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Sweden's Wireless Wonders: The Diverse Roots and Selective Adaptations of the Swedish Internet Economy

Henrik Glimstedt and Udo Zander

Sweden—Why and How?

Fascination for the Internet and the Web grew quickly in Sweden in the early 1990s. Like so many times before in the twentieth century, the Swedes rapidly took a promising new technology to their hearts. The story of early and fast adoption of the telephone, radio, TV, color TV, personal computer, and cellular phone repeated itself with the Internet. Unlike PCs, which at introduction were surrounded by a certain skepticism and hesitation as to their effects on childrens' learning and family life, the Internet was from day one perceived as a gift from heaven. The often shy and interaction-hungry people in the sparsely populated north of Europe saw the beauty of the net and embraced it.

Our contribution to this volume develops the argument that the development of the Swedish Internet economy came about through the *disbundling of network elements* and *the existence of entrepreneurial pockets of competition.* The Swedish telecommunications network was modularized and it became possibly, under the deregulated telecommunications market regime, for private actors to add innovations that improved network elements without changing the system as a whole. This opened business opportunities not only for large and established actors, but also for small and more focused firms specializing in more narrow technologies or Internet services. Once the system was disbundled, new actors in the financial arena—venture capital—targeted the emerging technological specialists and creators of Internet services, leveraging the emerging new specialist firms. But this raises the issue of how technological coordination between large multinational telecom operators and the small firms took place. Our investigation draws attention to the importance of modularity and interoperability interfaces in disbundled systems. We thus emphasize the role of standardization of bodies and the relaxed antitrust regimes that permit large corporations to abandon the slow formal standard setting organizations and create new private ones. It is in this intersection between the entrepreneurs' ideas as to how to appropriate rents in modular systems and his or her ideas for re-arrangements of factor markets, it seems to us, that crucial processes are defined and shaped.

Indeed, much suggests that Sweden's Internet economy took off early in a particularly forceful way (IDC 2001). It was not just that the number of users and Web sites grew more quickly than elsewhere in Europe. The quality of the IP infrastructure also improved rapidly, as did the quality of the services. Throughout the 1990s, the Swedish information and communication technology sector became increasingly populated by new firms that made heavy contributions to Swedish economic growth (Näringsdepartementet 2000).

Given these developments that were underpinned by the disbundling of the network elements, what can be said about the nature of change? Sweden did not stand out as a likely candidate for rapid transformations. The Swedish economy has been shaped by a coherent set of institutions and policies: centralized bargaining, active labor market policy, and solidarity wage policy. A tight coalition between the two core units of the social democratic movement—the party and the labor union—was central to the realization of these policies. Although there are significant differences, Sweden furthermore shared many features with, for example, the German economy[1]: a centralized labor market, conservative banks with a long-term view on investments, strong employer associations, and home-market-centered large multinational firms (Glete 1994; Henrekson and Jakobsson 2000; Jagrén 1993; Lindbeck 1997; Lindholm Dahlstrand 1997; Pontusson 1992) In the embedded capitalism view, Sweden would be a laggard in launching start-up firms in the Internet economy due to relative centralization of capital, absence of venture capital, and obstructive taxation of entrepreneurial labor (Isaksson 1999; King and Fullerton 1984; Södersten 1984).

But contrary to Germany—a tightly integrated national model held to be based on a relatively stable institutional configuration—Sweden experienced a "punctuated equilibrium" as the institutional configuration provided the economic and political actors with insufficient conditions to react to external economic shocks (Pontusson and Swensson 1996; Thelen 2000; Wallerstien 2000). One type of explanation for the breakthrough of the Swedish Internet economy would, hence, focus on the radical effects of globalization. It would make the principal point that once the national protective cousins have been removed by deregulation, in combination with free trade and the internationalization of finance, something will happen. In this view, there are no alternatives but adaptation to competitive pressures and best practice solutions. That view would emphasize the effects of the breakdown of centralized bargaining and the continued dismantling of peak-level unions, leading to the rise of entrepreneurship and more flexible organizations. Growth of the Internet economy would thus be associated with the spread of institutional reform and new organizational principles at the level of firms. In the case of the Swedish Internet economy, this implies a transfer of Silicon Valley's recipe for institutional solutions to achieve ends such as strengthened SME-entrepreneurship, more flexible organizational forms, and collective sharing of information and risks (Henrekson and Rosenberg 2000b). This notion is predicated on a belief in the convergence toward a single form of global capitalism.

An alternative view, one that comes closer to our own views and the introduction to this volume, is that the Internet economy is associated with a variety of different sorts of organizational solutions. Under this assumption, elements of economic strategies are much more modular and less tightly coupled to each other. Actors thus experience some degrees of freedom to create a mix of elements from both the new and the old systems. If that were the case, we would find evidence not of a full adoption of the Silicon Valley model, involving the scrapping of the old established organizations and institutions representing the old telecom system, but rather *evidence of selective adaptation, building on new re-combinations of new and old technologies and organizational principles.* This is a perspective that often is associated with the concept of hybridization and selective adaptation (Kogut and Zander 1992; Tolliday et al. 1998; Zeitlin and Herrigel 2000). This pattern supports the idea that the parts that make up the national systems are sometimes loosely coupled, which would allow continued diversity both within and across countries.

A closely related idea is that change occurs through re-combinations as economic actors explore diverse solutions. Previous case studies of Swedish industrial development by Glimstedt (2000) develop the argument that the Swedish model supported more than one type of industrial equilibrium. Rather than pushing firms onto a singular industrial trajectory, firm-level studies show that the centralized institutional framework supported selective adaptation and extensive borrowing of elements from different growth strategies. Moreover, studies of innovation in large Swedish firms suggest that strategies often have been fragmented, leaving room for independent skunk works and peripheral innovations (Regnér 1999). Spin-offs of large-firm-based entrepreneurial activities and subsequent acquisitions of entrepreneurial firms were also vital to innovative capacity of Swedish corporations before the much-discussed rise of Swedish venture capital (Granstrand and Alänge 1995).

What gets shattered here is not so much the idea of the large firm's weak innovative capacity, as the idea of Sweden's industrial structure as a homogenous reflection of certain more or less fixed institutional conditions. In this view, diversity within systems facilitates change. The important question is, then, how re-combinations occur as loosely coupled social systems develop as a historical process. Selective adaptation is here the operative word. By that term we flag the centrality of reflexive actors, their experiments, and their capacity to re-conceptualize the ways that organizations may work but also the logic of institutional structures and factor markets. In our view, they do this by "discursive" learning as they explore different ways and mechanisms to coordinate innovation, create markets, tweek production systems through recombining elements from different models, and adapt labor market systems. We place special emphasis on how "pockets of competition" served to bootstrap the larger process of change.

This chapter is structured as follows. The first section outlines when and how the ground for the Internet economy was prepared in Sweden. This section is of a historical nature. It bears the burden of explaining why disbundling network elements is so fundamental, also linking historical actors to institutional transformation of the Swedish communication business. The second section focuses on the take-off and the shape of the Swedish Internet economy, in order to investigate the extent of selective adaptation to Silicon Valley models of business. This section hence explores the interaction between the new economy and the old economy, with specific reference to how old parts of the communication economy interact with IP-based communication business. Part of this section is also an investigation of the way that enabling institutions supports decentralized innovation in disbundled networks.

From Bundled Telecom to Disbundled Infocom Networks

With few exceptions, telecommunications developed as vertically integrated national monopolies. The logic behind this particular structure was the conventional wisdom that telecoms were an example of a natural monopoly, because due to the increasing returns to scale, services could only be provided efficiently by a monopoly provider. The monopoly was considered to be "natural" because a new entrant would have to build parallel infrastructures, which in turn would drive down returns.

Integration of service providing (by operators) and manufacturing of telecom equipment (by vendors) went furthest in the United States, where complete vertical integration took place when the American Bell Company purchased the telecom equipment-manufacturing arm of Western Electric. We remember this vertically integrated system as the AT&T monopoly, which was fully established in 1934 (Vietor 1994).

The combination of monopoly and national suppliers resulted in stand-alone black-box telecommunications systems. Under this regime, telecommunication network architectures consisted of a set of tightly bundled subtechnologies consisting of three layers (see figure 4.1). Until the 1980s, the topology of telecommunications was such that all switches in the network and the transmission link connecting them constituted the *trunk network.* Access was mainly over copper, and early mobile markets such as radio were only developed slowly, although the technology existed. In particular, the fixed backbone, the trunk system, was only accessed from traditional phones that lacked independent intelligence, such as processor capacity memory and so on. All vital forms of *intelligence* resided in the switches in Layer 2, the network layer. Interconnections

Layer 3: Services: voice telephony, fax, 800-services, etc.
Layer 2: Network elements: backbone, switching, access technology
Layer 1: Technology supply: manufacturing of switches, transmission systems, etc.

Figure 4.1
Layers of the old telecom system

between national systems were made possible through international interface standardization under the auspices of ITU, the International Telecommunications Union.

Historically, there have been important variations of the national configurations with cooperation emerging as a dominant form of economic organization between monopoly network operators and the specialist technology suppliers (Fransman, 2002; Helgesson 1999; Lipartito 2000; Vogel 1996). Sweden represents another variation of this theme of long-standing integration between services and manufacturing. But a few unique features of the Swedish system merit our attention. On the one hand, the Swedish Postal, Telegraph, and Telephone (PTT) was active in system design and manufacturing of both telephones and electromagnetic switches designed for small towns and the less densely populated Swedish countryside. From 1970 on, innovative efforts in designing digital switches were more closely coordinated with those of Ericsson, the large Swedish private manufacturer of telephone systems. In 1970, Ericsson and Telia (formerly Swedish Telecom) formed a joint venture, Ellemtel, that successfully developed the Swedish digital switching system, AXE (Fridlund 1998b; Meurling, Jeans, and Ericsson 1995).

Creating Diversity from Within

Sweden's path to deregulation and technological renewal is rooted in the dual structure of the telecom market. Although Sweden in many ways looked precisely like many other monopoly markets, the resemblance was only superficial. There are two main sources of the unique structure that typified Sweden's post-1945 telecom market. First, the public operator, Swedish Telecom, grew as a de facto monopoly through aggressive acquisitions in the inter-war era. Even in the postwar years, which constituted fertile grounds for nationalization across Europe, the Swedish monopoly was not coded in Swedish law. According to the 1980 investigation of the status of the Swedish monopoly in telecommunications, Sweden was lacking a formal monopoly in telecommunication and there were no binding legal obstacles against private networks (Karlsson 1998).

From a legal point of view, the Swedish de facto monopoly was only regulated through the PTT's legally defined right to deny interconnection between the public telecom network and any private network. In fixed telephony, the economics of natural monopoly remained stable until the late 1970s to the extent that Swedish Telecom had faced no serious competition from private operators since the early 1920s. In mobile telecommunications and data communication, however, infrastructure competition had already emerged by the mid 1960s.

Within the framework of de facto monopoly, the Swedish PTT both operated the public network and regulated the industry because it also governed the degree of public-private networks interconnectedness. It also issued frequency licenses for mobile operators that used the regulated spectrum. In addition, the regulations stipulated that PTT could deny the potential private network operators the right to interconnect to the public network, greatly limiting the growth potential of private networks. But the law nevertheless opened space for private networks in areas such as cellular mobile telecommunication services and data communications. We will argue that the existence of two *pockets of competition* (mobile telephony and data communications) shaped the introduction of new information technology and information services from the mid 1960s on.

Pocket of Competition #1: Mobile Telephony Early movers in mobile telephony came from diverse backgrounds. Test systems grew out of military radio communication applications that were transformed to civilian systems. In the late 1950s, the military radio arm of Svenska Radio Aktiebolaget (SRA), the Ericsson/Marconi joint venture, took initiatives to pull together engineers from the private industry and Swedish Telecom to define signaling and switching interfaces, resulting in the first Swedish mobile telecom standards. The MTA standard thus laid the foundation for subsequent upgrades through the 1960s. Although Swedish plans for national mobile telecommunications were developed in the 1950s, these technological efforts were stimulated by the growth of private operators in the mid 1960s. End-users of the systems were banks, transport companies, top executives, public institutions (such as the police and custom authorities) and a limited number of small entrepreneurs (such as locksmiths, photographers, and freelance reporters). By the late 1960s, a total of 13 operators offered mobile telecom services. As of the early 1970s, these mobile operators were integrated into two main groups (Mölleryd 1999).

A significant boost to mobile telephony came in the late 1970s with the entry of Mr. Jan Stenbeck, a Swedish entrepreneur based in the United States. As the main owner of Kinnevik, Stenbeck was already involved in the mobile business through his company Millicom and through a joint venture with Racal, which later developed into Vodafone. On Swedish soil, Stenbeck's first move was to buy a small private operator, Företagstelefon, in order to turn it into a leading private operator. What attracted Stenbeck's interest was the fact that Företagstelefon, which operated a small regional network with transport companies as its main customers, had received a legally binding right to switch their calls into the fixed telecom network. With this right to public interconnection as its stepping stone, Stenbeck took steps to rapidly erect a nationwide mobile telecom network under the brand Comviq. To set up the initial mobile system, Stenbeck employed approximately twenty talented engineers (interviews with Håkan Ledin; Daniel Johannisson; Tony Hagström; Karlsson 1998).

Under the new competitive conditions, private entrepreneurs were moving to supply the emerging mobile telecom networks with key technologies. In all areas, system suppliers emerged. Of particular significance were companies such as Magnetics in radio base stations, and AGA-Sonab, Technophone, and Spectronic in portable mobile telephones (terminals). Both the private and the publicly owned operators profited from the technological radicalism that emerged in the unregulated subsector of Swedish telecommunications.

In response to this development within the private sector, Swedish Telecom's radio laboratory initiated development work under Östen Mäkitalo's legendary leadership. Sweden Telecom successfully initiated a joint Nordic effort to specify and set a standard for mobile telecommunications at the 450 MHz band. As the NMT 450 system was co-developed and recognized by the PTTs across the Nordic region, it constituted an important step toward global standards in mobile telephony (McKelvey, Texier, and Alm 1998; Mölleryd 1999).

Ericsson was surprisingly late entering into this game (Regnér 1999). It is true that its radio subsidiary, SRA, was among the early movers in many related radio technologies (police radio, military radio communications, and radio links) in the 1960s and early 1970s, but lack of technological sophistication in key areas such as radio base stations hampered SRA's market plans. Radio technology received only limited support from Ericsson's central management teams, which were concerned more with day-to-day operations and the core business of fixed systems than with new markets. As the first opportunities to sell mobile telecom systems in the international market emerged by the late 1970s, SRA successfully tapped into its parent company's main technology, digital switching. Although satisfactory to some of the initial customers, this combination was not judged as being advanced enough to meet the needs of more sophisticated buyers. The insight that Ericsson's subsidiary could not deliver entire systems that would meet market demands was the starting point for Ericsson's effort to gain control of the Swedish mobile telecom sector. Toward the end of the 1970s and the early 1980s, SRA took steps to vertically integrate the more advanced competitors, beginning with Sonab and Magnetics (Meurling and Jens 1994; Mölleryd 1999). A significant trend since the mid 1960s was the emergence of suppliers in mobile telecommunications. In fixed telecommunications, the quest for advanced services produced the same result. Swedish Telecom's strategy to meet international pressures to open the Swedish telecom sector to foreign competition involved a number of steps toward more advanced so-called value-added services. On the whole, these tendencies created opportunities for new suppliers to emerge.

In sum, Stenbeck's initial investments in Comviq's mobile network fed into the already established technology trend, further stimulating the growth of the still independent manufacturers such as Radiosystems.

Pocket of Competition #2: Data Communications Data communication is the other area where the lack of legal status of the Swedish monopoly created and allowed the emergence of private communication networks. By the late 1960s, the cost of data processing was still prohibitive for many firms, as well as many state agencies (Karlsson 1998). The private computer industry reacted by creating so-called data processing centers, to which firms could turn for outsourcing of the computer processing needs. Swedish Telecom identified the possibility of creating a public computer utility that could be networked over the telecommunication system.

For a few years in the late 1960s and early 1970s, this was clearly a priority within the public agency. But several obstacles were also identified. The main architects of the public utility proposal realized that the agency lacked skills and would have to rely on the private computer industry. In this situation, Swedish Telecom lacked the protection from a de jure monopoly, which possibly would result in fierce competition from other private firms. Therefore, key strategists in the public telecom authorities developed a plan aimed at forming a partnership with the computer industry and data processing centers. An increasing number of private networked data processing centers, relying on the telecom network for data communication, were established in the early 1970s. Actors such as Bull, IBM, and Honeywell offered data communication via modems. Others such as WM-Data built private communication networks between the user's facilities in and around Stockholm and the data processing centers. All in all, about 1,250 modems were installed by 1971, of which only a fraction operated at 2,400 baud. More common were baud rates around two hundred, but the speed of modems increased during the 1980s.

One should not overestimate the amount of data that actually was distributed via the telecom network to data processing centers. Neither should one focus too much on the offshoots of these activities in terms of domestic hardware and software production, because they were far more limited than in the case of mobile telecommunications. However, these findings reinforce the argument that the nature of Swedish regulation created pockets in which private entrepreneurs could establish and operate private communication networks.

The Take-off

The deregulation of Swedish telecommunications in the 1980s and the early 1990s stands out as a highly ambivalent affair. As we have already noted above, the de facto monopoly allowed for pockets of competition. In particular, the absence of a legally based de jure monopoly made it possible for strong actors to emerge within the telecom sector. As may be predicted, it was precisely this kind of already established private actors that made the first major assaults. Together with organized business interests within the Swedish Employers Confederation, which already in the 1970s had formed a forum for communication policy, entrepreneurs with interests in operating companies started to exercise increased pressure on the Swedish government to remove the de facto monopoly in fixed telecommunication networks. Taking the lead in this battle, Stenbeck formulated the basic vision for a re-regulation of the Swedish telecom sector. In his assault on the Swedish de facto monopoly, he used his own operating company. Stenbeck aimed to restructure the telecommunications regulatory system in such a way that an independent network operator with no end customers could operate the public network. The idea was that all operating companies selling telecom and data communication services would have equal status as customers of the public network operator. Hence, in this vision, the Swedish PTT would not enjoy the benefit of controlling the last mile that connects homes and offices to the network. But the more narrow goal and immediate concern was to make Comviq's interconnect agreement, which was disputed by Sweden Telecom, permanent (interviews with Daniel Johannisson and Tony Hagström).

In response, the director general of Sweden Telecom, Mr. Tony Hagström, created an alliance drawing together a number of political and commercial interests with long-term and short-term interests in the de facto monopoly. Significantly, industry actors such as Ericsson and the Association of Mobile Telephone Equipment appeared in the media in support of de facto monopoly, arguing that the construction of a national mobile telecommunication network was only feasible under a natural monopoly situation (interview with Tony Hagström).

But this was mainly a way of buying time, preparing for the inevitable. Against the background of the antitrust case against AT&T, Sweden Telecom ordered an investigation of future value-added services enabled by technological advances in information technology (interview with Bertil Thorngren). In conjunction with the experience of rapidly advancing communication services that Sweden had experienced since the 1960s, this report reinforced the claim that it would be extremely hard for any

PTT to single-handedly create and operate such a wide range of services. When faced with the pressures for a radical break-up of the Swedish de facto monopoly, the director general initiated a series of moves preparing the public operator for increased competition, including the creation of separate companies for value-added services such as a telecom-linked alarm system, TeleLarm (interview with Tony Hagström).

Despite frequent measures aiming at undermining Stenbeck's position, the transformation of the Swedish telecom market was relatively smooth. In the mid 1980s, the Social Democrats, who were back in power began a search process that lead to a more open stance in these issues. Public investigations into the matter brought forward the view that competition was already a reality and that it was time to reconsider the defense of the de facto monopoly. It was against this background that the responsible government officials, such as the minister of transport and communication, as well as the director general of Sweden Telecom, Tony Hagström, voiced a new approach to infrastructure competition. In particular, Swedish Telecom launched a three-year program that proposed full competition in value-added service based on leased lines and the introduction of third-party traffic (Karlsson 1998).

The new telecom laws that finally codified privatization and deregulation were passed in the early 1990s. They soon resulted in what by international comparison stands out as one of the most competitive and advanced markets. Following the introduction of a new telecom regime, competition increased rapidly as new players gained access to the Swedish telecom market. In international calls, BT, AT&T, and Tele2 soon gained large market shares. In fixed national telephony, Stenbeck's Tele2 and Telenordia (BT and Telenor) were established as competitors to Swedish Telecom. Mobile telephony was dominated by Comviq, Europolitan (Vodafone), and Telia Mobile (Swedish Telecom).

In addition, a host of international firms emerged in advanced value-added services and data communication. Private networks, including BT, Tele2 (40 percent cable and wireless), GEIS, Tymnet, and IBM, were established in Sweden, reflecting the increased demand for international corporate communications (Hagström 1997). As the demand for corporate services soared under the new regulatory regime, large public actors such as Telia, Swedish Railways, and the Swedish Power Board initiated a rapid expansion of the national fiber optic grid. Also, in response to the development of national grid, local authorities started to build municipal networks that connected to the local access network owned by Telia (PTS 2000). Although the principal operator, Telia, does not publish detailed data on investments in fiber optic networks, informed observers estimate that the growth rate has been at least a hundred percent on a yearly basis throughout the 1990s (OECD 2001). Although the public actors are making investments in the nationwide data communication network, private operators in the Swedish telecom market, Tele2, NETnet, and WorldCom, have made only very limited investments. For the services offered by the private operators, they instead rely on the surplus capacity in public investments (PTS 2000).

Package Switching—From Leased Lines and X.25 to TCP/IP

The concept of Wide Area Networks (WANs) raised questions concerning robust data communication protocols that would allow cheap broadband connections and, more generally, the issue of the coordination of development of national and international data communication. European initiatives to standardize data communication involved formalized ex-ante standards set by government agencies and international standard defining organizations, such as CCITT (Comité Consultatif International Télégraphique et Téléphonique) or ITU (International Telecommunications Union). Established in 1983 by the International Organization for Standardization (CCITT), the Open System Integration (OSI) model divided network protocols (standardized procedures for exchanging information) into seven functional "layers." The layering provides a modularization of the protocols and hence of their implementations. Each layer is defined by the functions it relies upon from the next lower level and by the services it provides to the layer above. Open System Integration can be perceived as an umbrella under which the CCITT technical committees gradually developed new services, such as the X.25 protocol for package switching and X.400 for e-mail.

In early packet switching networks, such as X.25 protocol networks, data was "piggy-backed" on existing circuit switched networks, which limited throughput to 64,000 bps. These early networks performed extensive error checking at each switching node, which ensured very low error rates, but also precluded higher transmission rates. Despite the advances in package switching, many leased lines were built on circuit switching. In Sweden, for example, the DATEX network, a circuit switched network operated by the Swedish PTT, was long seen by the operator as the preferred solution. Compared to the Swedish X.25 network, DATEX had more customers and transferred more data communication across the network until the breakthrough of IP in the early 1990s (Närings- och Teknikutvecklingsverket 1993).

The Trickle-down of the TCP/IP Begins Compared to point-to-point protocols, TCP/IP has significantly stronger functions, particularly addressing/routing, which generates far more "talk" between nodes of the network. (For the development of the TCP/IP protocol, see chapters 1 and 3 in this volume.) Therefore, TCP/IP was seen as a powerful but costly solution. Although package switching is more efficient than closed circuits in general, the TCP/IP standards used in the Internet only gained popularity over other package switched protocols, such as X.25, as the bandwidth prices dropped significantly due to the development of fiber optics as a carrier of information.[2]

But more than sheer network economics slowed down the spread of TCP/IP networks. In particular, the European telecommunication scene was clearly dominated by a strong political effort to undermine the U.S. dominance in data communication technology. European governments and their telecom agencies sponsored alternative network protocols developed under the umbrella of the International Telecommunication Union. Open System Integration led to a number of data communication services, such as the unsuccessful X-400 protocol for e-mail. Because European policymakers strongly backed the X.25 related datacom services, there were political barriers against adoption of the IP-based services (Schmidt and Werle 1998). Although Sweden remained outside the European Union until 1995, the blocking effect of OSI was felt also in Sweden through Telia's longstanding collaboration with public telecom operators within European standardization bodies.

However, the tide was turning against these European efforts, as network operators were looking toward IP. As in many other countries, early Swedish IP-based networks were initiated and run by universities. The Royal Institute of Technology (KTH) was the pioneering force through its effort to implement IP network technology in the Swedish university system, SUNET. (The IP protocol also received pioneering support by Swedish Radio, the public broadcasting company.) Links were then built to bridge islands of university IP networks across the Nordic countries, NORDUNET. The Nordic network was later linked to the growing European university IP network through Ebone, a European IP backbone also involving private IP network operators outside academia (Närings- och Teknikutvecklingsverket 1993).

The successful development of an IP network required financial resources. Also, managers of KTH's network operating unit felt that there was an increasing demand for IP services outside the strictly academic world. But commercialization of the IP network required that the network be spun-off to an outside operator that could tap into private sector demand. Björn Ericsson of KTH turned to Telia and proposed that SUNET should be operated by Telia. But the public operator was by then deeply involved in the development X.25 and OSI. At best, Telia's strategists thought, IP could be seen as a step toward full implementation of OSI. Hence, the offer was rejected. Having been unable to convince Telia that IP was not just a short-lived transitional stage, Björn Eriksson initiated contacts with Jan Stenbeck, the owner of Telia's main challenger, Tele2. Stenbeck did not need much time. By accepting KTH's business proposal, Stenbeck jump-started the Swedish proliferation of Internet services outside the university sector. Stenbeck saw what Telia failed to realize: the university's infrastructure was an excellent stepping stone for any operator that wanted to offer IP solutions to the corporate sector and even to private households. Rather than Telia, it was Stenbeck who saw the potential of TCP/IP as an alternative to traditional leased lines and to the X.25 protocol stack (Lindström 2001; Söderlund 2001).

We should, however, note that there was no direct convergence. Rather, a mix of protocols came to typify Swedish data communications. In the end, as concluded by Hagström, "What constitutes a typical corporate communications network are elements drawn from all ... categories. Private leased lines, dial-up modems, common public package- and circuit-switched links, and value-added communication services more often than not coexist in a corporate data communication network" (Hagström 1991, 219).

Summary

The absence of formal regulations created space for new technologies, as well as entrepreneurs with big ambitions and some experience of the nascent value-added services. In this context, the new regulations meant that the Swedish telecom market exploded with new initiatives and investments. According to OECD, Sweden emerged as the most open and most contested telecom market both in terms of deregulated subsectors and number of competitors (Boyland and Nicoletti 2000; OECD 1996). The transition was so rapid because the ground was already well prepared. A case in point is, of course, the fact that Stenbeck's operating company was already in place when the opportunity to operate the Swedish IP network emerged.

The new conditions created a new type of network structure. Compared to the closed network structure typifying the traditional telecom monopoly, deregulation resulted in a disbundled network structure. Many of the benefits of such an infrastructure can only be realized if the means to transfer information and interconnect its parts is effective and reliable. To establish meaningful communication the system has to take connectivity to a higher order of *interoperability*. Because computers need to communicate, the computer industry has had to tackle network-to-network communications issues in a more complex way.

To describe the technological architecture of the Internet, the world of communication engineering relies on the so-called "layered functional model." This model enables engineers and companies to handle increasingly complex technology as a modular design. A modular system is composed of units (modules) that may be designed independently but still function as an integrated whole. The principal means of achieving network externalities and developing a common infrastructure is the adoption of "technical compatibility standards" that provide rules for interconnecting parts of the communication system.

This type of network structure is also referred to as an open or disbundled network. Our next point is that the disbundling of the Swedish telecom network opened the scene for entrepreneurial efforts on a far larger scale.

The Swedish Internet Economy in the 1990s

It is hard to imagine better preconditions for being an early adapter of the Internet than the ones existing in Sweden. The rational, modernist, pro-technology mentality of many Swedes led to early high penetration of computer systems and personal computers.[3] This in combination with the country being a long-time world leader in the number of telephone

Layer	Service	Typical Firm Types
4	*Application Layer:* E-mail, FTP, Web design, including online information for business or private use, software platforms for B2B and B2C e-commerce, etc.	Entrepreneurial software firms
3	*Navigation and Middleware Layer:* WWW browsers, electronic payment systems, WAP related applications, search engines	Entrepreneurial software firms
2	*Connectivity Layer:* Internet access, Web server parks	Primarily large firms due to sunk costs of network provision
1	*Network Layer:* trunk networks, fixed local access networks, radio networks, Ethernet LANs	Large, integrated network equipment manufacturers

Figure 4.2
The layered functional model of the Internet

lines per capita made the Internet immediately accessible to interested Swedes. Early deregulation in 1992, leading-edge competing telecom equipment companies such as Ericsson and Nokia, and sophisticated international telecom operators such as Telia, Tele2, and Europolitan have not hurt adoption rates.

The general picture, including widespread use and high-quality infrastructure, was built on accelerating IT investments. From lagging behind the average EU members and the United States in 1980, Sweden picked up steam in the early 1990s. Today, Sweden invests more in IT and telecom in relation to its GDP than any other nation—almost 8 percent (OECD 1999a). Larger parts of its GDP are invested in education, software, and R&D than in any other country, according to OECD. As a result, Sweden has become one of the world's most wired nations. The national digital mobile network is a particularly important part of Sweden's telecommunications infrastructure, and three Global System for Mobile Communication networks cover all of Scandinavia. More than 40 telecom operators, both Swedish and foreign, are active in the market.

Internet Penetration and Usage

The rates of Internet penetration, cellular penetration, and home-PC penetration are among the highest in the world. Mirroring the U.S. figures, almost 70 percent of the Swedish population has a PC with Internet access at home, and over 60 percent own a cellular phone. The percentage of Swedish firms using Internet (93 percent), e-mail (94 percent), home pages (58 percent), and firms where more than three-quarters of the employees have a computer (47 percent) is consistently higher than for firms in the European Union. In the last five years, the share of the working population owning cellular phones has increased from 25 to 80 percent. Among young people (age 16–29), 90 percent own a cellular phone (International Data Corporation 2001; Statens Institut för Kommunikationsanalys 2001; TELDOK 2000).

The high levels of Internet penetration in the household sector is partly explained by the local entrepreneur Stenbeck's aggressive entry into this area. But the high levels were underpinned by public policies. As for increased diffusion of on-ramps to the Internet, the Swedish government's decision to heavily subsidize private personal computer ownership was a decisive factor. In particular, a chain of tax benefits, starting with firms and ending with employees, reduced the purchasing cost of PCs by some 50 percent. By 1998, about 20 percent of privately owned PCs were subsidized through the agreement (Statens Institut för Kommunikationsanalys 2001).

But the state was not the only one that developed schemes to increase the use of home PCs and the Internet penetration rate. To get more traffic through the network, Internet Service Providers initiated experimenting with the same tactics as previously used with great success in mobile telephony: private sector hardware subsidies. By bundling the PC with an Internet subscription, ISPs such as Tele2 contributed to an even higher penetration of Internet-connected PCs in ordinary Swedes' homes.

Seven out of 10 Swedes have used the Internet, according to figures from the Swedish Bureau of Statistics. There are clear patterns as to the demography and work situation. Not surprisingly, the use of Internet decreases with age. Although over 90 percent of teenagers use the net, fewer than 50 percent of those 55–64 are surfing. As for work groups, over 90 percent of salaried employees in higher positions use the net, in comparison to 50 percent of the workers. The most frequent Internet users are men aged 30–49, moderately educated (high school plus), who live in a major city. Interestingly, Sweden's northern region and the capital Stockholm are in the fast lane, displaying technological optimism, high use of PCs, online surfing, and shopping (Forrester Group 1999). In the north, communication is important due to the large, sparsely populated landmass. The Internet is, for example, used for ordering and paying for goods from former mail-order companies. Auto parts, hand tools, and clothes are some examples of northern shopping needs catered for via the net.

In world rankings of the quality of the Swedish IT infrastructure, Sweden regularly occupies first or second place together with the United States, which implies that the Swedish citizens are enjoying the benefits of a particularly useful infrastructure (Sveriges Tekniska Attachéer 1999). So what do they do on the Internet? Looking at the total population, the Internet is used mainly for information gathering (62 percent of the total population), e-mail (60 percent), Internet banking (29 percent), purchasing of goods or services (29 percent), communication with the public sector, such as tax authorities (27 percent), and discussion or chat groups (15 percent) (TELDOK 2000). Let us briefly comment on the three categories less obvious than information gathering and e-mail.

In international comparison, the relatively early and rapid penetration of Internet banking in Swedish society is especially interesting (Berg 1999; Finansinspektionen 2000). In 2000, there were two million bank accounts using the Internet. Over 30 percent of all Swedish customers of the five largest private banks used the Internet for accessing their accounts. A public Swedish analyst unit in a recent survey found that the percentage of households paying their bills via Internet banking has jumped from 9 percent in 1998 to 29 percent in 2001. In the age group 25–45 years, the use of the Internet for financial services reached 40 percent in December 2000 (Finansinspektionen 2000; Statens Institut för Kommunikationsanalys 2001; TELDOK 2000). Bank offices are increasingly populated with elderly clients, which makes the service slower and turns away younger clients pressed for time. The latest possibility is to use your cellular phone for banking (including transfer to other banks' accounts), paying bills, trading securities, and analyses. In SEB, a leading Swedish bank, 50 percent of all private account transactions are made via the Internet. In the financial markets, more and more Swedes are conducting trade from home. By the end of 2000, almost half a million private customers used the Internet for trading stock and other financial instruments (Finansinspektionen 2000).

Using the Internet, banks try to solve retail-banking dilemmas such as dealing with unprofitable transaction-intensive clients. New product penetration and customer understanding is up, commission-based income is added, and profits are leveraged on a large customer base. A study by IBM and Interbrand concludes that three of the five best Internet banks (as determined by the range quality of services offered) in the world are Swedish.

Purchasing of Non-financial Goods and Services (B2C plus B2B) In the retailing sector, 5 percent of Sweden's shops sell via Internet, as do 13 percent of the department stores and 93 percent of the mail-order companies. The Swedish purchase pattern follows what is going on in other countries: the main products for purchase are music, books, computer software and hardware, clothes, and movies. Once again, Sweden's northern region and the capital Stockholm are in the fast lane, displaying technological optimism and Internet shopping.

As indicated in figure 4.3, the financial sector in the Swedish context stands out as a stronghold of B2C transactions. But it should also be noted that outside of this sector, the impact of e-commerce is still very limited. E-commerce revenues as a percentage of all revenues on a yearly basis in retailing is insignificant, but has gone from 0.7 percent to 1.8 percent over the period 1999–2001 (Svensk Handel 2001). For 2000, the turnover relating to e-commerce trade is less than US $25 per capita for B2C. In B2B, the turnover relating to e-commerce is less than US $15 per capita. Secondly, there is strong evidence that only a handful of retailers are depending on the Internet for their distribution. A recent investigation of the e-commerce sector shows that less than 0.5 percent of all firms that have Web sites with functions that support e-commerce depend on the Internet for more than 50 percent of revenues (Statens Institut för Kommunikationsanalys 2001).

First Deep Technology, Then Web Applications

Not since the early twentieth century have so many new companies been established in one Swedish industry in a limited time as in the Internet-related boom in the late 1990s. Currently some 950 Internet companies operate in Stockholm, more than in any other city outside the United States. In addition to the hot spot for new companies in Stockholm, cities

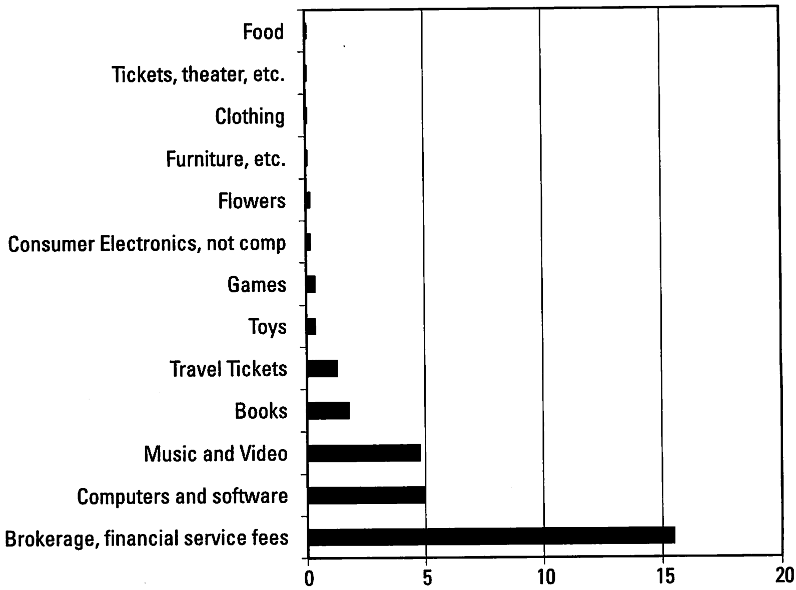

Figure 4.3
Internet sales in percent of total sales
Source: Statens Institut för Kommunikationsanalys 2001.

such as Gothenburg (home to the Chalmers Institute of Technology), Malmö/Lund, and Karlskrona/Ronneby host new Internet firms. However, if there is little evidence of a real breakthrough in e-commerce applications, there is more to be said about the predominance of deep technology as a defining aspect of the Swedish Internet economy. First, the IT sector's contribution to the Swedish economy has been relatively stable during the 1990s. The IT industry added value as share of GNP, for example, remained at levels around 3.0–3.5 percent between 1980 and 1996 (Söderström 2001).

At this point one might wonder to what *kind* of IT industry do these numbers refer? Is it hardware or software? Web consultants or complex data network technology? Is it relatively standardized and simple tasks or is it innovative and highly demanding tasks that require experienced system integrators and complex software modeling tasks? First, it should be pointed out Swedish IT, as compared to other European countries, has been characterized by a high degree of R&D intensity. Investments in

R&D have been significant. Together with a group of countries including Finland, Ireland, Greece, Italy, and Norway, Sweden scores high in terms of private R&D investments in IT as compared to all other R&D expenditures. Since the mid 1990s, Sweden has scored somewhat lower in relative terms (Söderström 2001).

A quick glance at the listings of the most important Swedish IT firms explains this pattern. Recent rankings of the firms constituting the Swedish IT sector (including software, hardware, IT consultants, multimedia, telecom and datacom equipment, telecom operators/ISP) show a complex layered structure with some large players at the bottom and hundreds of small firms in the higher layers.

In the basic layers we find Ericsson, Sweden's giant in infrastructure equipment manufacturing and Sweden's most important company in terms of employment, turnover, and exports. (For the distrubution of firms by subsector, see fig. 4.4.) In addition, there are a number of technology intensive suppliers of basic system integration solutions for this segment. In the next layer, we also find large telecom operators that are more and more dependent on Internet service providing and on data communications than the traditional core business, voice services. Just as

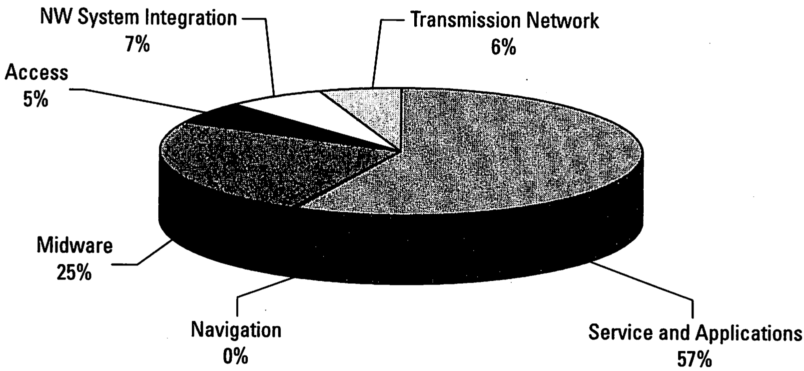

Figure 4.4
Distribution of Swedish Internet firms by sub-sector
Note: The distribution is based on a sample of firms with more than 10 employees, in total 407 joint stock companies. All in all, about 950 firms declare that they are active in Internet related technology or services.
Source: MarketManager; the analysis of the precise orientation of firms is based on the firm's mix of end-products as stated on the individual firms' Web sites (visited in June/July 2001).

important, but significantly smaller in terms of sales, turnover, employment, and revenues, are middleware firms that sell their services to Ericsson and the large operators/ISPs. The main function of the technology consultants is to implement sophisticated technologies relating to infrastructure, middleware, and corporate IT projects for large firms such as ABB. The large technology consultants, such as WM-Data, Tietoenator, and AU-Systems, are deeply rooted in the first wave of deregulations leading to demand for new communication technologies. Much smaller ones, such as Bluetail and E-Hand, are equally technologically capable but with a far more narrow focus in terms of products and services.

In the upper layers we find the Web integrators or Web consultants that provide basic technology for home pages and dot.com companies. In general, even the large Web consultancies, such as Icon MediaLab, have far more limited capacity than, say, middleware specialists. Their specialty is in creation of Web sites and they tend to migrate toward management consulting rather than the deep technologies. Hence, they often find themselves to be in an area typified by fierce competition because the technologies are fully standardized. Therefore, a large number of firms are marketing general e-commerce platforms that can be adapted to fit specific needs at relatively low cost. Costs, and to some extent brands, more than technology account for success in this business. Only a handful of Web integrators are successfully moving from the relatively simple tasks of constructing stand-alone Web sites to more demanding tasks. Infovention, for example, has successfully specialized in solutions for Internet banking, which involves the construction of complex middleware systems that integrate Web interfaces with the banks' computerized transaction systems.

Only above this level do we find the large Internet and Web consultants that are focused on creating Web applications and platforms for e-commerce solutions.

By the way of summary, there is something remarkably "complete" about the Swedish Internet economy. Although the large R&D intensive firms still remain stable players in the high-tech race, there has been a phenomenal growth in the higher strata of the layered functional model of the Internet. In the European setting, Sweden is a special case because it has players of relative importance not just in areas where it is relatively easy to enter, such as Web applications, but also where the U.S.-

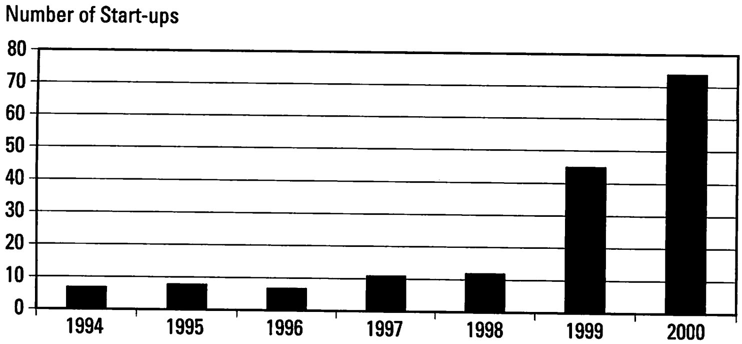

Figure 4.5
Number of start-up firms in the wireless sector
Source: Gustafsson 2000.

dominance is most well established by players such as Cisco, Microsoft, IBM, and Compaq, in networks, sophisticated middleware, and on-ramp technology.

. . . And Now a Focus on Wireless

As is often asserted by observers of the communications industry, the establishment of Ericsson as principal hub in the development of mobile Internet technologies has attracted wider investments, resulting in a large number of entrepreneurial start-up firms. But also already large, established firms have located "centers of excellence" of wireless solutions in Stockholm. As indicated in figure 4.5, a remarkable number of firms have been established since 1999.

A large chunk of these firms are trying to take the concept of portals and e-commerce into the world of mobility and wireless Internet. Many of these companies, at least judging from the financial performance as of fall 2001, seem to have an uncertain future. Even the more successful producers of wireless portals, WAP and SMS Solutions, have announced major layoffs, as owners and financiers have become more careful. But more interesting, and perhaps promising in a commercial sense, are the technologically more sophisticated firms that develop middleware technologies. Middleware firms focusing on enterprise databases, such as E-Hand, are using the WAP protocol to provide links between enterprise databases and smart wireless phones. In other words, they work as bridges between the enterprise software industry and the makers of advanced wireless terminals (Nokia Communicator, Palm VII, etc.). Even more sophisticated Internet solutions providers, such as Infovention and Entra, have targeted the financial sector with relatively standardized platforms for the development of Internet banking services. WirelessCar, a Volvo/Ford joint venture with Ericsson and Telia, has inaugurated a lab focused on wireless safety systems. This lab is closely linked to the research and development at Ford's two centers of excellence located in Sweden for safety technology and computerized electrical systems. General Motors is currently forming an alliance with Ericsson and Delphi, the world's dominating supplier of automobile components, to develop mobile Internet solutions.

Ericsson's strength in international standardization games is well documented (Funk 2002; Glimstedt 2001). The company was early in emancipating itself from the idea that standard wars should be fought according to national industrial policy agendas. By promoting global standards and marketing equipment based on non-Ericsson technology, such as AMPS and TACS, the company built a large customer base outside the "natural" Nordic camp. Moving away from national technological priorities helped Ericsson secure a central position in the GSM standardization process as the European Union tried to free it from parochial interests. In the marketplace, Ericsson's bet on global analog standards before GSM paid off in terms of securing a wide customer base of mobile operators using other analog standards than the Nordic NMT standard. It was precisely those operators that turned to their supplier of analog systems—Ericsson—as they were upgrading to the digital GSM standard.

The fact that Ericsson has become a key player in the development of mobile Internet solutions has certainly reinforced this aspect of the Swedish Internet economy. Leading foreign firms have established Swedish subsidiaries on their own or in cooperation. What is notable about these investments is that the large IT multinationals are not just setting up small outlets to monitor the development in Sweden—listening posts—but they are establishing themselves in a much more extensive way. IBM, Sun, Oracle, Intel, Compaq, Motorola, Nortel, and Microsoft hired 4,825 engineers to work in their respective Stockholm subsidiaries, focusing on wireless solutions. Oracle emerged on the Swedish scene as a partner to Telia and Ericsson as they co-developed added value services for GSM. Microsoft acquired a successful Swedish start-up company with strong technology for e-mail that promised rapid transfer into the wireless services. In 1998, Microsoft invested in a joint venture with Ericsson to co-develop applications that would link the wireless applications to Windows and the Office suite. Intel, IBM, and Sun have chosen a different path by establishing centers of excellence for the development of wireless technologies (Leijonhufvud 2001).

Judging from the size and number of firms operating in the Swedish Internet economy, disbundling of network elements has led to a new type of organizational solutions: small firms can enter into this industry because they can focus on narrow tasks. Even if they develop new network functions or even if they are just an improvement of a single aspect of the network, this improvement tends to leverage the functionality of the network as a whole. This, it seems to us, is undisputable. But it only raises another question: if the number of independent actor increases, how then is innovation coordinated across firms?

Enabling Institutions in Transformation

Sweden has historically experienced many cases of public technology procurement that have served the purpose of influencing technical development and contributing to the competitiveness of national firms (Edquist 2000). Well-known cases involved the creation of a public/private interface through so called "development pairs" based on joint R&D efforts by public agencies and large, export-oriented private firms. Examples of industries in which this happened are telecommunications, power generation, and communications. In successful cases, the creation of development pairs led to organized pools of competencies across organizational boundaries (Fridlund 1998a; Glete 1983).

The development pair as a mechanism for knowledge transfers between public institutions and the private corporate sector was closely associated with monopoly markets. Under deregulated market conditions, the telecom operators are assuming a much smaller share of the R&D costs. Given the transformation associated with the deregulation of the Swedish communication market, private industry and the university sector generally assume a larger share of the R&D costs, as a recent study by Martin Fransman (2002) reports. Although the Swedish governments—be they social democratic or liberal right wing—have long taken the view that basic research is key to economic gains derived from applied R&D, the most recent tendency indicates that this is even more so under deregulated market regimes. Since the mid 1980s, Sweden has had the highest R&D/GDP ratio of all OECD countries (Henrekson and Rosenberg 2000a).

The large volume of R&D raises, nevertheless, the issue of changing connections between public R&D and the private corporate sector. New mechanisms and organizational solutions are thus emerging to bridge public and private R&D efforts.

As in most other European countries, a number of additional mechanisms aimed at bridging university research and entrepreneurship in the private sector have been created. At least twenty science parks have been established to host small start-ups and R&D departments of large companies. Together these parks employ more than ten thousand engineers. The Swedish National Board for Industrial and Technical Development, NUTEK, has set up "broker institutions" that aim at helping university researchers commercialize their patents. The government has also been instrumental in developing legal and financial infrastructures aimed at facilitating exploitation of university R&D efforts, including granting university personnel full patent rights for their innovations.

A recent investigation of the effects of the most celebrated industrial park, Telecom City located in Karlskrona, in the southeast of Sweden, shows how government's top-down processes are connected to localized SME-programs. The government's re-location subsidies explain, at a first glance, why large-scale telecom and IT-related activities were transferred to Karlskrona. Additional decisions to create an IT-focused university college as part of the decentralization of the Swedish university systems were also part of the top-down process. Having received these resources, the local actors started programs to facilitate the creation and recruitment of new IT start-ups to the Telecom City project. After these resources had been moved to the region, start-ups focusing on mobile and Internet technology began to crop up (Engstrand 2002).

The success of these bridging institutions can be questioned. Little is known about the effect on technology transfer between firms and universities within regional parks. Our view is rather that the standardization process is a more deep and profound factor in technology coordination than sheer co-location of firms and institutions. This takes us into the area of standards and how larger firms direct smaller firms' R&D through stacks of interoperability protocols.

Open Interoperability Standards

The Internet is a "system product." Several products need to work together simultaneously to produce the desired output. The components of the system must be compatible with one another or, differently put, must be held together by a set of interoperability standards and system architectures. For firms, the strategic value of standards is increasing with the number of actors in an industry. "Network externalities" is thus an economic term that reflects the fact that the value of networks increases as the number of connected users increases. As more users adapt to the standard, that standard becomes increasingly attractive to others—and so on, in a way that can be described as a positive feedback loop. In cases where the network effects are not exhausted at a small scale relative to the market size, Paul David demonstrated in his landmark article on QWERTY typewriting that the market "tips" when a standard has gathered a critical mass of adherents (David 1985).

It should thus not come as a surprise that efforts to tip the market in favor of standards sponsored by leading Swedish actors, such as Ericsson in alliance with Nokia of Finland and Motorola of the United States, have been a prominent feature of the Internet economy. Some of these standards have been intensely contested. A case in point is the battle over interface standards for mobile Internet services, or the so-called "third generation" of mobile telephony, known as Universal Mobile Telecom Services in the European context[4] (Glimstedt 2001). UMTS covers only a single aspect of mobile Internet, namely the air interface that connects the handheld phone to the radio base station in the spectrum. On closer inspection, the mobile Internet initiative consists of a set of open standards that have been far less contested. Table 4.1 shows the key areas of standardization in wireless Internet services in which Ericsson, together with mainly Nokia and Motorola, figures as a main sponsor or co-sponsor of particular mobile Internet related standards.

Two different but interrelated sets of ideas underpin the development of open standards. First, traditional ways of creating and agreeing upon

Table 4.1
Service by Standardization Body and Type

Service	Standard	Comment
Radio Interface for wireless broadband services	W-CDMA	This is Ericsson's version of CDMA technology, which was adopted by ETSI in 1999 for UMTS. Europe's UMTS strategy is coordinated with other GSM-related standards within the global Third Generation Partner Program (3GPP).
Package switched and faster GSM, also kown as GSM 2.5.	GPRS + EDGE	Voluntary standards set by ETSI
MultiLayerSwitchingProtocol for integration of ATM and IP in mobile swirches	MLSP/ATM	Voluntary standards set by ATM Forum, MPLS Forum and adopted by IEFT. Co-sponsored by Cisco, Nortel, and Ericsson, among others, which have participated in joint interoperability tests.
Wireless LAN and WLAN	IEEE 802.11	Widely used voluntary industry standard sponsored by IEEE, adopted by Ericsson.
Short distance wireless connections	Bluetooth	Voluntary industry standard with Ericsson and Nokia as major sponsors and developers
Enhanced SMS, adds graphics and sound to the popular SMS standard	MMS	Sponsored by Ericsson and Nokia through 3GPP and WAP Forum
Wireless internet access via WAP browsers	WAP Forum	Voluntary industry standard sponsored and co-developed by Ericsson and Nokia with support of a large group of firms
OS for handheld communicators	Symbian	Open-but-owned OS standard developed by joint venture between Motorola, Psion, Ericsson, Nokia, and Panasonic.

telecommunication standards have proved too slow and cumbersome to be effective in a world in which technology changes at a fast rate. Second, it is a well-established fact that Europe's bodies that develop ex-ante standards (i.e., standards that are set before products are put to the market) suffer from being too late and being out of touch with end-user demand. The fate of OSI, which was unsuccessful compared to the TCP/IP protocol, is a particularly illuminating example of this. It shows, in particular, the dangers of creating standards in splendid isolation from end-users' preferences (Schmidt and Werle 1998).

As indicated in table 4.1, which lists the main technological standards involved in the convergence between Internet and mobile communications, there is movement toward small and focused standardization groups sponsored by several firms. These so-called standardization consortia's set publicly available specifications that are used as interoperability standards. A major implication of communication standards is that they make the thorny task of system integration relatively simple because the standards provide the developer with a clear interface and protocols for how functions should be implemented.

Take the recent version of the ATM technology (asynchronous transfer mode), also known as Multi Protocol Layer Switching (MPLS). This technology has become significant because it underpins a series of applications, ranging from fixed multi-service networks to next-generation radio base stations and mobile switches. Standardization consortia are heavily used to develop quickly new standards and get firms onboard the project.[5] In the case of ATM/MPLS, the private consortia (ATM Forum and MPLS Forum) developed standards that were coordinated with end-customer demands in the corporate LAN sector in order to ensure compatibility between end customers' preferences and the development of core network technology. Large-scale voluntary standardization bodies, such as the Internet Engineering Task Force, IETF, can later adopt these standards.

Network externalities are also generated through the creation of a growing community of producers of a particular technology. From a firm's perspective, the common adoption of a particular communication technology or a stack of communication protocols by a large number of firms tends to create a pool of skilled developers of that technology. In other words, open standards have become attractive because they allow many actors to improve technology at the level of the modules in parallel lines to the extent that the innovations improve the parts of the system and not the way that the parts are hooked up to each other.

To continue our ATM example here, the involved firms have arranged joint interoperability tests to demonstrate to the end customers that ATM-based products by Nortel, Ericsson, and Cisco are fully compatible with each other and that the components live up to the promises of differentiated quality-of-service across the whole network. So one aim behind the combined standardization and interoperability tests is to build markets for products that can be derived from the generic protocols. Another effect is that the standardization consortia enable the large firms to connect to the smaller but technologically sophisticated ones. In case of the ATM-related standardization processes, connections were built up between Ericsson, Cisco, and smaller firms such as General Data Communications, Mariposa, and ACC through the work within the standardization organizations. Later, these firms were acquired by Ericsson or gained position as first tier system suppliers of advanced routers and switches.

Seen from this perspective, the Internet economy is typified by both intense *intersystem* competition and *intrasystem* competition. Open standards are critical to both forms because they (1) allow sponsors of new architectural designs to rapidly define new standards, and (2) facilitate the modular innovations that increase the number of innovative actors and the number of entry points for innovation.

These two forms of competition and collaboration are, in practice, indistinguishable. Take Symbian, the joint venture by the three major wireless phone manufacturers (Motorola, Nokia, and Ericsson, later joined by Panasonic and Sony) to leverage an operating system known as Epoch for use in future smart phones. This was popularly regarded as an "anti-Microsoft" strategy, as it was widely reported that Microsoft had been courting the manufacturers to use PocketPC (earlier Windows CE). Because the Epoch operating system was technologically superior to PocketPC (consuming less memory and having better real-time determinism), it provided the manufacturers with an alternative that made them stay independent of Microsoft, and let them keep control of the "smart phone" market.[6] Symbian opens new entry points for innovation. The main sponsors share the burden of improving the basic core of the operating system within Symbian's basic operations while the modular design facilitates adapting the OS it to firm-specific user interfaces. Thus Ericsson has to develop one user interface while Nokia is collaborating with Palm Computing to implement its popular interface on top of Epoch. Also, Symbian has become an attractive partner for a wider range of actors seeking to explore wireless technologies.

Similarly, an effort to create industry standards for mobile games has been linked to Symbian's operating system and related standards such as Wireless Application Protocol (WAP) and Multimedia Messaging Service (MMS) (interview with Bo Nordblom). Ericsson, Motorola, Nokia, and Siemens have launched the Mobile Games Interoperability Forum, paving the way for gaming on multiple servers and wireless networks. By fall 2001, about ten producers and publishers of digital games had joined this consortium. The MGI Forum aims to write global standards so that users can play games across different servers, on wireless networks, and on different mobile devices in the same way that Counterstrike is played across the Internet. This strategy calls for implementation at many levels of the mobile network: in dedicated game servers inside the networks, in network functions in Epoch, and in WAP browsers or in MMS. The main sponsors thus aim at providing other industry leaders and innovators, game developers, mobile operators, game service providers, and systems integrators with a platform that makes designing and launching mobile games simpler because the platform contains standardized routines for complex software design and programming tasks. The four companies define application programming interfaces (APIs) and a Software Development Kit (SDK), developing certification procedures to ensure wide acceptance of the standard and providing recommendations to ensure an open environment for developing mobile games.

Standardization of Software Tools within Local Developer Environments As we have seen above, network externalities are generated through the creation of a growing community of users for a particular technology. From an employer's perspective, the common adoption of a particular communication technology or a stack of communication protocol by a large number of firms tends to create a pool of skilled software designers and programmers in the use of that technology. In other words, common technological standards are a way of solving the problem of technological coordination across firms.

From the perspective of software development, major actors such as Ericsson have adopted the use of standardized tool kits that are well established in the local environments that embed the development units. Instead of their old in-house proprietary software languages, such as PLEX and Erlang, Ericsson is aiming to use open industry standards such as Unified Modeling Language (UML) in combination with object oriented languages such as Java and C++ in the new platforms (interview with Hans Brolin).

The decision by Swedish firms to use UML has a lot to do with the reported productivity increases that users of formal UML modeling have experienced, but there is also the recruitment question. One might ask rhetorically what developer in his or her right mind would develop software expertise in languages that are not used outside Ericsson. The decision to stop using PLEX had a clear bearing on making Ericsson an attractive employer for ambitious programmers (interview with Hans Broström).

There are equally strong incentives for relatively small firms to use the same kind of high-level software language. Even E-Hand, a 25-programmer software house specializing in middleware for wireless connections between SAP databases and handheld devices, is implementing UML in order to prepare for rapid scaling up and increased complexity in software tasks (interviews with Eric Boman and Viktor Kotnik).

UML has become a standard for large-scale software projects in the Swedish telecom and data communication sector, serving as a widely understood language spoken by most programmers. This common language makes it possible for programmers to help each other independently. In light of this, it should be noted that software development tools vendors (such as Telelogic and Rational) with more than 60 percent of the Swedish market for software tools in the telecom sector have experienced a soaring demand for UML-based modeling methods (Svensson 2000).

Privatization of the Standardization Process and the Relaxed Competition Law

Collaboration within private standardization bodies facilitates collaboration in the market. But are standard consortia really different from cartels? Fundamental to the technological exchange between the private firms is, for example, an emerging private regime for exchange and distribution of revenues from intellectual property rights or patents. In the case of mobile Internet services, the world's leading wireless companies have completed the definition of what is known as the *3G Patent Platform* (UMTS Intellectual Property Association 2001). This arrangement provides a system for evaluating, certifying, and licensing "essential" 3G patents. The platform specifies the maximum amount of royalties per product category to be paid by any licensee. Patent fees are to be collected and distributed through a system in which the last manufacturer in the value chain constitutes the collection point so that all formerly involved activities that result in the product are covered.

One would think that this type of combined arrangement would raise the eyebrows of, say, Ms. Ann-Christin Nykvist, the vigorous director general the Swedish Competition Authority, or her European counterparts. All this organized technological collaboration between groups of firms, including the IPR platform described above, has only been possible under the relaxed antitrust legislation in Europe and in the United States (Jorde and Teece 1992). On a strict legal interpretation of antitrust regulations in both the United States and in Europe, sharing technical information between firms is similar to sharing pricing and other types of essential market information. Recent case law permits sharing technical information in connection with standardization processes without interference from antitrust enforcement since the late 1980s. In the United States, the passing of the National Cooperative Research and Production Act in 1993 made it safer for firms to relocate standardization from formal standardization bodies to private consortia (Tate 2001).

The core of the more recent thinking in European and U.S. antitrust law is that it, in modular technologies, construes the firm's and the standardization consortia's problems as being related to long-term innovation rather than to short-term profits. To work properly, complex modular technologies require collaboration between suppliers and users of the various components. In Europe, the commission has allowed the possibility of exemption under Article 81(3), which regulates information sharing. In both cases, information sharing is seen as crucial in network markets, which may ultimately benefit consumers (Seabright and Halliday 2001; Toth 1996).

Open standards allow intrasystem competition, which is consistent with variety through recombinations of modules rather than through competition between different systems. In other words, the existence of private standardization consortia is tolerated by recent competition policy because the modular systems provide more entry points for innovation. A variety of design and organizational alternatives become available to end customers on this assumption. What needs to be watched most carefully by antitrust authorities, in this perspective, is how patents with a broad scope (e.g., covering more than one module) can create barriers to this experimentalism.

Venture Capital

Of course, standards and disbundling alone are not sufficient for the creation of start-ups; finance is also needed. To a considerable extent, Sweden has followed the U.S. model in developing a venture capital market to invest in entrepreneurs.

At a limited scale, venture capital has been available in Sweden since the early 1980s. Limitations applied not only to volume but also to direction of funds—the emerging Swedish VC industry first and foremost aimed at already existing business firms. Few financial resources were supplied to the establishment of new firms or in the first critical phase of expansion in firms' development (Isaksson 1999). The public sector has, within the framework of regional policy, tried to offset the lack of private venture capital by introducing numerous support schemes. In 1998, there were more than 140 such schemes. There is no coordination of the different schemes, and the net effect is far from clear. Bold regional projects, however, proved unsuccessful and the failure of the so-called Uddevalla Package effectively cooled off both the state's and regional authority's interest in regional development programs (Landell 1998; Landström 1993).

The tide has, however, turned in terms of availability of finance. As in the United States, the emergence of small Internet companies is closely related to a particular transformation of the financial sector, the emergence of independent venture capital firms. Swedish venture capital investment between 1995 and 1999 showed an approximately 200 percent annual average growth (Isaksson 1999; Karaömerlioglu and Jacobsson 2000).

In February 2000, there were some two hundred venture capital firms in Sweden, of which 40 were foreign-owned. These firms together man-

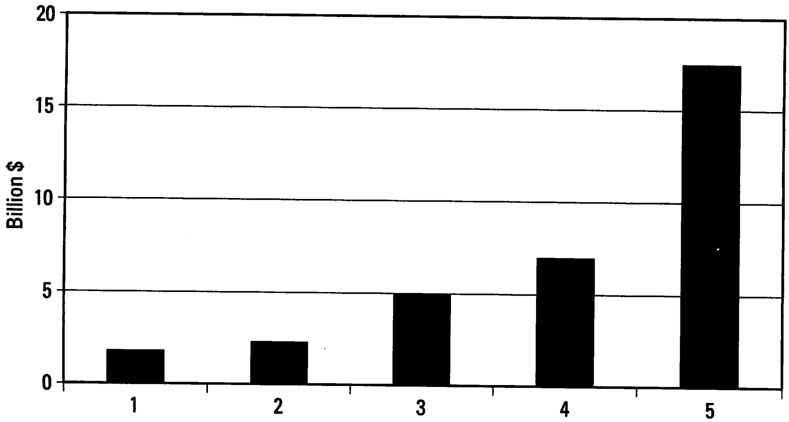

Figure 4.6
Available venture capital
Source: Swedish Venture Capital Association 2000.

age funds of $18 billion, to be invested over the next three to seven years. By January 2001, the amount had jumped to $25 billion (see fig. 4.6).

A very large number of the firms that focus on IT, Internet, and wireless were founded within a few years in the late 1990s. In 2000, they provided almost $2.5 billion to some five hundred Swedish IT projects. In 1999, around $1 billion were invested in 335 projects.

As indicated in figure 4.7, our estimations show that the high-tech subsectors—middleware and networking technologies—received 42 percent of the investments, whereas application oriented firms that dominate in terms of the number of firms received 58 percent of the invested venture capital.

Specialized VCs, such as BrainHeart Ventures, which raised $200 million, and Ericsson Ventures with $290 million, have focused all investments on the wireless Internet business, building on the expertise in third generation mobile telephony. BrainHeart's CEO, Ulf Jonströmmer, left his position as CEO of the leading telecom and networking technology consultancy (AU Systems) to invest in and help develop wireless Internet start-ups.

Although VC firms function as focused investors in IT, they rely principally on three types of sources for the available VC funds: institutional

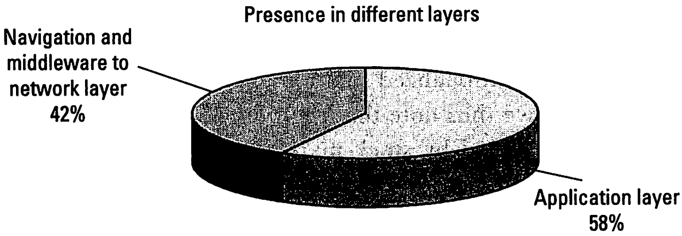

Figure 4.7
Distribution of invested funds
Source: Swedish Venture Capital Association 2000.

investors (49 percent of the invested capital), private placement (41 percent), mother companies (5 percent), and others (5 percent). Initially, however, the existing Swedish venture capitalists were very cautious and did not take high risks. Their security portfolios included blue-chip companies and the expected returns were 15–25 percent over 10 years. Around 65 percent of the capital was traditionally invested when the business concept and management team already functioned. In 1992, only 10 of these old-style cautious private venture capital firms worked with technology endeavors.

Among the new American-style actors were business angels, senior entrepreneurs (often former CEOs of large companies), new venture capitalists, and foreign capital interests. There are thus today two types of Swedish venture capital companies. One consists of newly formed firms focusing on IT and the Internet from the very start. A small team with entrepreneurial background manages the typical venture capital company of this type. The average company is capitalized by the owners' private funds combined with institutional investors' funds. During the last year, mutual funds, funds managers, and insurance companies have also supplied around $10 billion. The other is a group of older, established investment companies and venture capital companies with a recent interest in the Internet and biotechnology. The old industrialist spheres, including the traditional financial families, are represented in this group.

Venture Capital and the Point of Exit Generally, venture capital investments are based on exit points, the moment when the VC firm sells off its equity in a particular firm to reap profits from the investment. This ties the venture capital closely to the stock market, which provides the venture capital firms an institutionalized solution to the problem of exits. For Sweden as elsewhere, we thus note that the number of initial public offerings (IPOs) has been fueled by stock market expectations. For example, the Swedish AFGX index for IT and telecommunication stocks reveals the nature of the boom. Information Technology and Internet stocks soared from the level of roughly 300 points to the 800 level in 1999 alone. Telecommunication stock displayed an even more spectacular boom, going from the 350 level to 1,500 points between February 1999 and February 2000.

Between 1996 and 2000, the number of IT and telecom stocks on the OM Stockholm Stock Exchange increased tenfold. In 2000 alone, there were about 35 initial public offerings by IT and telecom-related companies, a new record high. Of the total of 311 companies listed on the OM Stockholm Stock Exchange at the end of 2000, 95 were IT and telecom companies, some 30 percent of the market's total value. This made OM Stockholm Stock Exchange one of Europe's leading markets for technology stocks, and a viable alternative to listing on NASDAQ or other exchanges.

Venture Capital and Competency Orchestration One of the most vital functions of the VC industry in the United States has been the combination of financial services and strategic advice, although the sheer number of ventures supported in recent years clearly limits the venture capital firms' ability to monitor each venture (Kenney and Florida 2001). Investigations of the Swedish VC industry reveal a skill shortage. Compared to their US counterparts, for example, the Swedish VC firms have less management and technology expertise. Isaksson (1999) shows that only about 20 percent of the firms that have received VC investment have also received significant inputs in terms of strategic advice, networks, and recruitment of key personnel.

At the level of boards, we note that interlocking directorates is of increasing importance. A recent study shows that at least 30 percent of Swedish Internet firms are linked through interlocking directorates. Although the bulk of these firms are parts of small networks with only two or three nodes, there are examples of larger networks involving 10–20 firms (White and Coronado 2000).

In particular, the institutionalized family ownership in Swedish business has resulted in strong ties between financial actors, leading IT firms, and main users of IT solutions. Investor, the Wallenberg family's main holding company, has strong ties to Ericsson, WM Data, and to a host of smaller IT firms through Investor's interlocks with venture capital firms (Adams-Ray and Sandberg 2001). In this regard, we note that the historical financial institutions have remained actors in investing in Internet-related businesses.

On the content side, Sweden's dominant private publishing group, Bonnier, is interlocked directly to Internet consultants, software producers, and to other Internet media actors. Another hub, Icon MediaLab, also has a large set of direct interlocking directorates that ensure direct information flows from firm to firm. Other actors, such as RamsinCoMedia, are less impressive in numbers of direct links but hold positions as mediators between larger networks (White and Coronado 2000).

Conclusion: Convergence or Cross-fertilization?

Many analysts suggest that entrepreneurial activity ushers in venture capital-backed high-tech industries; newly financed companies compete with and then overturn the established firms. It is also widely believed that the Internet economy is closely associated with a particular organizational model, involving (1) decentralized innovation in networked production networks, (2) high-risk oriented venture capital firms, and (3) high-powered personal incentive structures. In particular, the Silicon Valley model is a societal machinery that rapidly produces start-up companies, aiming at commercialization of new technologies quickly in a highly flexible labor market (see Kenney in this volume, chapter 3). Proponents of this view are suggesting that because venture capital has overcome the liquidity and incentive dilemmas that traditionally have limited the small firm's level of innovative activity, the rise of venture capital will be associated with systematic pro-competitive consequences. Ultimately, small-firm financing is accelerating the "gale of creative destruction" (Christensen 1997; Forster 1986). Many analysts seem to agree, at least until recently, that the Swedish Internet economy needs to adapt to this pattern.

The interesting question is to what extent the coming of the Internet economy in Sweden has been associated with international pressures to converge with Silicon Valley, and to what extent it has evolved historically as a series of selective adaptations from within? In assessing this issue, we have looked at two main themes: stability and change (actors and institutional transformation), and hybridization (patterns of cross-fertilization between old and new elements).

Stability and Change

A core argument has been that the historical roots of the disbundling of the Swedish telecom network were not a result of convergence pressures; change did not assume the character of a punctuated equilibrium. Rather, "change through diversity within" seems to be a more accurate thematic description. Swedish regulatory style allowed pockets of competition in which new services, new technologies, and new challengers grew into serious conflicts between regulators and private actors. Sweden's telecommunications system was already a hybrid at the outset.

As we compare the realities of the more bundled network of the 1960s and 1970s with the disbundled network of present days, we are hence struck by the degree of cumulative developments. An essential feature of the developments within Sweden's information and communication technology sector is the continued co-existence of new and old elements. Although balance between old and new elements may shift over time, it is still true that the old organizations, such as Ericsson and Telia that formed the core of the old network, still remain key players. What is new, however, is the intensified exchange between small and large firms under disbundled network structures. Rather than introducing new organizational forms, the Swedish Internet economy stands out because it makes far more intensive use of the organizational opportunities available to firms.

Hybridization

The sheer intensity in the exchange between small and large established firms needs to be understood in terms of a set of underlying problems. These arise in connection with established forms for preservation of firm-specific skills in large organizations and the need for destruction of these skills as new disruptive technologies come into the large organizations from the small firms.

The introduction of new technologies in disbundled systems has been conceived as closely related to horizontal specialization that is facilitated by standardization; firms are specializing in a subset of technologies without actually having to tackle the more complex task of mastering all technologies that make up the network structure. Disbundled networks are often associated with emergence of small- or medium-sized business organizations that make efforts to commercialize new IT innovations.

We have certainly mentioned venture capital supporting start-ups and different approaches to coordinating innovation, such as virtual communities and standardization of software tools, facilitating cooperation between horizontal specialists. These are elements that we associate with Silicon Valley. But unlike the Silicon Valley start-up machinery, Sweden's Internet economy is associated with *reinforcement* of incumbent market power. Although the emergence of TCP/IP was heralded as a force of creative destruction, market leadership has remained constant.

We can explain this pattern by two factors. First, innovative start-ups are often closely coordinated with the large incumbent, Ericsson, through collaborative standardization consortia. This collaboration allows for a high rate of innovativeness by start-ups alongside stability in the product market. A second explanation for this pattern is that the Internet, or the TCP/IP protocol to be more precise, is less dominant than often assumed. It should be remembered that the network structure still contains some elements that are relatively stable over time. Older and newer protocols are moreover often mutually dependent, as demonstrated by the discussion of MPLS ("IP over ATM"). Under these circumstances, it is not surprising that incumbents such as Ericsson, with their expertise in network architecture and large-scale system integration, remain significant market forces.

In other words, the unusual strength of the Swedish Internet economy has been its ability to operate at several points in the overall system: from infrastructure, to modular innovations, to software, and to commercial business models. This wide diversity, for a country with about a fifth of the population of California, is a remarkable achievement. It suggests that large national systems can migrate to new institutional settings when the critical players, namely the government and the established firms, carve a future for themselves in this new economic order. They were not passive observers, or victims, but active participants in their roles of providing the resources and the regulatory frameworks to exploit the innovative potential in a disbundled network. But the ultimate source of this diversity was the entrepreneurial pockets of competition that gave the impetus to a radical institutional change, based upon an evolving technological progress. It is these two elements, disbundled networks and entrepreneurial pockets of competition, that explain the Swedish transformation from a corporatist to an innovative economy.

Acknowledgments

In writing this essay, we are indebted to a number of friends and colleagues. Much was initially gained from the close interactions within the so-called Kråkmarö Group at the Institute of International Business. We have also profited from discussions with the participants of the Global Internet Economy Project. We especially thank Mr. Håkan Ledin for financial support and access to his vast personal network in the world of communications. But that was not Håkan's main contribution to this project. Above all, we have gained immensely from his inspired visions of the effects of technological dynamism within the communication business.

Notes

1. Economic institutions within Germany, Japan, and some Scandinavian countries have more regulative and "organized" characteristics that, although conducive to many successful innovation strategies within established industries, seem to hinder the creation of technology start-ups (see Casper et al. 1999). Deep patterns of vocational training within firms, consensual decisionmaking norms, long-term employment, and patient finance are all linked to the systematic exploitation of established technologies to a wide variety of niche markets, a strategy Streeck (1992), focusing on Germany, labels "diversified quality production." By contrast, the more regulative nature economic institutions combined with pervasive non-market patterns of coordination within the economy create constraints against the organization of industries that best perform within shorter-term, market based patterns of industrial organization (Soskice 1997).

2. We thank Axel Fromell pointing this out to us.

3. The majority of surveyed Swedes believe that IT creates new jobs and that most people (young and old) want to adapt it. Only 10 percent were scared by the development, although 20 percent felt that the development is too fast to follow.

4. In sum, Europe's bold strategy for 3G services—UMTS—was perceived in negative terms by leading American firms, such as Qualcomm, as well as trade strategists in the US Congress. It was Ericsson's and Nokia's move to punch through its version of so-called spread spectrum air interface standards (W-CDMA) that irked the Americans, who insisted that the ITU should adopt a approach that allowed a family of interoperable standards. At this point, the original champion of CDMA technology, Qualcomm, threatened to block the international standardization process through aggressive protection of its vast intellectual property rights in CDMA. The United States positioned weakened as Motorola, the holder of the majority of the essential GSM patents, and the US GSM operators joined forces with the European 3G effort. United States GSM operators also cut a deal with US TDMA operators, agreeing to make TDMA and GSM compatible. Qualcomm was thus isolated. The Europeans, on the other hand, became troubled by Qualcomm's success in the Asian markets. China's sudden interventions as the Chinese authorities hinted they would consider Qualcomm's technology if the United States were to adopt a positive stance toward China in the upcoming WTO-negotiations. These developments constituted the backdrop to the deal between Ericsson and Qualcomm in March 1999, which resulted in (1) extensive cross-licensing of patents, (2) Ericsson's acquisition of Qualcomm's network manufacturing operations in United States, and (3) an agreement on how CDMA and W-CDMA should constitute the core of a family of interoperable 3G standards backed by the ITU. According to congressional sources, Trans-Atlantic Business Dialogue, a private industry forum for coordination of European and US business interests, provided the venue for the final rounds of negotiations between the parties.

5. The following draws on Glimstedt 2001.

6. Although the independence of Microsoft is routinely questioned by analysts (Shosteck 1999), the selection of an independent browser (Opera) for Symbian's reference products indicates the parties' ambition to remain outside Microsoft's control.