THE ECONOMIC IMPACT OF THIRD-GENERATION WIRELESS TECHNOLOGY

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EXECUTIVE SUMMARY

"Third-generation" (3G) wireless technology provides high-speed mobile access to the Internet and other communications networks. This technology offers significant benefits to consumers and telecommunications providers and complementary benefits to the U.S. economy. It is urgent that the United States follow other advanced countries in making adequate spectrum available for 3G applications. This report documents the likely benefits of 3G technology and explains why adequate spectrum is needed to provide these services efficiently. The key points are these:

- **Telecommunications and the Internet are among the most important sectors of the New Economy.** Telecommunications represented 3 percent of GDP in 1998, having grown at a 7 percent annual rate over the previous 10 years. Wireless carriers employ over 150,000 people in the United States and generate $44 billion in annual revenue. At the end of 1999, the United States had 86 million wireless subscribers; today that number exceeds 100 million. By year-end 2000 there will be over 600 million wireless subscribers worldwide. The Internet has spawned thousands of companies, as entrepreneurs have raced to provide content, commerce, and new services to consumers and firms. Consumers purchased $5.5 billion of goods and services over the Internet during the second quarter of 2000 alone. Sales over the Internet between businesses are estimated to hit $251 billion in 2000, up from only $43 billion in 1998. The most successful Internet startup companies have created hundreds of billions of dollars of market value.

- **Third-generation wireless technology combines two powerful innovations: wireless communications and the Internet.** Today's wireless devices are designed to transmit voice and brief text messages and cannot handle digital multimedia and other high-bandwidth Internet content. 3G devices, by contrast, provide high-speed mobile connections to the Internet and other communications networks, giving users full access to the rich content and commercial possibilities of the "information superhighway."

- **This new technology promises substantial benefits to consumers, producers, and the economy as a whole.** The annual consumer benefit from today's wireless telephone services is estimated at $53–$111 billion. The consumer benefits from 3G services will likely be of this order of magnitude. Providers also stand to reap substantial gains. Recently completed 3G spectrum auctions in Europe have raised $150–$600 per capita. These auction revenues indicate the expected producer benefits from operating 3G licenses.

- **To provide 3G applications most efficiently, adequate spectrum must be made available for commercial use.** In telecommunications, the most important scarce resource is spectrum. While current U.S. carriers can develop 3G applications using currently allocated spectrum, the allocation of additional spectrum could lower the cost of bringing 3G to U.S. consumers. However, parts of the spectrum being considered for 3G applications are already in use.

- **Delays in introducing 3G products and services can be costly.** Besides the foregone benefits to 3G consumers and providers, delay may be harmful to U.S. firms seeking to provide complementary products and services. Early investments are necessary to develop a vibrant U.S. industry for 3G applications. Knowledge spillovers, which are important in high-tech industries, tend to be geographically localized. Finland, which allocated its 3G spectrum licenses in March 1999, has already taken the lead in developing an industry to provide mobile applications.

- **Government policy in allocating spectrum must weigh carefully all benefits and costs.** Consumer benefits, provider profits, and the potential benefits of industry leadership should be weighed against the possible costs of moving incumbent users to ensure that adequate spectrum is made available for 3G applications.

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1. INTRODUCTION

The U.S. economy has performed remarkably over the last several years. Productivity growth has accelerated from about 1½ percent per year from 1973 to 1995 to about 3 percent per year from 1995 to 1999. This acceleration is heavily related to technology, both the investment in IT hardware and software and the extraordinary productivity of the industries producing the technology. Between January 1993 and September 2000 the total market value of firms on the NYSE and NASDAQ increased by 400 percent. Knowledge and intangible capital are increasingly important: R&D spending has soared, along with the numbers of patents.

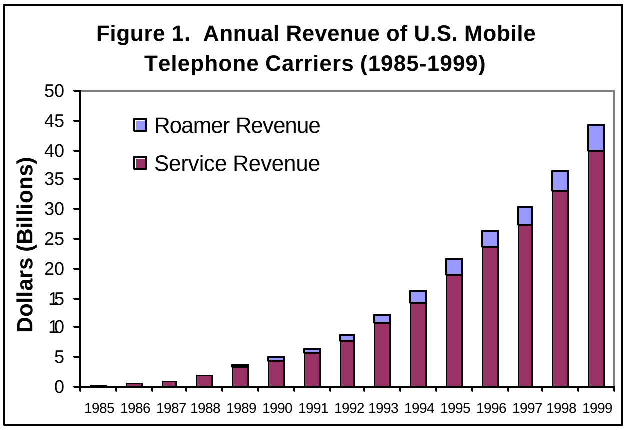
At the heart of this "New Economy" lie a series of dramatic technological innovations. Advances in computing, information storage, and data transmission have reduced costs, created new markets, and expanded existing markets. These innovations came from a remarkable flourishing of entrepreneurship, often concentrated in Silicon Valley and other high-technology corridors in the United States. Firms and other organizations have moved quickly to exploit the opportunities provided by these new technologies. Firms are spending billions on enterprise systems, sophisticated software and hardware packages that integrate ordering, procurement, inventory, finance, and human resources. Consumers are offered an increasing array of goods and services for communication, entertainment, shopping, education, and other activities. In some industries, firms are taking advantage of technological improvements by expanding and consolidating their operations to reduce costs; in other industries, startup companies are using technology to create new products and markets. These changes explain a large portion of recent U.S. productivity gains.

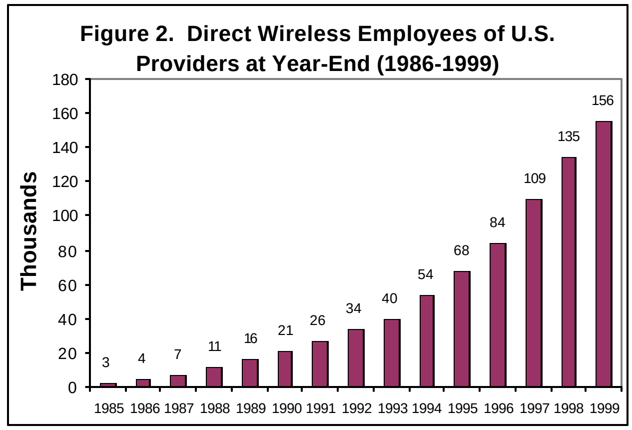
The telecommunications sector has been a primary beneficiary of these technological advances. Radical improvements in computing power, along with healthy competition in the communications sector, have reduced the costs of communications dramatically. As costs have fallen, and capabilities have expanded, the wireless telephone and pager markets have expanded rapidly. Wireless carriers employ more than 150,000 people in the United States and generate over $44 billion in annual revenue (see Figures 1 and 2). Mobile-phone penetration in the United States now exceeds 35 percent. Today, the number of U.S. wireless subscribers exceeds 100 million. Experts estimate that by year-end 2000, there will be over 600 million wireless subscribers worldwide.[1]

The Internet is also transforming the ways individuals and organizations communicate and manage information. Nearly 54 percent of U.S. households have access to the Internet and surveys indicate that over 50 percent of U.S. businesses will sell products online in the year 2000.[2] Traditional firms and new firms alike are competing to deliver consumers higher-speed access to the Internet and more sophisticated services for this new medium. Internet sales to

[1] Cellular Telephone Industry Association (www.wow-com.com); Electronic Trend Publications, "The Worldwide Wireless Network," July 2000.

[2] NUA Internet, "How Many Online," September 2000 (www.nua.ie/surveys/how_many_online); Internet Economy Indicators, October 6, 2000 (www.internetindicators.com/facts.html).





Source: CTIA Semi-Annual Wireless Survey, 1999.

consumers—so-called B2C ecommerce—were $5.5 billion for the second quarter of 2000 alone.[3] Sales over the Internet between businesses (B2B) have increased even more dramatically. B2B sales are estimated to hit $251 billion in 2000, up from only $43 billion in 1998.[4]

The latest advance in mobile communications technology, "third-generation" (3G) wireless, will be capable of combining the powerful technologies of wireless communications and the Internet.[5] Today's wireless service, used for analog and digital cellular phones and pagers, was designed to transmit voice and brief text messages. These devices transfer data at relatively slow speeds, around 9.6 kilobits per second (kbps)[6]—significantly slower than conventional 56 kbps dial-up modems. 3G devices, by contrast, will transmit data at speeds between 144 kbps and 2 megabits per second, about as fast as a cable modem or digital subscriber line. Increasing the data-transfer rate allows mobile phones, hand-held computers, and other products to become multimedia access devices. Further, the international standards that have been developed for 3G allow global roaming with a single device.[7]

The market for high-speed, or "broadband," wireless access has tremendous potential. Broadband applications such as streaming audio and video are already becoming increasingly popular on the Internet, as evidenced by the rapid growth of high-speed cable and DSL modems.

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[3] U.S. Department of Commerce, Press Release, August 31, 2000.
[4] Forrester Research, Inc., "Resizing Online Business Trade," November 1998.
[5] First-generation (1G) wireless phones, introduced in the United States in 1983, use analog technology to transmit voice calls. Second-generation (2G) wireless phones use digital technology and were introduced into widespread commercial service in 1996 following the FCC's auction of PCS spectrum licenses in 1994 and 1995. While both technologies are currently used in the United States, since 1999 the number of 2G subscribers has exceeded the number of 1G subscribers. Judy Berck, "A Brief History of PCS (Digital Cellular) Technology Development in the United States," April 1998 (www.pcsdata.com/history.htm); Federal Communications Commission, *Fifth Competition Report*, August 18, 2000.
[6] Competitive Intelligence Publications, "3G Mobile: Future Markets," Research Report #103, Chapter 2, May 2000 (www.electronics.ca/reports/global/cit103.html).
[7] Throughout this document we generally use "3G" to refer to the entire class of high-speed wireless communications technologies. Other writers distinguish between 3G and an intermediary set of technologies, "2.5G," which offer mobile data services at rates between 56 kbps and 144 kbps, the speeds of conventional modems and ISDN lines, respectively. Both 3G and 2.5G will offer substantial upgrades to the existing mobile data transmission capabilities, and development of both technologies benefit from allocation of additional spectrum.

As these and other applications multiply, wireless devices will require 3G capabilities to access existing Internet materials, along with new Internet sites optimized for mobile access. The bandwidth provided by 3G facilitates secure mobile commerce, real-time videoconferencing, online gaming, and other, not-yet-imagined applications. The 3G technology also gives the user an "always-on" mobile Internet connection.

More importantly, the development of 3G technologies will encourage investment and innovation in complementary services such as specialized content and billing and payment systems. The Internet has spawned thousands of companies as entrepreneurs have raced to provide content, products and new services to consumers and to firms. The most successful of these startup companies have created hundreds of billions of dollars of market value and have impacted the economy dramatically. The combined market capitalization of 15 leading internet applications companies—Yahoo, Verisign, eBay, Inktomi, Commerce One, Amazon, CMGI, Infospace, Vignette, Lycos, Internet Capital Group, Akamai, Real Networks, Healtheon/WebMD, and Cacheflow—was $193 billion on October 2, 2000. An appropriate allocation of commercial spectrum licenses and other policies that favor investment have the potential to unleash a wave of innovation in 3G applications. The impact of these yet-to-be-developed applications is impossible to predict precisely, but history suggests that they may be profound.

Several other countries, including Finland, Japan, Spain, the U.K., the Netherlands, and Germany, have already allocated new spectrum specifically for high-speed wireless devices and applications.[8] It is urgent that the United States follow other advanced countries in making adequate spectrum available for 3G applications. As explained below, delay is costly.

This report documents the likely benefits of 3G technology and explains why an adequate supply of commercial spectrum licenses is needed to provide these services efficiently. In general, benefits of technological innovation accrue to the consumers who use the new technology, the producers who provide it, and other firms that supply complementary goods and services. Introducing new technologies is also costly: research and development must be funded, existing technologies must be modified or abandoned, and new capital must be provided. In telecommunications, the most important scarce resource is spectrum. Commercial spectrum licenses allow firms to transmit data over a particular frequency in a particular area. To provide high-speed and other wireless applications efficiently, spectrum must be allocated to its highest valued use. This may require a reallocation of spectrum.

2. Benefits from New Technologies

Technological innovation does not occur in a vacuum; it requires a particular structure of incentives and institutions. Firms' demands for new technologies are derived from consumers' demands for new products and services. Those firms that quickly learn to satisfy consumer needs stand to reap substantial gains, particularly in markets where network effects and first-mover advantages are important. There can also be significant spillover benefits to firms that provide complementary goods and services.

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[8] European regulators have mandated that newly allocated spectrum be used only for 3G technology. U.S. law generally permits carriers to use their allocated spectrum for a variety of technologies.

A. Benefits to Consumers

The potential consumer benefits from introducing 3G technology are substantial. While it is impossible to predict the precise demand for any future product, one can see the order of magnitude by studying the introduction of related technologies. For instance, a well-known study attempts to measure the "consumer surplus" created by the introduction of analog cellular service (1G).[9] Economists define consumer surplus as the difference between the prices consumers actually pay and the maximum amounts they would be willing to pay for a particular good or service. Consumer surplus is thus a measure of the net benefits to consumers created by a particular market. Using data on price and number of subscribers in the top 30 cellular phone markets between 1989 and 1993, the study estimates that consumer surplus generated by the introduction of the cellular telephone was in the range of $31 billion to $50 billion *per year* in constant 1994 dollars.[10] In light of such potential benefits, delays in the introduction of these services can be extremely costly to consumers.

How have the benefits from the introduction of digital wireless (2G) compared with the benefits of (1G)? Updated calculations estimate that the combined consumer surplus from 1G and 2G was between $53 and $111 billion in 1999.[11] This new consumer surplus is the product of several factors. First, to the extent that consumers value the quality improvements such as improved clarity provided by digital wireless, their willingness to pay rises and overall demand increases. Second, because digital wireless uses spectrum more efficiently, providers can offer the same service at lower cost. Consumers benefit to the extent that providers pass along these gains through price reductions. Third, allocating new spectrum for digital wireless introduced new competitors into the market. The average number of competitors in major metropolitan areas has increased from two to more than four. Increased competition pressures firms to lower costs, ensuring that the cost savings from technological improvement are passed on to consumers.

The combined results have been dramatic, as shown in the figures below. Following the allocation of new spectrum for digital services starting in 1994, total wireless use has risen sharply, prices have fallen rapidly, and subscribership has increased substantially. As shown in Figure 3, total minutes of use by U.S. wireless customers more than tripled from 1995 to 1999. During the same period, consumers' fully weighted cost per minute dropped by nearly 50 percent (Figure 4), and average local monthly prices fell from $51 in 1995 to $41 in 1999 (Figure 5). In 1999, more than half of all mobile subscribers were using digital technology (Figure 6).

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[9] Jerry A. Hausman, "Valuing the Effect of Regulation on New Services in Telecommunications," *Brookings Papers on Economic Activity, Microeconomics* (1997), pp. 1–37.

[10] An earlier study concluded that the total consumer welfare loss from the 10-year delay in licensing the cellular (1G) spectrum at $86 billion in 1991, or 2 percent of GDP in 1983 when the licensing finally occurred. J. Rohlfs, C. L. Jackson, and T. E. Kelley, "Estimate of the Loss to the United States Caused by the FCC's Delay in Licensing Cellular Telecommunications," National Economic Research Associates Report (1991).

[11] Jerry A. Hausman, "Mobile Telephone," *Handbook of Telecommunications Economics,* forthcoming.

Figure 3. Total Minutes of Use for U.S. Wireless Subscribers (1991-1999)

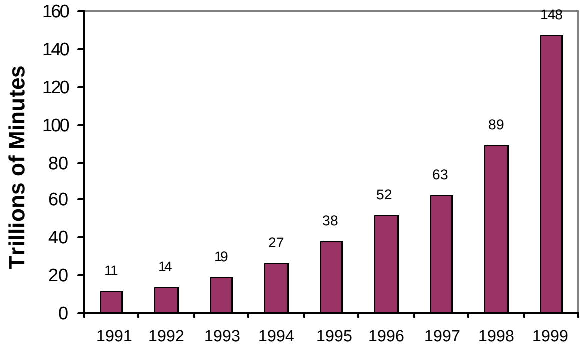


Figure 4. Estimated Total Expense Per Minute for All Calls Made by U.S. Wireless Subscribers (1991-1999)

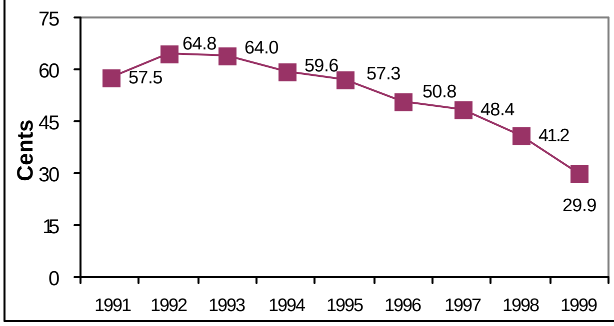


Figure 5. Average Local Monthly Bill for U.S. Wireless Subscribers (1988-1999)

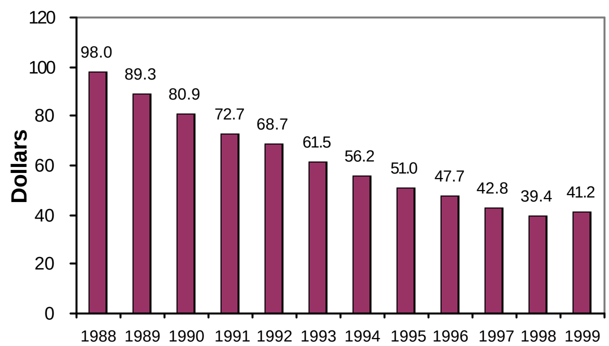
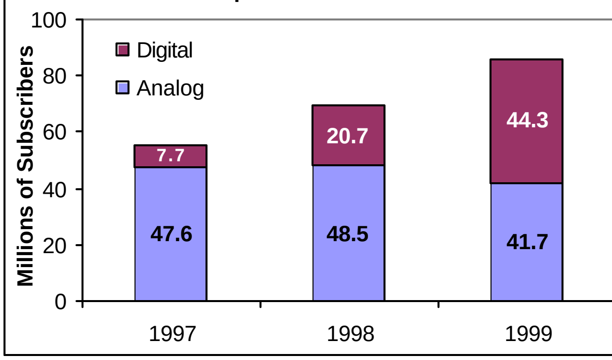


Figure 6. U.S. Analog and Digital Mobile Telephone Subscribers



Source: CTIA Semi-Annual Wireless Survey, December 1999; FCC, *Fifth Report on Commercial Mobile Services*, August 18, 2000.

Moreover, digital wireless has allowed new services, such as voice messaging, text messaging, and caller ID, to be integrated into mobile phones. The introduction of voice messaging services for basic telephony created an estimated $1.3 billion in consumer surplus in constant 1994 dollars.[12] This technology, which is included in the service provided to many digital wireless subscribers, may be even more valuable to consumers when combined with the freedom that mobility provides.[13]

Consumers in other countries are already enjoying wireless Internet applications using 2G technology. In Japan, for example, Nippon Telegraph and Telephone's DoCoMo subsidiary has launched a service called i-mode. Over 10 million Japanese customers have subscribed. Subscribers use an i-mode phone that can send and receive e-mail as well as access websites optimized for tiny screens. With a thumb-controlled joystick, subscribers can tap into online news, browse through restaurant guides, buy airline tickets, and trade stocks. Using another technology called wireless application protocol (WAP), several European firms have turned phones into

[12] Hausman, "Valuing the Effect of Regulation."

[13] Hausman, "Telecommunications: Building the Infrastructure for Value Creation," in R. Nolan and S. Bradley, eds., *Sense and Respond* (Cambridge, Mass.: Harvard Business School Press, 1998), provides a method to estimate an upper and lower bound for consumer surplus for other goods using limited data, and he applies this method to internet access.

electronic wallets, allowing customers to pay for goods and services via their mobile phone bill rather than via credit cards or cash. According to recent news reports, Finnish consumers can make vending machine purchases, pay rent, phone, or electricity bills, and pay for parking spaces with their mobile phones.

Possible 3G applications are even more impressive. According to the International Telecommunication Union (ITU), 3G devices will be compact enough to fit into a pocket or handbag and will integrate the functions of a range of existing devices. The ITU suggests that the 3G device

> will function as a phone, a computer, a television, a pager, a videoconferencing center, a newspaper, a diary and even a credit card. [It will] support not only voice communications, but also real-time video and full-scale multimedia via a screen that can be pulled-out and flexible. It will also function as a portable address book and agenda, containing all the information about meetings and contacts and able to remind you automatically before an important appointment or automatically connect to an audio or videoconference at a specified time. It will automatically search the Internet for relevant news and information on pre-selected subjects, book your next holiday for you on-line, and download a bedtime story for your child, complete with moving pictures. It will even be able to pay for goods when you shop via wireless electronic funds transfer. In short, the new mobile handset will become the single, indispensable "life tool," carried everywhere by everyone, just like a wallet or purse is today.[14]

B. Benefits to Providers

In a dynamic, rivalrous market such as the U.S. telecommunications market, firms compete aggressively to provide new goods and services to consumers. First-mover advantages can be important in many telecommunications markets, so the profits from establishing an early lead in these markets can be substantial. Of course, the precise value to U.S. operators of additional spectrum for 3G technology is uncertain. A simple analysis of the existing wireless industry indicates that, in the aggregate, U.S. wireless operators earned $238 million of revenue per MHz under the existing spectrum allocation in 1999. At similar rates, an additional 150 MHz of spectrum could bring an additional $35.7 billion of service revenues per year, depending on what services are provided. Mobile data technology may also facilitate new business models for providers, as revenues from advertising, licensing content and applications providers, transaction processing, and billing may augment or replace the traditional fee-for-service (subscription) model.

A second, more precise measure of the order of magnitude of provider benefits is given by the recently completed auctions for 3G spectrum in Europe. Auctions in Germany and the U.K. raised $46 and $35 billion, respectively, representing total payments in excess of $500 per inhabitant in these two countries. An auction in the Netherlands raised about $2.5 billion, or $150 per inhabitant. Table 1 describes the results of these auctions.

[14] International Telecommunication Union, "The Next Generation of Mobile Communications," October 10, 2000 (http://www.itu.int/imt/what_is/3rdgen/index.html).

Table 1. Comparison of European Spectrum Auctions

	UK	Germany	Netherlands
Start Date	3/2000	7/31/2000	7/10/2000
End Date	4/27/2000	8/17/2000	7/24/2000
Net Proceeds	$35.4 billion (£22.5)	$46.2 billion (98.8 DM)	$2.5 billion
Net Proceeds per Capita	$599	$563	$158.4
Number of Licenses	5*	6**	5***
Fees Paid by Winners	$7.1 billion	$7.7 billion	$0.5 billion
Winning Firms (*parent company country of origin*)	• Vodafone Airtouch *(UK)* • BT Cellnet *(UK)* • Orange *(France Telecom)* • One2One *(Deutsche Telekom)* • Telesystem International Wireless *(Teleglobe – Canada)*	• Deutsche Telekom *(Germany)* • Viag Telekom *(British Telecom)* • Mannesmann *(Vodafone)* • Telefonica / Sonera *(Spain / Finland)* • E-Plus *(Netherlands)* • MobilCom *(Germany)* / France Telecom	• Libertel *(Netherlands)* • KPN Mobile *(Netherlands)* • Dutchtone *(Netherlands)* • Telfort *(British Telecom)* • 3G Blue consortium *(Tele Danmark / Deutsche Telecom / Belgacom)*

Source: UMTS Forum; population figures from *Statistical Abstract of the United States, 1999.* All figures converted to current U.S. dollars.
*National licenses
**Each operator purchased 2 sets of 2x5 MHz licenses. The result is 6 national licenses.
***National licenses

The most a company will be willing to pay for a spectrum license is the present value of the future profits (after tax) it expects to make from using this license.[15,16] In a competitive auction with multiple bidders, the price paid by each winning firm will come close to, but will not exceed, this willingness to pay.[17] Using the data from Table 1, this suggests that winners of the German auctions, for example, expect to earn at least $7.7 billion in present value of profits from operating 3G licenses in Germany. Annuitizing this present value at a 15 percent rate suggests

[15] The present value of expected future profits is the sum of all expected future profits discounted by the project's cost of capital. Future profits are all cash flows from operating the service less operating costs and additional investments required to bring the service online.
[16] A more refined view also considers the value of profits foregone if the firm does not win the license. Since 3G is partly a substitute for existing services, incumbent firms must consider their expected reduction in profits from 1G and 2G services in the case in which they do operate a 3G license and in the case in which they do not operate a 3G license. For example, incumbents without the new technology may lose customers to entrants that provide the newer services. In theory, this can increase a firm's willingness to pay for the license (and will depend on its existing market share with the current technology). By contrast, new entrants consider only their expected future profits from operating using the license.
[17] It is possible for a firm to overpay if its expectation and that of other bidders is too optimistic.

that each of the six winning firms expects future after-tax profits in excess of $1 billion per year.[18]

Will 3G be as profitable for U.S. companies? While these auction results suggest that European firms have high expectations for 3G, European and the U.S wireless markets differ in important ways. First, three of the bands under consideration for 3G applications in the United States—the 806–960 MHz, 1710–1850 MHz, and 2500–2690 MHz bands—are currently used by analog cellular phone providers, the Department of Defense, fixed wireless providers, satellite broadcasters, school systems, and private video teleconferences. The U.K., Germany, and the Netherlands, by contrast, did not face significant incumbency problems when spectrum was auctioned for 3G applications.

Moreover, wireless Internet access may be less popular here than abroad because U.S. prices for wireline Internet access are already low. The average monthly U.S. price for 30 hours of Internet access at off-peak times is $22; the average monthly price for all OECD countries is $35.[19] To the extent that wireless and wireline Internet access are substitutes, these price differences could reduce the potential market for 3G services in the United States. On the other hand, wireless and wireline Internet access may be complements, and providers could choose to provide combined service. Of course, firms in the United States and abroad may change their pricing strategies for wireline Internet access once 3G services become available.

Finally, firms' expectations about the profitability of 3G may change. Carriers will learn more about the technology and about consumer demand between now and a U.S. auction. If 3G applications developed within the next 2 years turn out to be highly successful, carriers may decide that U.S. licenses are more valuable than previously thought. Firms that win 3G licenses in other countries may also view U.S. licenses as more valuable if bargaining power with equipment suppliers and learning-by-doing decreases anticipated costs. Additionally, as information about 3G emerges, financial markets' willingness to finance license purchases may change. Early evidence suggests that financial markets are not as willing to finance European 3G licenses as firms had anticipated. After bidding an average of $7.7 billion for German UMTS licenses, companies including Deutsche Telekom have seen their credit ratings fall. France Telecom's credit rating was lowered from AA– to A after it supported winning bidders in the U.K. and Germany. (Of course, these downgrades may reflect other factors as well.) A ratings downgrade of this sort typically increases a firm's cost of borrowing significantly. Macroeconomic changes, too, may have an impact on firms' cost of borrowing. A significant increase in U.S. interest rates, for example, would likely depress firms' bids.

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[18] Besides the cost of the license, firms will have additional capital expenditures to operate their networks in Germany. Cash flow from operations must cover the expense for this as well.

[19] OECD, Directorate of Science Technology and Industry, "Internet Access Price Comparison," September 21, 2000 (www.oecd.org/dsti/sti/it/cm/).

C. Benefits to U.S. Industry

Besides the direct benefits to consumers and 3G providers, the introduction of this technology could unleash a wave of secondary innovations in related goods and services, and to foster the development of new "technology corridors" such as Silicon Valley. The spillover benefits to the U.S economy could be significant.

The emergence of the Internet economy, particularly in the United States, shows how technological innovation can generate large social returns. Communications protocols such as TCP/IP and HTML provide a standard platform for exchanging information between computers. Opening a new platform stimulates investment not only for the provision of the necessary hardware and software, but also for applications and content delivered over that platform. Widespread diffusion of these communications standards has given rise to entire industries devoted to providing Internet content and commercial services to consumers and businesses. Startup companies, along with established retailers and information services, have created hundreds of billions of dollars of shareholder wealth through Internet-related activities. Employment in several IT sectors more than doubled between 1993 and 1999.[20] These investments in IT and complementary services have been major contributors to productivity improvements over the latter half of the 1990s.[21]

Importantly, the sectors producing these technological innovations often cluster geographically. One reason is that knowledge spillovers between firms, and spillovers between firms and academic institutions, are particularly significant in high-technology sectors. A recent study of knowledge flows used patent citations to show that these spillovers tend to be geographically localized, even after controlling for pre-existing research activity.[22] In the technology sector much of the relevant knowledge is "tacit," rather than explicit, making close social ties (between entrepreneurs and venture capitalists, for example) all the more important.[23] Investigators have shown that spatial concentration of innovations was significantly higher in industries in which knowledge generation—as measured by industry R&D/sales, the use of skilled labor, and the importance of academic research—was particularly important.[24] In short, location matters.

[20] U.S. Department of Labor, Bureau of Labor Statistics, "National Employment, Hours, and Earnings," series EEU00500001 and EEU80737001.

[21] Dale Jorgenson and Kevin Stiroh, "Raising the Speed Limit: US Economic Growth in the Information Age," Working Paper, Department of Economics, Harvard University (May 2000); Stephen Oliner and Daniel Sichel, "The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?" Working Paper, Federal Reserve Board (February 2000).

[22] Adam B. Jaffe, Manuel Trajtenberg, and Rebecca Henderson, "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations," *Quarterly Journal of Economics,* Vol. 108 (1993), pp. 577–98.

[23] Gunnar Eliasson,, "Business Competence, Organizational Learning, and Economic Growth: Establishing the Smith-Schumpeter-Wicksell Connection," in F. M. Scherer and M. Perman, eds., *Entrepreneurship, Technological Innovation, and Economic Growth: Studies in the Schumpeterian Tradition* (Ann Arbor: University of Michigan Press, 1992); Jacqueline Senker, "Tacit Knowledge and Models of Innovation," *Industrial and Corporate Change*, Vol. 4 (1995), pp. 425–77.

[24] David B. Audretsch and M. P. Feldman, "R&D Spillovers and the Geography of Innovation and Production," *American Economic Review,* Vol. 86 (1996), pp. 630–40.

Besides this academic work on spillovers, strong anecdotal evidence suggests that location can be important in the early-stages of high technology industries. Silicon Valley is the most famous example. Moreover, in Finland—which allocated its 3G spectrum in March 1999—a vibrant cluster of startups developing commercial applications for 3G and existing digital wireless technologies has emerged. Nearly 3,000 companies in Finland are involved in telecommunications and other IT industries, including work on wireless technologies and applications ranging from bill-payment systems to wireless portals and entertainment. Recently, major companies such as Hewlett-Packard have chosen to base their wireless applications development programs there, where wireless penetration is the highest among the OECD economies. (See Appendix 2 for a description of the Finnish wireless cluster.)

Economic clusters such as these play a major role in advanced economies.[25] Firms within economic clusters are often able to perceive new customer needs more clearly and more rapidly. According to one important study on economic clusters, "cluster participation also offers advantages in perceiving new technological, operating, or delivery possibilities."[26] Moreover, new business formation occurs more readily in economic clusters, because the barriers to entry are lower there than elsewhere. The required assets, skills, inputs, and staff are readily available at the cluster location and are more easily assembled there.[27]

Finally, it should be noted that first-mover advantages are particularly important in markets with network externalities.[28] Many Internet markets display strong network externalities,[29] and wireless Internet markets may be subject to the same effects. In short, to promote a domestic cluster of internationally competitive wireless firms, it is essential that adequate spectrum be made available for commercial use.

3. THE NEED FOR ADEQUATE SPECTRUM

If the benefits to firms from operating 3G are so large, why aren't U.S. mobile operators and owners of other spectrum already scrambling to offer this service? No law prevents providers from using their currently licensed spectrum for mobile data services such as 3G. In principle, some (or all) of the roughly 200 MHz currently in use for wireless telephone technologies could be converted by its owners to provide 3G service. However, there are several reasons why converting currently used spectrum to this new technology may be costly.

[25] Michael E. Porter, "Location, Competition, and Economic Development: Local Clusters in a Global Economy," *Economic Development Journal*, Vol. 14 (2000), pp. 15–34. Porter defines economic clusters as "geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions (e.g., universities, standards agencies, trade associations) in a particular field that compete but also cooperate." See also Porter, *The Competitive Advantage of Nations* (New York: The Free Press, 1990).

[26] Porter, "Location, Competition, and Economic Development."

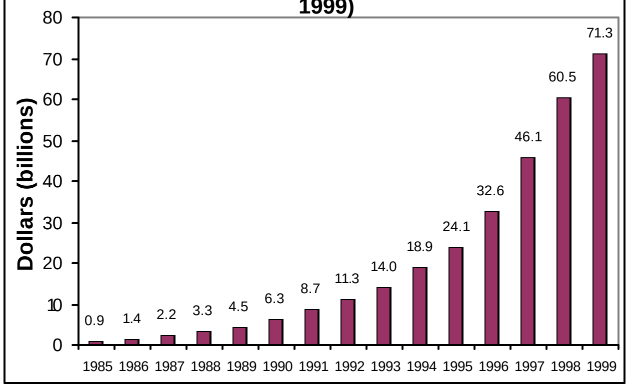
[27] *Ibid.*

[28] Michael L. Katz and Carl Shapiro, "Systems Competition and Network Effects," *Journal of Economic Perspectives*, Vol. 8 (1994), pp. 93–115.

[29] For example, consider this explanation from CEO Meg Whitman for eBay's dominance of the online-auction business: "We have the largest marketplace by far. That does matter because the sellers want to be where the buyers are and the buyers want to be where the sellers are." *Wall Street Journal*, November 22, 1999.

First, as bandwidth becomes increasingly scarce, the costs and prices for current mobile phone services such as voice will increase. Second, much of the existing capital stock would have to be replaced. Through the end of 1999, wireless carriers had invested over $70 billion in capital equipment (see Figure 7). A carrier that tried to use its existing spectrum for 3G would find some fraction of its current capital stock obsolete. Third, the allocation of new spectrum licenses could lower the cost of entry into the wireless market, reducing costs by increasing competition.

Figure 7. Cumulative Capital Investment of U.S. Wireless Carriers by Year-End (1985-1999)



Moreover, physical capacity limitations may set in with wireless technology before the consumer demand for additional bandwidth is exhausted. Although technological improvements have increased the amount of data that can be transmitted per unit of spectrum, transmitting more wireless data will, at some point, require allocation of more spectrum for these services.[30]

Given these considerations, the provision of additional spectrum for high-speed applications should be considered a cost reduction for mobile data services. Depending on competitive conditions, this cost reduction could lead to substantially lower prices and higher quantities for consumers.

Uncertainty itself can also cause firms to delay investments and hinder the diffusion of new technologies.[31] In the current environment, U.S. firms face three types of uncertainty: regulatory, technical, and business. Whether and when the FCC will allocate new spectrum licenses are the key elements of regulatory uncertainty. If firms are required to use existing spectrum to introduce 3G services, technical uncertainty will be high, because equipment manufacturers and service providers must learn to squeeze both existing and 3G applications into existing bandwidth. Customer demand for new services is the major source of business uncertainty. Because the demand for mobile data services will be dependent on the applications developed for it (i.e., the software that will run on the 3G hardware), the timing of customer demand must also be considered. The decisions made by software developers will depend on their estimates of the size of the user base. If developers believe that the user base will be small or slow to develop—because of high service prices or because service providers themselves will delay investments—they will choose to develop fewer applications. This may, in turn, stall the development and diffusion of the technology.[32]

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[30] Splitting cells requires very expensing additional network infrastructure, especially in congested areas (Berck, "A Brief History of PCS"). Goldman Sachs (Wireless Data, 2000) points out that in large metro areas, carriers are already hitting capacity constraints. This allows them to sustain higher prices.

[31] Michael E. Porter and A. Michael Spence, "The Capacity Expansion Process in a Growing Oligopoly: The Case of Corn Wet Milling," in J. McCall, ed., *The Economics of Information and Uncertainty* (Chicago: University of Chicago Press, 1982).

[32] Katz and Shapiro, "Systems Competition and Network Effects."

In short, while some mobile data services would probably be forthcoming without the provision of additional commercial spectrum licenses, one can assume that the amount would be dramatically lower (at significantly higher prices) without adequate spectrum.

4. COSTS OF DELAY

The process of allocating additional U.S. spectrum for 3G applications is complicated by the presence of incumbent users. The costs borne by these incumbents must be figured into any calculation of costs and benefits. Nonetheless, the potential benefits from the allocation of additional spectrum that have been documented in this paper are substantial. Each year of delay in introducing 3G will deprive consumers of the surplus that technology will generate. Producers, of course, will also lose the potential profits from providing 3G devices and applications. Finally, the U.S. Treasury will lose the interest on delayed auction revenues, which could be substantial.

Perhaps the most important cost of delay is the forgone benefits from the creation of internationally competitive industry clusters dedicated to 3G products and services. As discussed above, these clusters are already emerging in Finland and elsewhere. The most important providers of wireline Internet services—firms like AOL, Amazon.com, Yahoo!, and eBay—are located in the United States. For U.S. firms to develop similar leadership in wireless technologies, it is essential that the supporting institutions be developed as quickly as possible.

5. CONCLUSION

3G applications promise substantial benefits. In the United States, however, parts of the spectrum suitable for 3G applications are already in use. In judging the costs of delaying 3G development, it is important to take into account not only the expected revenues from auctioning spectrum licenses, but also the expected consumer benefits. These benefits are likely to be substantial—on the order of tens of billions of dollars per year. Further, greater delay in providing additional spectrum licenses for high-speed applications reduces the likelihood that U.S. industry will take the lead in developing wireless technology and applications.

APPENDIX 1. CHARTS AND TABLES

Table A-1. Schedule of Allocations of Commercial Licenses to 3G Spectrum

Country	Date Scheduled Month	Year	Completed?	Type	Comment
Finland	Mar	1999	yes	Beauty Contest	• 4 national licenses awarded
Spain	Mar	2000	yes	Beauty Contest	• 4 national licenses
United Kingdom	Apr	2000	yes	Auction	• 5 national licenses awarded • $35 billion
Japan	Jun	2000	yes	Beauty Contest	• 3 licenses awarded; service to commence 5/01
The Netherlands	Jul	2000	yes	Auction	• 5 national licenses • $2.5 billion
New Zealand	Jul	2000	no	Auction	• 4 national licenses
Germany	Jul	2000	yes	Auction	• 6 national licenses • $45 billion
France	Sep	2000	no	Beauty Contest	• 4 national licenses • fixed cost of FFr 32.5 billion ($4 billion) per license
Sweden	Nov	2000	yes	Beauty Contest	• 4 national licenses
Italy	Nov	2000	no	Hybrid Auction / Beauty Contest	
South Korea	Year end	2000	no	Beauty Contest	
Singapore	Year-end	2000	no	Hybrid Auction / Beauty Contest	
Australia	Jan	2001	no	Auction	
Taiwan	Early	2001	no	undecided	
U.S.	Sep	2002	no	auction	

Source: UMTS Forum, August 18, 2000 (www.umts-forum.org).

Note: In a beauty contest, license winners are generally chosen by government regulators on the basis of firms' competing business plans. Firms' business plans include descriptions of service offerings, pricing, geographic coverage, and timing of new technology introduction.

Table A-2. Wireless Subscribers as a Fraction of the Population in G7 Countries and Scandinavia

	1995	1998	1999
Finland	19.9%	58.0%	65.0%
Norway	22.6	48.6	61.8
Sweden	22.8	46.5	57.6
Italy	6.9	35.8	52.5
Japan	8.2	37.7	44.9
UK	9.8	25.6	40.3
France	2.5	19.1	34.9
U.S.	**11.8**	**25.5**	**31.5**
Germany	4.6	16.9	28.6
Canada	8.8	17.8	22.7

Source: OECD Telecommunications Database. By October 2000 the U.S. figure exceeded 35 percent.

Table A-3. Wireless Subscribers, Internet Access, and Wireless Internet Access as a Fraction of the Population in G7 Countries and Scandinavia

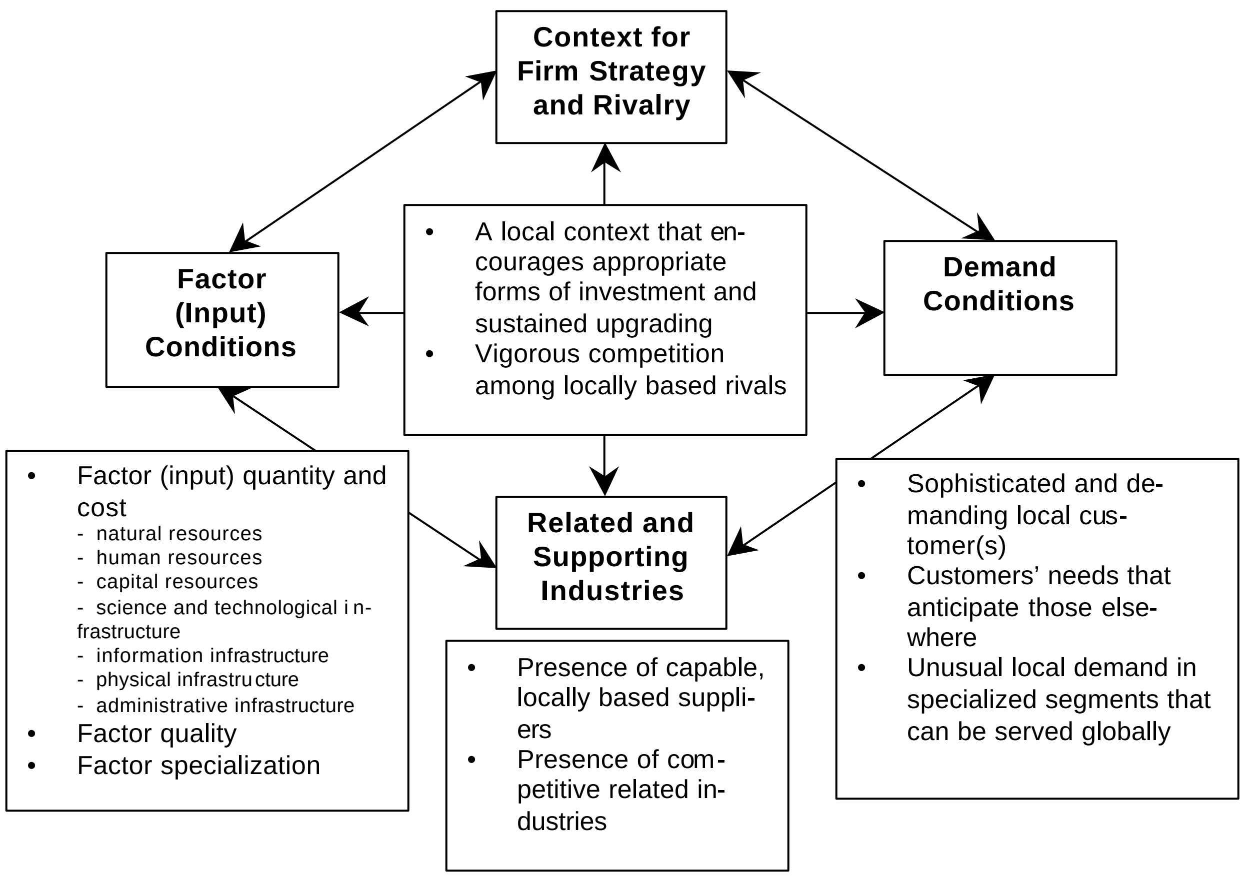
	Mobile phones, year-end 1999	Internet access, mid-year 2000	Wireless Internet subscribers, 2000 estimates
Finland	65.0%	42.6	3.7%
Norway	61.8	49.4	3.4
Sweden	57.6	50.3	3.5
Italy	52.5	19.6	2.1
Japan	44.9	20.8	7.9 *
UK	40.3	32.7	1.4
France	34.9	11.0	1.5
U.S.	**31.5**	**49.8**	**1.3**
Germany	28.6	18.0	1.2
Canada	22.7	41.8	N/A

Sources: 1999 OECD Telecommunications Database; Nielsen Netratings, September 7, 2000; International Data Corporation; Statistical Abstracts of the United States, 1999; Forrester Research, Inc., “Europe's Mobile Internet Opens Up,” December 1999; Goldman Sachs; (*) Estimates for Japan are from press releases claiming that i-mode has 10 million subscribers.

APPENDIX 2. CASE STUDY OF FINNISH WIRELESS CLUSTER

Michael Porter offers a framework for analyzing the sources of competitive advantage in geographically concentrated industry clusters such as the California wine industry, the Dutch flower industry, or Silicon Valley's high-tech industry.[33] His framework identifies 4 complementary factors that promote "locational competitive advantage," which is characterized by above-average productivity and profitability among industry players in a particular region. These factors are (1) the context for firm strategy and rivalry, (2) factor (input) condition, (3) demand conditions, and (4) the existence of related and supporting industries. Figure A-1 diagrams the framework, used here to analyze the emerging Finnish wireless-applications cluster. The Finnish wireless industry displays advanced characteristics in each of the four areas.

Figure A-1. Sources of Locational Competitive Advantage



Reproduced from Porter, "Location, Competition, and Economic Development."

[33] Porter, *The Competitive Advantage of Nations*, and Porter, "Location, Competition, and Economic Development."

Finland is a country of 5.2 million people situated between Sweden and Russia, with per capita GDP of $23,780 (1999), or 69 percent of the U.S. per capita GDP in purchasing power parity terms.

Context for Firm Strategy and Rivalry[34]

Finland has had competition in telecommunications throughout the 20th century. The national Post and Telecommunications never enjoyed a monopoly. After the U.K., Finland was the first country to deregulate in several areas related to telecommunications: the manufacture of end-user terminals, basic telecommunications services, and data services. Today there are one hundred telecommunications operators in Finland, or two operators per 100,000 residents.

Two mobile operators, Sonera and Radiolinja, have actively developed and launched new mobile services and applications. This has created a favorable environment for small companies in related areas. Currently the Finnish telecommunications and IT sector is populated by approximately 3,000 firms. A consortium of more than 30 smaller operators has recently been granted a license to build a competing mobile network.

Besides domestic competition from Finnish carriers and equipment companies, Finnish firms face staunch competition from neighboring Sweden.

Factor (Input) Conditions

Finland was the first country to allocate licenses for third-generation wireless networks. These licenses were granted free of charge to Sonera, Radiolinja, 3G (a consortium of local phone companies and Swedish Netcom), and Telia (Sweden).[35] Some of the firms awarded 3G licenses plan to provide mainly network operations, leasing their assets to other firms that will provide consumer marketing and service.

The public sector in Finland has been supportive of R&D in telecommunications. Tekes, Finland's National Technology agency, has jointly sponsored a program, "TLX: Creating a Global Village," with the private sector and Finnish research institutes. This program has provided FIM 710 million ($120 million) over three years to fund technology development, including 3rd and 4th generation wireless systems and wireless value-added services. Tekes has also funded the "Electronics for the Information Society Programme," and the Academy of Finland has sponsored a research program in "Teletronics."[36] Tekes also funds R&D programs conducted in small and medium sized enterprises.[37]

A recent *Financial Times* Survey of Finland indicates that private sector funding—outside of the major equipment providers and carriers—for mobile applications has become widely available as well. In this survey, a partner at venture capital firm Eqvitec claims that $2 billion in venture capital funding has been made available in the last year and a half.[38]

[34] The major source for the following section is Finland Ministry of Transport and Communication, "Telecommunications Statistics 2000."
[35] "Finland opposes auctioning, because it considers this a form of indirect taxation, slowing down the spread of new technologies." *Ibid*.
[36] Tekes Web site (www.tekes.fi).
[37] Vijay Maheshwari, "Survey—Finland 2000: All Wired Up and Going Many Places," *Financial Times*, July 10, 2000.
[38] *Ibid*.

Demand Conditions

Finnish consumers may be the world's most sophisticated consumers of mobile technology. At the end of 1999, mobile phone penetration in Finland reached 65 percent, and by August 2000 penetration reached 70 percent.[39] The average household has 1.35 mobile telephone connections (subscriptions). In early 2000, 20 percent of all Finnish households abandoned their wired telephones altogether and opted only for mobile phones. Wireless revenue exceeded wireline revenue for the first time in 1997.

In 1999, more than 650 million short message services (SMSs) were sent in Finland. SMSs are value added mobile services that use the narrow-band data transmission capability of GSM. Examples of SMSs include instant news, financial information, or sports reports, and online chat.

Because of its high mobile penetration rate, Finland has become a test-market for WAP (Wireless Application Protocol) applications. Applications developed in Finland include using phones to make vending machine purchases and to purchase time at parking lots, sending and receiving e-mail, and reading public transportation timetables. As a result, major international corporations and venture capitalists have identified Finland as the development site for mobile phone applications. Hewlett-Packard has headquartered its WAP development unit in Helsinki.[40] Germany's largest technology company, Siemens, has announced that it will locate a new mobile data unit in Finland. Extensive venture capital money has been distributed in Finland to create mobile Internet products.[41]

Related and Supporting Industries

Nokia, the world's largest producer of mobile handsets, is headquartered in Finland. Formerly a widely diversified company, Nokia has focused exclusively on mobile technology since 1992, and has shed its non-mobile businesses. Nokia has become one of the world's most competitive telecommunications equipment suppliers. Its market capitalization of nearly $160 billion is second largest among telecom equipment producers and exceeds that of Lucent, Ericsson, Siemens, Alcatel, and Motorola, and represents about 65 percent of the Helsinki stock market's capitalization.[42]

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[39] Ministry of Transport and Communications Press Release, August 17, 2000 (www.mintc.fi).
[40] Tero Kuittinen, "Finland: WAP Pioneer," October 6, 2000 (www.wapland.com).
[41] Maheshwari, "All Wired Up and Going Many Places."
[42] Source: www.hex.fi/eng, as of October 6, 2000. Nokia shares also trade on the New York Stock exchange.