The United Nations University
WIDER
World Institute for Development Economics Research

Working Papers No. 163
August 1999

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Development Economics Research
(UNU/WIDER)

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This study has been prepared within the UNU/WIDER project on Information Technology and Economic Development, which is directed by Professor Matti Pohjola.

UNU/WIDER gratefully acknowledges the financial contribution to the project by SITRA (Finnish National Fund for Research and Development.)

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Camera-ready typescript prepared by Liisa Roponen at UNU/WIDER
Printed at Pikapaino Paatelainen Oy, Helsinki

ISSN 0782-8233
ISBN 952-9520-98-0 (printed publication)
ISBN 952-455-008-3 (internet publication)

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ABSTRACT

This paper discusses the theoretical concepts underlying recent developments in the regulation of telecommunications in Europe, the USA and developing countries with respect to efficiency and welfare. It focuses on analysing standardization problems, pricing rules and entry condition related to networks and network effects and derives preliminary policy recommendations for the telecommunications industry through a discussion of network models and related empirical evidence.

I INTRODUCTION

It seems appropriate to ask what is special about information and information technology before one sets out to answer the question how investments in information infrastructure should be valued and regulated. What comes immediately to one's mind is the extreme external effects of information—it has been said that the Rothschilds used carrier pigeons in order to be the first to know the outcome of the Battle of Waterloo. When they learned that Wellington was successful, they sold British government bonds in public to make London believe that the English had lost the battle. The price of the bonds lapsed into decay and the Rothschilds were secretly able to even buy a larger number of bonds at the lowest price.[1] This story, irrespective of its truth, illustrates nicely the strategic aspect of information and the power that lies in the control and selective application of information technology (i.e. the carrier pigeons).

Most of the study will deal with information technology and the related infrastructure. But it is obvious from the story above that information technology is a decisive element with regard to the nature of information and the value that accrues from it. Had the Rothschilds chosen a technology that made the victory of the English known earlier, they would not have become as wealthy as they did. Consequently, if we focus on the analysis of the economic aspects of information technology by generally neglecting the effects of technology on the nature and volume of information and the secondary effects of information on economic performance, then this is only the tip of the iceberg. Accordingly, all conclusions with respect to welfare are preliminary and subject to further scrutiny.

This is especially true because there is ample evidence to indicate that information does not *per se* enchance welfare. Information sharing among oligopolists is an example of the possible negative welfare effects of information, which is why 'antitrust authorities often take the simple view, that, when oligopolists communicate their views on the state of the market or on the evolution of costs of production to each other, this is the proof of collusion' (Phlips 1995: 81f.). Standard limit price theory tells us that constraints on information can lead to an increase in market efficiency.[2] Nijkamp and Ouwersloot (1997: 66) conclude in a more rigorous study on information and communication technology that 'informatization leads to an increasingly chaotic economy, with more products, less stability and involving a widening spatial area. At the same time, the self-regulating power of the economy increases. Consequently, both the possibility and the necessity of government intervention diminish.'

I am afraid that if we consider these secondary effects of information, we can say little about the value of investments in information infrastructure and appropriate measures for regulation. However, we have to accept that in today's international context the secondary effects and the overall welfare impact of information are not the burning questions—rather, the question is, who produces and transmits information and who gains the rents from it.

The following study will therefore limit itself to the primary effects of information and focus on information industry, and more specifically, on the telecommunications industry. Telecommunications covers a multilateral dimension of information. Computers are prerequisites of modern information, but when they transmit information between the sender and the receiver that is different and is characterized by a different level of information, can their immense communication potential be fruitfully exploited.

When Robert Solow conjectured that we 'can see computer age everywhere but in the productivity statistics', he triggered a rather intensive discussion on what became known as the productivity paradox. Although empirical results are ambiguous, it seems that the growth of national productivity declined in the United States during the 1970s and 1980s, despite large investments in information technology (IT) and the positive correlation of economic performance and IT investments on the corporate level. In the 1990s, however, both corporate and national productivity are positively related to IT investments.[3]

Network fundamentalists would argue that we have seen the invention of computers and their adoption ('innovation' in Schumpeterian terms) and diffusion while networking lagged behind for a long time and has become effective only in recent years. Indeed, as long as network effects do not prevail, it does not seem likely that IT investments provide a competitive advantage to an individual firm even though they do not increase overall productivity. In fact, it could well be that the competitive advantage of one firm depreciates the capital of other firms at an excessive rate so that these firms cannot earn the amortization of their previous investments and have to cut down future investments. In the end, the competitive edge triggers a *rat race* which, on the one hand, leads to over-investment in IT and, on the other, to a reduction of complementary investment and overall output.[4]

Incompatibilities in computer hardware and software, the lack of common standards and coordinating institutions and the fundamental problem of excess inertia and inefficient lock-ins,[5] existing price and entry regulations, on the one hand, and the want of mechanisms to internalize network effects, on the other, are likely factors to explain deficiencies in networking. To some extent, it is the telecommunications component that makes the networking problem in IT prominent. If the telecommunications network does not work properly, then, in general, one computer cannot 'speak' to another computer and the network effects of IT are limited to local performance. For this reason the following discussion focuses on telecommunications (as a component of IT) in order to clarify the problems of market regulation and efficiency that are embedded in IT and its network dimension.

Information industry covers a large range of activities. The question as to whether this is good or bad is irrelevant from an economic point of view. What we are interested in is how it performs (e.g., whether it is efficiently organized) and how its performance can be improved so that it meets the social welfare target. A special feature of information technology is that success is, by and large, determined by relative rather than absolute performance. Often the *relatively* better information renders the *relatively* lesser information *absolutely* invalid. In the contest on information and information technology, it generally holds that the 'winner takes all'. In general, if one supplier improves his performance, he often worsens everyone else's performance. But contrary to a zero-sum game (or, more general, a game of pure conflict), it is possible in the described game situation to make everybody better off by reducing the inputs. While there might be still winners or losers, it is less costly for everyone to play the game.

The winner-takes-all result that seems to be inherent to information technology and can often be only countered by substantial regulation, is correlated with critical mass constraints and network effects. However, in case of critical mass constraints and substantial network externalities, the corresponding information technology may not prevail and there might be no winner at all. Market failure could be corrected by regulation and public support. For instance, in many countries (e.g., in Germany) the introduction of a videotext system (called BTX in Germany) suffered from the critical mass problem while in France the problem for the corresponding videotext system, called Minitel, was solved through substantial public support.

The following sections will look at network effects and network externalities, i.e. network economies, increasing returns to adoption, or local positive feedback—all terms used synonymously—in more detail. From what we have discussed so far, it seems obvious that not much can be said about the welfare effects of investments in information infrastructure on a very general level, i.e., with reference to the world economy, or its secondary effects. We will see that the web of markets is incomplete inasmuch as prices are not determined by the invisible hand of supply and demand, but are subject to bilateral or multilateral bargaining or external regulation. The standard welfare theory has little to offer once markets move from a regulated monopolistic structure to an oligopolistic structure that is still characterized generally by a high degree of regulation.

With respect to analysing the international effects of information technologies, it is important that the discussion of welfare often decomposes into partial (or local) problems. Whether developing country A adopts the information technology standard of industrialized country B or C, respectively, might have negligible effects on other countries in the world and even smaller effects on countries B and C. If so, the evaluation of welfare effects is reduced to the decision taken within country A and the effects this has on the welfare of the inhabitants of country A. In the following sections, we discuss welfare effects in a very small society—a society sometimes consisting of only two agents.[6] Often the discussion degenerates to the analysis of whether the welfare of a single agent (country) improves, assuming that the impact of a particular investment in information infrastructure or a particular regulation of price, quantity, quality, or entry has only a marginal impact on the welfare of other agents.

Before we discuss the allocation problems related to information technology which result from network effects and companion externalities, we will briefly illustrate the network problem of information technology as related to the standardization and incompatibilities in the case of electronic interchange networks. Then, the theoretical discussion follows the principle of looking at more and more complex models of networks and of their components.[7] Examples are used to illustrate the results. Section 8 contains policy conclusions.

The following models are static inasmuch as time is not an explicit variable. Time is of strategic nature in these models; it is embedded in the sequence of moves that defines, e.g., which costs are sunk, whether investments are irreversible and what information is available to whom and when.

II ELECTRONIC DATA INTERCHANGE NETWORKS

In a forthcoming paper, Belleflemme (1998) studies the diffusion of an electronic data interchange (EDI) message standard. EDI belongs to the class of inter-organizational systems (IOS) that reduce the cost of movement across organizational boundaries. It implies the transfer of structured data by agreed message standards from one computer system to another which, for example, allows business documents to be automatically interpreted by computers in different organizations without costly and time-consuming efforts to re-enter the information.

Obviously, a universal standard would represent an efficient solution. However, the process of diffusion of such a standard may be hindered by the installed bases of already existing EDI-specific facilities and the slow process of developing an efficient standard that could be unanimously accepted. Direct costs (i.e. prices) for utilizing the standards are zero (or negligible).

Different message standards have been developed by private organizations as well as by public institutions over the last two decades. The first efforts were made in the USA and in the UK which resulted in ANSI-X12 (from the American National Standard Institute [ANSI]) and the TRADACOMS syntaxes (which stands for Trade Data Communications Standards). In the late 1980s, the International Organization of Standardization (ISO) and the United Nations Economic Commission for Europe (UN/ECE) developed the EDIFACT message standard, which derived its name from Electronic Data Interchange for Administration, Commerce and Transport.

EDIFACT was meant to become the universal message standard in the corresponding areas. However, the current situation is characterized by competition between a number of message standards that correspond to different needs, different geographical and sectoral scopes. Examples for sectoral standards include SWIFT (Society for Worldwide Interbank Financial Telecommunications) and ODETTE (Organization for Data Exchange by Tele-Transmission in Europe), the latter being employed in the European automotive industry. In addition, there exists a large number of company-wide message standards. Although these standards are more or less compatible with each other, there is a general view that a single standard could be an efficient solution. In 1992, the Accredited Standards Committee X12 of the ANSI announced that by 1997 it will bring all ANSI-X12 standards into alignment with EDIFACT. On the same footing, the Article Number Association has decided to migrate all TRADACOMS standards to EDIFACT.

However, the development of a universal standard like EDIFACT is a rather slow process, because of its all-encompassing scope and its open participation. It is therefore poorly equipped to challenge the already existing standards that serve more specific needs. Even though it is expected that the attractiveness of a universal standard will increase at a later date, it might well be that the universal standard—because of 'inefficient lock-ins' and of 'excess inertia'[8]—never comes into being.

Moreover, the positive network externalities of message standards are often strongly localized inasmuch as they are predominantly related to decisions made by business entities located in the present, immediately foreseeable area of transaction. A common message standard either evolves within the business community, or is likely to be agreed upon by community members. Generally, problems arise when information needs to be transmitted from one community to another.

Belleflemme (1998) develops a model that addresses the slow development of the universal (and efficient) standard and the locally-bound network effects of specific message standards. He analyses two implementation mechanisms for the universal message standard: verbal negotiation among interacting agents (which functions as a standardization committee) and adoption of a message standard through unilateral action. By means of a simple game theoretic model that represents the inherent coordination problem as a repeated Battle of the Sexes game of three periods, he shows that the implementation of a universal message standard depends on whether the interlinkages between the alternative business communities to which the two firms belong, are intensive or not. Of course, the implementation of a universal message standard also depends on the time preference of the decision-makers. The dynamics of the model derives from the fact that the payoffs from the universal standard are smaller in the first period, and larger in the third period than payoffs from the local standards: this is meant to reflect the performance of a universal EDIFACT standard if implemented.

The prevalence of low-scale interlinkages between firms in different business communities mirrors the view expressed by Liebowitz and Margolis (1994) that substantial network externalities are the exception and not the rule. In this case, we can expect the implementation of EDIFACT only when it is *better* (more mature) than the specific EDI standards. When it comes to information, network effects generally are not negligible—however, in well-defined communities they can be strongly localized so that a universal message standard would hardly add to the network effects. However, as Woeckner (1997: 397) observes 'it is an open question whether by use of EDIFACT additional realisable scale and network effects outweigh the loss of utility that results from the fact that EDIFACT cannot meet the specific requirements of each sector of the economy'. Blankart and Knieps (1993) are very sceptical about the net benefits of EDIFACT. They prefer a medium degree of standardization as suggested by international standard committees such as ISO, CCITT and ETSI which imply standardization of the lower layers only, with the upper layers left to market competition. However, EU bureaucracy favours deeper standardization despite possible friction and loss of variety. Blankart and Knieps (1993: 51) argue that the bureaucracy's 'behaviour is quite rational. The enforcement of EDIFACT promotes its power and its interests as a unique expert in matters of standardization'.

III BASIC PROBLEMS WITH NETWORK TECHNOLOGY

Most basic questions on the agenda for the discussion of network effects and pricing problems can be illustrated by Figure 1 which portrays the case of a non-sustainable natural monopoly.

The upper half of Figure 1 describes the cost curve C(x) when there is a single supplier to the market of good x. It also applies if there is a combination of two individual suppliers which are close enough to share fixed costs and joint benefits. The angles α, β, and γ express corresponding average costs. (For the discussion in this section, please ignore the horizontal line at the level of C(x) = 14.) The average cost curve, C(x)/x, is drawn in the lower part of the figure where D_0, D_1, and D_2 represent alternative demands for (information) good x and thereby illustrate possible dynamics of the market. The average costs for the quantities x', x_1, and x'' are represented by tanβ, P_1, and tanα, respectively (where P_1 corresponds to angle α in the upper part of the figure).

FIGURE 1
NONSUSTAINABLE NATURAL MONOPOLY

3.1 Natural monopoly

We will select two alternative scenarios that are represented by this figure: *monopoly supplier* and *joint network*. However, irrespective of which scenario we pick, the assumed cost curve implies subadditivity of costs and thus satisfies the condition of a natural monopoly. If we assume that production incurs a minimum cost of 10 units, then whatever the quantity $x°$ supplied to the market, average costs are lower if the quantity $x°$ is produced by one entity of production than by two (or more). In other words, if total output $x°$ is delivered by two or more producers in isolation, then total production costs *will not decrease*—this is the subadditivity property that defines the natural monopoly (see Baumol (1977, 1982) and Baumol *et al.* (1982)—in fact, in our example, total costs will increase to a minimum of 20 units if two or more independently operating suppliers are involved in production.

The *monopoly supplier* arrangement could be the result of *market growth* or, alternatively, of a *merger*. In the merger case, we can think of the initial position of two suppliers who perhaps under the threat of entry by a third supplier decide to integrate their business into one firm in order to save overhead costs and thus to be able to supply quantities $x > x'$ at total costs of 17 instead of 20. The cost threshold at $x = x'$ could be the result of generic capacity constraints in the production of x (i.e. due to the geographical limitations of a network) or the heritage of the pre-merger structure. In the second case, potential competitors could have cost advantages—a case that we will discuss in detail below. However, in case of market growth the incumbent can face a similar threat of entry. If the production structure of the incumbent was cost minimal for the production of $x < x'$, it might no longer satisfy this property if the incumbent adds a second production unit to match the growing demand in the range $x > x'$. Despite the fact that the incumbent saves administrative overheads, etc. when expanding into the production of $x > x'$, the history of expansion could well imply a production and cost structure that does not minimize total costs and could thus invite the entry of competitors. In the following sections, we therefore have to distinguish between the *monopoly supplier* which produces at minimum costs and those characterized by non-minimal costs. If we do not specify this issue, then minimum costs of production are assumed in the sequel. (We will see that even in this case, potential competition can be relevant and even entry may be possible.)

If we interpret Figure 1 as a representation of a *joint network* arrangement, then what was said about monopoly and entry in the case of non-minimal costs also holds. There is, however, the additional problem of how to share the costs and revenues between the two suppliers cooperating in the network. For instance, if demand is such that each supplier contributes x = x', then total costs are 17. A supplier could produce its share at costs of 7 if the other takes care of the overheads of 3. If the product price is equal to average costs, then the two network suppliers have to share the overheads equally in order to avoid one supplier operating at a loss. If there is the threat of partial entry in a section of the network or the potential for appropriating consumer rents via price discrimination, then one of the network partners may argue that the other should cover a larger share—or all—of the overheads. The discussion of the various pricing (or evaluation) schemes of network goods in general and information networks in particular (which is summarized below) deals with this problem. If prices are split and for example, the price of supply x' does not even cover the incremental cost, then this supply is cross-subsidized by the supply that exceeds x' and perhaps attracts clientele with greater willingness to pay.

Cross-subsidization is but one way of deterring entry in networks. Pre-emptive investments, vertical price squeeze, and predatory pricing are others.

3.2 Contestability

In order to shed light on the entry problem, we may assume that the market for the (homogeneous) good x is contestable. The concept of *contestability* is a standard one in industrial organization literature. Irrespective of its rather unrealistic assumptions,[9] it serves as a cornerstone to the regulation policy discussion where it pays to be more explicit about its definition. According to Baumol (1982) and Baumol et al. (1982) a market is contestable if entry into the same is free, and exit does not entail any costs. Consequently, contestability excludes the existence of sunk costs. Further, hit-and-run is assumed, i.e. if markets are contestable, then competitors can enter and exit before incumbent(s) can react by lowering prices, for example. In an equilibrium, incumbent firms produce in a technically efficient way, maximize profits, and prices will be equal to average costs—then there will be no market entry and market structure is determined.[10]

However, such an equilibrium may not exist. Given the situation described in Figure 1, the incumbent network cannot block entry if demand x° is in the range x' < x° < x" if price is equal to average cost C(x°)/x°. A competitor can enter supplying quantity x' at a price p' that is below

$C(x°)/x°$ but above $C(x')/x'$ and earn positive profits, irrespective of whether the incumbent is a *monopoly supplier* or *joint network*. Although the incumbent can block full entry by charging the zero-profit price $p° = C(x°)/x°$, it cannot prevent selective entry (raisin picking, cream-skimming, etc.) characterized by quantity $x < x°$. In fact, x' is profit-maximizing for an entrant. In other words, the natural monopoly described in Figure 1 is not *sustainable* if zero-profit demand $x \in (x', x'')$ can prevail.[11] Then the result will be disequilibrium situation.

The incumbent is able to block entry, even with the threat of raisin picking, if it is not constrained to a single price. However, expected rationing and queuing are generally considered as inconsistent with market equilibrium. It has to be noted here that if selective entry is profitable, then a mechanism of rationing is also needed to allocate the scarce supply because there will be no single price that can clear the market. An obvious policy to avoid causing frustration to buyers willing to pay the market price but who cannot find goods to buy, is to ban selective entry. Requirements of universal services are a result of this pattern of regulation. The example in Figure 1 shows that the need for such a regulatory policy is a dynamic problem. It is relevant only if demand is such that the zero-profit supply x° is in the interval $x' < x° < x''$. If demand grows further so that a D_2 curve applies, contestability guarantees an efficient market result. In this case, regulation has no effect at all or creates distortions that are likely to provide the incumbent with some ways to earn profits.

Let us now assume that there is no threat of selective entry because $x° > x''$ holds for zero-profit demand. However, we assume contestability so that price equals $C(x°)/x°$. Then, in the case of *joint network,* the contribution of the supplier of the quantity $x° - x'$, denoted by unit B, has to cover an increasing share of the costs related to the supply of x' (produced by unit A) if the zero-profit demand increases, and average costs and the resultant market price decreases. The necessary transfer from B to A is $C(x') - p°x' > 0$.

If the transfers from B to A are lower than $C(x') - p°x'$, A will make either a loss or the prices are in conflict with the contestability of the market. The existence of a sustainable (fully-sized) network therefore depends on the size of market demand and the possibility of side-payments (i.e. cost sharing) between the units forming the network. As we will subsequently see, the amount of side-payments becomes more ambiguous if contestability does not apply and cost sharing becomes subject to bargaining between network members, or to regulation, or to a combination of both.

We have interpreted the cost saving effects of joint production as network effects. Inasmuch as unit A provides the infrastructure (which corresponds to the overheads of 3 units) and B does not pay for it, the infrastructure implies *positive network externalities*. Standard theory says that measured by social optimal procurement, there will be an under-provision because B's willingness does not affect A's investment decision. However, contestability forces the internalization of externalities irrespective of whether they are benefits or costs because otherwise there is a potential for profitable entry. Contestability and the corresponding cost sharing that supports zero-profit prices thus form a mechanism of internalization.

Potential entrants in telecommunications networks include competitive providers of access, interchange carriers, cable companies, cellular telephone services, satellite providers, electric utilities, and large end-users that can internalize various functions of the switched network. Contestability implies that entrants can produce in accordance with the cost function of the incumbent supplier(s). If this is not possible, then there exists a *monopolistic bottleneck*. This might be the case because of patents and other exclusive property rights, imperfections of factor markets, sunk costs or physical constraints which could, for example, make it impossible to build up fully identical networks of wired telecommunications. Physical constraints are perhaps more obvious in the case of railroads but the duplication of telecommunications networks is also constrained by existing networks—and, of course, by corresponding sunk costs that imply a strategic cost advantage for the incumbent. Sunk costs have no influence on the decision of the incumbent, but the possibility to recover sunk costs in the future is highly relevant in an entry decision.

3.3 Economies of scope and natural monopoly

Let us now interpret Figure 1 so that x no longer represents a homogeneous good, but the total quantity x'' represents a combination of a quantity x' of good y and a quantity x''-x' of good z. Then Figure 1 illustrates a multiproduct firm and the definition of natural monopoly has to be revised if we assume that the production of x' and x''-x' in isolation (i.e. by two completely separated firms) costs 10 units each and therefore economies of scope are relevant because the combined production costs are only 17 units. In fact, it is cheaper to produce any quantity of the two different goods jointly than to produce them 'in isolation'.[12] Economies of scope are a necessary condition of a natural monopoly. Sufficient conditions for a natural monopoly are that of economies of scope and declining average incremental costs (see Evans and Heckman 1984).

Again if a natural monopoly exists, it is efficient that the total supply is produced in combination and if the supplying monopoly is not sustainable and (near-) contestability conditions, then it has to be protected by regulation against entry of raisin pickers—if efficiency is the sole welfare target and dynamic considerations are excluded. However, economies of scope are more difficult to identify because they imply a comparison of costs of different products at different levels of production. For example, there is an ongoing discussion with regard to the US telephone system as to whether local exchange carriers experience—or do not experience—economies of scopes. In the second case, efficiency gains can be achieved if they are broken up into component facilities: the local loop, switching and trunking. The latter is used to connect the central offices ('wire centres') where the switching is accomplished.

Gabel and Kennet (1994: 390) report that 'the judge who oversaw the 1974 AT&T anti-trust case, Harold H. Greene, concurred with the Department of Justice which monitored and controlled the activities of the Bell Operating Companies because the local exchange market was a "natural monopoly". Judge Greene argued that effective competition was not likely to occur in the near future because there were "very substantial economies of scale and scope".' Using data constructed from the statistical material of the Federal Communication Commission (FCC), Shin and Ying (1992) conclude in their empirical study that local exchange carriers do not qualify as natural monopolies and should therefore be broken up. Gabel and Kennet (1994) criticize Shin's and Ying's study on the grounds that the analysis, among other shortcomings, did not adequately take care of the fact that (a) firms included in the dataset were simultaneously providing such vertical services as private branch exchange and key systems, and (b) many of the local exchange companies were also providing inter-exchange services, and therefore owned the interchange facilities used to transport calls for hundreds of miles. Consequently, Gabel and Kennet promote their own study which addresses the issue of economies of scope by analysing data generated by an optimization model they call LECOM (local exchange cost optimization model). The model selects the combination and placement of facilities (i.e., local loop, switching and trunking) in a manner that minimizes the cost of production and approximates the production function by means of simulations. More specific, LECOM takes a city's dimensions and customer usage levels as data. It then searches for a technological mix, capacity, and location of switches that minimize the annual cost of production. Switched toll and exchange services, and toll and exchange private line services have been selected as products. The results indicate that costs can be minimized by providing service through four different central offices to do the switching. However, for a stand-alone private line system, costs could be minimized by having all loops terminate at one central office only. The additional trunking costs that result from using three additional offices in a common network with switched services create some diseconomies-of-scope—especially in densely populated areas. Not surprisingly, the competition of entrants has been observed to be the strongest in the private line market.

3.4 Lock-in and critical mass

The market situation illustrated by Figure 1 can also be used to discuss the interplay of lock-in effects and effects of critical mass. We assume that at the outset, there is a single incumbent supplier, A, so that its cost function corresponds to the upper half of Figure 1. Now, let us assume that a potential newcomer firm, B, which can produce any quantity $x°$ at total costs of 14, enters the market. As a consequence, B is cost efficient for any quantity $x° > x'$ because the supply of $x° > x'$ implies 17 cost units for the incumbent A and only 14 units for the newcomer B. However, if there is no regulation that prescribes universal services by any supplier and $x°$ is in the interval $x° \in (x', x_1)$, then the incumbent can offer a quantity x' at a price which is marginally below $14/x°$ and can even gain profits. In this case, the newcomer can only hope for sales $x°-x'$. However, it is not at all clear that these buyers are willing to pay a price which covers average costs of size $14/(x°-x')$ while other buyers have to pay only $10/x'$. We are thus in disequilibrium and, again, it depends on the rule of rationing and queuing as to whether the more expensive supplier will find customers. (Note that our story reverses the raisin picking argument which is now in favour of the incumbent.) Thus, if contestable, the market is locked-in with a cost inefficient supplier in the interval (x', x_1). The quantity x_1 is the *critical mass* that B has to gain in order to exploit the cost efficiency it enjoys for outputs larger than x'. A demand which is represented by a curve to the right of x_1 guarantees that critical mass will be achieved if customers have no specific relationships with the incumbent A and the product x is homogeneous in their evaluation. To conclude, a growing market can cure the lock-in effect and solve the problems of critical mass. The simple model thus illustrates how newly introduced technology may be able to successfully disseminate itself in a market characterized by a substantial lock-in potential.

We would perhaps be over-stretching the above model if we interpreted the cost advantage of B's new technology versus A's old technology in terms of network effects. Witt (1977) introduces a model that is more explicit on network externalities. His model refers to the bilateral relation of users and the matching problem results from the assumption that potential users independently decide which technology to adopt. In principle, there are alternatives of efficient matching, inefficient matching and (inefficient) non-matching (like in Paul David's well-known keyboard case [1985]). The model specifies a dynamic process that overcomes the lock-in effect. Since externalities 'always favour existing and more widely used variants, all success conditions seem to come down to one and the same prerequisite—the capacity to pass a "critical mass" threshold or, more precisely, to attract a critical number of potential adopters who then make an adoption decision. This condition may, in many cases, be considered as a prerequisite for industrial change ...' (Witt 1997: 771).

Peters (1997) presents an *evolutionary critical mass* concept. He introduces a (critical) size of invasion ε^{CR} so that the set of evolutionary stable strategies EES(ε) is not empty but $\varepsilon = \varepsilon^{CR}$ is maximal.[13] In other words, the invasion of a new (and perhaps more efficient) technology has the chance to succeed if the size of its invasion, ε, is larger than ε^{CR}. From the definition of ESS(ε) it is obvious that the stability of an incumbent strategy *s* (the established technology) depends on its fitness and the fitness of the newcomer strategy (the newcomer technology) *m*. That is

$$ESS(\varepsilon) = \{s \mid \varepsilon' \cdot f(m,m) - (1-\varepsilon') \cdot f(m,s) < \varepsilon' \cdot f(s,m) - (1-\varepsilon') \cdot f(s,s) \quad \forall \varepsilon < \varepsilon', \forall m \neq s\}$$

The expected payoff of an incumbent *s* equals $f_s = \varepsilon' \cdot f(s,m) - (1-\varepsilon') \cdot f(s,s)$. Here $f(s,s)$ is the fitness that *s* earns in interaction with s and $f(s,m)$ is the fitness that *s* earns in interaction with *m*. The expected fitness of the newcomer *m* equals $f_m = \varepsilon' \cdot f(m,m) - (1-\varepsilon') \cdot f(m,s)$ where $f(m,m)$ and $f(m,s)$ are defined correspondingly. If we redefine the fitness function $f(\cdot)$ by the profit function $\pi(\cdot)$ then the evolutionary critical mass concept can be used as a proxy to discuss stability conditions and conditions for successful entry of technologies. Of course, we have to specify how profits develop in the entry process, e.g. by means of a replicator function (see Mailath 1992).

IV ALTERNATIVE PRICING RULES AND MARKET EXCESS

The network in Figure 1 is represented by a homogeneous output x produced by each of its components. In this case, an identical price can be derived straight away if the market is not distorted and an equilibrium prevails. However, heterogeneous networks in which the various components produce different goods—and network benefits including gains from specialization—seem to be more frequent also in the telecommunications industry.

4.1 Monopolistic bottleneck and price regulation

Tye discusses four alternative regulatory pricing rules for markets in which a vertically integrated firm controls access to a 'bottleneck' or 'essential facility' and most other firms have access to that facility 'if there is to be effective competition' (1993: 39). For illustration, Tye uses the rail industry as an example, but this example is directly applicable to the telecommunications networks as well. We assume that there are two competing long distance networks: AB is connecting A and D via B and AC competes from A to D via C. Both use the local network DE for switching services which has a market dominance for this service, i.e., it qualifies as monopolistic bottleneck. Figure 2 summarizes the network structure given in Tye's example.

All three network carriers are assumed to have incurred substantial investments and have to choose prices above incremental costs in order to cover corresponding costs assumed to be sunk. Tye further assumes that the revenues per unit of a total service (i.e. unit of final good AE) are *given* as \$30, the incremental per unit costs for long distance service AD are \$20 and incremental per unit costs for the switching service DE (provided by a local network) are \$4. That is, the lines ABD and ACD are assumed to be equally efficient. Total incremental costs therefore are \$24 per unit. Prices for the final good have to be above \$24 to recover sunk costs. The revenue/incremental cost ratio with respect to the final good is thus

30/24 = 1.25. If we apply this ratio to both long distance and switching services, then the *revenue adequate prices* are $25 for AD and $5 for DE, respectively.

FIGURE 2
NETWORK WITH MONOPOLISTIC BOTTLENECK

In principle, revenue adequate prices correspond to the *total element long-run incremental costs* (TELRIC) prices as suggested by the FCC in its interpretation of the Telecommunications Act of February 1996 that legalizes overall entry into local networks and intrastate long distance telecommunications (see Brock and Katz 1997; Harris and Kraft 1997). In the USA, telephone companies submitted studies on long-run incremental costs to the State and Federal Commissions. In order to reflect their overheads, the reporting companies developed loading factors to take into account administrative and marketing expenses. These served as input to regulations. Thus, TELRIC allows for the recovery of fixed costs and variable costs, but makes no allowance for the sunk costs that characterize telecommunications investment (see Hausman 1997).[14]

On the contrary, the 'Working Document on Interconnection Pricing in a Liberalized Telecommunications Market' issued by the European Commission on August 6, 1997, states that interconnecting prices should be equal to long-run incremental costs because this would enable a firm to recover all of its costs related to the provision of interconnection. Knieps (1997b) argues that mark-ups are necessary to guarantee the long-run survival of (efficient) incumbent firms and to provide adequate incentives for future investments. If sunk costs are involved, then, at least, the second argument is straightforward.

In order to evaluate the difference between TELRIC and the European version of cost pricing, one has to note that TELRIC is not based on actual costs but on 'estimating the cost of reconstructing an entire hypothetical network using the best available forward looking technology' (Harris and Kraft 1997: 104). Thus, by application of TELRIC, the incumbent local exchange carriers were not permitted to recover their actual incurred costs of providing unbundled components of their telecommunications systems to competitors. In fact, TELRIC 'effectively allows all capital expenses to be treated as variable costs' (Harris and Kraft 1997: 104).[15]

Now, if AB and DE merge to form a company AB/DE, firm AC cannot satisfy consumers' needs for telecommunications without access to competitors. Because of the bundling of services, AC will suffer from 'vertical foreclosure' of competition if AB/DE do not allow AC to use the local network DE. If efficiency implies that market access must be granted, the question of how to price *competitive access* for switching service DE needs to be answered. Tye proposes that the following three objectives be considered by (price) regulations:

> 1. Regulation should be strictly limited to specific components of the network and services where there is a lack of effective competition;
>
> 2. Ownership of facilities or control of services where there is a lack of effective competition should not be allowed to confer an artificial anti-competitive advantage in competing over other facilities or for other services where effective competition would otherwise prevail; and
>
> 3. A successful transition to deregulation (or lessened regulation) should be enhanced.' (Tye 1993: 46)

According to Tye, the first principle means in short, 'fix it only where it is broken' while the second principle implies that no breakdown of effective competition should be allowed in one part of the network (or industry) that infects other parts.[16] The third, principle proposes 'to minimize the scope of regulatory intervention and enhance a successful transition to increased reliance upon competition.' (Tye 1993: 46). While it should not be too difficult to find arguments to support the first and the second principle on the grounds of efficiency, the third principle seems to emerge directly from the deregulation ideology that characterizes the discussion of network industries in general and telecommunications in particular.

4.2 Alternative pricing rules

In the sequel, we summarize the results that Tye (1993) derives from his numerical example with respect to the following four regulatory pricing rules: competition on equal terms, long-run incremental cost, the parity principle, and voluntary negotiations.

As long as the three network providers are independent, *competition on equal terms* prescribes *revenue adequate prices* of \$25 for long distance services AD and of \$5 for local services DE. If AB and DE merge to form the company AB/DE, firm AC must seek to connect itself with what has become the competitor's network. We abstract from the problem the fact that AB/DE controls the interface and may cause extra costs for AC, e.g. by choosing an incompatible standard that requires converter technology. Following the argument in Farrell and Saloner (1992), we may conclude that the mere existence of converters invites the introduction of some degree of incompatibility that gives the monopolistic bottleneck a degree of discretionary power and, in all likelihood, a cost advantage. Obviously, if converters were declared illegal, then AB/DE would have to refrain from interface manipulation if it wants to do business with AC.

Given that the regulator applies a pricing rule based on *competition on equal terms*, AC should be able to buy local services DE at per unit price of \$5. This price is free of cross-subsidies and satisfies the stand-alone test.[17] *Results:* AB/DE gains a net revenue of \$6 for each unit of the final good and 1\$ for each operation of AC if AC enters. Furthermore, AC earns net revenues of \$5. (Net revenue is defined as the difference of revenue minus incremental costs.)

Alternatively, if the regulator prescribes prices for monopolistic bottlenecks that correspond to *long-run incremental cost (LRIC),* then the unit price for local services DE is \$4. This price is below the stand-alone cost and does not satisfy the revenue adequacy requirement. In this case, it is profitable for the long distance carriers to seek access rather than to own the facility. *Results*: AB/DE gains a net revenue of \$6 for each unit of the final good and zero for each operation of AC if AC enters. AC earns net revenues of \$6 (i.e., a surplus of \$1 over total costs). This result implies that the local services can be adequately remunerated only if the final good is produced by AB/DE since the long distance network AB pays a cross subsidy of 1$ per unit to the local network DE.

If the regulator prescribes a pricing rule that follows the *parity principle*, then the supplier of a component (such as local services) can charge a price for this component that makes the supplier indifferent to whether it provides other components of the final good itself (i.e. the long distance service) or whether these are supplied by potential competitors. This implies that the price of the component has to be such that the net revenues of other components are zero. In the given example, this will be the case if the pricing rule allows AB/DE to charge $10 for local services DE. *Results:* AB/DE gains a net revenue of $6 for each unit of the final good, irrespective of whether the long distance service is provided by itself or by AC. The net revenue earned by AC is equal to zero. This result implies that AC cannot recover sunk costs, and thus revenue adequacy is not satisfied. The parity principle allows AB/DE to impose a price squeeze on AC. This is feasible, since internally the local network DE cross-subsidizes the long distance network AB. The joint company AB/DE recovers all costs and gains a surplus of $5 if it sells switching services to the competitor AC. However, $4 of this $5 are the opportunity costs to AB/DE of not earning net revenues to cover the sunk costs of its own long distance carrier AB and the $1 is foregone revenue if the long distance service of AC substitutes service equal to AB.

Application of the parity principle provides results such that entrants to potentially competitive components of the network do not recover set-up costs. The regulator, therefore, cannot rely on competition for an efficient organization of the network. This is even more so, since the parity principle creates incentives to merge rather than to achieve any productivity gains from an extended network, to appropriate rents from users of bottleneck components. Needless to say, the parity principle violates the stand-alone test.

Violation of the stand-alone test and the related revenue inadequacy block entry. If we assume that an established country supplies the integrated AB/DE service and a newcomer country (e.g., a developing country), without the capacity to offer an alternative to DE, plans to develop the AC long distance network, then it seems obvious that parity rule pricing or, alternatively, long-run incremental cost pricing has an impeding effect on international competition. This leads to straightforward welfare losses for latecomer countries and regions. This briefly illustrates the range of the economic and political impact of regulation on the world economy.

However, the lack of competition is also expected to create cost inefficiencies (e.g., X-inefficiency) within the established network and will, therefore, trigger welfare losses to its clients as well. Gabel (1994) quotes two successive presidents of the American Telephone and Telegraph Company (AT&T) who maintained that their company failed to develop its market fully and to provide quality telephone service. However, protected by Alexander Graham Bell's patents before 1893/94 and benefiting later from predatory pricing, AT&T was by and large able to block entry for a substantial period and to accumulate profits. Gabel reports that it has been estimated that in its monopoly era, AT&T earned an average annual return on investment of 46 per cent.

Instead of prescribing a pricing rule for the overall network, the regulator might take recourse in *voluntary negotiations*, hoping for an efficient bargaining outcome to determine AC's price for buying switching services DE. In this market situation, it seems that in the above example, there are no benefits to be distributed through bargaining. Given that AB/DE can earn net revenues of $6, AC has to pay $10 for switching services. Otherwise, it is profitable for AB/DE to lock out AC and earn the $6 by selling the final good to the client. Tye points out that it might well be that the results of *voluntary negotiations* concur with the (unfavourable) outcomes that accrue from the *parity principle*.

Knieps (1997) argues that private bargaining leads to efficient results only if markets are contestable. Contestability might prove to be a too strong condition, but bargaining with service bundles that contain a monopolistic bottleneck are never likely to produce socially efficient and fair results. If we consider that a customer served by AB will not be served by AC, and vice versa, then the equivalence of the result of *voluntary negotiations* to the application of the *parity principle* derives itself straightforwardly from the theory of bilateral markets (see Morgenstern and Schwödiauer 1976).

Obviously, AB/DE has no incentive to open the local network for switching services on a *voluntary basis* at the price called for by the parity principle: AB/DE earns $6 irrespective of whether AC or AB supplies the long distance services. But if AC contains a more efficient long distance network than AB, then the *parity principle* still prescribes a price of $10 for the switching services while AB/DE is likely to achieve a higher price for switching services and thus appropriate a part of the rent of AC if the regulator relies on *voluntary negotiations*.

Inasmuch as bargaining agreements are enforceable and the transaction costs of bargaining are not substantial, a solution concept of efficient bargaining—such as proposed by Nash (1950, 1953) or Kalai and Smorodinsky (1975)—can be applied to describe the outcome, i.e., the price of the local switching services. In general, bargaining solutions describe an outcome depending on the threat point that is determined by the payoffs of the bargaining partners in case of conflict. Policy measures that have an impact on the threat point, therefore, also influence the bargaining outcome. For instance, Brock and Katz (1997) argue that the FCC's local competition provisions of Telecommunications Act of 1996 have no immediate legal impact, because 'the court' indicated that the states and not the FCC have the authority to interpret the pricing provisions. Nevertheless, the FFC provisions change the threat point 'to the social better' in case an incumbent (or a bottleneck supplier) faces a bargaining situation with an entrant (or a potential partner which faces competition) because state authorities take the FCC pricing rule as a guideline.

4.3 Market transition and vertically integrated production

It seems obvious that the threat of alternative pricing rules has a strong influence on the bargaining outcome because these determine the conflict payoffs (i.e. the threat point). So far the concept of *voluntary negotiations* is linked to pricing rules based on *competition on equal terms, long-run incremental cost,* and *the parity principle.* Whatever may be the adequate solution for the described bargaining situation, a part of the efficiency gains will be appropriated by the carrier controling the bottleneck network (i.e. the switching service). This reduces the incentives of the non-bottleneck carrier (AC) to invest in R&D or in the reorganization of production and in other efficiency enhancing means. In fact, 'few' non-integrated competitors would ever be motivated to invest in efficiency-enhancing innovation under these market conditions.

To conclude, it should be observed that Tye (1993) discusses the four alternative regulatory pricing rules with respect to the process of deregulation. They are meant to encourage competitive access to sunk facilities in order to create market conditions so that the invisible hand of competition can promote economic efficiency. Thus, there is a dynamic aspect to Tye's theory that should not be neglected when applying his results. According to Tye (1993: 55), 'the objective of regulating prices of total services *during transition* is to encourage carriers and shippers to sign the type of contracts which would have been in effect had there *never* been rate regulation'.

This quotation refers to the rather abstract *original position* of network markets if we consider that Tye's theory assumes that an efficient market solution implies that access must be granted. In any case, proponents of the permissive approach argue that a vertical foreclosure of competition does not generate any significant welfare loss to the consumers, confining instead its impact to the distribution of producer rent. It is well-known that a two-sided monopoly produces an output which is identical with the quantity of a perfectly competitive market if the supplier and buyer maximize joint profits and the final good, and that the initial inputs are traded in perfectly competitive markets. The market result of the two-sided monopoly is therefore socially efficient if these conditions are satisfied. However, in this case, prices are determined only within upper and lower limits so that distribution of jointly maximized profits is open for an efficient bargaining solution (see above).

Now, if supply and demand side of the two-sided monopoly gets vertically integrated, this, in principle, has no effect on the production outcome and the welfare of the consumers of the final good. The result concurs with Pareto optimality if the markets for the final goods and the primary inputs (e.g. labour) are competitive. In fact, entry of competitors on a specific level of the vertically integrated production could challenge the efficiency of the market outcome. For instance, a Cournot oligopoly solution in the market of an intermediate good could put an end to overall efficiency since the produced quantity is smaller than in the case of the two-sided monopoly, maximizing joint profits, or perfect competition. (See also comments above on voluntary negotiations and the appropriation of efficiency gains.)

The efficiency result of vertically integrated production and the related absence of ownership effects on quantities and consumer prices are based on the assumption that all agents are perfectly informed; have access to a perfect capital market; that transaction costs are zero, and all monopoly profits can be extracted at one stage in a vertically organized production chain with a sufficiently high price. These, however, are rather heroic assumptions.

Other issues which have to be considered in the discussion of the above pricing rules and the model on which they are based, are (a) costs of production are difficult to identify and (b) they might be dependent on the regulation itself. The extensive discussion on the information contained in accounting is valid for the cost identification problem.[18] We will focus on the second argument. It has been repeatedly argued that if regulation renders market entry more difficult—or even blocks market entry, because of revenue inadequacy—the incumbent suppliers may resort to inefficiencies in production and are thus likely to produce at higher costs than in the case of contestability. However, the interdependence of costs and regulation can be much more indirect, and the corresponding distortions can rather difficult to identify as the following example indicates.

4.4 On the interdependence of costs and regulation: the Brandon effect

In a recent paper, Parsons and Ward (1996) analyse the influence of regulations on marginal factor costs. The object of their study is access markets in US telecommunications where local suppliers offer switched access to companies providing long distance services at regulated prices. Alternatively, the long distance companies (i.e., the suppliers of long distance services) can directly serve a large share of their customers also through the so-called special access. In many cases, special access is a close substitute to switched access as indicated by the positive sign of empirical measures of cross price elasticities.

In general, prices of special access are lower than regulated prices of switched services which are three times the accounting costs. When stating this fact, Parsons and Ward (FN1: 97) add that 'there is no reason to believe that the accounting data will overstate economic marginal costs'. Since prices of special access are likely to be substantially higher than the marginal costs of switches access, substituting special access for switched access creates social inefficiency. It seems straightforward to conclude that the price regulation of switched costs is welfare reducing.

Of course, the high regulated prices for switched access that were excessively above marginal costs were established by the FCC in order to recover fixed costs resulting from the setting-up of switched access equipment. Again, a dynamic argument of welfare may well justify that the regulator chooses prices which enable the carriers of network services to recover their fixed costs, as most of these are sunk. As a consequence of this price regulation, the supply curve of switched access is negatively sloped. 'If marginal costs do not rise too steeply', smaller amounts of services are necessarily burdened with a larger share of fixed costs if regulators seek, for any period of time, to recover a constant amount. As we argued above, marginal costs are roughly constant.

The negatively sloped supply curve can induce long distance companies to buy more of switched access than what seems appropriate by looking only at the relative access prices. Parsons and Ward report that it was an AT&T executive, Brandon, who was the first to conclude that it might be profitable for a long distance company with a substantial market share (like the AT&T) to save on bypassing switched access even when prices for special access are significantly lower. The so-called Brandon effect refers to the possibility that the gains from substitution can be smaller than the losses a company suffers from higher regulated prices for switched access—which are immediate consequences of a reduction of sales of switched access.

The long distance company has to appraise the impact of its substitution on the prices of switched access in order to determine the profitable degree of substitution. For long distance companies with very large or very small market shares, the effects should be easy to calculate if they know the costs of switched access that the regulators apply. If the market for long distance services is characterized by medium sized firms, the firms will find themselves in a oligopolistic game for the substitution of switched access by special access if they accept the reasoning that underlies the Brandon effect.

It follows that the preliminary result which predicts the price regulation of switched costs to be welfare reducing, needs some qualification. Parsons and Ward (p.104) conclude that, 'under the current regulatory pricing regime', traditional bypass models based on the factor price are likely to overstate actual levels of bypass, particularly bypass by AT&T. In other words, the efficiency loss due to deviation from marginal cost pricing is likely to be overrated if we do not consider the Brandon effect in the case of AT&T.

V PRICE CAP REGULATION

On the one hand, it has been argued that pricing rules are static inasmuch as they do not specify a procedure for revising prices if costs or benefits are subject to change over time. On the other hand, Tye (1993) and many others consider regulations as just temporary events on the way to perfect deregulation.[19] History, however, shows that regulations persist. Moreover, there are good theoretical arguments as to why some sectors should be regulated, at least as long as they constitute monopolistic bottlenecks (see the example in the preceding section). Price cap regulation is one way of responding to this problem.

By-and-large, all price cap regulations follow the principles proposed by Littlechild (1983) for British Telecom, British Gas, and the UK public electricity suppliers. The price cap sets any percent rise in prices that the supplier proposes, equal to the general inflation rate minus an 'X-factor' that may be identical to the percent increase in productivity. More specifically, an average price increase of some bundle of the firm's output must not exceed the increase in the retail price index (RPI) minus an exogenously fixed constant X which reflects the firm's potential for price reduction, i.e., X should be high if productivity increases lead to a substantial reduction of costs. The idea is that this reduction should be passed from the firm to the customer—at least, to some extent.

Widely shared arguments against price cap rules following this pattern include the application of inaccurate and ill-defined indices which measure inflation (e.g., RPI or CPI), regulation of group prices instead of single prices, problems of measuring an increase in productivity and the lack of incentive if the progress of productivity is passed through to the customer. On the one hand, price caps do not exclude anti-competitive pricing that blocks entry and thus do give incentives to increase efficiency. On the other hand, Mixon and Hysing (1997) conjecture that the price cap regulation encourages, for example, AT&T and the other firms to become more innovative and cost efficient. However, price cap baskets need to be defined along functional rather than product lines in order to enable suppliers exploit new technologies in innovative ways (see Schankerman 1996) and avoid ossified product patterns, locked-in by prescriptions contained in price cap regulation.

As the discussion of price caps shows, the result depends largely on the information various agents have and the extent to which this information is verifiable. In an unpublished paper, Bös (1998) demonstrates that first-best solutions are possible through the price cap regulation even when the costs of bottleneck supplier are unknown to the regulator or, alternatively, the costs are not verifiable before the court.

The model of Bös is based on the assumption that both a bottleneck supplier and buyers of bottleneck services have to incur relationship-specific investments that create bilateral relations between the bottleneck and the potential client. The investments increase the expected benefits from buying such bottleneck's services and decrease the anticipated costs for the seller inasmuch as they increase the probability that large benefits and low costs will occur. After learning about the realization of costs and benefits, the buyer and the seller may unanimously decide not to trade in spite of the fact that the costs of the relationship-specific investments are sunk. Accordingly, it is likely that buyers and sellers under-invest in these specific assets.

Bös shows that the under-investment problem can be solved by choosing adequate price ceilings for the service of the bottleneck. More specifically, Bös demonstrates that first-best regulations are possible, (a) if costs can be observed by the regulator even though they cannot be verified by a court and, e.g., agreements of cost sharing are not enforceable and (b) if costs can be verified by the seller of the bottleneck's services before a court but they cannot be observed by the regulator. However, unlike Littlechild's price cap proposition, the price ceilings are not necessarily chosen in accordance with the monopolistic bottleneck's potential for price reduction: for strategic reason (i.e., in order to create appropriate incentives) the regulator may have to choose a low cap for some high-cost realization and vice versa.

Note that the model discussed implies a non-cooperative game where the result is described by a equilibrium decision and thus depends on incentives. Although the agreed outcomes are enforceable, they may differ from outcomes that would be selected if the regulator (and buyers and sellers) were fully informed and information could be verified by the court.

VI FAIR AND EFFICIENT PRICING RULES

So far we have exclusively discussed the efficiency implications of pricing rules without considerations of whether the pricing rule will be accepted when it goes beyond the constraints described by costs. Acceptability, however, determines whether a pricing rule can be implemented and can operate as intended by the regulator. The acceptability of a pricing rule depends, to a large extent, on whether it is considered to be fair. This applies to individual buyers and sellers, but even more so to international interaction and cooperation. Experiment shows that the consideration of fairness is highly relevant for the individual decision-maker.[20] In the political arena, the discussion of the relationship between the rich and the poor countries stresses the concern for fairness. The fact that fairness is not as well defined as efficiency[21] should therefore not prevent us from taking a broader view on welfare than the one described by Pareto optimality. One could well argue that a broader view is necessary if international cooperation is not to be hindered by focussing exclusively on efficiency. In order to illustrate the problem of fair and efficient pricing rules, we will now discuss a model characterized by a pricing scheme which is designed to cover the costs of a joint telecommunications system based on the assumption that participation in this network is voluntary and contributions towards the costs vary among the participants.

The example discussed has been taken from Faulhaber (1975) and Holler (1991) and has been applied to the discussion of power indices in Holler and Li (1996).[22] The example could be understood as a proxy of the AT&T telephone network at the turn of the century. While AT&T provided long distance service, AT&T licensees called Bell Operating Companies served the larger cities. Gabel (1994) reports that in exchange for exclusive right to develop the market in a local region, the operating companies provided the AT&T parent with 35 percent of their stocks, purchased their equipment from the AT&T subsidiary Western Electric, interconnected with AT&T's long distance network, and allowed the parent company to monitor their engineering practice.

Alternatively, the following model can be interpreted as a scheme for distributing revenues to cover sunk costs. If we assume that marginal costs are covered by the prices users of the network pay in their regular bill, then we can assume that the vector for tariffs as derived in the sequel, represents the lump-sum payments from the users that are necessary to cover the fixed costs of the network.

6.1 The information network model

A user entity N consists of three regions, 1, 2, and 3, such that $N = \{1,2,3\}$. Each user $i \in N$ consumes a fixed amount of information services. Accordingly, we can assume that users do not differentiate with respect to benefits. In order to process the information, a user needs the service of (a) a long distance switching unit, (b) a local switching unit, and, (c) a transmission unit if the user is not in the western neighbourhood W = {1,2}. The capacity of the long distance switching unit is large enough to simultaneously serve all three users at a fixed total cost of 200. The costs of local switching services, including terminal equipment which codes and decodes telecommunications signals, are 100, 400, and 200 for the users 1, 2, and 3, respectively. The region N is geographically divided into two neighbourhoods—a western neighbourhood W = {1,2} and an eastern neighbourhood E = {2}. Users in different neighbourhoods may set up a long distance switching unit and use it jointly. In this case, the involved users have an additional fixed cost of 100 for regional transportation. If user 3 runs a long distance switching unit exclusively for itself, then it still needs the transmission unit which incorporates costs of 100. In this case, total costs incurred by 3 are 500.

There are various options of forming information networks for the three users. If, e.g., each user sets up its own long distance switching unit, then the corresponding costs are 300, 600, and 400 for 1, 2, and 3, respectively. Thus, total costs are 1,300. If the two neighbourhoods are served by separate systems, the cost for W and E are 700 and 500 respectively, if we assume that E has to cover the costs of connecting the two neighbourhoods. Total costs are minimized if a single long distance switching unit serves the user entity N. The described cost structure is characterized by *subadditivity of costs* such that

(1) $C(S) + C(T) \geq C(S \cup T)$ if $S, T \subseteq N$ and $S \cap T = \varnothing$.

In equation (1), C(S) represents the costs of *coalition* S to operate an information network where S is formed out of users contained in N. C(T) and $C(S \cup T)$ express the costs of coalitions T and $S \cup T$ if they run an information network *in isolation.*

6.2 Stable and efficient network fees

Figure 3 summarizes network costs if a single integrated information network serves entity N. Given subadditivity of costs, this arrangement implies the unique cost minimizing (and therefore efficient) solution of supplying an information network to N.

If costs are covered by fees (contributions, tariffs, prices, etc.) then the fundamental question is, what arrangement should be acceptable on a voluntary basis with regard to fees that can be assigned to various communities (e.g., without cross-subsidization initiated or authorized by the state). The answer is that the *grand solution* N, as described in Figure 3, and the corresponding fees $r = (r_1, r_2, r_3)$ have to be preferred by each coalition $S \subseteq N$ to alternative solutions. In other words, a *sustainable* fee

FIGURE 3
INTEGRATED INFORMATION NETWORK

vector (or pricing scheme) r has to be such that the related payoff vector is in the *core* of the cooperative game (N,v) where v(S) = -C(S). If we write

(2) $$R(S) = \sum_{i \in S} r_i$$

then the core conditions can be specified as

(3) $$R(S) \leq C(S) \quad \text{for all } S \subset N$$

and

(4) $$R(S) \geq C(N) - C(N \backslash S) \quad \text{for all } S \subset N.$$

It is easy to show that the *stand-alone test* (Eq. 3) and the *incremental cost test* (Eq. 4), both extended to coalitions, are equivalent if the zero-profit condition holds such that R(S) = C(S) for any coalition $S \subseteq N$ that operates *in isolation*, and more specifically R(N) = C(N) for the *grand solution* N. The conditions (Eq. 3) and (Eq. 4) ignore externalities inasmuch as they do not take the benefits into consideration which result to user i if j's local network gets connected to i's network, i.e., they only consider the sharing of costs of building up a network that makes use of joint facilities.

A fee vector $r = (r_1, r_2, r_3)$ is in the *core* of the game (N,C) and therefore sustainable, if it satisfies the following constraints:

(5a) $r_1 + r_2 + r_3 = 1000;$

(5b) $100 \leq r_1 \leq 300;\ 400 \leq r_2 \leq 600;\ 300 \leq r_3 \leq 500;$

(5c) $400 \leq r_1 + r_3 \leq 600;\ 500 \leq r_1 + r_2 \leq 700;\ 700 \leq r_2 + r_3 \leq 900.$

Given the constraint (Eq. 5a), conditions (Eq. 5b) obviously imply conditions (Eq. 5c) and vice versa.

FIGURE 4
THE PRICE SIMPLEX

The (non-normalized) simplex in Figure 4 illustrates the constraints and the set of fee vectors r, Ω, which correspond to the set of subsidy-free assignments of costs of the information network to its users. The set Ω is represented by the shaded area and it describes the *core* of the cost sharing game. The absence of cross-subsidization implies a fee vector r in Ω which guarantees that no individual user and no subcoalition can do better with an arrangement in isolation. In this sense, a fee vector r in Ω represents a *stable outcome*.

Note that the vector of uniform prices, r* = (333.3, 333.3, 333.3), is not in Ω. In other words, r* implies cross-subsidization if exogenously enforced and an unstable solution if exogenous enforcement weakens. Knieps (1983: 582) ascertains that 'the principle of cross-subsidization has played an important role in telecommunications. In particular, wide use has been made of the principle of uniform tariffs, which do not discriminate between high- and low-density routes, although the costs of providing the telecommunications services differ markedly between the two routes'. It seems obvious that uniform tariffs are easier to administer than graduated fees and thus save transaction costs. In some cases, the cross-subsidization implied in uniform tariffs seemed to serve the objectives of regional and social policy. In fact, cross-subsidization was a favourite policy instrument in many West European countries. In Germany, deficits in postal services were financed from the telecommunications sector surplus for many years. This was feasible because both services were integrated into a single public entity which formed a legal monopoly (headed by a member of the Federal Government): the entry of a competitor that could successfully challenge the cross-subsidization potential of the telecommunications sector was legally impossible.

6.3 Fair and reasonable network fees

In the above model, it is assumed that there are no legal barriers to block entry. Since the vector of uniform prices, r*, is not in Ω, it is therefore necessary to differentiate the fees in order to achieve a *stable and efficient* outcome. In general, there is more than one fee vector r in Ω and each of them implies a different distribution of costs to the users—and thus different payoffs to the players of the corresponding cost sharing game. Quarrelling over differences could be hazardous to efficient solutions which result from forming the grand coalition N. It seems obvious that a stable outcome can only be achieved if there exists a unanimously accepted single fee vector r. In the following sections, we apply several solution concepts which are said to produce *fair and reasonable* outcomes. The concepts form a part of the tool box of cooperative game theory and for the theoretical discussion we refer to the quoted literature.[23] Here we are only interested in the application of these instruments to the distribution game outlined above.

TABLE 1
ORDERINGS AND COST ALLOCATION

Orderings	Unit 1	Unit 2	Unit 3
(1, 2, 3)	300	400	300
(1, 3, 2)	300	400	300
(2, 3, 1)	100	600	300
(2, 1, 3)	100	600	300
(3, 1, 2)	100	400	500
(3, 2, 1)	100	400	500
Total	1000	2800	2200

Nash (1950) maintains that his bargaining solution, i.e., the well-known Nash solution, satisfies a set of properties that define a *fair and reasonable* solution for bargaining games. If the result of disagreement is given, and not subject to strategic considerations, and thus the bargaining situation can be described by a *simple* bargaining game, then the Nash solution coincides with the Shapley value for this type of bargaining games (see Harsanyi 1963). It is straightforward to calculate the Shapley value by listing all orderings (permutations) of the set of players N of the game (N,C).[24] Then, following the sequence of a specific ordering N' of the set N, we assign the incremental costs, $c_i(N')$ to each player i in N where $c_i(N') = C(S) - C(S\backslash\{i\})$ for all i in N and i = 1,...,n. For example, let us look at the specific ordering N' = (1,3,2) in the above game. Given that the coalition S = {1,3} provides a functioning information network, 2 has to cover 400 cost units only so that $c_i(N') = C(S) - C(S\backslash\{i\}) = 400$ for i = 2.

In case of the ordering N° = (3,2,1), a cost value of 500 is imputed on user 3 as we assume that it will pay for the transmission unit even if user 3 provides its own long distance switching unit. Next we sum up the $c_i(N)$ values for each player i for all orderings of N which gives us a distribution of weights $w = (w_1,...,w_n)$ and distribute the total costs C(N) in accordance with the ratios implied by w. Through this we get the fee vector, r_S =

(1000/6,2800/6,2200/6) which distributes C(N) in accordance with the Shapley value and the Nash solution as well.

There is an alternative fee vector r° = (1050/6,2850/6,2100/6) which is not only an element in the core, but also satisfies the conditions of the nucleolus and the kernel and thus a set of properties which make it a likely outcome of bargaining.[25] In order to evaluate the fee vectors r_S and $\hat{r}$ and to decide which cost distribution is more likely to be implemented, we should discuss the properties of the various solution concepts. However, we will refrain from doing so, as this project is very demanding and so far non-conclusive. For example, the nucleolus is defined by the set of imputations that lexicographically minimize the excess. In above bargaining game, the excess of a coalition $S \subseteq N$ is defined by the difference C(S) - R(S, r°) i.e., the costs of coalition S if it 'stands alone' and the sum of the fees which the members of S have to pay in accordance with a vector r°. Minimization is with respect to the alternative excess vectors which correspond to the alternative tariff schemes r. An excess vector, related to a specific tariff scheme r°, results if we order the excesses of all $S \subseteq N$ from the largest to the smallest value. One might argue that through the minimization of excesses and the resultant gains of standing alone, which are non-negative for all r-vectors in the core, the nucleolus is more concerned with stability than with fairness: it balances the advantages which the agents (i.e., the users if the information network) derive from the all-encompassing network N. However, balancing the advantages may also be considered as a procedure which leads to a 'maximum of fairness', given the asymmetries of the bargaining problem inherent to the cost function.

6.4 Cross-subsidization and policy implications

If we summarize our experience using the above example, the result although not conclusive, is that we have gained some insights of how to specify sustainable tariffs (i.e., pricing schemes) which cover costs. The discussion makes it obvious that the regulator has to have the power to block entry if cost allocation is be used for cross-subsidization. In the above model, entry is blocked if the complete entity N can provide long distance switching services only, and no real subset of users can supply long distance switching services of its own. We may think of user 3 as a newcomer country to the world's information network. If the Shapley value is applied to regulated prices, it has to pay a fee of about 366 money units instead of covering the costs of 500. If the integration of user 3 is be supported, then its contribution could be reduced to a fee as low as 300 without triggering cross-subsidization through users 1 and 2. Fees below 300, however, imply cross-subsidies and a corresponding vector of tariffs cannot be justified on the basis of voluntary contributions. The responsibility of the policymakers thus becomes obvious if they suggest fees for user 3 below 300. If they do not take precautions so that an integrated network emerges, it is possible that user 3 is excluded because of the low tariff that price regulation assigned to it.

However, if the network is under a single decision-maker's authority, then cross-subsidization could be used to increase the range of its performance. Gabel (1994: 545) reports that, 'at the start of the century, AT&T's managers believed that residential service should be priced at a rate that was less than the direct cost of services. This 'loss' was more than made up by the higher charges that could then be set for business lines'. Because of network externalities, it could in fact be that the business clients profit from this cross-subsidization via price discrimination because it brought new telephone users onto the network and thereby raised the value of service to existing customers. But AT&T did not always try to exploit network effects. Because marginal efficiency of capital was higher in densely populated markets, AT&T focussed on serving the business community in larger cities and largely ignored rural areas, towns, and smaller cities. This invited the entry of so-called independent suppliers, once Alexander Graham Bell's patents expired and 'the telephone quickly became a popular item on the farm.' (Gabel 1994: 547). In order to fight the new competitor, AT&T turned down requests between 1894 and 1899 from companies serving the rural areas for interconnection with its networks and corresponding long distance services.

AT&T is also a good example of a network using cross-subsidization to invade the territory of another network. Gabel (1994) reports that at the beginning of this century, AT&T feared that the local service stronghold of a 'network of independent suppliers' located in upstate New York would serve as a lever for gaining entry to the profitable AT&T New York City monopoly. Cross-subsidized by the parent organization, the upstate Bell Operating Companies of the AT&T network operated at a loss and finally succeeded not only in blocking the expansion of the 'network of independent suppliers' into New York City but also in discouraging the upstate New York local service: it defaulted on its bonds and sold its properties to AT&T. In the sequel, the value of neighbouring members of the 'network of independent suppliers' experienced a severe reduction in their stock values. Of course, being a network industry, the profitability of an individual member of the 'network of independent suppliers' depended on the number of customers who could be reached by the network and this number was reduced when the AT&T network conquered upstate New York through its cross-subsidization strategy. Gabel (1994: 549) adds that 'AT&T's aggressive pricing was effective because some of its markets were partly protected by barriers to entry'.

In order to generalize Gabel's AT&T story, we can use the network model in Figure 3 and assume that there is a second network of the same type competing with it. Then the illustration of cross-subsidization effects should be straightforward. However, in order to draw conclusions, we have to assure a consensus of how the networks are organized and how the decisions are made. For example, Gabel's AT&T story tells us that because of its potential of cross-subsidization, a network strongly resists entry if it is coordinated by a single decision unit (and perhaps led by common ownership). Networks are weaker in fighting entry when network externalities dominate.

Cross-subsidization also plays an important role when the performance of an industry such as that of telecommunications is not only measured in terms of efficiency but also in terms of equity. For example, using the standard efficiency framework, Albon (1988) estimates that a doubling of access charges along with the proceeds being used to cut long distance telecommunications charges to marginal costs would generate welfare gains of $ 212 millions when applied to Australia. Albon's argument is based on the fact that fixed access charges are equivalent to a poll tax and today's user charges are above marginal costs. To Quiggin (1997), Albon's policy suggestion is only welfare improving if the deadweight loss of taxation is not larger than the gains from the redistribution of charges. However, Quiggin argues that an analysis which takes the cost of redistribution through the tax welfare system into account shows that Albon's proposed policy reduces welfare.

Quiggin's optimal policy, derived from a simple model, involves a reduction of the cross-subsidies related with long-distance charges above marginal costs but not their elimination, i.e. it aims at an optimal cross-subsidy between long distance telecommunications service and access charges for all consumers. Shifts from the use of rates to fixed access charges are equivalent to an increase in the regressivity of taxation. Considering the equity target, access charges should therefore not be used as the sole means of recovering fixed costs. Quiggin (1997: 303) concludes that 'the more distinct are the usage patterns of high and low income households the greater the income distributional benefits of subsidizing services used more heavily by low income people'.

VII DOMINANT FIRMS AND ASYMMETRIC REGULATION

The discussion of regulation policy can be said to be characterized by two dimensions: global versus local regulation on the one hand, and symmetric versus asymmetric regulation on the other. The two dimensions are not necessarily seen as independent of each other.

In recent discussions, the solution of local regulation is favoured. Only monopolistic bottlenecks should be regulated while contestable sectors of the economy should be left entirely to the invisible hand of the market. This approach has, however, three obvious shortcomings. To start with, if we reconsider the conditions of contestability (see subsection 3.1), it appears that not many sectors of the economy come even close to satisfying these conditions. Secondly, the above recipe ignores raisin picking: as demonstrated in section 3, even in the case of subadditivity of costs, contestability does not guarantee efficiency *per se*. Thirdly, the concept ignores the dynamic aspect of markets, e.g. the possibility of inefficient lock-in market situations (see subsection 3.3). Schankerman (1986: 15f.) advocates a more encompassing concept of regulation 'governing competition at the earliest possible stage, not postpone it until competitive incursion is at an advanced stage. The key is to design regulations which ensure that market price signals guide private investment decisions.' The aim of this is to avoid distorted price signals and a socially inefficient pattern of entry and investment.

It is not always obvious as to what is meant by symmetric regulation. A regulation can be symmetric as the means but concur with an asymmetric (or even discriminatory) outcome. Obviously, there can exist a conflict between symmetry as the means and the objective of symmetry as the ends. The discussion does not always reflect this differentiation and therefore sometimes gets caught in a circle of inconsistency and contradiction. This applies to political as well as theoretical discussions.

Knieps (1997a) argues that the new telecommunications laws in most European countries and the USA imply a more or less complex asymmetric set of regulations based on the concept of the *dominant firm* and the conjecture of market power of former network monopolies. To illustrate, Knieps discusses the new German Telecommunications Law (the *Telekommunikationsgesetz* of July 1996; TKG in what follows). The TKG is not explicit in the distinction of incumbents versus newcomers with respect to regulation and the concept of dominant firm, but refers to Article 22 of the German competition law (*Gesetz gegen Wettbewerbsbeschränkung*, GWB). The GWB classifies a firm as dominant by its relative power in the relevant product market and its access to input markets, its financial strength, etc. However, the conjecture that a firm has a dominant position based on market shares, given that revenues exceed a certain threshold needs qualification, as the AT&T example shows and as we will discuss below. Firms may be classified as dominant because of their relatively large market share despite being active, but much smaller competitors and potential entrants force them to choose marginal cost prices or, in case of a natural monopoly, average cost prices.

The classification as a dominant firm obviously has consequences under asymmetric regulation schemes. Article 35 of TKG stipulates that dominant providers of telecommunications networks are obliged to provide network access and interconnection services to other active or potential providers. In this context, it is important to note that tariffs for network access and interconnection services are heavily regulated. Approval of tariffs is required if telecommunications infrastructure and voice telephone service are involved. Tariff regulation is based on the costs of providers. The regulatory agency, however, has wide scope for discretion when it comes to acknowledging relevant costs and evaluating corresponding revenues. It may ask for detailed information on past earnings, reliable estimates of future revenues and corresponding cost accounts, justification for mark-ups, allocation of fixed costs, the choice of depreciation schemes and price differentiation. However, price caps are the expected normal form of regulation. But, of course, the application of price caps may imply that regulated firms have to provide detailed information regarding costs to allow for the evaluation of the size of the productivity changes. In general, productivity gains reduce the firms' discretion to increase prices, which are regulated by price caps. (See section 5, for price cap regulation.)

Contrary to the German TKG, the new Swiss Telecommunications Law, also designed in 1996, is less restrictive inasmuch as government interventions are considered necessary if private bargaining on interconnection services is not successful. This keeps the need for regulation modest. However, as Knieps (1997a) rightly argues, if a firm exerts monopolistic market power (because it constitutes a monopolistic bottleneck) then it should be regulated ex ante. Otherwise, its market power may have serious effects on the outcome of bargaining with the other network users and the overall result could well be to the disadvantage of the consumers.

Mixon and Hsing (1997) argue that AT&T's large market share as provider of long-distance telecommunications services—they still cover more than 50 per cent of the market—does not imply market dominance.[26] To support this conclusion, they analyse the factors affecting AT&T's market share. They find that the AT&T market share is mainly determined by long distance rates among major carriers, a fact which contradicts market dominance, and government regulations (price caps). Advertising may play a role, too. But there are no factors which indicate market dominance. This concurs with historical facts: in 1984, the so-called Baby Bells, providers of local services, were separated from AT&T. However, already from 1979, long distance carriers such as MCI and US Sprint were competing with AT&T, resulting in lower rates and an increase in services for long distance consumers. AT&T's market share in the long distance market dropped from 82 per cent in 1984 to 59 per cent in 1994.

Schankerman (1996) argues that long-run market shares are a reflection of the relative efficiency levels of different firms, provided that there are no barriers to entry and there is an expansion of new entrants and incumbents. Rather than compare market shares, the test is to determine whether pre-emptive investments, vertical price squeeze, predatory pricing, and cross subsidization prevail. These are the classical instruments to deter market entry and to hinder the profitable expansion of competitors. To use the incumbent's market share as an indicator of market power 'is wrong on analytical grounds and creates perverse economic incentives that undermine efficiency' (Schankerman 1996: 19).

Asymmetric regulation encourages inefficient entry and discourages incumbents from further investments (Knieps 1997a). If the market is contestable and a firm is considered dominant, asymmetric regulation can be detrimental. It gives distorted price signals and thus induces inefficient investments and entry. Schankerman (1996) argues that all forms of asymmetric regulation contain an intrinsic bias toward some firms or technologies and run the risk of imposing large costs of inefficiency. 'Regulatory reforms ... must be designed to promote development and efficient utilization of a modern and flexible telecommunications infrastructure at minimum cost. Above all, this requires that the regulatory framework supports the market in providing appropriate price signals to induce efficient investment in this infrastructure' (Schankerman 1996: 4).

In general, the principle of symmetric regulation necessitates that regulation provides the same price signals, the same restrictions and the same obligations for all market participants. This is a very general and perhaps not even a very helpful description. More specifically, the principle of symmetric regulation is said to imply that the regulator deviates from equal treatment only in cases of demonstrated market power. So, given the empirical results of Mixon and Hsing (1997) and of Kahai et al. (1996) an AT&T regulation does not seem to concur with this principle. Still the market result is characterized by substantial asymmetries in market shares. Further, the principle is said to imply that rules should be formulated in early phases of transition to competition in order to ensure an efficient pattern of entry and investment. It should be formulated early, before it is applied to a specific case, also to allow implicit reference to a Rawlsian type of veil of ignorance and thereby to guarantee procedural fair treatment.

VIII UNBUNDLED SERVICES, NEW FACILITIES AND POLICY CONCLUSIONS

Waverman and Sirel (1997: 25) ask the question '... should incumbent firms be required to unbundle their services as the American model and in a hope of encouraging entry by firms who will add value in some way and resell? Or should regulators follow the British model of not focusing on unbundling in the hope of encouraging facilities-based entry?' This is a fundamental question and its answer by and large determines how the telecommunications industry, with its productivity impact on other information technology items, is organized and how the corresponding markets perform.[27]

In Britain, regulation policy was characterized by privatization and market conditions that approximately amounted to contestability. This policy was designed to force entrants to provide their own facilities. In principle, this meant slower entry. As a result, according to Waverman and Sirel, British Telecom still has more than 90 percent of the basic telephone market. However, a similar regulation policy, which implies the absence of unbundling requirements '...has helped unleash a remarkable level of competition in the provision of local services' in Chile (Spiller and Cardilli

1997: 135). Moreover, eight companies providing long-distance services emerged after liberalization of the Chilean telephone industry. Prices have plummeted. Robert Crandall and Leonard Waverman estimated that, in 1995 only, this resulted in a consumer welfare gain of US $120 million.[28] There is, however, ample evidence that the threat of entry can also lead to an increase in efficiency of the British Telecom when compared to other, formerly state-controlled European providers of telecommunications services which were only recently 'expelled' into a competitive market arena (see Waverman and Sirel 1997).

The Telecommunications Act of February 1996 and its interpretation by the FCC requires that incumbents' networks be unbundled at all technologically feasible points, irrespective of whether the corresponding services are *essential facilities*, and allow 'new entrants to recombine the incumbents' unbundled network elements, effectively recreating the incumbents' retail service, but avoiding the price mechanism specified by the act for resold services (that is, retail price less avoided costs)' (Harris and Kraft 1997: 105). Combined with TELRIC pricing, which is not based on actual costs but on cost estimates referring to best available forward looking technology—and which does not allow to recover sunk costs nor to compensate the risk of innovative investments if they fail—entrants have little incentives to establish their own facilities and concentrate on the usage of the incumbents' services. 'Under this regime, unbundling requirements in telecommunications are likely to stifle innovations of entrants and investments of the incumbents. The result will be a decrease in new investment in telecommunications services and network infrastructure below economically efficient levels' (Hausman 1997: 35). Nonmyopic suppliers can only be expected to invest in markets which imply competitive advantages for newcomers if the technology and the market conditions allow for rather quick amortization. This can be the dominant constraint to technology selection and exclude more efficient solutions.

The future will show whether the USA can afford such consequences in the long run. In the short run, however, this policy is likely to increase market efficiency. The Telecommunications Act not only suggests TELRIC, but also prescribes conditions which are supposed to prevent the monopoly power of US local services being 'exported' to the vertically-related complementary and rather competitive long distance services via cross-subsidization (see Economides 1988).

Developing countries which often suffer from a negligible installed basis in telecommunications have virtually no possibility to derive efficiency gains from a policy pattern as described by TELRIC and the Telecommunications Act, at least in the short run. If there is no mechanism to help them escape from this short-term perspective or if no change can be introduced to the regulatory policy, then they will remain in this inefficiency trap.

As the above-mentioned example of Chile indicates, the British model seems more appropriate to trigger substantial investments in telecommunications. There is, however, the danger of inefficient duplication of network facilities. The related over-investments, although implying a misallocation from the microeconomic perspective, could nevertheless be beneficial from a macro perspective, enhancing overall economic activities, providing employment for skilled labour and creating human capital.

NOTES

1 See Dixit and Nalebuff (1991: 143) for this story.

2 See Tirole (1988: 371) who concludes that the welfare consequences of asymmetric information and potential limit pricing are ambiguous. In general, first-period welfare is increased because the high-cost type of the incumbent monopoly chooses a price below monopoly price in the separating equilibrium of the market entry game. But there is less entry, which, in general, lowers second-period's welfare.

3 For empirical results, see, e.g., Kraemer and Dedrick (1999).

4 The all-pay-auction model seems to be an adequate representation of such a *rat race game* (see Amann and Leininger 1996); an application to information industry is still wanting.

5 In terms of Farrell and Saloner (1985).

6 Note that textbooks on welfare economics do not look at more than two (types of) agents.

7 The components of a telecommunications system are (see, e.g., Knieps 1983): *terminal equipment* to code or decode signals, *transmission facilities* to transport signals, and local and long distance *switching equipment*.

8 The phenomena of 'inefficient lock-ins' and 'excess inertia' which imply the persistence of inefficient standards are widely discussed in the literature (see, e.g., Farrell and Saloner 1986). The QWERTY keyboard case became the standard illustration for it. See David (1985) for the seminal paper and Liebowitz and Margolis (1990; 1994) for a critical review of the QWERTY case.

9 For a critical review of the theory of contestable markets, see Holler (1985), Shepherd (1984), Schwarz and Reynolds (1983), and Weitzman (1983).

10 There are, however, market equilibria for which the number of firms is not determined, for instance, where average costs are constant (see Holler 1985).

11 For a discussion of sustainability, see Baumol *et al.* (1977).

12 If we consider the sequence which defines the cost function in Figure 1, then good y (of quantity x') could be interpreted as a joint good. Joint goods are inputs which 'once acquired for use in producing one good, they are costlessly available for use in the production of others' (Panzar 1989:17).

13 For pioneering work on the evolutionary stable strategy concept, see Maynard Smith and Price (1973) and Maynard Smith (1982).

14 Hausman (1997) discusses TSLRIC (total service, long-run, incremental cost) and argues that TELRIC, chosen by FCC, is just a variant of TSLRIC (see Hausman 1997:29 footnote).

15 For an extensive discussion of TELRIC versus the 'efficient component pricing rule' *à la* Baumol (1983), see *Economides* (1998).

16 German electric power industry intends to invest in telecommunication in order to gain market domination. However, there is some degree of joint production like taking care of network with a potential of economies of scope.

17 The resulting allocation is therefore in the *core* of the corresponding price game (see Faulhaber 1975).

18 For a recent discussion of the aims and scope of accounting systems, see Hedlin (1999).

19 Knieps (1997) argues that as a result of technical progress (that allows, e.g., radio based networks) and the unbundling of market components monopolistic bottlenecks in telecommunication will disappear and regulations will not be needed in the long-run.

20 See, e.g., Güth and Tietz (1990), Güth *et al.* (1996), and Harrison and McCabe (1996) for experiments that confirm individual behaviour as explained by fairness.

21 Varian (1984: 285) defines an allocation as fair if it is efficient and equitable (i.e. envy-free) so that no agent prefers the bundle of any other agent to his own.

22 For a similar approach, see Littlechild and Thompson (1977) and Knieps (1988) .

23 Owen (1995: chapters XII-XIII) contains a brilliant theoretical treatment of these concepts along with applications.

24 Holler and Li (1996) apply an alternative method of calculating the Shapley value which refers to the formula given in Shapley (1953) and which is a standard in game

theory textbooks. This method is perhaps more elegant, but requires a more intensive discussion of the theoretical framework.

25 See Owen (1995: 319-40) for these solution concepts.

26 The result of Mixon and Hsing (1997), by and large, coincides with an earlier result of an empirical study by Kahai *et al.* (1996).

27 'Interconnection, equal access, unbundling and industry structure are the four key building blocks that determine how quickly facilities-based competition will emerge once the telecommunication sector is demonopolized' (Spiller and Cardilli 1997:127f.)

28 Spiller and Cardilli (1997) quote the so far unpublished study of Crandall and Waverman. For a method to calculate consumer surplus based on the estimated demand curve, see Hausman (1997). This method provides *ex-post* estimates of the consumer surplus of various FCC regulation policies, including estimates for foregone consumer surplus due to regulatory delay.

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