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Dark clouds over the Internet?

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Abstract

Currently, the Internet is characterized by excess capacity, which benefits consumers and producers of Internet-based services alike. High quality and declining prices of interconnection are the basis for many e-commerce, software and equipment businesses. However, tough competition in the Internet backbone market driving these developments could ruin network operators and threaten other markets, too. This paper will pursue the idea of the Internet backbone market's decline based on standard economic theory. The paper will present several scenarios and discuss potential market- and policy-based remedies. It is argued that due to a phenomenon called *capacity paradox* the industry's future development is overshadowed by "dark clouds".

Keywords: Internet backbone market; Industry analysis and outlook; Internet regulation; Capacity paradox

1. Introduction

The Internet, since its commercialization in the mid-1990s, has been an impressive success story. Worldwide online population surpassed one billion in 2005.[1] In almost any Internet-based industry, competition is vital, capacity constraints no longer exist and broadband access is on the move, letting consumers enjoy even more innovative services and technologies.[2] The Internet has become a virtual marketplace of increasing importance and has been reshaping the industrial organization of diverse markets and businesses around the globe.[3]

This paper addresses the following questions: Will the present, seemingly rosy looking state prove sustainable, or is the Internet undergoing a process of transition? If so, which fundamental changes should be expected?

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[1]See the Computer Industry Almanac (2006).

[2]According to OECD (2004), the availability of digital subscriber line (DSL) approaches 80% in the OECD area.

[3]The Economist (2004) notes that "according to America's Department of Commerce, online retail sales in the world's biggest market last year rose by 26%, to $55 billion". The same source adds "online retailers might capture 10–15% of retail sales over the next decade. That would represent a massive shift in spending. The Economist (2005) claims that most analysts reckon about one-third of America's $200 billion travel market will be booked online this year. Some sectors, such as airlines, will see almost 40% of their bookings coming from the Internet in 2005".

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Jahn and Prüfer (2006) find that perfect competition among the top-level Internet BackbFone Providers (IBPs) threatens not only their own existence but also the revenue streams of Internet Service Providers (ISPs) selling Internet access to consumers and content providers. This, in turn, could become a real obstacle for further development of many Internet-related goods and services. Those theoretical implications are supported by empirical studies.[4]

According to the Computer Industry Almanac (2005), over 65% of the world's broadband subscribers are situated in OECD countries. It is on these countries that this analysis is primarily based, as the availability of broadband technologies is a prerequisite for most novel, innovative Internet applications. At least, in OECD countries' Internet backbones there is no doubt about the availability of excess capacity and this constitutes a major starting point for the claims in the paper.

This paper pursues the idea of the Internet backbone market's decline one step further using arguments based on standard economic theory. The paper presents a set of scenarios and discusses potential market-based and policy-based remedies. As a final result, it concludes that due to a phenomenon called *capacity paradox* the industry's future development is overshadowed by "dark clouds": on the one hand, advanced IP-services require excess capacity because they can only be offered as long as a high-quality level of data transmission is ensured which, in turn, depends heavily on excess capacity. On the other hand, however, excess capacity erodes networks' profit potential. If, for any reason, capacity constraints were reached, networks could realize positive economic profits, but consumers would suffer from the diminished quality of data transmission. As no simple, clear-cut solution to this paradox exists, this contribution is intended to spur academic discussion regarding the future of the commercial Internet.

Since the currently non-regulated Internet backbone market could serve as a regulatory (yet imperfect) blueprint for a potentially deregulated telecommunications market, lessons from this paper might also be transferred to the latter—in particular in the light of the ongoing convergence of both markets.

The paper is organized as follows. Section 2 briefly explains industry specifications for the Internet backbone market. Section 3 presents network operators' fundamental sources of revenues and, supported by some descriptive data, discusses their profit potential from a theoretical point of view. Section 4 follows up by speculating about market exits in the light of Section 3's findings, while section 5 builds alternative scenarios for the future of the Internet. Section 6 concludes by suggesting a market-based and a policy-based set of measures about how to escape the capacity paradox.

2. Industrial organization of the Internet

Up to the mid-1990s, when the American *National Science Foundation* began to privatize its network, Internet infrastructure had largely been owned by governmental institutions. By the end of the 1990s, huge (overoptimistic) expectations had led to excessive investments in IP-infrastructure incurring huge sunk cost for network operators.[5] Therefore, there is a high-quality global network with a dense coverage of broadband Internet access today.[6]

As a network of networks, the Internet's infrastructure is owned by many different IBPs of very asymmetric size. Within the industry, it is advisable to distinguish between a handful of "top-level" or "Tier 1" networks offering termination of calls/data requests to any destination on the Internet without having to purchase transit services themselves, and all other networks that have to buy a share of upstream transit from these if

[4]OECD (2002) states that prices for IP-Transit had fallen by up to 55% annually from 1998 to 2000. TeleGeography (2005c) notes that "in 2004, backbone access prices around the world fell about 505 over the previous year. This year [2005] prices fell between 23% and 33%."

[5]See Nuechterlein and Weiser (2005, p. 36) or TeleGeography (2004a).

[6]In this context, *high* or *perfect quality* is defined as the characteristic of IP-data transmission that due to excess capacity does not reduce consumer benefit distinctly through *package loss* or *delay*. Nuechterlein and Weiser (2005, p. 43) point to the fact that this requirement is service specific: "One-second delays are barely noticeable when someone is downloading a webpage, but they are quite distracting in an ordinary telephone conversation." Note that the notion of perfect quality refers to data streams between networks. The last mile, i.e. the distance between the end-user's computer and his/her ISP's point-of-presence (POP), could still be congested and decrease speed and, hence, perceived quality of data transfer.

they want to offer their own customers worldwide connectivity.[7] At the lower end of this network hierarchy there are ISPs that provide end-users and content providers with access to the Internet. UNCTAD (2005, p. 93) mentions that over 300 operators were providing commercial backbone services as at the end of 2004 and the "broader network services industry sales are estimated at about $1.3 trillion worldwide. [...] Of the 300 backbone networks mentioned before, the top 50 carry nearly 95% of all IP traffic, and only five of them can be considered to have a truly global presence." Of these five networks, the same source lists only three, AT&T, MCI and Sprint.

An important notion when studying the backbone market is the insight that the technical marginal costs of carrying a piece of data are zero.[8] Furthermore, IBPs' cost structure is characterized by huge sunk cost (for initial infrastructure deployment) and periodic fixed cost of operating the backbone (for personnel and maintenance).

3. Sources of network revenues

There are two fundamental types of revenue sources for network operators: ISPs sell access to the Internet to end-users and content providers, while IBPs sell interconnection to other (smaller) IBPs and ISPs. Often ISPs are vertically integrated into IBPs. Selling Internet access is typically affected by one-way access price regulation while selling interconnection, referred to as two-way access, is not subject to regulation.[9]

3.1. Selling Internet access to end-users and content providers

The Internet may be considered as a platform, which brings together traffic receivers and traffic senders (content providers). Content providers' utility of being connected to the Internet is increasing with the number of traffic receivers, and vice versa. Thus, the Internet is subject to indirect network effects and is sometimes referred to as a "two-sided market".[10] However, the traditional distinction between senders and receivers is becoming less convincing due to the emergence of Peer-to-Peer applications such as file sharing, IP-based telephony and online gaming.

Selling pure Internet access to end-users, i.e. households and small content providers, has become a commodity or homogenous good, with low barriers to market entry due to regulation. Therefore, this market segment is characterized by fierce competition as there are many competing firms and excess capacity.[11] Under such circumstances, standard textbook economics would call for a Bertrand outcome, i.e. prices should approach marginal cost. Consequently, profits should fall steeply. This theoretic claim is supported by data on prices for access to the Internet and by a fall in (regulated) prices for unbundled network elements.[12]

The textbook solution to this awkward situation for ISPs would suggest that they differentiate their products, either horizontally (e.g. by letting consumers customize their Internet access software) or vertically (by offering ever faster last mile access, i.e. higher quality, or bundling access with complementary services).

In practice, one can observe exactly this behavior. ISPs are looking for alternative ways to earn money with residential customers, mostly selling services running on current broadband infrastructure, e.g. online games, video-on-demand or music downloads.

The market segment for selling Internet access to (large) corporate customers, however, is characterized by less intense competition.

It is the nature of this market that large companies have more specific, diverse needs, e.g. guaranteed connection reliability, high level support, and integrated IT-solutions. This demands a priori differentiation of services and, hence, permits positive economic profits.

[7] This definition is widely used in the backbone industry itself and coincides with the one used by Nuechterlein and Weiser (2005, p. 133).

[8] See Atkinson and Barnekov (2004), Nuechterlein and Weiser (2005, p. 38) or Faulhaber and Hogendorn (2000, p. 313).

[9] See, for example, Laffont and Tirole (2000) or Vogelsang (2003).

[10] See Laffont, Marcus, Rey, and Tirole (2003) Laffont et al. (2003) and Rochet and Tirole (2003, 2006) for more details.

[11] OECD (2005, p. 198) notes that prices in all OECD countries for DSL lines had eroded by 16.93% (PPP adjusted) from 2002 to 2004.

[12] According to the European Commission (2003), monthly average total costs per full unbundled loop had been declining by some 12% in the EU between 2002 and 2003.

3.2. Selling interconnection to other networks

Apart from revenues from end-users and content providers, networks' second fundamental source of income is based on charging other networks for interconnection. A network's revenue potential is strongly dependent on its size, including access to customers of other networks with whom it has a partnership or *Peering* arrangement. It is, however, decisive whether a network has Tier 1 status, or not. This is because Tier 1 networks have the lowest costs for providing IP-Transit as, by definition, they do not have to pay for a single interconnection. Consequently, Tier 1 networks are able to provide IP-Transit at the lowest possible price. Reselling solely IP-Transit cannot be profitable from a theoretical perspective.

3.2.1. Interconnection practice on the Internet

The Internet as a communications technology is subject to network externalities. Therefore, in order to maximize consumers' willingness-to-pay, firms have to provide so-called "world-wide connectivity", i.e. each end-user has to be enabled to send data to and to receive data from any other end-user or content provider on the Internet.[13] Nevertheless, worldwide connectivity is only achievable by interconnection of IBPs. This is why the question of how to interconnect with other networks is a crucial one.

There are three main types of interconnection: IP-Transit, Bill-and-Keep Peering, and Paid Peering.[14] In the case of IP-Transit, networks that are not connected to each other by a direct cable save the cost of setting up such a connection by each one paying an intermediary network—typically a Tier 1 network—for data transmission. Each of the networks pays the intermediary on a variable basis which is dependent on traffic volume but not on the direction of traffic.[15]

Under a Bill-and-Keep Peering agreement, two networks build a (costly) direct physical link, cut out the intermediary, and exchange traffic without charging any fees to each other. No participating network has the obligation to terminate traffic to or from a third party while each network needs only to process traffic from the Peering partner to its own customers (and the customers of their customers, and so on if existent), but not to the rest of the Internet. Bill-and-Keep Peering used to be the dominant type of interconnection at the beginning of the commercial era of the Internet and is still widespread.[16]

Apart from IP-Transit and Bill-and-Keep Peering, there are several hybrid forms of network interconnection.[17] An intuitive one is Paid Peering. This regime combines the same rights and obligations as Bill-and-Keep Peering—Peering partners do not have to terminate data to/from the entire Internet—but does involve compensation payments flowing from one network to the other, just as is the case with IP-Transit. According to industry representatives, Paid Peering, which some refer to as *Transit light*, has only just commenced in practice but has a great revenue potential for networks under certain circumstances.

Jahn and Prüfer (2006) show that networks use Bill-and-Keep Peering in equilibrium if they are sufficiently symmetric in size. For medium levels of asymmetry, the smaller network pays the larger in a Paid Peering agreement.[18] Clearly asymmetric networks use an intermediary to exchange traffic.

3.2.2. Revenue potential of interconnection fees

The main problem of IP-Transit sellers is that they offer a homogeneous product being characterized by excess capacity and the absence of bottlenecks, which could involve market power. This makes IP-Transit a commodity. Standard economic theory would predict that prices approach marginal costs, which are zero.

[13] Note that as it is today's standard, market prices for Internet access are already based on worldwide connectivity. If a network wanted to depart from this standard, its sales would probably vanish.

[14] Refer to Kende (2000) or Atkinson and Barnekov (2004) for more details.

[15] There are diverse billing mechanisms. It is common to lease an upstream line with a certain capacity for a certain period of time. The lessor agrees to terminate sending and receiving data within this capacity to/from any Internet destination. He/she bills the full capacity or a certain percentage of it, for instance by "95th percentile billing".

[16] OECD (2005, p. 146) mentions that in September 2004 some 80 000 Peering agreements existed worldwide.

[17] Other interconnection regimes are often based on virtual networks. Service Overlay Networks, for instance, purchase bandwidth with certain quality guarantees from individual networks and offer the composition of single routes as a virtual network to end-users.

[18] If two networks, which are in this range of medium network asymmetry where Paid Peering dominates the other interconnection regimes, consider Paid Peering as an option, they can both be better off compared to a situation in which they only decide between Bill-and-Keep Peering and IP-Transit.

Again, this is exactly what is happening in practice.[19] Nevertheless, price erosion has come in line with demand expansion. It is interesting to note that TeleGeography (2005d) points to the fact that during 2003 and 2004 the demand expansion effect exceeded the price erosion effect in many countries, including the United States, Germany, China, India, Brazil and also for Trans-Atlantic and Trans-Pacific traffic. Therefore, revenues have increased despite declining prices. However, in the long-term revenues will erode more and more. This results from the fact that demand expansion has an upper boundary (set by the world's online population) while the prices' lower boundary is zero—and from the definition of revenues as price times quantity sold. As a consequence, allowing for the fact that marginal costs are zero and networks only have fixed costs for operations and maintenance, long-term profits of Tier 1 networks will vanish.

According to Jahn and Prüfer (2006), all but the very small networks could make use of selling Paid Peering agreements to even smaller players, thereby tapping another source of revenue. Unfortunately, income from Paid Peering is closely (and positively) correlated with prices for IP-Transit as Peering is, in part, a substitute for IP-Transit. On the basis of the above facts one might conclude that network operators focusing on sustainable revenues from Paid Peering may well be disappointed.

To summarize, IBPs have four main sources of revenue. Of those, selling access to end-users, selling IP-Transit (by Tier 1 networks) and selling Paid Peering arrangements are homogeneous goods with virtually no capacity restrictions. Hence, in these segments profit potential is low to negative. In the fourth segment, bundling Internet access for large corporate customers with value-added services, the current profit situation due to larger possibilities for product differentiation looks somewhat better. Nevertheless, a reasonable share of those profits is taken by suppliers of Internet infrastructure and equipment. Furthermore, as the de facto revenue source is not selling access to the Internet but selling complementary services (and perhaps consulting) which are less scalable, barriers to market entry are not very high. This enhances competition, whereby more and more players can expect increasingly declining revenues.

4. Market exit ahead?

As indicated above IBPs' and ISPs' long-term profit expectations are very modest. Taking this into consideration as well as the fact that technology firms with many highly skilled personnel, managing a partly global network, have to bear substantial fixed costs for the operation and maintenance of equipment, it can be concluded that market exit of some players will be unavoidable.

This theoretical view is supported by real-world facts. CoCombine (2005), a report co-funded by the European Commission, provides a detailed study of takeovers in the Internet backbone market and identifies an ongoing wave of mergers and acquisitions (p. 7): "This shows how a significant number of the early backbones, including UUNet, ANS, and BBN were absorbed into other companies, and in turn, how even Tier 1 backbones such as MCI, Cable & Wireless, Genuity, and PSINet changed hands, often on the heels of Chapter 11 filings." Market exit of more and more independent players is still ongoing, as the Federal Communications Commission (2005) suggested recently: on October 31, 2005 the FCC approved mergers both of SBC Communications Inc. and AT&T Corp. and of Verizon Communications Inc. with MCI Inc., all top players in the industry.

The market exit of some players, however, would shift market power to the remaining networks. If a substantial number of networks were to leave the market, sooner or later bottlenecks, which currently do not exist apart from the (regulated) last mile, would appear, changing the industry's organization. Some networks could become dominant and exercise market power à la Crémer, Rey, and Tirole (2000) by "targeted degradation" of interconnections with one smaller network after another: they could strategically reduce the quality of data transfer to a specific network, thereby making use of network externalities giving the customers of the attacked network the idea of switching to a larger, better interconnected provider.

[19] TeleGeography (2004b) noted on September 14, 2004: "average price for STM-1 (155 Mbps) connectivity to the global Internet has dropped 49% in European cities and 55% in US cities over the last 12 months. Prices in Asia have declined at a comparable rate." Giovannetti and Ristuccia (2005) question full competitiveness of the IP-Transit market. However, they speculate themselves (p. 283) that market power "may be specific to the role reputation factors still play in the infancy stage of online trading markets." Therefore, it can be concluded that the degree of competitiveness is large enough to justify the assumption of Bertrand competition. Footnote 6 provides more data sources to support this claim.

Since this behavior would yield even more bottlenecks, or "monopolistic links", leading to "monopolistic regions" of the Internet, the remaining Tier 1 network(s) could increase prices for IP-Transit, which would also have increasing effects on Paid Peering settlement fees charged to networks or by networks within the monopolistic regions. According to this argument, small networks would be discouraged from market entry because of larger expected costs for interconnection, while consumer prices for Internet access or Web hosting would rise.

Consumer prices could not rise to the monopoly level though, as parts of the entire Internet's infrastructure would be inactive after market exits but still physically in existence. This fact would dramatically reduce market entry costs since setting up a competitive large network would not require the entrant to lay cables and physically build an entire network infrastructure itself but only to buy the *dark fiber* and equipment from the network of bankrupt predecessors. The last Tier 1 network in the market would be threatened by this scenario and forced into a limited pricing strategy aimed at end-users, meaning its prices would have an upper ceiling below the level of monopoly prices.[20]

The only way for the would-be monopolist to reach a full monopolist's market power would be to acquire *all* competitors leaving the market. This, however, could become a critical undertaking from the point of view of policy makers, leading them to intervene in order to prevent a real monopolization of the Internet.[21]

In turn, being constrained to limit pricing profits in the long-run could restrict dominant firms' incentives for research and development and infrastructure improvements, which would hurt consumers who are thereby excluded from the latest technologies.

5. Alternative scenarios

How can low prices for access to the Internet along with high-quality connectivity between networks arising from excess capacity—the current situation that seems so pleasant for consumers—be sustained? Are market forces unable to safeguard such an environment? Is government intervention necessary? The reader should refer to the argumentation in Section 4 above regarding the *market-based scenario with durable excess capacity*. This section will discuss other possible development paths, including a *market-based scenario with capacity* constraints, a *policy maker-based scenario* and some thoughts on conceivable loopholes out of the market-based scenarios without government intervention.

5.1. Capacity constraints and the capacity paradox

It has been explained in detail that previous contemplations were driven by the assumption that excess capacity would persist. However, there are alternatives. Demand for IP-traffic is growing. This is due to two main developments. First, the worldwide Internet population is growing. The Computer Industry Almanac (2006) declares that it "surpassed 1 billion in 2005—up from only 45 M in 1995 and 420 M in 2000. The 2 billion Internet users milestone is expected in 2011." This source also states: "Much of future Internet users growth is coming from populous countries such as China, India, Brazil, Russia and Indonesia."

Secondly, apart from growth in the number of users there is also growth in the intensity of demand due to the ongoing diffusion of new broadband applications such as Video-on-Demand or Peer-to-Peer (P2P) exchanges.[22] These services spur usage per head. Hence, the existing transmission capacity of the Internet could be exhausted in the foreseeable future.[23]

[20]For more information refer to the standard literature on contestable markets, e.g. Baumol, Panzer, and Willig (1986) Baumol et al. (1986).

[21]CoCombine (2005, p. 9) notes that an attempt by MCI WorldCom to purchase Sprint was already rejected by US and European regulators.

[22]Note that P2P already accounts for a large share of Internet traffic. Azzouna and Guillemin (2003) report that regarding the links of France Telecom's network, which they have studied, P2P's share of total traffic is around 50%.

[23]TeleGeography (2005a) indicates that "aggregate average international Internet traffic appears to be growing at 115% annually. If traffic were to continue to grow at this current rate, existing Internet capacity would be exhausted in less than 2 years."

On the other hand, there is not only demand expansion but also supply expansion. First, global IP-bandwidth numbers were still growing by some 46% in 2004, following 74% in 2003 and 38% in 2002.[24] This may sound startling, but according to industry representatives the price for new capacity is modest in relation to earlier set-up costs since capacity expansion is often carried out by new compression technologies, i.e. software. Digging up the ground or physically installing new expensive transcontinental cables is usually no longer necessary.

Secondly, as is shown in Jahn and Prüfer (2006), substituting IP-Transit by Paid Peering arrangements can be an equilibrium strategy for two networks: as long as the networks are sufficiently symmetric in size. Despite the fact that it is costly to expand capacity, they are better off bearing these costs as they then eliminate the intermediary from their data exchange. In that way global capacity supply is increased, too.

What is the impact of Voice-over-IP (VoIP) on these developments? On the one hand, VoIP ceteris paribus increases IP-traffic. This is due to the fact that this technology uses IP-bandwidth instead of the telephone network to transmit voice data. On the other hand, it is feasible for network operators to turn equipment that currently transmits telephone calls, i.e. a circuit-switched voice network, into equipment transmitting IP-data or a packet-switched data network.[25] Consequently, the introduction of VoIP does not necessarily increase total capacity requirements, since former telephone networks can just be reconfigured and used for VoIP. Moreover, according to industry representatives, VoIP requires only about one third of the capacity needed for a traditional phone call. Thus the introduction of IP-based telephony could even *decrease* total capacity demand.

To summarize, it may be said that it is not clear when capacity constraints are reached. This would probably be a very asymmetric process starting in some rural areas and slowly spreading to the rest of the Internet.

Suppose this point is reached. Because of continued demand expansion of IP-bandwidth, networks would have to build even more new capacity. As indicated above, the major share of this would probably take place in currently less well-connected, populous countries. Hence, it would be unlikely to absorb the entire upcoming demand by software upgrades. Expensively digging up the ground and installing new cables and other costly equipment would be necessary. This would transform today's fierce price competition (á la Bertrand) into capacity competition, which, in turn, can be expressed by Cournot competition models, according to the well-known article by Kreps and Scheinkman (1983).[26] In such models, oligopoly players determine their output quantities—how much new capacity to provide—and receive positive economic profits in equilibrium.[27] Thus, while competing for those profits, network operators would also have incentives to innovate, leading to improvements in the quality of their services and consequently to higher profits. Equally important is the fact that capacity-based competition would also endow network operators with the financial resources necessary to invest in research and development.

However, capacity constraints per se would have a negative impact on the quality of high-end broadband applications, since those require high-quality transmission levels. A *capacity paradox* exists: advanced IP-services depend on excess capacity that, in turn, erodes networks' profit potential. This is why innovative broadband applications may fail due to capacity constraints ensuring profits (and survival) of networks on the one hand but impeding innovation on the other. To put it more succinctly: the fundamental trade-off in this scenario is reaping profits from Cournot competition (including less market exits) versus increasing consumer surplus by higher network quality resulting from Bertrand competition with excess capacity (leading to more market exits).[28]

[24]See TeleGeography (2004a, 2005a).

[25]Refer to Economides (2005) for more details.

[26]Faulhaber and Hogendorn (2000, p. 313) discuss the importance of (excess) capacity in the broadband telecommunications market to determine the appropriate competition model.

[27]See Cournot (1838) for the original paper.

[28]Note that the capacity paradox is specific to the Internet backbone market. According to representatives of one network operator, they extend the capacity of a specific route as soon as 60% of its capacity is exceeded. This procedure cannot simply be transferred to other industries.

5.2. Product differentiation and price discrimination

What if the Internet backbone industry does not reach capacity constraints? What could networks do to survive both in the short and the long-run? This section will discuss several potential loopholes from the market-based scenario with durable excess capacity.

First, networks could differentiate products horizontally. Assuming that excess capacity continues, this, however, seems impossible for IP-data transmission as mentioned above. The same applies to vertical differentiation, as quality of IP-data transmission in the backbone is already perfect.

Selling services to end-users is a different market segment. Here, ISPs work hard to differentiate their products by offering music downloads, Video-on-Demand and other broadband applications to their customers.[29] In general, increasing profits by differentiation depends to a large extent on the absence of close substitutes for the new services offered by competitors. Because of low barriers to market entry in this segment, however, positive economic profits will induce competitors to enter the market, thereby creating close substitutes and eroding the long-term profit potential.

Price discrimination could be considered as another loophole leading to escape from the capacity paradox. Odlyzko (2004, p. 340) discusses the issue in detail and concludes, "price discrimination and fine-grained pricing are likely to prevail for goods and services that are expensive and bought infrequently." He goes on to say: "For purchases that are inexpensive and made frequently, simple pricing is likely to prevail." The latter statement is applicable to Internet access by end-users, while the first could be attributed to connecting large companies to the Internet and offering complementary services.

5.3. Policy intervention

It has been argued above that due to the capacity paradox, the profit expectations of networks seem meager. Therefore, more and more networks can be expected to exit the market. If networks somehow reach capacity constraints, transmission quality would be necessarily reduced, making consumers suffer as they cannot avail of new, innovative services that require large capacity, or they could even be excluded from Internet access altogether. These considerations should provide enough motivation for policy makers to consider regulatory interventions.

One way to intervene would be to re-nationalize the Internet. This, however, might be perceived as practically unfeasible on a larger scale due to laws and property rights in western democracies that still constitute the major share of Internet traffic and population.

Alternatively, one could try to regulate global Internet connectivity. But this would require a central organization with international scope and tremendous rights to intervene in both international and national markets. The recent debate on global connectivity, which culminated in the World Summit on the Information Society in Tunisia in November 2005, demonstrates the difficulties of achieving mutual consent on an issue of transnational scope: the heterogeneity of interests between developing countries, on the one hand, and the western world, mainly the United States, on the other, has prevented the formation of a central organization endowed with sufficient decision-making power to regulate Internet interconnection.[30]

Even if such an organization could be formed, a common problem of regulators would still exist: what is the "right" price (e.g. for IP-Transit)? Jahn and Prüfer (2006) show that national welfare considerations in the Internet backbone market strongly depend on the geographical location of Tier 1 networks' headquarters. Currently, a US-based regulator maximizing the welfare of his/her country has other objectives than a non-US-based regulator because all Tier 1 networks are situated in the United States.[31]

A third option would be to regulate either retail prices or quality levels of ISPs' services. In this regard, national motivations could differ too, thereby creating unequal opportunities among ISPs across countries. Additionally, as can be observed in the telecommunications industry, retail price regulation is a sensitive and

[29] See AOL.com, Yahoo.com, MSN.com, Wanadoo.fr or T-Online.de, for instance.

[30] For more information on the World Summit, see www.itu.int/wsis/. UNCTAD (2005, p. 99) takes a closer look at the specific problems of developing countries with respect to Internet interconnection.

[31] Fixedorbit.com/stats.htm lists the top ten networks by control of IP addresses, all of which are US based.

difficult topic since a large amount of technical specifications, upon which prices often depend, have to be considered.[32]

To conclude, somewhat pessimistically, it may be said that due to the global scope of the Internet there is apparently little opportunity for appropriate policy intervention to improve the future prospects of the Internet industry.

6. Conclusion and remedies

Hitherto, this paper has mainly explained why the Internet backbone industry's outlook, which greatly influences all other Internet industries such as e-commerce, Internet equipment and many software applications, can be considered to be rather gloomy. Below, this section will present two ideas—one market-based and one policy based—that do not contradict our above line of argumentation but offer potential remedies for the dark clouds hanging over the Internet.

In the discussion on policy measures, it was assumed that international cooperation was absolutely necessary but very hard to achieve. However, the development of quality and prices all over the Internet strongly depends on the competitive behavior of the handful of Tier 1 networks, which are all based in the United States. Therefore, a single authority that is legally entitled to regulate those networks already exists and hence can enormously influence the development of the global Internet industry: the US Federal Communications Commission (FCC).[33]

This government agency could, for instance, set a minimum price for IP-Transit. Following the Bertrand argument, this minimum price would quickly turn out to be the new equilibrium market price. Of course, calculating the "right" price would be a huge challenge, but the FCC has already gained some experience in such calculations while regulating retail prices both for telephone and Internet lines. Such a minimum price would probably have to consist of two components: a unit contribution equaling Tier 1's average cost (for personnel, maintenance, and so on) plus a premium to enable the networks to invest in new infrastructure and research, thereby sustaining excess capacity and high quality for end-users.

As infrastructure investments exhibit positive externalities, the FCC would have to provide top-level networks with appropriate incentives for investing. One way would be to set up a *Capacity Fund*—similar in structure to the Universal Service Fund described in Laffont and Tirole (2000)—according to which the FCC would "tax" the premiums mentioned above to endow the fund with financial resources. This money would be redistributed to the Tier 1 networks, not on a pro rata basis but rather based on the outcome of a tournament. This means that a network whose interconnection quality with other networks is higher would receive a larger share of the fund than a network providing lower quality. One suggestion would be to use interconnection quality as the main criterion because this is a technical, comparably objective measurement that can be obtained accurately with relative ease. Using this criterion, while optimizing additional costs for infrastructure on an individual basis, network operators would internalize a part of the externality they create, if only because higher infrastructure investments would increase the likelihood of gaining a larger share of the fund.

Of course, this idea faces many obstacles, among them the necessity to avoid collusion among tournament participants or the threat that another, non-US-based network could become a Tier 1 network. In that case, the new top-level network would not (or would only partly) be subject to the FCC's regulations and could slightly undercut the minimum price of the US networks, thereby taking a large market share away from them and making a huge profit. The FCC would have to react by adjusting the regulatory scheme, which could undermine the entire idea of a Capacity Fund. However, given the present situation, one might consider FCC intervention as the best practical policy-based solution.

Our second approach is market-based, and it is only applicable to the *scenario with capacity* constraints, not to the *scenario with durable excess capacity*. As more and more network operators make use of *Quality of Service* (QoS), "preferential treatment" of a certain type of data, e.g. VoIP packets, becomes

[32] Refer to Laffont and Tirole (2000) for a comprehensive discussion of regulatory issues in telecommunications.

[33] See http://www.fcc.gov/aboutus.html.

technically feasible.[34] Consequently, one should expect market splitting: a high-quality segment would take as much capacity as necessary to support innovative broadband services yielding Cournot profits for the network operators. The remaining backbone capacity would be allocated to another segment focusing on applications where the quality perceived by consumers is less sensitive to loss or delay of some data packets. That segment would be subject to larger quality variance, hence reducing consumer benefit. It should still earn network operators some profits as the limited overall capacity of the segment also entails Cournot competition.

This means that, given that there are consumer segments with different willingness-to-pay, the number of end-users and content providers in the upper segment enjoying top interconnection quality would be limited. This limitation lets prices increase. High-speed access would be available to consumers who really value it while the networks make profits. In the lower segment, consumers would pay less, but they would obtain no quality guarantee since the residual capacity would be allotted to all of them, not on an individual basis. Here, Cournot prices would be cheaper, yet still above marginal cost. The quality received by each single consumer, however, due to negative externalities (congestion) would decline.

Both types of (expected) profits would provide networks with incentives to invest in infrastructure and to innovate. The networks would be able to estimate demand and gradually increase total bandwidth supply. However, if one network invested considerably in capacity in order to be able to serve more upper segment consumers profitably, the rat race described in Sections 3 and 4 might start again. Moreover, Quality of Service has not yet been installed completely all over the Internet. Thus it is unclear whether "preferential treatment" of certain types of data can inexpensively be used practically everywhere.

Finally, what could be anticipated if FCC regulation of Tier 1 networks does not work—or does not take place—and capacity constraints are not reached? Then, the only scenario that seems to be realistic is that excess capacity would further erode prices for IP-Transit and the capacity paradox would determine the future development of the industry. Demand could grow for some more years, but not indefinitely, to counter-balance the price decline.[35] Long-term profits of Tier 1 networks would decrease. Some networks would have to exit the market thereby changing the market structure towards monopolization. No new infrastructure would be implemented, capacity constraints would be reached and prices would increase. To summarize, in comparison to the present situation consumers would suffer from higher prices for a given level of quality.

This paper has presented modest theoretical ideas on potential directions for development and two remedies which seem most appropriate to dispel Internet gloom. However, it has merely set the stage for further research on the (mainly game theoretic) details of future scenarios. For the time being, dark clouds would appear to prevail over the Internet; Hopefully, electronic climate change may soon be perceptible.

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[34]Quality of Service refers to the technical possibility of network operators to classifying IP data packets, and hence to prioritizing certain services. This issue has been researched by computer scientists for a long time but there is still no common standard among network operators. See Nuechterlein and Weiser (2005, p. 43) for more information.

[35]The Computer Industry Almanac (2006) notes that "Internet user penetration is now in the 65–75% range for the leading countries and future growth is limited. Internet user penetration for the populous and developing countries is in the 10–20% range." It is a question of time when saturation will be a global obstacle for the backbone industry.

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