-jump times and jump sizes and race closeness measures.

(d)An empirical proliferation of racing in these global industries can be explored, comprising of datasets identifying 'relationship between technological positions (ranks) of firms in successive years' (15 year period).

(e) Do observed racing patterns in respective industries contribute to equilibrium and stable outcomes in the world economy ? To which extent are cooperative ventures (global governance) between states justified to intervene? In particular we investigate the claim, as put forward by the Group of Lisbon (1995) that as a likely future scenario triadization will remain 'the prevailing form of economic globalization', in view of observations that increased intensity in racing patterns within key industries could lead to instability and welfare losses in triadization.

(g)More specifically, in an era of ongoing deregulation, privatization, liber- alization and lifting of trade barriers, we explore whether industry racing patterns are sufficiently controlled by open world-wide markets or whether complementary international agreements (regulations, controls) are needed to eliminate or mitigate negative externalities (without compromising the positive externalities that come with industry racing).

The effects of racing patterns on the industrial organization of particular industries are assessed: how does the behaviour of leading firms influence the subcontracting relation between the purchasing firms and their subcontractors that is , which racing pattern induces a strengthening of their vertical links and what behaviour of the parent firm in technological racing encourages their subcontractors to be technologically (and thus managerially) independent?

2. State of research

Economic models and observations on 'technology races' are the most direct intellectual precursor to this chapter (Reinganum, 1989, Scherer, 1991, Tirole, 1988). This follows from the tradition of investigating the varied implications of the notion, first advanced by Schumpeter, that it is the expectation of supernormal profits from the temporary monopoly position following an innovation that is the chief driver of R & D investment. The simplest technology race model would be as follows. A number of firms invest in R & D. Their investment results in an innovation with the time spent in R & D subject to some uncertainty (Gottinger, 1989). However, a greater investment reduces the expected time to completion of R & D. The models investigate how many firms will choose to enter such a contest, and how much they will invest.

Despite some extensive theoretical examination of technological races there have been very few empirical studies on the subject (Lerner, 1997) and virtually none in the context of major global industries, and on a comparative basis. This will be one major focus in this paper.

Technological frontiers at the firm and industry race levels offer a powerful tool through which to view evolving technologies within an industry. By providing a roadmap that shows where an individual firm is relative to the other firms in the industry, they highlight the importance of strategic interactions in the firm's technology decisions.

Does lagging behind one's closest technological rivals cause a firm to increase its innovative effort ? The term 'race' suggests that no single firm would want to fall too far behind, and that every firm would like to get ahead. If a firm tries to innovate more when it is behind than when it is ahead, then 'catchup' behaviour will be the dominant effect. Once a firm gets ahead of its rivals enough, then rivals will step up their efforts to catch up. The leading firm will slow down its innovative efforts until its rivals have drawn uncomfortably close or have surpassed it. This process repeats itself every time a firm gets far enough ahead of its rivals. An alternative behaviour pattern would correspond to a firm increasing its innovative effort if it gets far enough ahead, thus making catchup by the lagging firms increasingly difficult. For any of these forms there appears to be a clear link to market and industry structure, as termed 'intensity of rivalry' by Kamien and Schwarz (1982). We investigate two different kinds of races: one that is a frontier race among leaders and „would-be" leaders and another, that is a catchup race among laggards and imitators.

These two forms had been applied empirically to the development of the Japanese computer industry (Gottinger, 1996), that is, a frontier race model regarding the struggle for technological leadership in the global industry between IBM and 'Japan Inc.' guided by MITI, and a catchup race model relating to competition among the leading Japanese mainframe manufacturers as laggards.[1]
Furthermore, it is interesting to distinguish between two kinds of catchup behaviour. A lagging firm might simply try to close the gap between itself and the technological leader at any point in time ('frontier-sticking' behaviour), or it might try to actually usurp the position of the leader by 'leapfrogging' it. When there are disproportionately large payoffs to being in the technical lead (relative to the payoffs that a firm can realize if it is simply close enough to the technical frontier), then one would expect that leapfrogging behaviour would occur more frequently than frontier-sticking behaviour (Owen and Ulph, 1994). Alternatively, racing toward the frontier creates the 'reputation' of being an innovation leader facilitating to maintain and increase market share in the future (Albach, 1997). All attempts to leapfrog the current technogical leader might not be successful since many lagging firms might be attempting to leapfrog the leader simultaneously and the leader might be trying to get further ahead simultaneously. Correspondingly , one should distinguish between attempted leapfroggings and realized leapfroggings. The leapfrogging phenomenon (though dependent on industry structure) appears as the predominant behaviour pattern in the US and Japan frontier races (Brezis, Krugman and Tsiddon, 1991), Albach (1993) cites studies for Germany that show otherwise.

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[1] A catchup race is likely to occur when innovators fall too far behind in a frontier race or if innovators turn to imitators and follow just one or several leaders. It could also occur in markets that are saturated or technologically mature with a lack of breakthroughs.Therefore, at some point every frontier race can turn into a catchup whereas it is more difficult to imagine that any catchup race will turn into a frontier race.

Leapfrogging behaviour influenced by the expected size of payoffs as suggested by Owen and Ulph (1994) might be revised in compliance with the characteristics of industrial structure of the local (regional) markets, the amount of R&D efforts for leapfrogging and the extent of globalization of the industry. Even in the case where the payoffs of being in the technological lead is expected disproportionately large, the lagging firms might be satisfied to remain close enough to the leader so as to gain or maintain a share in the local market. This could occur when the amount of R&D efforts (expenditures) required for leapfrogging would be too large for a lagging firm to be viable in the industry and when the local market has not been open enough for global competition: the local market might be protected for the lagging local firms under the auspices of measures of regulation by the government (e.g. government purchasing, controls on foreign capital) and the conditions preferable for these firms (e.g. language, marketing practices). When the industrial structure is composed of multi-product firms, as for example, in the Japanese computer industry, sub-frontier firms may derive spillover benefits in developing new products in other technologically related fields (e.g. communications equipment, consumer electronic products). These firms may prefer an R&D strategy just to keep up with the technological frontier level (catch-up) through realizing a greater profit stream over a whole range of products.

What are the implications of the way the firms split cleanly into the two technology races, with one set of firms clearly lagging the other technologically? The trajectories of technological evolution certainly seem to suggest that firms from one frontier cannot simply jump to another trajectory. Witness, in this regards, the gradual process necessary for the firms in the Japanese frontier to catch up with the global frontier firms. There appears to be a frontier ‘lock-in’ in that once a firm is part of a race, the group of rivals within that same race are the ones whose actions influence the firm’s strategy the most. Advancing technological capability is a cumulative process. The ability to advance to a given level of technical capability appears to be a function of existing technical capability. Given this ‘path dependence’, the question remains: why do some firms apparently choose a path of technological evolution that is less rapid than others? We propose two sets of possible explanations, which need not to be mutually exclusive. The first explanation hinges primarily on the expensive nature of R & D in industries like the computer industry which rely on novel scientific discovery for their advancement. Firms choosing the subfrontier will gain access to a particular technical level later than those choosing the frontier, but will do so at a lower cost. Expending fewer resources on R & D ensures a slower rate of technical evolution. The second explanation relates mainly to technological spillovers. Following the success of the frontier firms in achieving a certain performance level, this fact becomes known to the subfrontier firms. In fact, leading edge research in the computer industry is usually reported in scientific journals and is widely disseminated throughout the industry. The hypothesis is that partial spillover of knowledge occurs to the subfrontier firms, whose task is then simplified to some extent. Notice that the subfrontier firms still need to race to be technological leaders, as evidenced by the analysis above. This implies that the spillovers are nowhere near perfect. Firm specific learning is still the norm. However, it is possible that knowing something about what research avenues have proved successful (for the frontier firms) could greatly ease the task for the firms that follow and try to match the technical level of the frontier firm.

3. A Model Framework for a Simple Stochastic Race

The Problem: On an Euclidean plane let N be a set of n points (x_i,y_i); $i = 1,\dots n$; let n probabilities $p_i; i = 1,\dots , n$ be given such that $\Sigma p_i = 1$. We use the Euclidean distance on a plane because innovation characteristics are at least two-dimensional, that is, it would apply to so-called system products that consist of at least two components. The probabilities will most likely be subjective probabilities determined by the individual firm's chances to position itself , endogeneously determined by its distance to the finishing line or its proximity to the next rival in the race. They may be formed by considering the firm's own position in the race as well as depending on the stochasticity of the rivals' efforts. As a first approximation we may let the firm's R&D investment x_i, in relation to the total investment of its rivals Σx_j , determine the probability $p_i = x_i/\Sigma x_j$ .Let a starting point, point (x_0,y_0) or (point 0) also be given; let c(S); $S \geq 0$ be a function such that

(1) $c(0) = 0$,

(2) $c(S) > 0$; for all $S > 0$,

(3) $c(S + \varepsilon) \geq c(S)$; for all S, $\varepsilon > 0$,

and such that except for S = 0, c(S) is (not necessarily strictly) convex and represents the cost of racing at speed S; let F > 0 be given (the fixed time value); and finally let T > 0 be given (the decision period). It is required to minimize the following function by choosing $t \equiv (x_t,y_t)$ and S (i.e., choose a point t, to be at T time units from now, and a speed S with which to proceed afterwards, so that the expected total cost to cross the 'finishing line' will be minimized):

(4) $Z(t,S) = FT + c(d(0,t)/T)d(0,t) + (c(S) + F/S) \; \Sigma p_i d(t,i)$

where d(i,j) is the Euclidean distance between points i and j. The Euclidean distance can be seen as a metric how close the destination has been hit. The last term of (4) indicates the mixture of costs of speed racing and the cost of the time resource weighted by the probabilities of reaching alternative stochastic destinations.

We denote the optimal S by S*, and similarly we have t* and Z* = Z(t*,S*). Note that FT is a constant, so we can actually neglect it; the second term is the cost of getting to t during T time units, i.e., at a speed of d(0,t)/T. Now, clearly the problem of finding S* can be solved separately, and indeed we outline the steps toward solution..

The Speed Race Problem

If we look at the list of stipulations for c(S), (1) just means that we can stop and wait at zero marginal cost (which we first keep as a strict assumption to justify the flexibility of the race). (2) is evident, and (3) is redundant, given

(1), since if c is not monotone for S > 0, then it has a global minimum for that region at some S, say S_{min}, where the function assumes the value c_{min}<c(S) for all S > 0. Now suppose we wish to move at a speed of λS_{min}; $\lambda \varepsilon$ (0,1], during T time units, thus covering a distance of λTS_{min}; then who is to prevent us from waiting (1 - λ)T time units, and then go at S_{min} during the remaining λT time units, at a variable cost of c_{min} per distance unit? As for the convexity requirement, which we actually need from S_{min} and up only, this is not a restriction at all! Not only do all the firms we mentioned behave this way in practice generally, but even if they did not, we could use the convex support function of c as our 'real' c, by a policy, similar to the one discussed above, of moving part time at a low speed and part time at a higher one at a cost which is a linear convex combination of the respective c's. Hence, our only real assumption is that we can stop and wait at zero cost, i.e., (1).

Lemma : let c(S); S>0 be any positive cost function associated with moving at speed S continuously and let (1) hold, then by allowing mixed speed strategies, we can obtain a function c(S); S > 0 such that c is positive, monotone nondecreasing and convex, and reflects the real variable costs.

Now, since each time unit cost is F, and we can go S distance units during it, each distance unit's 'fair share' is F/S. To this add f(S), to obtain the cost of a distance unit at a speed of S when the firm knows where it is going, and requires their fixed costs to be covered. (On the other hand, not knowing what it wants to do means that the firm has to lose the F money, or part of it.) Denote the total cost as above by TC(S), or TC(S) = c(S) + F/S.

But, F/S is strictly convex in S, and c(S) is convex too, so TC(S) is strictly convex.

Choosing t Optimally

Our problem is to find the point t, or the 'decision point', where we elect to be at the end of the decision period. Then, we will know with certainty what we have to do, so we will proceed at S* to whichever point i is chosen, at a cost of TC(S*)d(t,i). Denoting TC(S*) = TC*, we may rewrite (4) as follows:

(5) $Z(t) = FT + c(d(0,t)/T)d(0,t) + TC^* \sum p_i d(t,i).$

Theorem : Z(t) is strictly convex in t.

Proof: Clearly FT is a constant so it is convex. Let h(w) = c(w/T)w, hence our second term, c(d(0,t)/T)d(0,t) is h(d(0,t)). By differentiation we can show that h(w) is strictly convex, monotone increasing and nonnegative. d(0,t) is convex (being a norm), and it follows that h(d(0,t)) is strictly convex as well (see Theorem 5.1 in Rockafellar(1970), for instance), As for the third term it is clearly convex (since $\{p_i\}_{i=1, \dots n}$ are nonnegative probabilities), and our result follows for the sum.

The Stopping Line and the Waiting Region

For $T \geq T^*$, we obtain $S = S_{min}$, and by $W(S) = c(S) + Sc'(S)$ it follows that $W(S) = c_{min}$. For $G(t^*) = W(S)$ we have

(6) $G(t^*) = c_{min}$.

Now, starting at different points, but such that $G(0) > c_{min}$ and $T > T^*$ as defined for them we should stop at different decision points respectively . Actually there is a locus of points satisfying (6), which we call D as follows

(7) $D = \{ t \in E^2 | G(t) = c_{min} \}$.

We call D the stopping line (although it may happen to be a point). Now denote the area within D, inclusive, as C, or

(8) $C = \{ t \in E^2 | G(t) \leq c_{min} \}$.

C is also called the waiting area, since being there during the decision period would imply waiting. Clearly $C \subseteq D$, with $C = D$ for the special case where one of the points $N \cup 0$ is the only solution for a large T. In case $C \neq D$, however, we have a nonempty set E as follows

(9) $E = C - D$ (or C/D).

Specifically, there is a point in C, and in E if $E \neq \emptyset$, for which $G = 0$. We denote this point by t_{min}, i.e.,

(10) $G(t_{min}) = 0$.

Clearly, in order to identify t_{min}, we do not need any information about the starting point or any of the costs we carry, but just the information on N and $\{p_i\}$

4. Discussion

The model sets out to examine and measure racing behaviour on technological positions among firms in network industries, as exemplified by the globally operating telecommunications, and computer industries . In measuring the patterns of technological evolution in these industries we attempt to answer questions about whether and to which extent their racing patterns differ from those firms in respective industries that do not operate on a global scale. Among the key issues we want to address is the apparent inability of technology oriented corporations to maintain leadership in fields that they pioneered. There is a presumption that firms fail to remain competitive because of agency problems or other suboptimal managerial behaviour within these organizations. An alternative hypothesis is that technologically trailing firms, in symmetric competitive situations, will devote greater effort to innovation, so that a failure of technological leaders to maintain their position is an appropriate response to the competitive environment. In asymmetric situations, with entrants challenging incumbents, research could demonstrate whether startup firms show a stronger endeavour to close up to or leapfrog the competitors. Such issues would highlight the dynamics of the race within the given market structure in any of the areas concerned. We observe two different kinds of market asymmetries bearing on racing behaviour: (a) risk-driven and (b) resource based asymmetries.

When the incumbents' profit are large enough and do not vary much with the product characteristics, the entrant is likely to choose the faster, less aggressive option in each stage as long as he has not fallen behind in the race. The incumbent's behaviour is influenced by what is known as the 'replacement effect' (Tirole, 1988). The conventional 'replacement' effect says that, in an effort to maximize the discounted value of its existing profit stream, the incumbent (monopolist) invests less in R & D than an entrant, and thus expects to be replaced by the entrant (in the case where the innovation is drastic enough that the firm with the older technology would not find it profitable to compete with the newer technology). In one of our models, when the incumbent's flow profit is large enough, the same replacement effect causes the incumbent to be replaced only temporarily (if the innovation is drastic). Subsequently, she is likely to regain a dominant position in the market since she has a superior version of the new technology.

In view of resource based asymmetries, we observe, as a firm's stage resource endowment increases, it could use the additional resources to either choose more aggressive targets or to attempt to finish the stage quicker, or both. This hypothesis suggests two interpretations, suitable for empirical exploration: (a) if the demand for new products displays different elasticities for different local/regional markets, then we might expect there to be only imperfect correlation between aggressiveness and resource richness when products from different markets are grouped together, (b) if, however, demand for these products is not inelastic enough, then we would expect resource rich firms to aim for both higher speed in R&D and greater aggressiveness.

A further point of exploration is whether chance leads result in greater likelihood of increasing lead, or in more catchup behaviour. Previous work in this regard (Grossman and Shapiro, 1987; Harris and Vickers, 1987) has suggested that a firm that surges ahead of its rival increases its investment in R&D and speeds up while a lagging firm reduces its investment in R&D and slows down. Consequently, previous work suggests that the lead continues to increase. However, based on related work for the US and Japanese telecommunications industry (Gottinger, 1997) when duopoly and monopolistic competition and product system complexity for new products are accounted for, the speeding up of a leading firm occurs only under rare circumstances. For example, a firm getting far enough ahead such that the (temporary) monopoly term dominates its payoff expression, will always choose the fast strategy, while a firm that gets far enough behind will always choose the slow and aggressive approach. Then the lead is likely to continue to increase. If, on the other hand, both monopoly and duopoly profits increase substantially with increased aggressiveness then even large leads can vanish with significant probability.

Overall, this characterization highlights two forces that influence a firm's choices in the various stages: proximity to the finish line and distance between the firms. This probability of reaping monopoly profits is higher the farther ahead a firm is of its rival, and even more so the closer the firm is to the finish line. If the lead firm is far from the finish line, even a sizeable lead may not translate into the dominance of the monopoly profit term, since there is plenty of time for the lead situation to be reversed and failure to finish first remains a probable outcome. In contrast, the probability that the lagging firm will get to be a monopolist becomes smaller as it falls behind the lead firm. This raises the following question. What kind of actions cause a firm to get ahead? Intuitively, one would expect that a firm that is ahead of its rival at any time t, in the sense of having completed more stages by time t, is likely to haven chosen the faster, less aggressive strategy more often. We will construct numerical estimates of the probability that a leading firm is more likely to have chosen a strategy less aggressively (faster) to verify this intuition.

Moving away from the firm-led race patterns revolving in a particular industry to a clustering of racing on an industry level is putting industry in different geoeconomic zones against each other and becoming dominant in strategic product/process technologies. Here racing patterns among industries in a relatively free trade environment could lead to competitive advantages and more wealth creating and accumulating dominance in key product / process technologies in one region at the expense of others. The question is, whether individual races on the firm level induce such like races on the industry level and if so, what controlling effects may be rendered by regional or multilateral policies on regulatory, trade and investment matters.

Similar catchup processes are taking place between leaders and followers within a group of industrialized countries in pursuit of higher levels of productivity. Moses Abramovitz (1986) explains the central idea of the catch-up hypothesis as the trailing countries' adopting behaviour of a 'backlog of unexploited technology'. Supposing that the level of labour productivity were governed entirely by the level of technology embodied in capital stock, one may consider that the differentials in productivities among countries are caused by the 'technological age' of the stock used by a country relative to its 'chronological age'. The technological age of capital is an age of technology at the time of investment plus years elapsing from that time. Since a leading country may be supposed to be furnished with the capital stock embodying, in each vintage, technology which was 'at the very frontier' at the time of investment, 'the technological age of the stock is, so to speak, the same as its chronological age'. While a leader is restricted in increasing its productivity by the advance of new technology, trailing countries 'have the potential to make a larger leap' as they are provided with the privilege of exploiting the backlog in addition of the newly developed technology. Hence, followers being behind with a larger gap in technology will have a stronger potential for growth in productivity. The potential, however, will be reduced as the catch-up process goes on because the unexploited stock of technology becomes smaller and smaller. This hypothesis explains the diffusion process of best-practice technology and gives the same sort of S-curve change in productivity rise of catching-up countries among a group of industrialized countries as that of followers to the leader in an industry.

Although this view can explain the tendency to convergence of productivity levels of follower countries, it fails to answer the historical puzzles why a country, the United States, has preserved the standing of the technological leader for a long time since taking over leadership from Britain in around the end of the last century and why the shifts have taken place in the ranks of follower countries in their relative levels of productivitiy, i.e., technological gaps between them and the leader. Abramovitz poses some extensions and qualifications on this simple catch-up hypothesis in the attempt to explain these facts. Among other factors than technological backwardness, he lays stress on a country's 'social capability', i.e., years of education as a proxy of technical competence and its political, commercial, industrial, and financial institutions. The social capability of a country may become stronger or weaker as technological gaps close and thus, he states, the actual catch-up process 'does not lend itself to simple formulation'.This view has a common understanding to what Mancur Olson (1996) expresses to be 'public policies and institutions' as his explanation of the great differences in per capita income across countries, stating that 'any poorer countries that adopt relatively good economic policies and institutions enjoy rapid catch-up growth'. The suggestion should be taken seriously when we wish to understand the technological catching-up to American leadership by Japan, in particular, during the post-war period and explore the possibility of a shift in standing between these two countries. This consideration will directly bear on the future trend of the state of the art which exerts a crucial influence on the development of the world economy.

Steering or guiding the process of racing through the pursuit of industrial policies aiming to increase competitive advantage of respective industries, as having been practised in Japan (Gottinger, 1996), in that it stimulates catchup races but appears to be less effective in promoting frontier racing. A deeper reason lies in the phenomenon of network externalities affecting high-technology industries. That is, racing ahead of rivals in respective industries may create external economies to the effect that such economies within dominant industries tend to improve their international market position and therefore pull ahead in competitiveness vis-a-vis their (trading) partners.

As P. Krugman (1991, 1997) observed: 'It is probably true that external economies are a more important determinant of international trade in high technology sectors than elsewhere'.

The point is that racing behaviour in key network industries by generating frontier positions create cluster and network externalities pipelining through other sectors of the economy and creating competitive advantages elsewhere, as supported by the 'increasing returns' debate (Arthur, 1996). In this sense we can speak of positive externalities endogenizing growth of these economies and contributing to competitive advantage.

It is interesting to speculate on the implications of the way the firms in major network industry markets, such as telecommunications, split clearly into the two major technology races, with one set of firms clearly lagging the other technologically. The trajectories of technological evolution certainly seem to suggest that firms from one frontier cannot simply jump to another trajectory. Witness, in this regard, the gradual process necessary for the firm in the catchup race to approach those in the frontier race. There appears to be a frontier 'lock-in' in that once a firm is part of a race, the group of rivals within that same race are the ones whose actions influence the firm's strategy the most. Advancing technological capability is a cumulative process. The ability to advance to a given level of technical capability appears to be a function of exisiting technical capability. Given this path dependence, the question remains: why do some firms apparently choose a path of technological evolution that is less rapid than others. Two sets of possible explanations could be derived from our case analysis, which need not be mutually exclusive. The first explanation lingers primarily on the expensive nature of R & D in industries like telecommunications and computers which rely on novel discovery for their advancement. Firms choosing the catchup race will gain access to a particular technical level later than those choosing the frontier, but will do so at a lower cost.

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Part E Networks and Competition : The Telecommunications Industry

1. Issues in the Telecommunications Industry

The starting point here is to look at a fairly comprehensive list of issues connected with the dynamics of the telecommunications industry that were subject of an emerging telecommunications policy for the European Union as well as for its member countries.

(i) Regulation.

Regulation should not stand as an end itself but should be used to support market forces , increase the chances of fair competition., and achieve wider social, economic and general policy objectives, A reliance on economic incentives suggests that one should place greater reliance on the ability of market forces to ensure regulatory objectives.

If this cannot be achieved in particular instances we should seek a balance between competition rules and sector-specific regulation,

Market Entry and Access. A particular issue is market entry in a given market structure. In this context, one might argue that where any network can potentially carry any service, public authorities should ensure that regulation does not stop this happening. Artificial restrictions on the use of networks, or to maintain monopolies where other parts are fully open to competition, may deny users access to innovative services, and create unjustified discrimination. Such an approach could be seen as running counter to the technological and market trends identified with convergence.

Types of restrictions are particularly important where competition is at an early stage or where a particular player enjoys a very strong position (for example, over a competing network)In such cases, specific safeguards can ensure that potential competitors are not discriminated against or that there are adequate incentives for them to enter the market. According to this argument, appropriate safeguards might take the form of accounting separation or transparency requirements, structural separation or even full line-of-business restrictions.

Access at either end of the transmission network will be of crucial importance.

In general, the terms on which access is granted to networks, to conditional access systems, or to specific content is a matter for commercial agreement between market actors. Competition rules will continue to play a central role in resolving problems which may arise. The emerging market will consist of players of very different sizes, but as indicated above there will also be strong vertically-integrated operators from the telecommunications, audiovisual (principally broadcasting) and IT/software industries building on their traditional strengths and financial resources. Issues which could arise across the different sectors include bundling of content and services, or of network capacity and services, predatory pricing, cross-subsidisation of services or equipment, and discrimination in favour of own activities.

Within the telecommunications sector, the development of the Internet is raising a range of issues connected to the terms on which Internet access providers get access to current fixed and mobile networks. One issue is whether they should enjoy the same interconnection rights as other players and whether they should be able to get access to unbundled service elements, whilst another issue is whether such providers in offering a range of telecommunications services should share some of the obligations of providing telecoms services

. *Frequency Spectrum* The provision of services (and the development of effective competition) will depend on the availability of sufficient network capacity, which for many services means access to radio spectrum. The parallel expansion of television broadcasting, mobile multimedia and voice applications, and the use of wireless technologies within fixed networks will lead to a significant growth in demand. The take up of wireless local loops and the arrival of Universal Mobile Telecommunications Services (UMTS) early in this century all point to a steady growth in demand for spectrum. Given the importance of spectrum, variations identified in between sectors with regard to how much spectrum is available and how much that spectrum will cost may have an important impact on the development of existing and new delivery channels. Though overall allocations are determined at an international and regional level, current differences across sectors to the pricing of frequency may create potential competitive distortions. One example could be where a broadcaster offering multimedia or on-line services uses spectrum obtained free or at low cost, competes with operators from the telecommunications sector who have paid a price reflecting the commercial value of the resource allocated.

From an economic standpoint, pricing spectrum may encourage its more efficient use and may help to ensure that frequency is allocated to the areas where it is most needed. Clearly, such an allocation also bears a lot of risk for the telecom operators. Frequency auctioning is favoured by many economists as the way to best ensure outcomes which are in the consumer's ultimate interest. Although others express concern about the impact of such pricing on prices charged to users.

(ii) The Internet

Two different developments in Internet service provision could be observed in an international context. One, mostly an American phenomenon, was an entrepreneurship drive to establish new companies to do e-business from the bottom up, while in Europe a top down approach emerged through established telecom carriers to launch internet service subsidiaries. Those spinoffs are now by far the largest ISPs, and most of the smaller players rely on the services offered by the bigger players (depending on them for the supply of internet connectivity).Given this heterogeneous market structure, network effects could bias competition to the effect that if one network becomes larger through positive feedback by comparison with his competitors, those competitors may no longer be able to compete, because their subscriber base is too small to attract customers away from the dominant network.. It is unable to offer the same access to subscribers. And although that may not matter when interconnection is free, any operator who becomes dominant may not be able to resist the temptation to charge others for connection to his network, thus further hampering competitors from offering any effective constraint to the dominant player's pricing. A case in point

was the potential problem in deciding on the MCI Worldcom case

Another issue is of merging internet and content providers, such as the AOL Time Warner case, or other joint ventures that are designed to improve the quality of the content on the Internet and enable customers to be charged for accessing that content.

At present the Internet is a relatively open and competitive environment, so there is a comparatively conservative task in applying the competition rules to ensure that it stays that way. But the speed of development of the Internet is such that competition issues could be raised very quickly, and therefore one needs to be vigilant when examining the sector in the context of competition law.

Internet regulation and telecoms regulation come from completely opposite directions. Telecoms regulation has been born out of the liberalisation of the monopoly, single provider environment and new entrants have been introduced into the market. Internet regulation before now has been largely self regulation, if any regulation existed at all. Now the Internet is becoming a system over which more and more business is being done, as opposed to the simple exchange and sharing of data which it used to be. This commercialisation asks for a more robust regulatory system to protect users and suppliers. An important element of that protection is the assurance of the application of competition law.

We see no problem with the Internet continuing to have strong elements of self regulation in the future. That is one of the reasons why it has developed in such a dynamic manner in the past. .

One has to be wary, however, that self regulation does not lead to private monopolistic practices that run counter to competition law.

(iii) Market Access

Access (and the related issue of network interconnection) is one of the central issues in the telecommunications / media / information technology market and the way in which competition rules are applied to the players within it.

The central problem is that, given the evolving market structure, the converging sectors depend upon ensuring access to bottleneck facilities. These are essential for entering the market to reach customers .

In particular, through vertical mergers and joint ventures there is the potential danger that thresholds are exceeded at which point the concentration of market power in the whole value chain - content, distribution, cable - becomes unacceptable. This can be shown in a number of recent telecom and media cases, In these cases particular developments deserve attention such as, for example, attempts by market players to gain control : for digital TV based services in view of set top boxes or decoders; or for Internet services in view of the browser, the server, and the access provider.

These are developments which link up critical elements of the future information infrastructure with other dominant market positions., that is, link ups between telecoms, online providers, and content providers
Backbone access.
The Internet is a network of interconnected networks. In order to provide a full Internet service any operator will need access to all, or at least the vast majority, of the networks connected to the Internet. Market definition in this area is difficult: the distinction between competitors to whom an operator will provide reciprocal access to its customers, and customers to whom an operator will provide access to all other Internet users appears more fluid than is the case in traditional telecommunications, such as voice telephony.
Notwithstanding these difficulties of market definition and quantification, similar concerns in relation to the power of particular networks appear to arise as with traditional telephony and interconnection These concerns include the risks that a dominant network operator: charges supra-competitive fees for network access; , seeking to reinforce its position, for example, by concluding lengthy exclusive arrangements with its customers; or favouring its own operations at the expense of third parties.

(iv) Local Loop

Given the commercial and technological constraints on providing competing local access mechanisms, it will be fundamentally important to ensure, that competition in the local loop develops and, that network operators of local loops are not at the same time the only service providers over those networks.
Of particular interest is unbundling the local loop**.** Unbundling entails the separate provision of access to the switch and to the copper wire: this allows alternative operators to use only the copper wire of the incumbent, to invest in their own switching equipment and thus bypass the switching infrastructure of the incumbent.
Bundling can in itself constitute an abuse under Article 86 (EC Treaty) , in addition, however, refusing to unbundle where such unbundling would allow competitors to invest in infrastructure which would upgrade the narrowband copper telecommunications network to broadband capability could, depending on the circumstances, constitute a separate abuse under Article 86(b) - that of limiting production, markets or technical development.

(v) Competition Cases

Within this new framework, competition policy is increasingly being applied to deal with antitrust and merger cases Already some major telecom competition cases came up in recent years On the basis of Article 85 (anti-competitive agreements), Article 86 (abuse of dominant positions, including issues of unfair pricing and refusing access and interconnection), and the Merger Regulation, were the basis for examining the planned mergers or alliances. Some of the cases were only acceptable from a competition point of view with sufficient remedies. Increasingly competition cases involve telecom companies and companies from neighbouring sectors, indicating the emergence of convergence.

(vi)Telecom Framework

Competition policy will have an increasing role in telecoms markets and in markets with converging services. Sometimes the conclusion is therefore drawn that sector specific regulation must be gradually replaced by the application of competition law. Indeed, the application of competition rules can correct anti-competitive developments or interpret initially unforeseen challenges according to the spirit of the framework However, competition policy will not entirely replace regulation .
The issue is not one of specific sector regulation versus competition rules, but rather which evolution of the existing regulatory framework should be envisaged. This evolution will be accompanied by competition cases based on the experience they carry.

2. Evaluating Complex Telecommunication Competition Cases: Methodology

In view of the issues listed the public policy focus would be directed toward (i) market definition, (ii) dominance and oligopolies, (iii) allocation of frequency licences, (iv) competition rules vs. sector specific regulation, (v) internet issues and (vi) access to networks we develop a methodology that map any of those cases to be investigated into a system complexity associated with a qualitative assessment those issues.
For the evaluation of any of those cases, system complexities are aggregated to a case specific score reflecting the multiple aspects of each case subject to particular tradeoffs and supporting particular policy guidance.
An effective antitrust analysis is no more than an anatomy of competition effects of a particular transaction or activity. That means a practice or transaction will be reviewed to see whether it originates in any anti-competitive or pro-competitive effects that have to be balanced against each other.

An assessment scheme could be designed to obtain the (aggregate) competition value of different modes of pro-competitive effects (enhancing economic efficiencies , reducing wasteful duplication) and anti-competitive effects (collusion, reducing innovation and rivalry, exclusion, leveraging market power and raising rivals' costs).

*A. **Pro-competitive Effects***

Enhancing Economic Efficiencies (EEE)

There is widespread agreement that the goals of antitrust law are to promote economic efficiency and consumer welfare through competition. Economic efficiencies, which emphasise lower prices, cost savings, and technical innovation would be rooted in three elements: allocative efficiency, production efficiency and innovation efficiency. In fast paced telecommunications markets innovation efficiency is the most important because it increases social wealth most effectively. Unlike allocative efficiency which only pushes prices close to cost and diminishes dead weight loss, an innovation may promise consumers a new product, or new process to manufacture products or to improve existing products or processes which benefit consumers most. Second, in social importance is productive efficiency because it increases social wealth over the whole range of output, while allocative efficiency increases social wealth only at the margin. In addition, production efficiency directly affects the growth of future social wealth because the gains from lower production costs are expanding, recurring and cumulative. Allocative efficiency can be achieved through price competition. When price equals marginal cost, there is no dead weight loss and society is better off.

//Fig.1. Allocative Efficiency//

Strategic alliances do not necessarily impede allocative efficiency. Although cost-reducing alliances may simultaneously enhance market power and enable the combined firms to raise prices, output may increase or remain unchanged hence satisfying allocative efficiency.

Costs of production are reduced when production processes or methods improve. Lower costs not only increase production quantity but also increase consumer surplus. Production efficiency makes
costs go down, thus increasing consumer surplus.

//Fig. 2 Production Efficiency and Consumer Surplus//

This is particularly obvious where firms enter into strategic alliances to reach economies of scale, learning curve effects work immediately, and to lower research, production or marketing costs in short time. The costs of R&D also will dramatically be lowered since participants share the risks associated with investments that serve uncertain demand or involve uncertain technology; economies of scale and scope in production, procurement and logistics will be attained.
Alternatively, innovation efficiency resulting from technological improvement, economically increases consumer welfare, not merely through the lower cost, expanded production capacity;
But it also increases demand and consequently consumer surplus.

//Fig. 3 Demand Induced Consumer Surplus//

//Fig. 4 Supply Induced Consumer Surplus//

Since new products or production processes resulting from innovation often increase market demand, this results in an increase in consumer welfare. Nevertheless, the introduction of many new products or new processes could not come into being without the combination of resources owned by two or more different companies. Different firms forming strategic alliances may spread the costs of R&D and encourage the participants engaging in new innovation that an individual firm would not or could not otherwise achieve because of huge sunk costs or the lack of technologies. Moreover, the combination of complementary technologies, the exchange of information, and circulation of technicians owned by different firms ensures for new production in the anticipated future. Synergies arise when participants sharing complementary skills or assets generate both private and social benefits. Strategic alliances between small innovative firms and large companies with the ability of mass production and marketing are often necessary for achieving technological breakthrough.

Reducing Wasteful Duplication (RWD)

The question of whether research and development is socially optimal of market concentration increases or decreases innovation has been controversial for a long time. There is no comprehensive theory or empirical study to support a general proposition, but there is general agreement that parallel R&D is socially undesirable. Competitors in network industries often pursue similar courses for the development of a new product or imitate their rivals' strategies while circumventing legal protection. In particular, when competitors strive to be the first in the market and to win the technological race, they may in large part duplicate one another's R&D effort. At the same time, in such races, each rival will invest to maximise his chance of success whereas society as a whole only cares that someone succeeds. This suggests that competitive levels of R&D may be socially 'excessive'. In those situations, one may argue that integration of competitors' resources in a strategic alliance often eliminates wasteful duplication. By combining their R&D programs , they can avoid unnecessary duplication and the attendant social waste. The resources saved may be employed in diversifying R&D strategies and arriving at a product that maximises innovation and expected consumer demand.

Further, research and development discoveries usually involve public good character. That means a given research finding can be used in many applications at little extra cost. A large scale research project may be attractive only if the research finding can be used by a number of downstream producers. When the minimum efficient scale of R&D is much larger relative to the scale in production and distribution, it makes little sense for several downstream firms to each conduct similar research projects. Several downstream producers combining to fund a large-scale research project is more efficient.
Besides increasing efficiency through economies of scale and scope and the avoidance of wasteful duplications, strategic alliances provide a vehicle to jointly carry out research and development more efficiently by transferring new information they have jointly developed among themselves at marginal cost and applying that information to manufacturing. In other words, strategic alliances can internalise positive technological spillover.

B. Anti-Competitive Effects

The traditional classification into horizontal as well as vertical arrangements highlights the antitrust concerns only on the collusion effects when looking at horizontal arrangements whereas on the exclusion effect when

looking at vertical agreements. Nevertheless, horizontal arrangements can have exclusion effects while vertical arrangements can have the collusion effects. For example, horizontal agreements such as price fixing and market division create a collusion effect between the partners to the arrangements while group boycott and membership exclusion creates an exclusion consequence. Conversely, vertical arrangements such as tying, exclusive dealing or refusal to deal reveal an exclusion effect, resale price maintenance and non-price restraints exhibit a collusion effect. In traditional goods markets, antitrust concerns principally come from the collusion dangers that competitors can provoke through their concerted activities regardless of whether they are horizontal or vertical ones. Exclusion effects, on the contrary, are actually rare because markets are basically constant and static. In network industries , as in telecommunications, the scenario may be totally different. Where products life cycles are short, competition is not based on price but innovation, collusion seems unlikely. At the same time, markets in these industries tend to be oligopolistic, network externalities are obvious, information is asymmetrical, and products are complementary, exclusionary strategies may be implemented more easily.
The various arrangements and effects that could happen are summarized in the following figure:

Horizontal Arrangements — Vertical Arrangements

Collusion: Price Fixing, Market Division
Exclusion: Group Boycott, Membership Exclusion
Collusion: Resale Price Maintenance, Non-Price Restraints
Exclusion: Tying, ExclusiveDealing

Fig. 5 Competition Effects

Collusion Effects (CE)

Traditional anti-competitive concerns with respect to the formation of strategic alliances stem from the conviction that these transactions usually facilitate reducing output, fixing prices. In other words, strategic alliances are thought to be like cartels. In network industries, nontheless, competition is based on quality and features far more than prices. The collusion concerns should be put on the risk of decreasing innovation when competitors form strategic alliances.
Decreasing competition is of major concern. Partners may collude by sharing information about costs of raw materials, labour, and transportation, volumes of orders and shipments or wholesale and retail prices of current and future products. The sharing of information can encourage oligopolistic pricing and output behaviour that interferes with the efficient functioning of the market. Such a reduction of competition will occur even without any perceived conspiracy because the partners will, in a natural course, refrain from competing with an alliance in which they have a financial interest. After all, when rivals become allies, even for limited purposes, industry concentration is very likely increasing and, other things being equal, industry competition is very likely decreasing.
The diminishing competition between alliance partners does not necessarily reduce competition in the relevant market, provided that there are other competitors in the market. Sometimes, the alliance formed by smaller market participants may increase the alliance's competitiveness allowing it to compete with larger firms more effectively in the market. Strategic alliances can be used as part of the competitive strategy of parent companies within the industry, serving to increase intra-industry competition rather than decrease it. Furthermore, even if collaboration between partners temporarily reduces competition, alliances of partners are very often necessary to overcome market failures and to reach innovation and production efficiencies. This is also illustrated in network industries , collaboration that allows industry groups to get together may lower the costs of achieving compatibility and thus make it more likely
Another competition concern results from the 'spillover' effects of strategic alliances. On the one hand, it is a general belief that strategic alliances should be treated more leniently than mergers because the participants of the arrangements are assumed to compete with each other outside the market in which the strategic alliances or joint ventures operate. On the other hand, unlike mergers where competition between participants no longer exists after the merger, strategic alliances or joint ventures, however, may sometimes serve as conduits for coordinating participants' market behaviour or for exchanging competitively sensitive information about other business activities.

The existence of alliances may also provide a mechanism for one partner to 'punish' the other for overly aggressive pricing in the spillover market. The existence of concern may depend on partners' competitive positions in that market, i.e., whether they have market power or the hope of exercising market power through collusion. To prevent the 'spillover effect', a joint venture may include operational or procedural safeguards that substantially eliminate any risk of anti-competitive spillover effects. Examples of such safeguards include a 'chinese wall' to prevent the participants from exchanging unnecessary information about price, cost and requiring the participants to make production, marketing, and pricing decisions independently. Contracts can require that certain types of competitively sensitive business information be disclosed only to neutral third parties. The use of effective safeguards may eliminate the need to conduct an elaborate structural analysis of the spillover market.

Reducing Innovation and Rivalry (RIR)

Some observations emphasise reducing innovation and rivalry when competitors enter strategic alliances. Empirical evidence suggests that for much R&D, the benefit to the public surpasses the private rate of return to the innovator, which would suggest that competitive levels of R&D may be socially insufficient. There is a firm belief among industrial economists that strong competition within an industry is fundamental to upgrade core skills, products and process technologies. Horizontal collaboration may reduce diversity, deter participating firms from pursuing parallel paths to develop new technologies and lower total research and development activities. In particular, when intangible assets are involved in a strategic alliance and a technological edge is necessary to maintain competitiveness, forming alliances may weaken a firm's ability to innovate and respond to changes in the market. Strategic alliances involving the cross-licensing or patent pools may reduce incentives to investment in R&D and innovation significantly, especially when the pools include the existing and future patents. Even when patents are complementary, vertical combination als can have anti-competitive effects in horizontal markets. The Antitrust Division of the US Justice Department noted that industry-wide research projects involving many or all firms in a line of commerce may pose antitrust concerns (US DOJ, 1980). . A single project may produce less innovation than will a variety of single and joint efforts employing alternative approaches. Parallel research projects are sometimes, not wasteful, but rather paths of new discoveries.
In general, reducing the number of separate R&D efforts may increase the cost to society of mistakes in R&D strategy because there will be fewer other businesses pursuing different and potentially successful R&D paths. If a large proportion of potential innovation in a chosen area of research participates in joint ventures, the incentive to make substantial investments in R&D may be sharply reduced. Because no member of the joint venture will risk being left behind, or can hope to get ahead of, fellow members, rivalry in the R&D may be suppressed and innovation retarded.
In network industries, the collaboration between dominant firms may easily form a standard that may lock in current technology and inhibit innovation. Standards may codify existing practices and introduce substantial barriers to innovation. Because of these effects, there is an inverse relationship between R&D activity and the presence of product standards promulgated by industry. The underlying premise of this analysis is that if more R&D is undertaken more innovation will occur unless that R&D may be made more efficient by collaboration. The danger of standard-setting activity is that innovation may be curtailed prematurely. If standardization is too early in the product life cycle, firms may reduce product innovation and compete only on the basis of process innovation. If a predominant standard is set before a technology reaches maturity, it is often economically disfavoured to radical innovation. A technology may thus be forced into 'early maturity' not because of technological limitations but rather the will of the competitors' collusion.

Exclusion Effects (EE)

In network industries the market tends to be oligopolistic on account of large economies of scale and high sunk costs. The 'lock-in' effect resulting from sophisticated and compatible technologies or network externalities prevent an easy switch. All of these characteristics suggest higher barriers to entry. Also, imperfect information and externality or other failures prevent markets from performing efficiently. In this state of affairs, both horizontal and vertical integration or restraints can be exclusionary tools that strategizing firms use to exclude competitors and diminish competition.
Anti-competitive exclusionary conducts deter competition as long as these acts frustrate the market function, since the market function assesses the relative social efficiency of market players. These conducts reduce the return to production efficiency while increasing the profitability of nonproductive strategic behaviour. They avert competition not through better technologies but by raising rival's cost.; foreclose the market not by merits of products but by leveraging market power in one market onto the other market or increasing barriers to entry.

Prevention of anti-competitive exclusionary practices is therefore vital to the promotion of production and innovation efficiency.
The economics of exclusionary practices is straightforward and demonstrated in the figure below. It shows when innovative products are excluded by exlusionary practices, choices are reduced and consumer demand decreases. As a result welfare is worse.

// Figure 6 Exclusionary Practice through Reduced Innovation//
Demand Curve D shifts leftward to D' when innovative products are excluded from the market . The demand of consumers shrink as choices of consumers decrease. As a result , the consumer surplus ADE is shrunk into BCE.

Exclusionary practices can be seen in the unilateral behaviour of dominant firms. It is more often seen in a strategic alliance which vertically integrates the dominant firm and its upstream input supplier or downstream manufacturer or outlet or horizontally collaborate competitors to exclude rivals. Exclusionary practices are embodied in strategic alliances , particularly in vertical strategic alliances for preventing from free riding, increasing profits or ensuring technical performance on innovation. More often than not exclusionary practices are utilized for expanding the breadth of innovation over another or future market or deterring sequential or complementary innovation.

Leveraging Market Power (LMP)

With the existence of some monopoly power in a major market , a particular abuse of such power in one market is of turning it into a second market. The resulting existence of monopoly power in the second market would not come from the merits of competition but through leverage. For example, in the case of a technology license the dominant firm very likely has more information about the advantages of the products in another market than its partner does or the partner might see accommodation to the dominant firm as relatively costless. Moreover, if the dominant firm bargains with its licenses one at a time. Even a licensee sharing the same information and attitudes might be unwilling to deny the dominant. The licensee, standing alone, would run the risk of being cut out of the dominant's license entirely. Only if all licensees acted concertedly could any one of the licensees confidently predict that the dominant firm could not use its power twice. Under such realistic market scenarios, leveraging may well increase the aggregate returns from monopoly.
This effect may be particularly significant in network industries where the products system is complementary and the complementary components extend over time. Sellers can indeed exploit aftermarket buyers regardless of the original equipment market being competitive if the complementary components of other manufacturers are incompatible , which is often the case. . Such exploitation is possible where the seller's immediate and assured gain from aftermarket exploitation exceeds what is at most a probable loss of future sales in the original equipment or primary market. The clearest case of aftermarket exploitation without market power arises when the seller intends to abandon the primary market and thus assumes no risk of future sales loss, or where the seller for other reasons applies a high discount to future sales in the primary market. In that event the loss of future sales becomes insignificant and the prospect of more immediate gain in the aftermarket dominates the analysis.
If leveraging allows a monopolist not taking its full return in the monopolised market instead of taking a higher return in the leveraged market, the monopolist will limit pricing in the monopolised market. Consequently, by not extracting the full profits-maximising price in that market, though still pricing above competitive price level, the monopolist currently gains a full monopoly return,
part in the monopolised market and part in the leveraged market. On the other hand, as a consequence of the limit price in the monopolised market, it extends the life of monopoly by reducing the incentive to enter. Therefore, leverage may suppress innovation which is most important in network industries.
Using tying the dominant firm may manipulate to lower its monopoly profits in monopoly markets while hiding its profits in the other market. The lower profits in monopoly markets thus reduce incentives to improved innovation in that market. The dominant firm would not lower its total profits still. In network industries , the markets are often oligopolistic rather than competitive owing to the enormous irreversible costs , economies of scale , sophisticated as well as compatible technologies , and network effects. As a result, for example, in the semiconductor industry, a dominant CPU producer can enter into cross licensing or grantback agreements with other semiconductor firms to obtain the next generation microprocessor technology developed by these semiconductor firms . The dominant firm thus can easily leverage its market power in the existing CPU market into next generation's microprocessor market. This is particularly true when the market power of existing product is reinforced by the network effects. That is to say, the existing CPU has technical compatibility with a computer operating system and the applications software desired by a significant number of computer users. For a new entrant it must be very difficult to attract support from software developers who are generally unwilling to consign development resources to an unproven demand. At the same time , consumers that already have many existing software applications that were written for a particular microprocessor architecture would be reluctant to

switch to a new and incompatible microprocessor architecture. Computer system manufacturers also would not risk alienating such consumers. Alternatively, a dominant firm in the market of primary products, thus can tie a complementary product to the primary product and then drive other producers of complementary products out of business, or at least foreclose them from competing in a substantial part off the market of complementary products. Through an exclusionary practice a dominant firm can create a monopoly in a second product market. As a result, a complementary product even superior may be excluded to access the market. The market function will be distorted and innovation will be suppressed. In network markets, the increasing returns from network effects also the raise the possibility of effectively leveraging from a non-network market into a network market or vice versa, leveraging from a network market into a non-network market through bundling the two products. Further, a firm that controls a dominant industry standard may leverage its market power in the primary product market onto the second market of complementary products. A supplier of complementary products may provide its products to the consumer only when the complementary product is compatible with the primary product standard. A firm controlling a primary product standard could exclude competitors in complementary product markets by changing , or withholding the key to the creation of a successful interface between the primary product and the complementary product in which it faces potentially more threatening competition. Consequently, the incentives to innovation in complementary products will be precluded because there is no market for the complementary innovation. Theoretically, "reverse engineering" might circumvent leveraging effects. That means analyzing the dominant firm's framework system in order to arrive at a workable interface for complementary products. The interfaces needed for many of today's complementary products , such as application software,, are often complex and not readily duplicated , however. Especially, where software product life cycles are short and first mover advantages are critical, reverse engineering may not provide competitors with a practical alternative. Further, reverse engineering is not an unarguably lawful alternative. Intellectual property rights today may cover many of the interfaces at issue, and the legality of accessing them for purposes of reverse engineering has been a matter of dispute.

It might be argued that monopoly profits earned in a primary market might reward the dominant firm for its innovation and legitimate business success. However, there is no basis for allowing it to reap monopoly profits in complementary markets as well. A too broad expansion of monopoly profits for the dominant firm only sacrifices the follow-on innovation. Foreclosing rivals' access to complementary markets reduces competition, product variety, and innovation in complementary markets. The complementary markets are susceptible to single-firm dominance because of the need to interface with the dominant firm's installed customer base in the primary market and because of the dominant firm's first-mover advantages derived from better and earlier access to the relevant interface. Complementary markets are the loocus of the next generation of innovation. Important innovation rivalry might be lost unless the complementary products are able freely to build upon the dominant primary-market standard.

Raising Rival's Costs (RRC)

If a dominant firm can negotiate with the input supplier not to deal with its rivals or deal on disadvantageous terms, the dominant firm may make it difficult for rivals to obtain the input or only obtain it at a higher cost. If the excluding firms can raise rivals' costs, they can exercise market power over the price, at least above the competitive level and up on the rival's level. It is not necessary to drive the rivals to exit the market. If a rival's costs increase , its ability of restricting market prices will proportionally decrease (Salop and Scheffman, 1983) The strategy of raising rival's costs can be more profitable and less risky than other predatory strategies like predatory pricing. Unlike predatory pricing which involves an initial loss to the predator, which might not be recouped later, raising rival's costs leads to immediate benefits for the firm employing the strategy. This is because the higher production costs for the rival force him to reduce his output immediately, permitting the excluding firm employing the strategy to reap the benefit of higher prices or enlarged output far sooner than a predator whose strategy requires the rival's exit before any recoupment will proceed. Raising rivals' costs can be employed through several anticompetitive exclusionary practices. For example, the dominant firm enters into an exclusive dealing with the major input suppliers not to provide the needed inputs to its rivals. In this situation, the remaining input suppliers can easily collude to raise the price forcing the rivals' cost higher. Or, if economies of scale exist in the downstream market, the refusal to grant access to the substantial input to rivals would drive up rivals' costs. That is to say the refusal to supply input to rivals' reduces the rivals' output depriving them of scale economies. As a result , rivals would be forced out of the market. Alternatively, in an output joint venture , if the venture possesses economies of scale or other strategic advantages, it may be able to exclude or disadvantage the participants' competitors by refusing to deal with them or by demanding unfavourable terms.

Increasing Barriers to Entry and Foreclosure

Anti-competitive exclusionary practices may raise the barriers to entry when economies of scale or other impediments forbid entry or make it more difficult. A tying arrangement may strengthen single firm dominance or oligopoly by denying market access to more aggressive competitors or potential entrants. An exclusive dealing agreement can prevent rivals from accessing the market. For example, a dominant CPU producer may sell its product to computer makers on the condition that the computer maker must not buy the rival's compatible CPU. These exclusionary practices prevent compatible CPU producers from accessing computer makers. They also make the competitors' product more difficult to access to computer makers although the competitors' later products may be better of cheaper . As a result, follow-on improvements are never to come onto the market. Alternatively, suppose most of existing firms in an industry form an alliance to develop a standard for the industry's next gteneration product. Suppose also that they exclude a number of potentially significant potential entrants from the alliance and from access to technical specifications necessary for a firm to develop the new product. This restriction, in and of itself, has the anticompetitive potential of excluding output from the market. In network industries an incumbent firm may control access to a critical standard because of network externalities that give the firm the power to make entry difficult or prevent competitors from entering the current market altogether. For example, once consumers purchase a primary good such as PC hardware or an operating system (collectively, "framework system") , they often invest heavily in complementary products , such as peripherals and applications software. They may also develop expertise and a reserve of files usable in conjunction with the assembled system. Unless competing framework systems are compatible with the installed base's peripherals (ssuch as printers or scanners) as well as application software, expertise, or files, the installed base may be locked into the incumbent framework system. Because switching to a competing framework entails the costs of replacing the complementary assets as well. Owing to this effect, a standard-setting body may intentionally set or manipulate a standard to exclude rival products. Standards may purposefully entrench technology that is available to few competitions because of patent protection and entry barriers.
Because adopting new technology in network industries is valuable only if others also adopt it, consumers may forgo the new technology because they are not sure what other consumers will do. The situation is exacerbated when the model takes into account the network effects of an installed base. Because early adopters of a new technology bear a higher share of transsient incompatibility costs , this inhibition is more likely to occur when an installed base is large or when the new technology only attracts a small number of users. The new technology cannot offer enough network externalities and it cannot generate positive feeddback unless the number of users is sufficient.It is therefore in an economic dilemma: on the one hand, the new technology would not be viable unless enough users leave the old technology, on the other hand, the new technology would not be attractive enough to draw away those users until they join. Furthermore, in computer software or semiconductor industry the markets for POC operating systems and microprocessors bear some characteristics of natural monopolies.The barriers to entry are reinforced through network effects generated by demands for interoperability and compatibility and by intellectual property rights that prevent competitors from simply copying another's work or infringing a microprocessor patent. As a result, not only does an installed base itself act as an entry barrier, but also firms producing the installed base technology may seek to buttress that barrier.
These barriers to the adoption of new technology may affect innovation at its roots. The presence of an installed base increases market risk. As with any other factor increasing market risk, an installed base may affect R&D allocation. To break up these barriers , compatible standards may therefore affect not only existing goods but possible innovations as well. Further, because compatibiliuty standards ensure that products made by various competitors can work together, , these standards may encourage innovation in the complementary goods market. Manufacturers may enter the peripheral markets when they know their products will be widely compatible with computers.

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