MOBILE TELEPHONE

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Contents

1. Introduction

Mobile (cellular) telephone is an example of a new product that has significantly affected how people live. Since its introduction in Europe and Japan in the early 1980s and in the U.S. in 1983, mobile telephone adoption has grown at about 25 percent-30 percent per year such that at year end 1999 about 86 million mobile telephones are in use in the U.S.[1] Approximately 32 percent of all Americans use cellular, and there are about 66 percent as many cellular telephones in the U.S. as regular (landline) telephones. Penetration rates in Europe are significantly higher, with the penetration in Finland exceeding 70 percent. The average U.S. cellular customer spends about $500 per year on cellular service. Thus, consumers and businesses have found mobile telephone to be a valuable addition to their lifestyles. Mobile telephones have created a significant increase in consumer welfare. They are one of the most significant innovations in the past twenty years.

Cellular telephone has been in commercial operation in the U.S. for seventeen years. Cellular telephone began operation in Chicago in late 1983 and in Los Angeles during the 1984 Olympic Games. Operation then began within the next year in the top 30 MSAs (Metropolitan Statistical Areas) and subsequently spread to the rest of the approximately 300 MSAs and more recently the RSAs (Rural Statistical Areas). Mobile telephone, which includes cellular plus PCS, is now available almost everywhere within the United States.

Mobile telephone, along with 800 telephone service, has been the great success story of new telecommunications services offered in the past 40 years. At the time of the AT&T divestiture, when it was not clear whether AT&T or the divested Bell Operating Companies (BOCs) would inherit the cellular spectrum which the Federal Communications Commission (FCC) had granted to AT&T, an AT&T prediction for cellular subscription levels in the year 1999 was about 1 million[2]. At year-end 1999 planning horizon, cellular subscribership in the U.S. exceeded 86 million, so that the AT&T forecast was off by approximately 85 million. In Figure 1, the number of cellular subscribers is graphed, with the growth rate of 25–30 percent a year holding for the past decade. Beginning in 1996 the next generation cellular technology, PCS, was introduced in the U.S. so that in most locations consumers have a choice among 5 or more mobile providers. AT&T Wireless, Sprint PCS, Verizon, and Nextel all offer nationwide networks, with a new nationwide network being constructed by Voicestream[3]. BellSouth and SBC offer large regional networks while many companies offer local or regional services[4].

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[1] Data are from Spring 2000 CTIA Semi-Annual Wireless Industry Survey. See http://www.wow-com.com/wirelesssurvey/.

[2] This prediction for AT&T was done by McKinsey, a well-known consulting company. The lost value to AT&T by giving the cellular licenses to the BOCs was approximately $50 billion.

[3] Verizon is the combination of the former Vodafone AirTouch and Bell Atlantic networks. Voicestream is the combination of the former Voicestream, Omnipoint, and Aerial PCS networks.

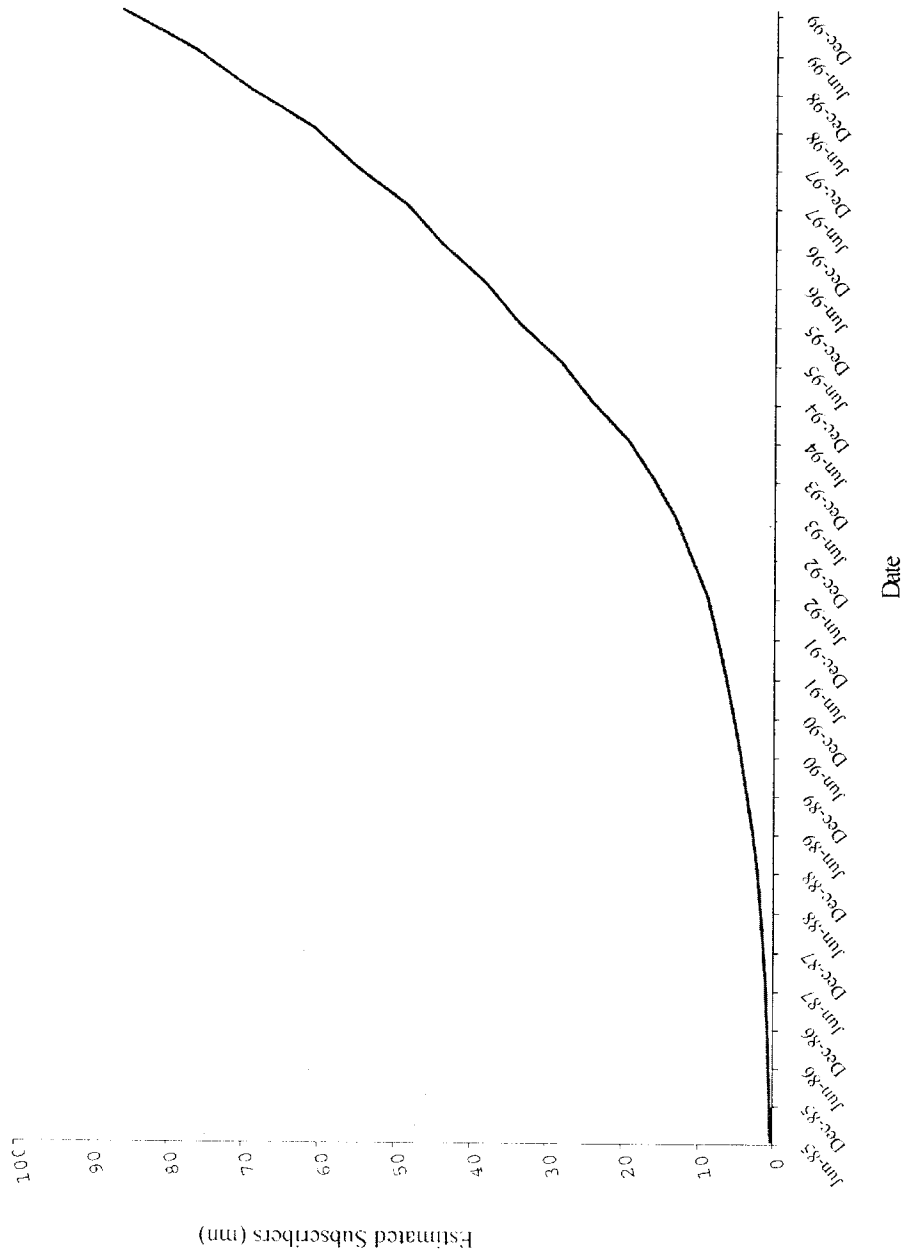[4] BellSouth and SBC are considering combining their mobile networks.

Fig. 1. Cellular subscribers in the U.S.

While mobile telephone has been a great success in the U.S., it has been even more successful in other countries. In Finland, Sweden, and Japan mobile penetration has now surpassed regular telephone (landline) penetration. In much of Europe, Japan and Australia mobile penetration is higher than in the U.S. The greater success in Europe and Japan of mobile is explained in part by the lack of subsidy and higher monthly price for local wireline telephone service that exists in the U.S[5]. Thus, mobile is relatively less expensive in these countries than in the U.S. Next, in Europe and Australia a single second generation digital mobile standard (GSM) was adopted, while in the U.S. three different standards are in use, which makes using a mobile telephone in non-local regions (called roaming) less convenient. Also, in Europe they have adopted a 'calling party pays' framework so incoming calls to mobile telephones are not charged to the recipient. In the U.S. the recipient pays, in a 'receiver pays' framework, so that a much lower proportion of mobile calls are incoming calls[6]. Lastly, in both Europe and Japan more innovative marketing has been used than in the U.S. Prepaid calling cards are have been highly successful in Europe, especially for young people, who need to control their budget[7]. In Japan, NTT DoCoMo has introduced Internet convenient mobile telephones that have a special appeal to young people[8]. Indeed, mobile companies worldwide are attempting to develop technology that will allow convenient combined use of mobile telephone and the Internet[9].

Given that mobile telephones and the Internet are the two outstanding telecommunications developments of the past 25 years, the question arises of the future of landline telephone. Modern digital mobile telephones are convenient to use, have good voice quality, are moderately secure, and the usage price is decreasing rapidly. For example, carriers offer monthly packages that cost approximately 10 cents to 15 cents per minute for combined local and long distance when large bundles of minutes are purchased. With the monthly subscription price at say $20 per month and long distance calls at approximately 7–9 cents per minute, landline telephone is still less expensive than mobile but lacks the convenience of 'anytime and anywhere,' especially the single number

[5] For instance in the U.S. residential local calls are free after paying a monthly fee while in Europe, Japan, and Australia local calls have a per minute or per call fee.

[6] In the U.S. many mobile subscribers do not give out their mobile telephone number because they have to pay for incoming calls. However, this policy seems to be changing as mobile subscriber use 'bucket' plans of buying a large number of minutes per month of mobile usage. I discuss these bucket plans below.

[7] In many European countries, e.g. Italy and the U.K., greater than 80 percent of new subscribers are using prepaid service. In the U.S. currently only about 6 percent of subscribers use prepaid service.

[8] In the first 14 months after its introduction NTT DoCoMo's I-mode telephone, which connects to the Internet, achieved approximately a 5 percent penetration among the Japanese population. Source: Wall Street Journal, April 17, 2000, p. A25.

[9] The leading technology at this time appears to be WAP (wireless access protocol) technology. A WAP browser will make Internet usage considerably easier for users.

capability of being reachable anytime and anywhere[10]. However, mobile prices do not have to decrease too much further before they could begin to have a significant substitution effect on landline telephone usage. The effect of mobile is already noticeable on payphone use, which has decreased by 17 percent over the past three years with significantly less usage and an absence of lines at airports.

However, in my view, it will be the Internet that will continue to provide an important role for landline service. Combined landline voice and DSL, which can provide high speed Internet access and combined cable Internet access and voice, will likely be used by customers to access the forthcoming broadband Internet. While next generation mobile (3G) may permit sufficient broadband access to the Internet, I believe that the shadow value of the spectrum, which is rationed by the FCC in the U.S. and other government agencies abroad, will limit its use. The value of the spectrum remains at a sufficiently high amount that mobile Internet access will not be widely used by residential customers except when they are 'on the go.' However, if government policy were to change from giving 'free usage' of the spectrum to other government bodies who do not use spectrum in an economical manner, the value of the spectrum could decrease sufficiently to make wireless the access method of choice ten years hence.

The average U.S. mobile telephone subscriber spends $41.24 per month on mobile service, or about $500 per year. Thus, about $41 billion per year is spent on mobile service, with additional amounts spent by consumers on purchasing mobile telephones. Mobile revenue now is about 40 percent as large as long distance revenue, so cellular telephone represents a significant expenditure category in telecommunications.

2. Description of the mobile industry

2.1. Technology

Cellular telephone technology introduced the concept of spectrum re-use within a given geographical area. Prior to the introduction of cellular telephone, car telephones made exclusive use of a given frequency band in a geographic area, which greatly limited the number of users. For instance in large U.S. cities such as New York and Los Angeles, IMTS service had waiting lists exceeding ten years[11]. Even for people that had service, repeated attempts to make a call often ended in failure because of system congestion.

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[10] A typical large user makes about 500–600 minutes of local calls a month so the charge is still significantly less than mobile.

[11] IMTS stood for improved mobile telephone service.

Cellular technology, by allowing different users within the same geographic area, allowed for a tremendous expansion of capacity. Indeed, the early cellular networks were engineered to permit 95 percent of call attempts to be completed during peak usage periods. Cellular technology allowed for frequency reuse by using a hexagonal network of cells (See Figure 2A). Each base station covered one of the hexagons in Figure 2A. When a user went from one cell to an adjacent cell, the user would be handed off seamlessly to the new base station. Thus, non-adjacent cells would be using the same frequencies to serve cellular users[12]. In Figure 2C the cells have now been split to allow for increase frequency reuse at the cost of additional base stations and antennae. Lastly, in Figure 2B cell sectoring is displayed which uses three antennae, each transmitting over a 120-degree angle, replacing a single antenna which transmits over the full 360 degrees. The combination of cell splitting and sectorization increases capacity by approximately a factor of 8 times.

The original radio technology used in cellular was analogue technology, called AMPS in the U.S[13]. The AMPS system operated in the 800 MHz frequency range. European network operators originally began with AMPS-type systems usually in the 900 MHz range, but they agreed (with government help) to adopt subsequently a common digital standard, GSM. GSM was the first of the second-generation (2G) technologies, and it is the most widely used technology currently in the world for mobile telephones. GSM operates in the 900 MHz frequency range.

The U.S. did not adopt a common 2G technology. One group of companies, including AT&T Wireless, adopted TDMA, which is very closely related to GSM, although not interchangeable in use. GSM and TDMA have the advantage of increasing the number of users per frequency by approximately a factor of 3 over analog networks[14]. In the early 1990s the U.K. government decided to permit three new mobile companies to enter using frequency in the 1800 MHz range. Standard GSM technology was used, but the service was called PCN, for personal communications networks. The U.S. followed the U.K. lead in the mid-1990s by auctioning spectrum for up to 5 new entrants in the 1900 MHz frequency range. In the U.S. the technology is called PCS, for personal communications systems. GSM/TDMA is, by far, the most commonly used technology worldwide for cellular and PCS services.

The other primary 2G digital technology adopted in the U.S. is CDMA, for code division multiple access[15]. Rather than using a unique channel for a call, as

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[12] Adjacent cells are not used because of potential interference problems.

[13] The switches to operate the system were often digital, which sometimes caused confusion in describing the systems. The analog systems were called TACS or NMT in Europe and operated in the 900 MHz or 450 MHz frequency bands.

[14] The increase in capacity is obtained by multiplexing voice messages so that 8 channels per frequency are permitted at a given time.
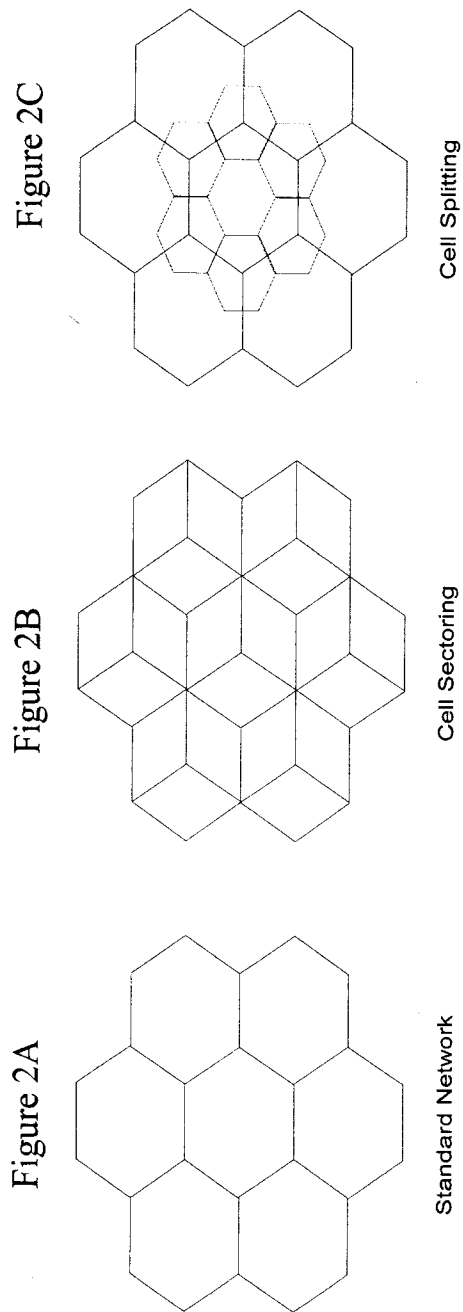
[15] CDMA is also called IS95.

Figure 2C

Cell Splitting

Figure 2B

Cell Sectoring

Fig. 2. Cell frequency design.

Figure 2A

Standard Network

does GSM/TDMA, CDMA instead uses all the available frequencies for a given call. The technology is somewhat similar to packet switching in which a voice call (or data) is divided into individual packets, sent over available frequencies, and then reassembled for transmission to the other party. CDMA has greater capacity potential than GSM/TDMA with an increase of about 3 times over GSM[16]. CDMA also has superior handoff capability when a user transits from one cell to the adjacent cell as in Figure 2. When a GSM customer changes cells, typically the customer receives a new frequency channel. CDMA uses a 'soft' handoff when for a period of time the customer uses both the previous and future cell. This feature has increased importance in data transmissions where file transfers can become corrupted more easily with GSM. CDMA technology initially had substantial problems and significant doubts existed about its eventual success. However, these early problems have been overcome, and CDMA technology is now widely used[17]. In the U.S. the largest cellular operator, Verizon and also Sprint PCS have adopted CDMA technology.

Future third generation technology, often referred to as 3G, will have increased data usage at significantly higher speeds, rather than being primarily voice based networks[18]. Future networks will be constructed around an upgraded CDMA technology, given its technical superiority for data transmission[19]. One form of next generation technology, W-CDMA, is currently being used in Japan by NTT DoCoMo. To date its performance has been successful, with widespread usage and customer adoptions by DoCoMo, which offers an Internet based service. The other proposed approach, CDMA2000, proposes to offer significantly higher data speeds. This evolving technology will be combined with two other innovations, which will allow for more convenient Internet usage.

The first development is WAP, wireless application protocol. WAP will speed up the Internet Data using the WML language, in place of the standard HTML, which is used on the Internet. WML is approximately 2 times more byte-efficient that HTML. The other development is *Bluetooth*, which is technology that allows rapid data transfer from mobile devices to LANs and PCs over short distances, within about a ten-meter range currently. Thus, mobile users will be able to conveniently upload and download large amounts of data automatically, without having to use the mobile network to do so. While the replacement for cable technology and modems is obvious for *Bluetooth*, the lack of a 'killer application'

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[16] The greater capacity might be pictured as using one 100 inch pipe rather than using ten 10 inch pipes to pass water through. Further, the problem of interference causing non-use of channels in adjacent cells is no longer a problem. Significant disputes exist about the actual increase in capacity that CDMA delivers over GSM.

[17] The resolution of the uncertainty is evident in the historical stock price and market capitalization of Qualcomm, the inventor of much of the CDMA technology.

[18] Most current mobile networks that are also used for voice do not allow for data transmission at speeds above 28.8 kbs, about 1/2 the speed of an analogue modem used with current PCs.

[19] Various intervening technologies, sometime called 2.5G, are currently being discussed and sometimes deployed. I will not discuss these interim technologies here.

to date may limit its acceptance. Personalized cash register information and vending machines with direct billing are much discussed future applications. Thus, the mobile telephone, or PDA (Palm), would permit an electronic payment system[20]. Also, *Bluetooth* might be useful to permit an intelligent personal phone number system that would give least cost routing depending on the customer location. Thus, calls would be routed over the landline system to a switch (PBX), which would transfer the call using *Bluetooth* to the mobile telephone without making use of the wireless network. This last application would greatly affect competition in telecommunications and in information networks. It would allow for 'edge networks' with most of the intelligence on the periphery of the network and with the mobile telephone used for communications and to integrate voice mail, email, internet information, and personalized transactions. This network design would be in sharp contrast to the centralized network model of the Internet, which has recently gained increased attention. Thus, the interaction of telecommunications and the Internet will greatly affect both network architecture and competition in the near future.

2.2. Competing firms and countries

Cellular technology was invented at Bell Labs (AT&T) in the 1960s and further developed by Motorola. These two firms, along with Ericsson, delivered the original analog cellular infrastructure, including base stations, radios, antennae, and switches (MSOs). However, neither AT&T nor Ericsson was successful in developing and selling handsets. Here Motorola took an early lead by incorporating modern electronics into its cellular telephones and introducing a very popular portable telephone. By the early 1990s the portable telephone surpassed 'car phones' because of its greater convenience and improvements in network technology that allow for high performance, even in automobiles. Motorola had well over 50 percent of worldwide sales of mobile telephones in the mid-1990s with Japanese and European manufacturers far behind.

In the late 1990s the competitive framework changed significantly. First, Nokia, a Finnish company that previously had gone from a forest products company to making televisions and PCs, became a major force in cellular handsets. Nokia was very successful based on its superior design approach to mobile handsets and their early embrace of digital technology, which Motorola was slower to concentrate on[21]. Nokia is now the leading producer of handsets, having surpassed Motorola[22]. In 1999 Nokia had approximate a 27 percent share of mobile telephone

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[20] A PDA personal digital assistant allows for wireless transmission of data, but it does not have voice capability.

[21] Motorola faced the classic problem of being the world's most successful analog cellular company. Nokia did not have this initial position to defend.

[22] However, Nokia has been much more successful in GSM/TDMA technology, not in CDMA. A future danger exists that Nokia may have similar problems to Motorola.

handset sales followed by Motorola with 17 percent, Ericsson, with 11 percent, and Samsung with 6 percent[23]. Nokia's market capitalization exceeded $200 billion, about 4 times as large as Motorola.

The other significant technological change was the emergence of Qualcomm, a U.S. based company that had done significant development work on CDMA. Qualcomm claims to have a significant intellectual property position in CDMA, protected by patents. While significant doubt existed initially about the success of CDMA in real world settings, in the past 3 years these initial doubts have disappeared. Qualcomm originally manufactured handsets, but sold this division in 1999 year to Ericsson. As almost a pure technology company, Qualcomm's market value was near $60 billion (in 2000) and exceeded that of Motorola.

European governments have adopted a common standard, GSM, and Ericsson and Nokia have largely specialized in this technology. Thus, the Europeans have adopted a common technology standard, in contrast to the U.S., which has no common standard. The Korean government has encouraged its telecommunications hardware company to concentrate on CDMA, so they are likely to become a significant competitive factor in the near future. An interesting question is whether government intervention to create a common standard will lead to greater innovation and adoption due to network externalities, or whether the U.S. approach of technology competition will lead to greater innovation.

In terms of service providers Vodafone is now the world's largest with significant holding in the U.K., the U.S. (AirTouch/Pacific Telesis), Germany (Mannesmann), much of Europe, and Australia and New Zealand. Vodafone's market capitalization was approximately $215 billion, over two times the market capitalization of AT&T, historically the world leader in telecommunications. The market capitalizations of Sprint PCS and AT&T Wireless in the U.S. were approximately $20–40 billion. The gain for Sprint is especially noteworthy because its investment in spectrum and networks is probably less that 20 percent of its market capitalization[24]. Lastly, mobile networks have provided much of the growth for landline network operators such as the BOCs in the U.S. and BT in the U.K. The traditional landline business has very low growth compared to the rapid growth of mobile usage and revenue.

2.3. Government frequency allocation

The U.S. government initially permitted two competitive cellular companies in each geographic region to obtain cellular licenses. The entry of competition,

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[23] Source of shares is Dataquest.

[24] MCI/Worldcom appears to have made a costly strategic mistake in 1995 when it dropped out of the PCS auctions, deciding that the spectrum prices were too high. Five years later it appears that mobile telephone may be an essential component to an integrated telecommunications company strategy. MCI/Worldcom attempted to purchase Sprint along with its PCS assets. However, the proposed merger was rejected by both U.S. and European antitrust regulators.

while not for the first time in U.S. telecommunications, was a departure from the usual practice in landline telephone where a single provider served a given geographic region[25]. In the U.S. one of the two frequency allocations was given to the local (landline) telephone provider. The other frequency allocation was originally designed to be given through comparative hearings – a 'beauty contest' in which Washington insiders, mainly lawyers, attempted to capture the maximum amount of future rents that were available. This procedure proved to be unworkable because so much rent was available that the procedure ground to a halt through legal maneuvering. Subsequently, (free) lotteries were held with the winner selling the lucky frequencies. A lucky dentist sold the frequencies for Cape Cod, a popular vacation spot in the U.S., for a reported $50 million.

Most European countries followed the U.S., although many initially allowed only the landline telephone provider to be awarded the cellular frequencies. Subsequently, most countries introduced competition with one or two 'additional providers. However, one important difference was that European and other nations typically awarded nationwide licenses, while the U.S. licenses were based on geographical areas the size of metropolitan areas, called MSAs. While the U.S. used a single analog AMPS technology, these regional networks led to higher transactions costs for 'roaming' customers' use of their mobile handsets outside their home territories[26]. However, with the current use of three incompatible technologies in the U.S. – TDMA, CDMA, and GSM – problems have arisen for roaming. Dual mode telephones are required which adds to the cost of service provision. Recently, nationwide networks have become increasingly important in the U.S., with Verizon, AT&T Wireless, Sprint PCS, Nextel, and Voicestream. Each network uses a common technology and allows for low cost roaming, since inter-network transactions costs are eliminated.

A major development in government frequency allocation occurred in the U.S. in 1993 when Congress, in need of a new revenue source, required the FCC to auction off spectrum, rather than using comparative hearing or other procedures[27]. Economists had long favored auctions, rather than a political process that awarded spectrum to the politically well connected. Auctions lead to the greatest value use of the limited resource since those users will bid the most. Thus, auctions lead to economic efficiency[28]. Furthermore, the government captures the rents associated with limited spectrum, rather than rents going to lawyers or lucky lottery winners.

The FCC adopted auctions for the initial PCS auctions of two 30 MHz bands in the U.S. in late 1994–95. The auctions were quite successful with approximately

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[25] Earlier, competition in the U.S. existed in both paging and in car telephone service, IMTS.

[26] In the U.S. roaming revenues have been approximately 10–12 percent of overall mobile revenues.

[27] The U.S. government had a significant deficit at this time.

[28] I will not discuss auctions in detail. See the chapter by Cramton in this *Handbook*.

$6 billion raised in revenue[29]. A subsequent auction for an additional 30 MHz of spectrum was limited to small companies as a political favor, but it led to a large number of bankruptcies and continuing litigation[30]. Subsequently, unrestricted auctions have not encountered difficulties. A number of other countries have also adopted auctions, e.g. the U.K. and Australia have recently held successful auctions. The recently (April 2000) completed auction in the U.K. for 3G technology spectrum raised approximately $35 billion for the government[31]. Germany also recently (August 2000) completed its auction for 3G spectrum that raised approximately $46 billion[32]. Evidently, the future promise of combined mobile telephones with the Internet has led firms to expect an explosion of use when 3G technology becomes available.

Auctions have demonstrated their superiority as an allocation mechanism for scarce spectrum allocation[33]. Thus, a number of other countries such as Italy, the Netherlands, Austria, and Belgium plan to auction off their 3G spectrum. However, France has decided not to renounce its Colbertian tradition and adopt a market allocation device. Instead, the French government will decide who the 'worthy' recipients of the 3G licenses will be. Perhaps, more surprisingly, the Scandinavian countries along with Spain and Portugal have decided to continue to use beauty contests[34]. Japan, Korea, and Hong Kong also plan to use beauty contests. The most-cited reason (at least in public) for the continued use of beauty contest spectrum allocation is because the large amounts paid by successful bidder will lead to high prices to consumers. This claim makes no economic sense unless future mobile prices to consumers will be regulated. Future demand, cost, and competitive factors will determine the service prices, with the license fees a sunk cost to the original winning bidders. Indeed, using the argument cited above, the European governments would soon be expected to begin beauty contests for the allocation of European football players so that the ticket prices would decrease to consumers.

[29] Actually, the FCC could not quite let go of its previous behavior. It awarded 3 "pioneer preference" licenses in New York, Los Angeles, and Washington at discounted prices. These awards were political giveways, e.g. the Washington Post, the dominant newspaper in the nation's capital, received one of the three pioneer preference awards. The award followed a dinner between President Clinton and the publisher of the Washington Post on Martha's Vineyard in August 1994.

[30] The FCC seems unable to stop its decades long practice of attempting to gain political favor by interfering in the efficient operation of the U.S. telecommunications networks.

[31] The U.K. government reserved one of five frequency bands for a new entrant.

[32] An interesting outcome is that the per capita auction amounts for the U.K. and Germany are extremely close, with the U.K. slightly higher.

[33] Potential problems of coordinated interaction among bidders have not occurred.

[34] A problem with beauty contests is choice of the 'best' technology. In December 2000, Telia, the largest mobile operator in Sweden, did not receive a 3G license. Telia announced it would appeal the decision by the government regulator. The regulator rejected Telia's bid on the ground of technical feasibility because it would not provide sufficient geographical coverage. Telia claims that the regulator made a technical mistake in evaluating its technology and rejected Telia's 3G bid "on false assumptions."

Another question that arises is inefficient spectrum use promoted by governments. The high value to spectrum arises because of spectrum scarcity. Much of the scarce spectrum is used by government agencies (both national and local) and the military, none of which have any economic incentive to use their spectrum efficiently. Given the modern technology that has been adopted by the mobile industry, these government agencies could also more economically utilize their spectrum. Governments have not yet fully realized the tens of billions (or hundreds of billions) of dollars of economic loss arising from their outdated spectrum policies. Government agencies should be required to bid for spectrum usage so that they will have the correct economic incentives for efficient usage. Given that the success of the future combination of mobile and Internet usage, for the broadband Internet, may well depend on sufficient spectrum being available, governments need to revisit their overall policies of spectrum usage. Spectrum policy is too important to be left in the hands of the FCC and similar government agencies, where politics typically is more important than economic efficiency or consumer welfare in making allocation and taxation decisions[35].

3. International comparisons

3.1. Performance across countries

Prices of mobile service are quite difficult to compare across countries because of currency fluctuations, differences in taxation, and differences in interconnection fees that cellular companies must pay landline telephone companies[36]. Thus, most inter-country comparisons focus on penetration[37]. However, as I noted above, penetration comparisons depend, in part, on the relative price of landline telephone service that varies greatly across countries.

In Figure 3, the graph shows recent (2000) mobile penetration levels for a sample of European countries. As previously noted, mobile penetration is particularly high in the Scandinavian countries—about 65 percent in each country[38]. In urban areas it is even higher, with estimates for Helsinki above 80 percent. Note that the U.S. penetration at about 35 percent is in the middle of the European penetration rates, around the level of the U.K. Thus, while the U.S. penetration levels are lower than many European countries, penetration is not closely related to income. Nor does the absence of 'calling party pays' in the U.S. nor the lack of a uniform national standard explain the differences between

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[35] See e.g. Hausman and Shelanski (1999), where we estimate the loss of economic efficiency and consumers welfare to be in the billions of dollars per year because of recent FCC taxation policy.

[36] In the U.S. over 80 percent of cellular calls terminate on the landline network. In European countries the percentage is lower due to higher mobile penetration.

[37] Ahn and Lee (1999) conduct an econometric study of penetration across 64 countries.

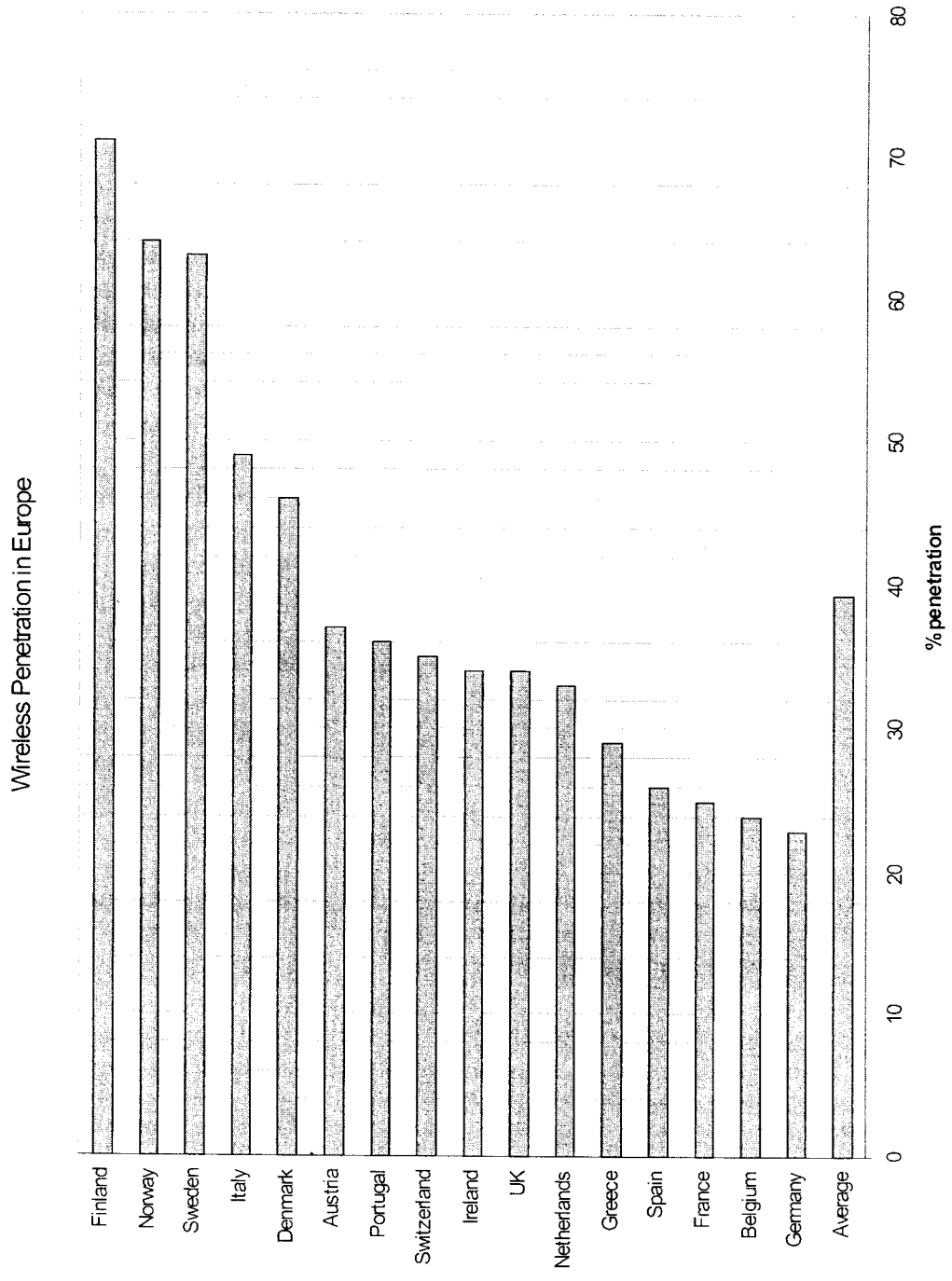[38] For a study of the determinants of mobile penetration in Europe see Gruber and Verboven (1999).

Fig. 3. Mobile penetration in Europe (2000).

Europe and the U.S[39]. Australian and Japanese penetration levels are above U.S. penetration levels and at around the European average penetration level of about 40 percent.

However, even high penetration ratios do not demonstrate that mobile has replaced landline to a large degree. Finland's penetration is above 70 percent, which far exceeds landline telephone penetration. Nevertheless in Finland mobile traffic only accounts for around 15 percent of total voice traffic in the Finnish network. I expect this number to grow over time as the 'younger generation' grows up using mobile as their primary choice. However, for now landline telephones still carry the large bulk of voice traffic in all countries[40].

Figure 4 presents price data collected by the OECD, which takes account of both monthly service price and handset prices. Handset subsidies are an important competitive factor since consumers place a great weight on the initial cost of cellular. Handset subsidies first became widely used in the late 1980 s in the U.S. and helped cause the rapid growth of cellular, after a rather slow start to consumer adoption[41]. Empirical research has demonstrated repeatedly that consumers pay 'too much' attention to the initial cost compared to the operating cost of a durable good. In the mobile context, competition has led to large discounts and subsidies for mobile handsets, as demanded by consumers. This outcome has been observed in Australia, the U.S., Canada, and the U.K. Mobile consumers are more likely to buy the service if the up-front handset cost is below the full (standalone) competitive price. Mobile companies' consumer research in the U.S. and Australia demonstrates that customers are most price sensitive to the up front costs of the price of handsets and monthly rental, which is consistent with market outcomes and my previous academic research[42].

As Figure 4 demonstrates, the U.S. has among the lowest total cost of mobile service. Among Scandinavian countries, Norway and Denmark are quite low, while Sweden and Finland are higher than the U.S. or Canada. Germany, which has relatively low penetration by European standards, does not have a particularly high price, while France has by far the highest total cost of mobile service. Thus, penetration is not particularly closely linked to prices charged to consumers[43].

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[39] Years since launch of the system has some effect on penetration rates, but its influence is decreasing over time, as expected.

[40] For a recent study on the substitution of mobile for fixed calls in Portugal, see Barros and Cadima (2000).

[41] The initial cost of a service has been noted in many consumer decisions. I first discovered its importance in consumer purchasing decisions regarding energy efficient appliances. See Hausman (1979). Many subsequent papers have found the same result over a wide range of consumer durables. Consumers behave as if they had high discount rates, placing a premium on upfront costs.

[42] An alternative explanation of handset subsidies is to build market share in the presence of switching costs. See Valletti (1999b).

[43] Jha and Majumdar (1999) find an important role for cellular technology diffusion on the overall competitiveness of the telecommunications sector for 23 OECD countries over the period 1980–1995.
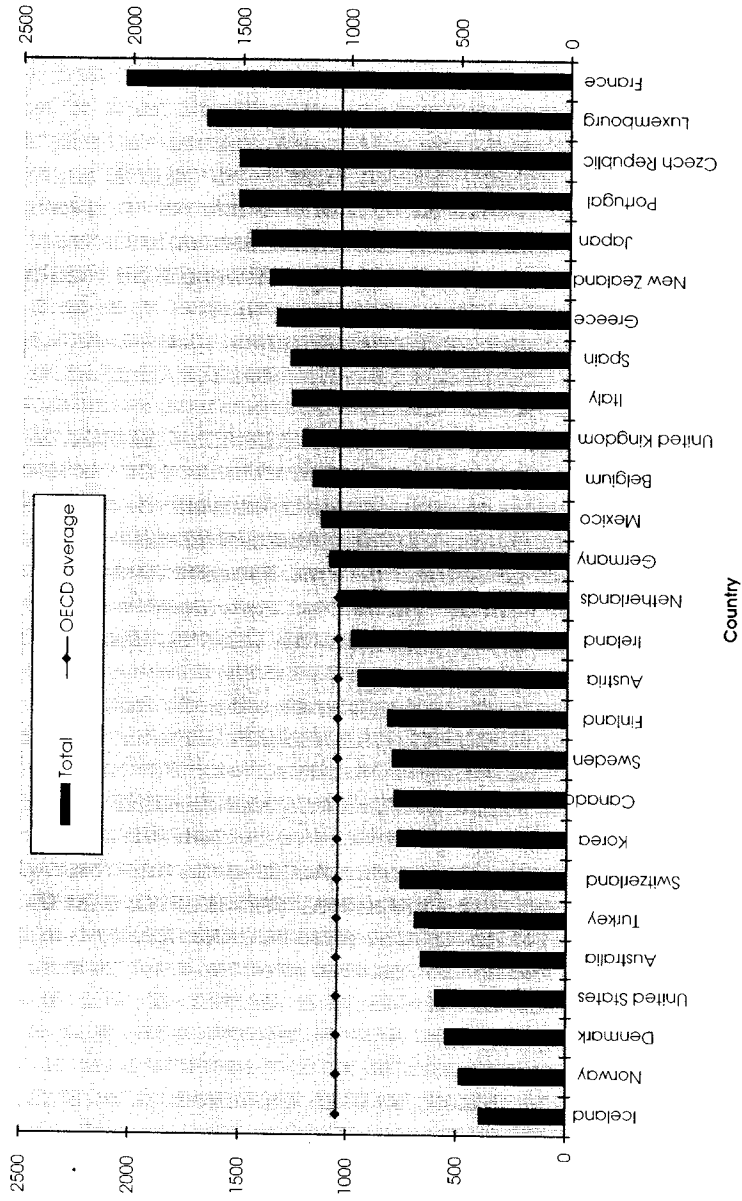
Fig. 4. Total cost of mobile service.

Source: OECD Bench marking "Communications Outlook" 1999.

3.2. Pricing within the U.S.

Up through 1996 mobile telephone in the U.S. operated as a cellular duopoly with two carriers in each region[44]. Beginning in 1996 two new mobile PCS carriers entered in most large MSAs, with additional entry since that time[45]. In Hausman (1999a), to construct a price index for cellular service, I used survey data from cellular companies in the top 30 MSAs since 1985. The top 30 MSAs comprise about 41 percent of the total U.S. population. To account for changes in cellular usage, the lowest price subscriber plan was calculated for 160 minutes per month of cellular usage with 80 percent peak and 20 percent off-peak usage. this plan was then used to compute a price index. In Figure 5, the price index for cellular service is graphed, with a base of 100 in 1985.

By the beginning of the year 1998 the index had decreased to 0.73 so that cellular prices had decreased by about 27 percent over the period, a decrease of about 2.6 percent per year. Note that price fell significantly in 1995–96 when the new entry of PCS occurred. Thus, as expected, new entry along with deregulation of prices by the FCC led to a faster decrease in prices than had previously occurred[46]. Combined with the significant decrease in retail cellular telephone prices, which is graphed in Figure 6, an overall index of the cost of cellular service and the cost of cellular telephones is graphed in Figure 7 where the overall decrease from the base of 100 in 1985 is 51 percent[47]. Thus, including both equipment and service prices the total cost of cellular decreased by about 5.8 percent per year over the period 1985–1997.

In April 1999 cellular pricing changed greatly in the U.S. Dan Hesse, president of AT&T Wireless, introduced an 'anywhere and anytime' (digital) one rate pricing plan. Thus, neither roaming nor long distance charges were assessed, and the customer paid a single rate wherever the call was placed and regardless of where (in the U.S.) the call terminated. Furthermore, AT&T and other carriers, such as Sprint, adopted 'bucket plans' where the customer bought a monthly bucket of minutes. The per minute prices are usually between 10 cents to 15 cents per minute, with lower prices arising with larger of buckets of minutes purchased. Most of the large mobile companies have since adopted these plans, which are by far the most widely advertised and sold plans.

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[44] Valetti (1999a) has a model in competition among coverage areas for product differentiation. Here I concentrate on price competition, which seems to be the major focus of competition.

[45] This time period is approximately when the Nextel network, using "iden" technology, became fully operational.

[46] State regulation of cellular prices in approximately half of the states had led to cellular prices about 15 percent higher in the regulated states. See Hausman (1995b). FCC deregulation of cellular prices led to prices dropping in previously regulated states by significantly more than they decreased in previously non-regulated states.

[47] To create the combined index I assume a 'churn' (customer drop) rate of 0.33, which has been the approximate rate for the past decade.
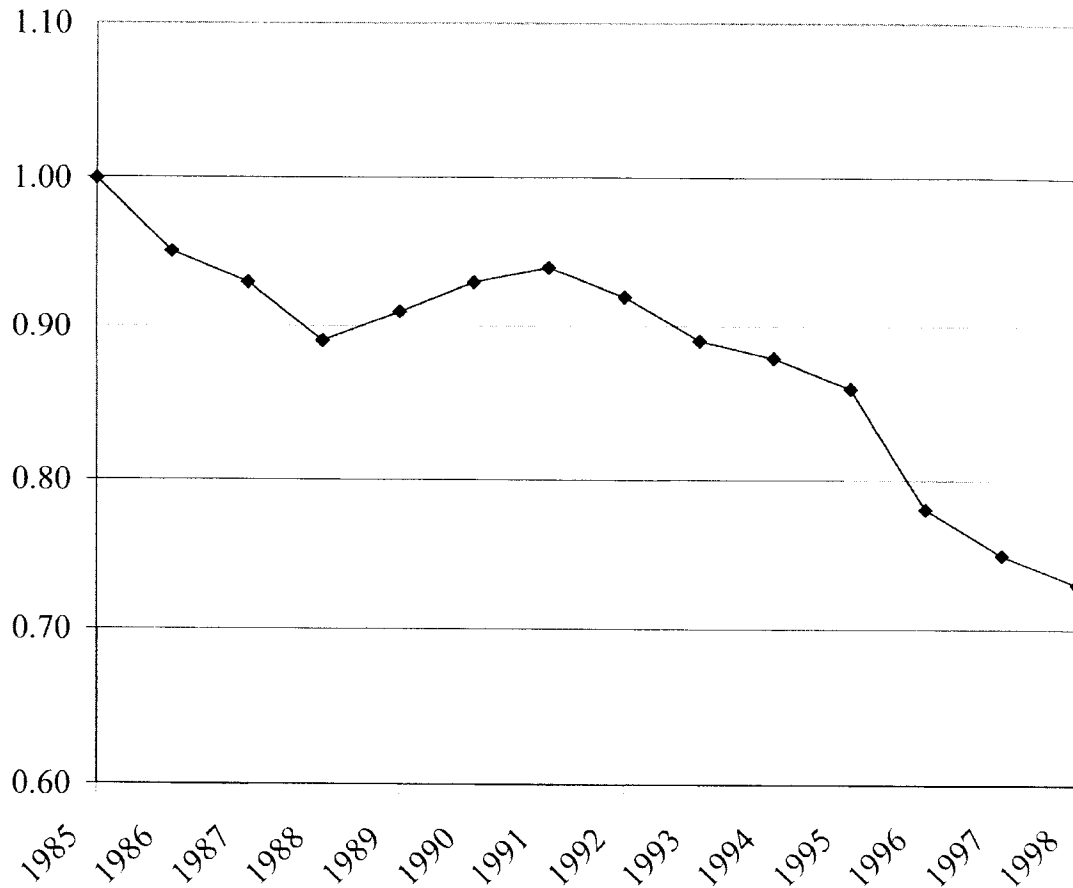
Fig. 5. Cellular average price index for top 30 MSAs: 1985–1998 (Base: 1985 = 100).

The first of the new PCS services began in late 1995, based upon the first two 30 MHz blocks of spectrum that were auctioned between December 1994 and March 1995. Since that time, a large number of companies have begun building facilities. All but 28 of the Top 100 metropolitan markets in the U.S. now have at least five wireless competitors: two cellular providers, two to four PCS services, and Nextel. Thus, about 70 percent of the U.S. population has a choice among five or more competing wireless carriers. The effect of the resulting competition on wireless rates in the U.S. has been significant. Throughout the 1984–1995 period real, inflation-adjusted cellular rates had fallen at a rate of 4 percent-5 percent percent per year[48]. Between 1995 and 1999, however, real cellular rates fell at a rate of 17 percent per year as PCS service providers offered service at prices per
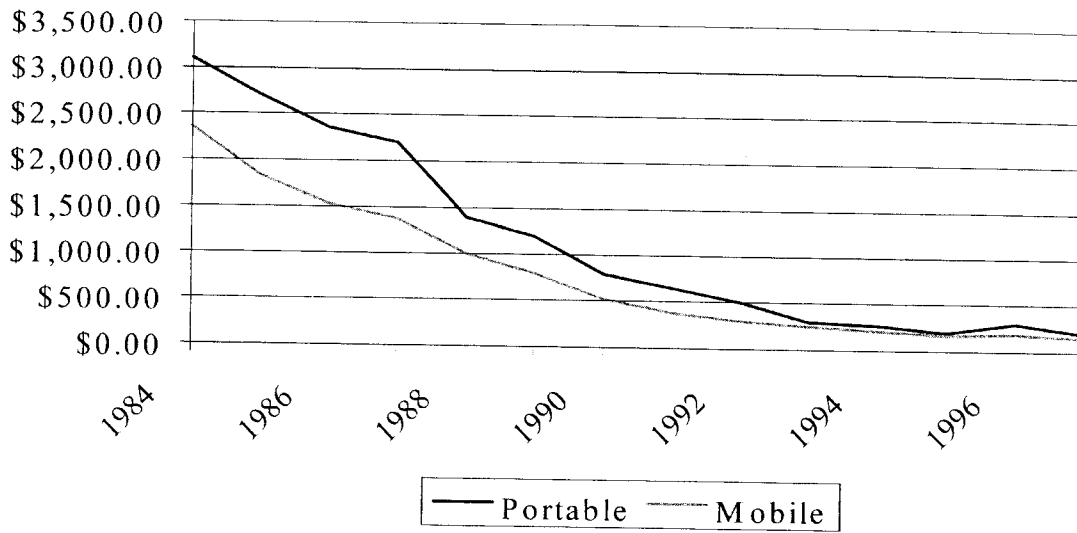
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[48] See Hausman (1999a).

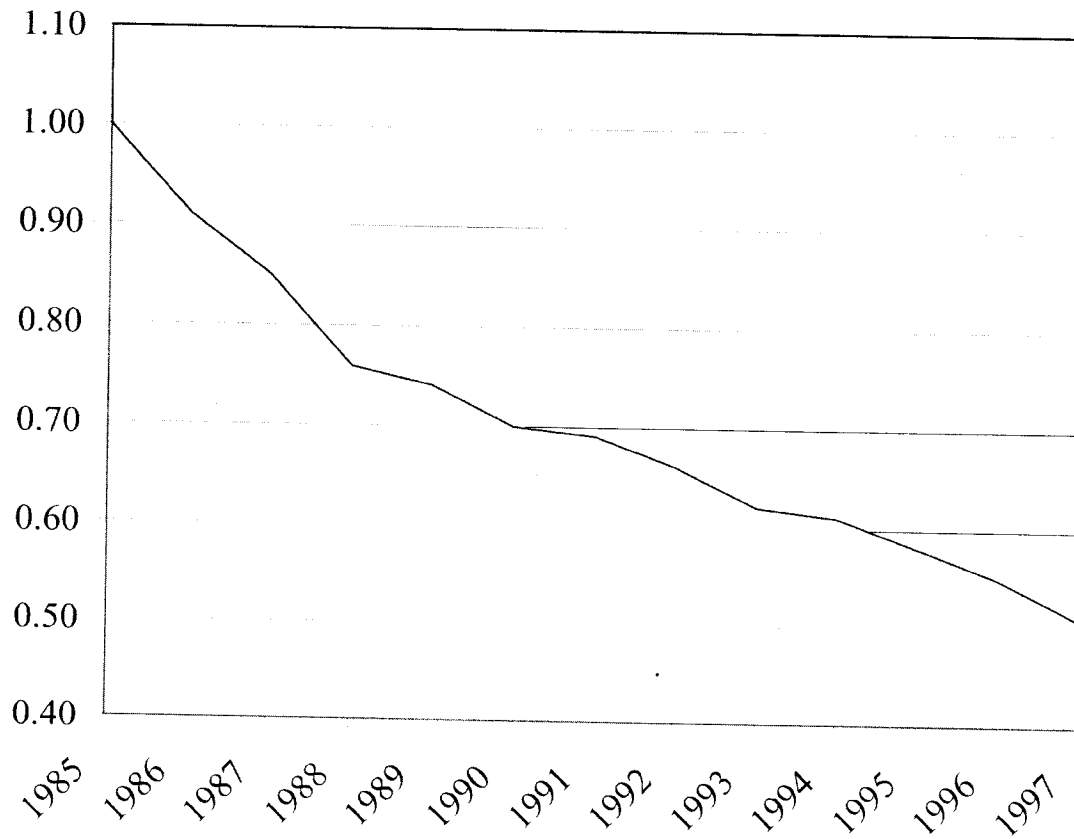Fig. 6. Cellular telephone average prices: 1984–1997.

Fig. 7. Combined cellular service and equipment prices: 1985–1997 (Base: 1985 = 1.00).

minute in bucket plans that were more than 50 percent lower than existing cellular rates[49]. The U.S. Bureau of Labor Statistics reports that mobile service price decreased by 11.3 percent in the 12 months ending in January 2000. Crandall and Hausman (2000) conclude that the evidence shows that with open entry, only one new operator is required to drive rates sharply lower. Subsequent entrants have no further statistically significant effect on rates. Of course, the presence of nationwide carriers may be enough to cause mobile rates to react on a nationwide basis to the presence of an additional nationwide carrier, e.g. AT&T.

3.3. Pricing in Europe

The path of prices in Europe is more difficult to determine because of the lack of government price indices or academic studies. Nattermann (1999) calculates price changes in Germany over the period 1992–1998. He chooses the beginning of the period when competition began in the German cellular market with the entry of Mannesmann (in a joint venture with AirTouch) and the government eliminated price regulation. He estimates that a market share weighted price index decreased by 45.7 percent for a change of −7.4 percent per year. This price decrease is greater than the duopoly period in the U.S. but less than the price decreases since the entry of PCS operators in the U.S.

Valletti and Cave (1998) analyze competition in the U.K.. They divide the period from 1985 into the initial duopoly period with BT Cellnet and Vodafone and the subsequent period since the entry of the two additional PCN (PCS) operators One2One and Orange. In the initial duopoly phase of competition Valletti and Cave report that retail prices were extremely stable with few packages designed for consumers[50]. Valletti and Cave posit monopoly-like behavior of the duopolists, but they do not discuss the effect of regulation in causing this behavior.

However, with the entry of the PCN operators, competition increased significantly. The number of different pricing options increased greatly. Demand also increased significantly with lower prices and increasing choice of pricing plans. Unfortunately, Valleti and Cave do not do a systematic study of price changes or construct a price index, so the extent of price changes cannot be determined. However, they do give a list of price changes over time, which demonstrates that prices did decrease significantly after the entry of the two additional PCN operators.

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[49] This estimate is consistent with an alternative estimate of a price decrease of 20 percent between 1998 and 1999. See FCC, "Fifth Report," August 18, 2000, p. 5. For comparison, in Australia Vodafone prices for an average mobile user decreased 60 per cent between 1993 and 1999, or about 8.2 percent per year, including access and handsets when 3 firms were competing. In the year after new network entry began to occur in Australia, mobile prices, including both access and handset prices, decreased by about 15 percent, which is consistent with the U.S. experience.

[50] Oftel, the telecommunications regulator, did not permit highly discounted handset prices as occurred in the US during this period.

4. Increased consumer welfare from mobile telephone

The introduction claimed that mobile telephone had created a significant increase in consumer welfare. I now measure this increased consumer welfare effect in the U.S. Two equivalent methods exist in economics to measure the increased consumer welfare: use of an expenditure function (consumers surplus) or estimation of a cost of living index (COLI). Both the expenditure function approach and the cost of living index approach answer the following question. How much more (or less) income does a representative consumer require to be as well off in period 1 as in period 0 given changes in prices, changes in the quality of goods, and the introduction of new goods (or the disappearance of existing goods)? I first explain the theory of cost-of-living indices and demonstrate how new goods should be included using the classical theory of Hicks (1940) and Rothbarth (1941) and then estimate the effect on consumer welfare[51].

4.1. Economic theory to measure increased consumer welfare

In either the expenditure function or the cost of living approach, we need to know what the price would have been in the pre-introduction period. The correct price to use for the new good in the pre-introduction period is the 'virtual' price, which sets demand to zero. Estimation of this virtual price requires estimation of a demand function that in turn provides the expenditure function, which allows exact calculation of the change in consumer welfare or the COLI. Given the demand function one can solve for the virtual price and for the expenditure function (or indirect utility function) and make correct evaluations of consumer welfare and the change in the COLI from the introduction of a new product or service. In period 1 consider the demand for the new good, x_n, as a function of all prices and income, y:

$$x_n = g(p_1, \ldots, p_{n-1}, p_n, y). \tag{1}$$

Now, if the good were not available in period 0, I solve for the virtual price, p_n^*, which causes the demand for the new good to be equal to zero:

$$0 = x_n = g(p_1, \ldots, p_{n-1}, p_n^*, y). \tag{2}$$

However, instead of using the Marshallian demand curve approach of Hicks (1940) and Rothbarth (1941) in Equations (1) and (2), I instead would use the income compensated and utility constant Hicksian demand curve to do an exact welfare evaluation. In Equation (2) income, y, is solved in terms of the utility level u^1 to find the Hicksian demand curve given the Marshallian demand curve specification.

[51] This section is based on Hausman (1999a).

In terms of the expenditure function one can solve the differential equation from Roy's identity which corresponds to the demand function in Equation (1) to find the (partial) expenditure function, using the techniques that was developed in Hausman (1981). The approach solves the differential equation that arises from Roy's identity in the case of common parametric specifications of demand:

$$y = e(p_1, \ldots, p_{n-1}, p_n, u^1). \tag{3}$$

The expenditure function gives the minimum amount of income, y, to achieve the level of utility u^1, which arises from the indirect utility function, which corresponds to the demand function of Equation (1) and the expenditure function of Equation (3). To solve for the amount of income needed to achieve utility level u^1 in the absence of the new good, I use the expenditure function from Equation (3) to calculate:

$$y^* = e(p_1, \ldots, p_{n-1}, p_n^*, u^1). \tag{4}$$

The exact cost of living index becomes $P(p, p^*, u^1) = y^*/y$. As with any index number calculation, one could use the pre-introduction utility level u^0 to calculate the cost of living index. However, almost no change would occur in y^*/y because of the relatively small percentage of expenditure on cellular telephone compared to income y.

Note that to use this approach one must estimate a demand curve as in Equation (1), which in turn implies the expenditure function and the ability to do the exact welfare calculation of Equations (3) and (4). Thus, the only required assumption is to specify a parametric form of the demand function[52].

Estimation of the expenditure function in Equation (4) as well as y^* typically requires significant amounts of data and estimation of a demand curve. Furthermore, estimation of the virtual price requires an estimate of the price at which demand equals zero. These data are typically unobservable and require extrapolation from the estimated demand curve. I also use an alternative conservative approach, which decreases the information requirements and provides a 'lower bound' estimate. Once the demand curve is estimated, an approximation can be used by taking the supporting hyperplane at the observed price and quantities, (p_1, q_1), which then leads to an estimate of the virtual price of the lower bound linear demand curve to the actual demand curve. Now I claim that this estimate is conservative because the estimated virtual price from the linear demand curve will be less than the virtual price from the actual demand curve, unless the 'true' demand curve is concave to the origin, which while theoretically possible would not be expected to occur for most new products and services. The change in

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[52] A non-parametric approach to the problem could be used with techniques developed in Hausman and Newey (1995).

expenditure to hold utility constant with the introduction of the new product $y-y^*$ is the compensating variation which again can be approximated by the area under the approximate demand curve above the observed price. This amount is easily computed as:

$$y - y^* \approx CV = (0.5 \, p_1 q_1)/\alpha \tag{5}$$

where CV is the compensating variation (consumers surplus) from the introduction of the new product and α is the own price elasticity of demand. To estimate Equation (5) current revenue $R = p_1 q_1$ is required. Here data from an industry source is used, the CTIA, which collects the data on a semi-annual basis. The only econometric estimate needed is for the price elasticity α, and this parameter appears to be the irreducible feature of the demand curve that is needed to estimate the change in the COLI from the introduction of a new product or service.

4.2. Estimation of the amount of increased consumer welfare

Now turn to the econometric estimation to implement the expenditure function approach of Equations (3) and (4) and the approximation approach of Equation (5). To do so, I collected price and subscribership data for the period 1989–93 from a (confidential) survey of cellular operators. These five years of data were used to run a log-linear regression of cellular prices in the top 30 MSAs. These top 30 MSAs contain about 107 million pops (population), or about 41 percent of the entire U.S. population. The estimated demand curve is reported in Hausman (1997). Using instrumental variables methodology to take account of possible joint endogeneity of price and demand, I estimate the demand elasticity to be -0.51 (standard error $= 0.17$). The results seem reasonable because the lower bound estimate (from the approximate linear demand curve) of the virtual price is \$97 per month, while the data set demonstrates that some actual monthly fees were as high as \$125 per month with significant demand at this price level. Thus, the conservative estimate of the lower bound virtual price does turn out to be quite conservative.

To calculate the expenditure function of Equation (4) the results of Hausman (1981) are used to calculate

$$e(p, \bar{u}) = [(1 - \delta)(\bar{u} + Ap^{1+\alpha}/(1 + \alpha))]^{1/(1-\delta)} \tag{6}$$

where A is the intercept of the demand curve, α is the price elasticity, and δ is the income elasticity estimate. The compensating variation is calculated from Equation (6) where y is income:

$$CV = \left\{ \frac{(1 - \delta)}{(1 + \alpha)} y^{-\delta}[p_1 x_1 - p_0 x_0] + y^{(1-\delta)} \right\}^{1/(1-\delta)} - y. \tag{7}$$

I then use Equation (7) to calculate the CV for the introduction of cellular telephone using the average revenue and subscribership data from the CTIA, which was discussed earlier, as well as the econometric estimates of the parameters of the demand function and associated expenditure function. I estimate that increased consumer welfare from cellular telephone in 1994 using Equation (7) was $49.8 billion, while using the more conservative approach of Equation (5) the amount was $24.2 billion. Using year-end 1999 data from the CTIA corresponding amounts of $111 billion and $52.8 billion were calculated. Thus, the average user of mobile telephone gains an increase in consumer surplus approximately equal to the yearly expenditure on the service.

In Figure 8, resulting price index for a COLI is graphed based on these results. Note that using a basis of 1988, the COLI index for cellular telephone decreases to about 0.116 by 1998. The calculated price index is extremely similar, whether the exact or approximate demand curve estimates are used. Note that the index of 0.116 is well below the price index, which is calculated in Section 2 to be 0.73. The index correctly captures the overall gain in consumer welfare from the introduction of cellular telephones.

4.3. Estimation of a corrected telecommunications services CPI

I now make a further approach to estimating the gain in consumer welfare from mobile telephone by re-estimating the telecommunications CPI in the U.S. to take account of mobile telephone. The BLS did not include mobile telephone in the telecommunications CPI until 1998 so that I recalculate a corrected telecommunications CPI that accounts for the effect of mobile telephones[53].

The BLS calculates a telephone services CPI each month. The three components of the telephone services CPI are local access charges, intrastate long distance (toll) charges, and interstate long distance (toll) charges. Cellular telephone had not been included in the telephone services CPI until 1998. The telephone services CPI is approximately 1.7 percent of the overall CPI.

I now estimate a corrected telecommunications services CPI where cellular service is included. I take into account the decline in cellular service prices, e.g. Figure 5, and also the gain in consumer welfare from the introduction of cellular service, e.g. Figure 8. Thus, a COLI based telecommunications services CPI is approximated.

To construct the corrected telecommunications services CPI yearly expenditures weights are used, based on total local and long distance expenditure for residential customers. Thus, I am estimating the welfare effect on consumers from cellular telephone, and eliminating the effect of business users, by assuming that consumers use cellular in the same proportion that consumers use long distance

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[53] When the BLS introduced mobile into the CPI in 1998, it made no correction for previous decreases that would have affected earlier values of the CPI.
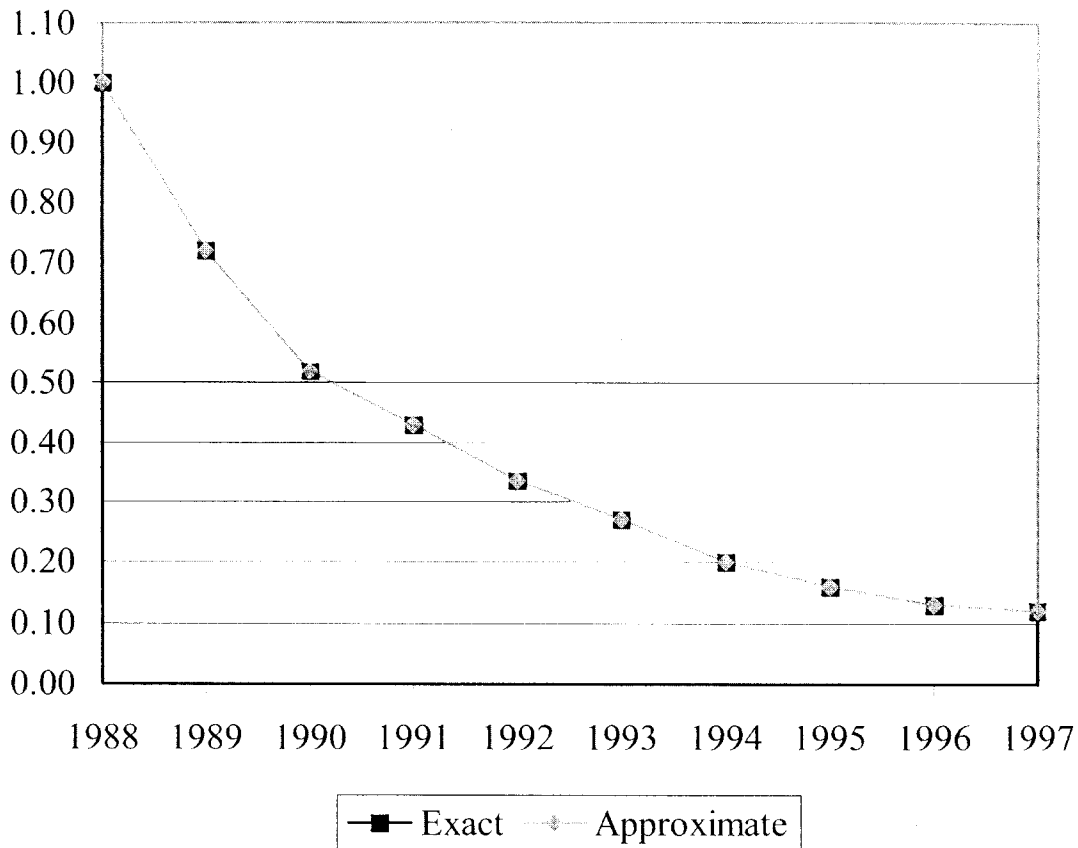
Fig. 8. Exact and approximate cost of living index.

service, compared to businesses. Since there is no expenditure share data across the various years, this method leads to an approximation. However, the approximation should be relatively accurate given the average expenditure of households on long distance with similar demographic characteristics to consumer cellular users. To the extent that the proportion of consumer usage of cellular is approximately equal to consumer usage of local and long distance services, these weights create a superlative price index[54]. Otherwise, the calculation leads to an approximation to a telecommunications CPI, which would need data on consumer expenditure shares to become a superlative index.

In Figure 9 the BLS telecommunications services CPI along with the corrected COLIs for telecommunications services is graphed. The price index from 'early inclusion' of cellular into the CPI in 1988 is also graphed. As demonstrated in Figure 9, the BLS telecommunications CPI estimates that since 1988, telecommunications prices have increased by 10.1 percent or an increase of 1.07
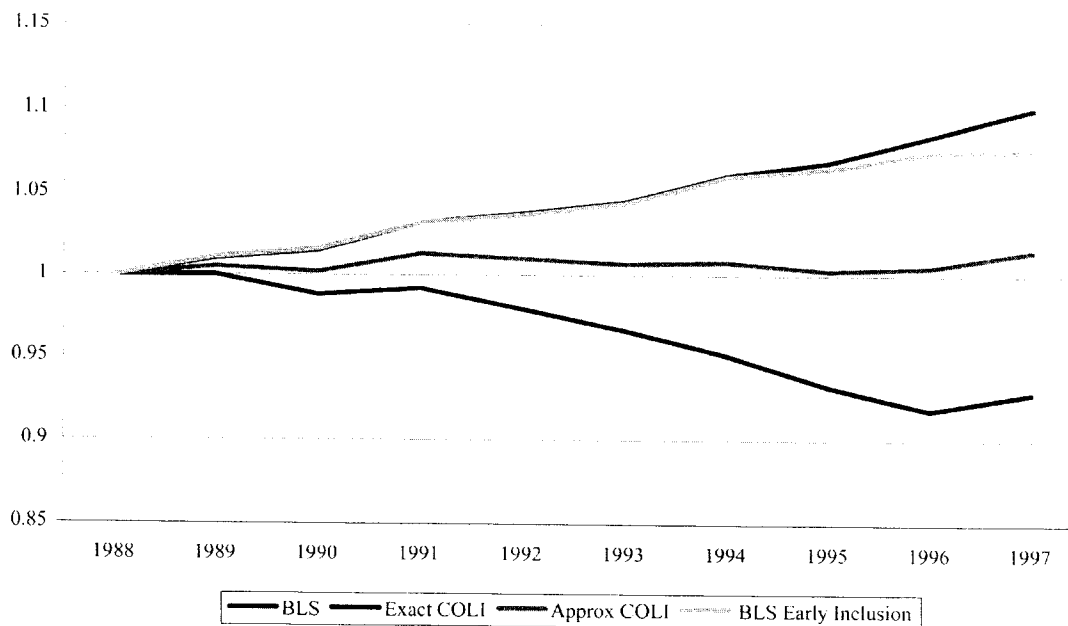
[54] See Diewert (1976).

Fig. 9. Telecommunications CPI: BLS calculations and correct COLI calculations.

percent per year. This estimate ignores cellular service. A corrected tele-communication services COLI that includes cellular service decreased from 1.0 in 1988 to 0.928 in 1997 for a decrease of 0.8 percent per year. Next, I do similar calculations using the lower bound approximation to the COLI using equation (5). In Figure 9, this approximate telecommunication services CPI that includes cellular service is essentially unchanged since 1988 with the increase only 1.8 percent over the entire period[55].

5. Government regulation of mobile telephone

Governments have a long history of regulating telecommunications in North America and actually operating telecommunications networks in much of the rest of the world. The introduction of cellular technology in the mid-1980s coincided with the privatization and introduction of competition in fixed line telephone over the next decade[56]. Questions arose whether cellular should be regulated. Questions also arose over whether two or three providers were sufficient to provide competition and limit the exercise of market power. A further question was whether cellular was a 'luxury' service and need not be regulated, in contrast to landline telephone service, which was a 'basic' service that many countries desired

[55] Sensitivity tests for these estimates are found in Hausman (1999a).
[56] See the Chapter by Brock in this Handbook.

to be provided with universal service. In this section government regulation of cellular and its effects on consumers are reviewed[57]. First, the effects of the approximately ten-year long delay in the introduction of cellular telephone in the U.S. by the FCC are considered.

5.1. Estimation of the cost of regulatory delay in the U.S.

I now use the estimates from the previous section to estimate how much consumer welfare was lost by the original approximate ten year delay by the FCC in licensing cellular in the U.S[58]. Cellular technology was available for deployment in the U.S. by the early 1970s. Yet regulation by the FCC delayed the deployment of cellular in the U.S. by approximately ten years. The delay in provision of cellular telephone was caused by regulatory indecision and the subsequent licensing procedure used by the FCC, which was in charge of cellular spectrum. The FCC could not decide whether to allow AT&T to provide cellular service alone or to allow non-AT&T companies to provide cellular alone or to allow competition between the two groups. AT&T had invented cellular and argued because of significant economies of scale in spectrum usage that only one cellular provider should be present in each MSA[59]. Potential entrants into cellular argued that cellular could provide competition to AT&T's landline local monopoly at some time in the future so that AT&T should be barred from cellular.

Cellular telephone technology was sufficiently developed to begin operation in the early 1970s in the U.S., see Lee (1982) and Calhoun (1988) for histories of development of cellular telephone. In practice, cellular service in the U.S. did not begin until 1983. Clearly, the demand for mobile communications existed in the U.S. in the 1970's. Here I explain the delay caused by regulatory indecision and the subsequent licensing procedure used by the FCC.

The FCC made decisions and subsequently reversed itself. Finally, in the early 1980's the FCC decided to allow two cellular providers in each MSA, after cellular service had already begun in Scandinavia, Japan, and the U.K[60]. This duopoly situation was a competitive departure for the FCC (although competition did exist in the provision of IMTS, 'Improved Mobile Telephone Service,' which was the previous non-cellular generation car telephone service, as well as

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[57] Government regulators unfortunately often attempt to protect competitors, rather than considering the interests of consumers. In the U.S. context and the failure of the FCC to promote consumer interests see Hausman and Shelanski (1999), and Hausman and Sidak (1999).

[58] This section is based on Hausman (1997).

[59] McKenzie and Small (1997) actually estimated decreasing returns to scale using U.S. data from 1993–1995.

[60] The FCC began its inquiry to reallocate additional spectrum for mobile telephone in 1968. By the time cellular telephone began operation in the U.S. in 1983, it had been in operation in both Scandinavia and Japan for over two years using the AMPS technology invented at Bell Labs.

paging service). The FCC decided to award 20 MHz of spectrum to each of the two cellular providers with 10 MHz of spectrum kept in reserve. In 1986 the FCC awarded 5 MHz of additional spectrum to the two cellular providers so that each now has 25 MHz of spectrum.

The FCC awarded the B block cellular frequency to the wireline telephone company in each MSA. Of course, this company was usually a BOC except for areas where GTE or an independent telephone company was awarded the spectrum. In a number of MSAs two or more wireline companies formed a partnership to operate the so-called 'wireline' network. To award the A block cellular frequency the FCC originally decided to conduct 'comparative hearings' (beauty contests) to decide who proposed the best cellular network. However, this procedure soon promised to create a morass of evidentiary and legal wrangling so that the FCC encouraged contenders to form partnerships. Companies such as Communications Industries, MCI, Metromedia, the Washington Post, and LIN Broadcasting became partnership members and were awarded the A block 'non-wireline' franchises. Because of procedural delays in awarding the non-wireline franchises, the B block networks typically began operation about 12–24 months earlier than the A Block non-wireline networks. Thus, a further delay was created. After realizing the fiasco of comparative hearings, the FCC subsequently used lotteries to award the non-wireline licenses in smaller MSAs and in RSAs. However, for these geographical areas it continued to award the B block license to the wireline carrier. Overall, the FCC delay was on the order of 7–10 years in the provision of cellular telephone in the U.S.

This regulatory indecision caused a new good, cellular telephone, to be unavailable in the U.S. when it was being offered in Scandinavia and Japan using technology invented by AT&T Bell Labs. This welfare loss is approximated by asking the question: if cellular had been available in 1983 with a 10 year history, but because of more limited and higher cost microprocessors and other semiconductor chips it cost twice as much (in 1983 dollars) as it did in 1994 and correspondingly, demand was lower because of the higher price, what was the lost consumer welfare?

The estimate of lost consumer welfare from the expenditure function of the previous section is approximately $49 billion in 1994 dollars. The lower bound approximation to the gain in consumer welfare from the introduction of cellular using the conservative linear approximation from the previous section is $24.2 billion. The gain in consumer welfare measured as the compensating variation from cellular is in the range of $24–49 billion per year, which demonstrates the substantial value to consumers from the introduction of cellular telephone.

My estimate of the loss in consumer welfare due to the ten-year delay, was approximately $24.3 billion in 1983 dollars or about $33.5 billion in 1994 dollars. Thus, the lost consumer welfare (compensating variation) was about

$76 per subscriber per month, which would be compared to an average monthly service price (with the 50 percent increase) of about $120 per month. Even if it is assumed that demand for cellular would only have been 1/2 as great in 1983 because of decreased functionality, there is still an estimated welfare loss of approximately $16.7 billion. This lost consumer welfare is extremely large and demonstrates how regulatory policy can significantly affect consumer welfare.

The consumer welfare cost of holding up the introduction of a new good is much larger than the effects of higher prices or other regulatory effects on demand, because the entire compensating variation is lost when regulatory delays cause demand to be zero. Looked at another way, the introduction of cellular has created significant value for consumers. Thus, new telecommunications services can improve consumer welfare by very large amounts. Regulatory delay can therefore have potentially large negative effects on the U.S. economy.

Again the possible question arises of why the FCC created such a large amount of harm to U.S. consumers and the U.S. economy. The FCC was confronted with a very difficult decision with respect to cellular. Delaying a difficult decision appeared to be the FCC's chosen response. Losses in consumer welfare arising from the regulatory delay did not appear to be involved in the FCC's regulatory approach. Indeed, if cellular service had not begun in other countries, which helped create pressure for the FCC to finally come to a decision, it is quite likely that the advent of cellular telephone service would have delayed for an even greater period in the U.S.

5.2. Regulation of mobile prices[61]

In the U.S. for the first 12 years of operation, cellular telephone operated as a duopoly. Given the significant fixed costs of cellular networks, the competitive outcome could not result in perfect competition[62]. In the U.S. each of 51 state regulatory commissions decided on whether to regulate cellular prices or to use market outcomes[63]. In an interesting natural experiment 26 states regulated cellular prices, while the other 25 did not. In Table 1, monthly service prices in 1994 are listed for the least expensive plan for average usage of 160 minutes per month (80 percent peak) for up to a 1-year contract.

The fact that regulation goes along with higher monthly service prices is evident from Table 1. Every regulated price in Table 1 is greater than every unregulated

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[61] This section is based in part on Hausman (1995a, 1995b).

[62] For a discussion of possible non-competitive outcomes in the mobile industry, see Parker and Röller (1997).

[63] In the U.S. the District of Columbia acts as the 51st state.

Table 1
Average cellular prices in the top 10 MSAs: 1994 160 minutes of use (80 percent peak)[64]

MSA No.	MSA	Monthly price	Regulated
1	New York	$110.77	Yes
2	Los Angeles	$99.99	Yes
3	Chicago	$58.82	
4	Philadelphia	$80.98	
5	Detroit	$66.76	
6	Dallas	$59.78	
7	Boston	$82.16	Yes
8	Washington	$76.89	
9	San Francisco	$99.47	Yes
10	Houston	$80.33	

price in Table 1[65]. The average price of regulated MSAs is $98.10 while the average price of unregulated MSAs is $70.59, which is a difference of $27.51 per month or 39 percent.

Table 1 demonstrates clearly that regulation of cellular telephone led to higher prices for consumers in the U.S. Econometric analysis allows one to quantify the higher prices that consumers pay in regulated states. I have run a regression on cellular prices in the top 30 MSAs which accounts for MSA population, average commuting time, and average MSA income[66]. These top 30 MSAs contain about 107 million pops, or about 41 percent of the entire U.S. population. Regulation is treated as a jointly endogenous variable and uses instrumental variables in estimation. The coefficient of the regulation variable is 0.149, which means that regulated states have cellular prices that are 15 percent higher, holding other economic factors equal. The coefficient is estimated very precisely (standard error = 0.052) and the finding is highly statistically significant (t statistic = 2.87). Thus, states that regulate do have significantly higher cellular prices in large MSAs. Now in the top 30 MSAs overall, regulated prices are 23.6 percent higher. Thus, other economic factors explain about 9 percent of the higher prices and regulation explains 15 percent. Regulation is the major factor associated with the higher prices[67].

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[64]This usage, 160 minutes per month, was the approximate average usage of cellular customers in 1994.

[65] The probability that every regulated price would exceed every unregulated price if the prices had no relationship to regulation is 0.00002.

[66] See Hausman (1995a, 1995b)

[67] See Duso (2000) for a recent paper, which considers the decision of states to regulate in terms of lobbying activity by U.S. cellular companies.

To explore this issue further I also collected data from cellular companies for the years 1989–93 and run a similar regression. Over this time period for 160 minutes of use regulation led to a higher price of 14.2 percent which is again estimated quite precisely (standard error = 0.029) and is very statistically significant (t statistic = 4.9). Thus, the results of the effect of regulation are very similar for the period 1989–1993 and for the single year 1994. I then did a similar econometric analysis, but used prices in the top 30 MSAs for 250 minutes per month for a typical 'high usage' customer. My estimate of the effect of regulation on price was 15.0 percent higher, which is again extremely statistically significant (t statistic = 6.57). Lastly, a similar econometric analysis was done for 30 minutes of monthly usage–a very light user of cellular. The coefficient estimate was 18.4 percent and it is highly statistically significant (t statistic = 4.2). Thus, econometric analysis demonstrated that in large MSAs for average usage of 160 minutes per month, for high usage of 250 minutes per month, and for low usage of 30 minutes per month that regulation is associated with higher prices of about 15 percent. Regulation led to higher prices, and it harmed consumers[68].

In 1993 Congress instructed the FCC to deregulate cellular prices unless a given state that was regulating cellular prices could show regulation was 'necessary.' Eight states petitioned the FCC to continue regulation, and the FCC turned them down in late 1994. One state appealed, but regulation completely ended in 1995. From Figure 5 above, it was previously noted that cellular prices decreased significantly in 1995–96 both because of new PCS entry and because of deregulation. As a test of econometric specification above, cellular (and PCS) prices in 1996 were taken and the previous specification reran. The regulation indicator variable was included to test the hypothesis whether it was regulation that caused prices to be higher in the regulated states, or whether it was some left out factor in the econometric model that would continue after prices were deregulated. The estimated coefficient on the (previously) regulated indicator variable is 0.9 percent (s.e. = 0.05). So regulation no longer had an effect in these states. Looked at another way, cellular prices fell after PCS entry, but they fell by about 14 percent more in states that had been previously regulated. I conclude that this excess 14 percent decrease was due to the elimination of regulation. Thus, when regulation was ongoing the prices in the regulated states (after controlling for other factors) were 15 percent higher than non-regulated states. In 1996 after price regulation was eliminated, the prices in the previously regulated states were not significantly different than the non-regulated states. Furthermore, the difference in prices was less than 1 percent. Thus, I conclude that state regulation of cellular prices led to higher prices to consumers by 14 to 15 percent. Regulators, by attempting to

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[68] Ruiz (1995) did not find a similar effect of regulation using the prices of the average user. However, her results seem inconsistent with Table 1 and with the subsequent decrease in relative cellular prices once regulation was eliminated.

protect resellers and other competitors from competition, led to significantly higher prices to consumers.

5.3. Regulation of mobile access and mandated roaming

Mobile is now largely deregulated in the U.S. However, in the U.K. and in the European Union regulation to require access on mobile network providers to other competitors has been approved[69]. No pricing formulae have yet to be determined, but the process is expected to be quite contentious. However, the basic question should be why is forced access necessary? Unless the mobile companies can exercise significant market power, regulation is likely to harm consumers. By giving other competitors a free option for the use of the network providers' investments, the result is to discourage investment and innovative services[70].

Two recent regulatory decisions are extremely peculiar in this respect. In 1999 the U.K. regulatory agency, Oftel, required Cellnet and Vodafone to provide network access and mandated roaming, while not making a similar requirement of the two competitors Orange and One2One with respect to network access. Yet, Orange and One2One are significant competitors, with Orange's and One2One's net new customer additions during 1998 and 1999 the same or greater than Cellnet's. With no barriers to expansion for Orange and One2One and the regulatory finding that they lack market power, the requirement that Cellnet and Vodafone provide required access does not seem to make economic sense, except as a competitor protection measure. To the contrary, the Australia regulator, the ACCC, denied a request for mandated access in January 2000 and earlier denied a request for mandated roaming[71]. However, the ACCC takes as its primary regulatory goal the long-term interests of end users (LTIE), while Oftel the U.K. regulator does not have a regulatory goal of consumer welfare. Instead, it tends to put competitor welfare ahead of consumer welfare.

The recent decision in April 2000 by the European Commission to require Vodafone to provide network access to its competitors as a condition that Vodafone be permitted to purchase Mannesmann is even more curious. No increase in concentration resulted from the merger, and one of Vodafone's goals was to provide lower priced inter-European roaming to its customers, a strategy that has been very successful in the U.S. as I discussed above. Competitors

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[69] I served as a consultant to Vodafone in the proceeding.

[70] By a free option I mean the ability to use the investment if it is successful, but not to help pay for the investment if it is not successful. For the distortionary effects caused by free options given to competitors see Hausman (1997, 1999b).

[71] No barriers to expansion exist given the ability of cell splitting discussed above and the economic factor that price significantly exceeds marginal (incremental) cost under competition because of the significant fixed costs in mobile networks.

claimed that they would be put at a disadvantage, and the European Commission required Vodafone to share its network with these competitors. In a non-tele-communications merger, this type of outcome would be almost unheard of. Consider the situation where Company A, an Internet switch manufacturer, buys Company B a fiber optics electronics manufacturer. No overlap in current products exist, but Company A announces it will be able to manufacture a better-combined product with Company B's technology. No competition regulatory agency would typically require Company A to allow another Company C access to Company B's technology. Otherwise, the adverse incentive to investment would limit future innovation and other companies would not invest since they could subsequently free ride off Company B's investment. However, regulatory agencies in charge of telecommunications seem to find it difficult to forbear from regulation, even when significant amounts of competition exist. One is put in mind of the famous statement, "It's no fun to be a regulator unless you get to regulate," (Anon).

5.4. Regulation of wireline call termination on mobile

In the U.S. up until the present, calls received on a mobile handset from a wireline origination have been paid for by the mobile customer[72]. In other countries a 'calling party pays' policy has been adopted where the wireline customer that originates the call is charged for it. As a consequence many U.S. mobile customers do not give out their mobile number with a higher proportion of originating calls in the U.S., about 80 percent, compared to other countries. However, the growing popularity of the 'bucket' plans in the U.S. has been decreasing this effect.

In a number of countries regulators and analysts have claimed that market power may be present for these fixed to mobile calls. Claims for regulation to lower termination prices have been made. In the U.K. fixed to mobile calls charges are claimed to be high, and Armstrong (1997) and in this Volume states that high call termination charges may be used to cross-subsidize new mobile subscribers. Doyle and Smith (1998) find in a model of competition that regulation is not required, but that the US receiver party pays approach would solve the problem. Recently, the Australian regulator, the ACCC, has examined the issue of mobile termination charges. Gans and King (1999) claim that a mobile operator has an 'effective monopoly' over its customers and that regulation is needed because of wireline consumer ignorance over the terminating charges when they place a call[73]. Gans and King (1999) call for terminating charges to be set at marginal cost by the regulator. However, Wright (2000) demonstrates that above cost termination charges lead to lower cellular price and high penetration rates because of competition among mobile companies.

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[72] The FCC has been considering a change in this policy to calling party pays.
[73] I consulted for Optus in this proceeding. See Hausman (2000b).

Almost all participants in the debate acknowledge that competition among mobile providers works well, with increasing entry and decreasing prices. Thus, no regulation is needed here. The question is who will pay for the fixed and common costs of the mobile network; mobile subscribers or fixed to mobile callers? The Gans-King proposal of setting terminating charges at marginal cost seem to make little economic sense. As Hausman (2000b) demonstrates, the standard Ramsey problem of the efficient method to cover the fixed and common costs will have both sets of customers paying above marginal cost to cover the fixed and common costs of the mobile networks. Indeed, given the estimated elasticities, the terminating call customers would pay a higher markup in an optimal solution than would the mobile originating call customers. Of course, a two-part tariff arrangement could be explored, but it is doubtful that regulators would require companies to pay a fixed charge for their customer's calls.

If a problem exists, it is because of customer ignorance of the charges they will pay for their terminating call. However, whether customer ignorance is a problem is not clear since many calls are repeat calls and customers receive itemized bills for their calls. But price regulation is not required to solve the problem if customer ignorance causes the problem. For terminating calls on mobile the operator could be required to identify itself, just as AT&T has done for many years in the U.S. when a long distance call is made on its wireline network. Consumer information would solve the potential market failure problem without the need for regulatory interference in competition and market determined prices. Both regulators and economists should first determine if a problem exists and then seek to solve the source of the problem, rather than turning to the highly distortionary solution of setting regulated prices, which has not worked well in the past in similar situations.

6. Taxation of mobile services[74]

In the U.S. federal, state, and local government authorities are now levying a wide range of taxes and fees on the use of mobile telephone services. The total effect of the FCC-imposed fees and other federal taxes is currently 4.52 percent (including the federal excise tax and the FCC's share of current universal service program funding)[75]. State and local taxes on wireless vary by jurisdiction, and commonly impose higher tax rates on wireless than on other businesses. Many localities charge a variety of direct and indirect fees to wireless providers. For example, the aggregate New York state tax is 20 percent so that the combined federal and state tax burden on a wireless user in New York is 24.5 percent or approximately $170 per year. Similar taxes on wireless users in California and Florida average about 21 percent. The resulting state tax obligation for the average wireless customer in

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[74] This section is based on Hausman (2000a).

[75] See Hausman (1998) and Hausman and Shelanski (1999) for a discussion of the FCC taxation program to provide Internet subsidies for schools and libraries.

these states exceeds \$152 per year[76]. When federal taxes are included, the overall tax rate increases to 25.5 percent, and average consumers' tax bills increase to \$185 per year. Even in states where lower taxes are levied on wireless, the median state tax rate is 10 percent, and the tax payment for the average wireless customer is about \$62. Including current federal taxes, the median tax rate is 14.5 percent and the yearly tax bill is about \$91.

Economists have well-developed tools, used for more than 100 years, to assess the distortionary effect of a tax on consumer welfare and economic efficiency. Taxes decrease the consumption of a good or service and, in this case, also lead to under-utilization of the infrastructure investment made by wireless providers. In this section, the effect on deadweight loss and economic efficiency from the distortionary effect of taxation on wireless are calculated. The change in economic efficiency accounts for both harm to consumers, from the deadweight loss term, and harm to wireless providers who have invested tens of billions of dollars in their networks and who have paid over ten billion dollars to acquire their licenses, often from the federal government[77].

6.1. Estimation of economic efficiency losses

Taxes (and subsidies) distort economic activity. Taxes increase prices and thus lead to lower demand. This lower demand has two adverse affects on economic efficiency which is defined (approximately) as the sum of producer surplus and consumer surplus[78]. To the extent that the industry is imperfectly competitive and price exceeds marginal cost to cover fixed costs, decreased demand reduces the amount of producer surplus, which is the product of quantity demanded times the difference between price and marginal cost. Decreased demand from higher prices also affects consumers adversely since consumer surplus decreases. Thus, the change in economic efficiency from the imposition of a tax is given approximately by the formula:

$$\Delta E \approx \left[-\Delta q_i(p_i - m_i) - .5\Delta p_i \Delta q_i \right]$$
$$\approx \left[\eta_i \frac{\Delta p_i}{p_i}(p_i q_i - m_i q_i) + .5\eta_i \left(\frac{\Delta p_i}{p_i} \right)^2 p_i q_i \right] \tag{8}$$

[76] For instance, a wireless user in California pays the following taxes: FCC taxes for the high cost fund, universal service and school and library internet subsidy, state, county and city sales taxes, taxes (fees) levied by the California Public Utilities Commission for universal service (3.2 percent), emergency telephone service (0.72 percent), high cost funds (3.14 percent), teleconnect fund (0.41 percent), hearing impaired fund (0.36 percent), local utility taxes (7 percent), and the federal excise tax (3 percent).

[77] PCS providers bought their spectrum in auctions conducted by the federal government. The cellular spectrum and much of the ESMR spectrum was distributed free of charge by the federal government in an earlier period before auctions were used. But, in many instances, current licensees obtained their spectrum by buying it at market prices from the original licensees.

[78] See, e.g. Auerbach (1985) for a further discussion of how taxation creates efficiency losses to the economy.

where the first term is the change in producer surplus and the second term is the change in consumer surplus, after the amount raised by the tax is subtracted[79]. Figure 10 provides a graphical demonstration of this relationship. Equation (8) demonstrates that taxes which cause prices to increase create losses in economic efficiency with the size of the efficiency loss depending on the price elasticity η_i, the magnitude of the price increase $(\Delta p_i/p_i)$, the revenue of the good or service being taxed $p_i q_i$, and the marginal cost of production, m_i[80]. For mobile telephone the price elasticity η_i has been estimated to be -0.51, Hausman (1997), which is relatively high for telecommunications services[81]. The magnitude of the price increase $(\Delta p_i/p_i)$ depends on the tax rate in each state with the median tax rate 10 percent and the high tax rates in the range of 20 percent-21 percent in California, New York, and Florida[82]. When current federal taxes are included, the median tax rate is 14.5 percent and in the high tax states the overall rate is 24.2 percent to 25.5 percent. The revenue of wireless service $p_i q_i$ is about \$525 per year, excluding taxes. Lastly the marginal cost of production for wireless, m_i, is relatively low, which is expected given the large fixed costs of wireless networks. The marginal cost is estimated to be about \$0.05 per minute[83]. Thus, the expected result from Equation (8) is relatively high efficiency costs to wireless taxation given the relatively high demand elasticity, the significant tax rates, and the low marginal cost of production.

Using equation (8), the cellular elasticity estimate considered above, and the fact that the marginal cost of wireless is about \$0.05 per minute while the median tax rate is 14.5 percent[84], I estimate that for average revenue raised by the tax on wireless:

$$\Delta E = 0.534^* TR \tag{9}$$

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[79] Thus, as discussed above, the possible distortion created by expenditure of the tax is not considered. All the quantities in the formulae are assumed to be Hicksian compensated quantities. See Hausman (1981) for computation of compensated quantities.

[80] A more accurate estimation approach using the technique of Hausman (1981) is discussed in Hausman (2000a).

[81] However, Nattermann (1999) estimates the industry price elasticity in Germany to be -2.3.

[82] In these calculations I put sales taxes in the 'numeraire' price of other goods under the assumption that it is paid on purchases of other goods and services.

[83] To estimate this marginal cost I take the expected growth rate of a given cellular company and perturb the growth rate up or down by a small amount. I take the difference in the present value of costs and divide it by the levelized increase in output. Thus, the estimate takes account of more rapid expansion (e.g. cell splitting) by the cellular company as well an increase in its variable costs which also include payment to local exchange companies and to interexchange carriers for the increased traffic. The main economic fact that price greatly exceeds marginal cost is not significantly affected by the exact details of the calculation. This relationship between price and marginal costs holds for almost all telecommunications services.

[84] This estimate of marginal cost includes customer acquisition cost which is amortized over three years, which follows from an estimate of the average churn rate for new cellular customers.
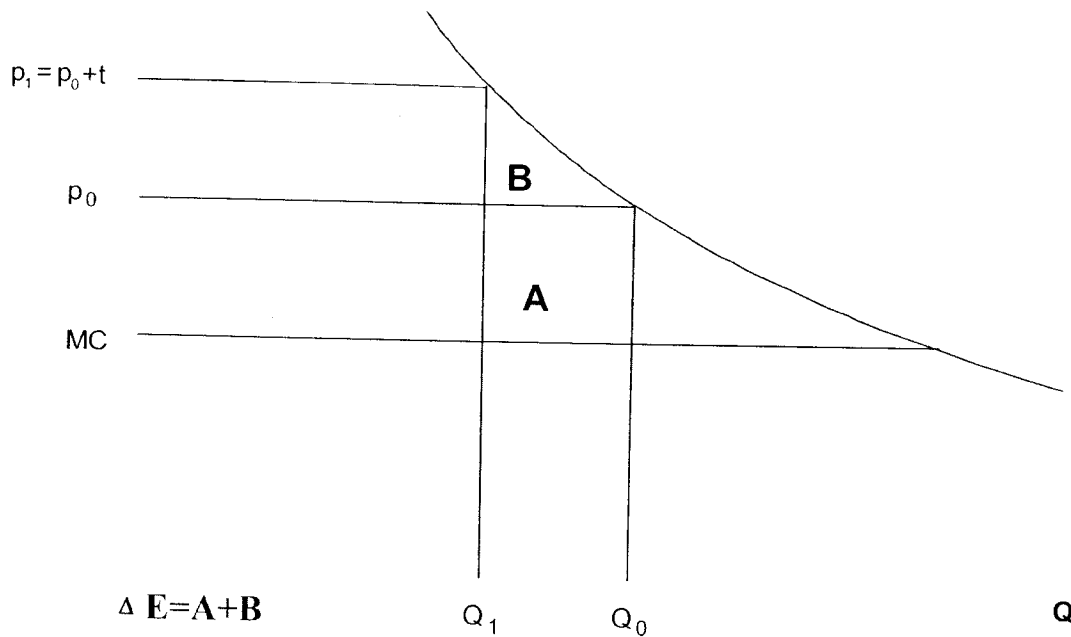
Fig. 10. Efficiency effect of tax.

where *TR* is total tax revenue raised. This calculation follows from dividing through Equation (8) by the tax revenue raised, $t_i p_i q_i$ (i.e. the tax revenue term *TR*), and using wireless revenue and tax amounts collected from wireless by the federal, state, and local jurisdictions.

For the high tax states the efficiency loss increases on average for each dollar of tax revenue raised from wireless customers. For a 21 percent state tax rate used in California, Florida and New York, the estimated efficiency loss increases to approximately $0.70 for each dollar of tax revenue raised. For lower tax rates, the estimated efficiency loss decreases accordingly. The elasticity estimate that was used to calculate equation (9), reported in Hausman (1997), is −0.51. This estimate was based on data up through 1993. Using more recent data, it has been estimated as an elasticity of about −0.71, although the estimate is not statistically significantly different from the earlier estimate[85]. An increased elasticity estimate might be expected given the rapid penetration of mobile telephone and the expected results that early adopters place a higher marginal valuation on their usage while later adopters are affected by decreasing prices. Thus, the higher penetration among residential users may be leading to a higher price elasticity,

[85] Recent estimates of the price elasticity in Australia have estimated an elasticity of approximately −0.8, which is close to my estimates.

since these non-business users have a higher price elasticity[86]. While one would need to collect more data before changing the elasticity estimate, note from equation (8) that the estimated efficiency loss is homogeneous of degree one in the elasticity estimate. Thus if the higher elasticity estimate were used to estimate the average efficiency loss, the amount would increase from 0.534 for the median tax state to 0.743. The efficiency loss for the high tax states would also increase accordingly.

Perhaps a more relevant calculation is the marginal efficiency loss to the economy from changes to the tax rates. The FCC and state and local tax authorities apparently view wireless as a ready tax revenue source so that they have been increasing the tax rates over time. The FCC has increased tax rates to provide universal service for landline telephone users and to provide Internet subsidies to schools and libraries[87]. These subsidies and the taxes (fees) to fund them are expected to continue increasing in the near future. The formula for the marginal efficiency loss of increased taxation is computed by taking the marginal change in equation (8) with respect to the tax rate, $\partial \Delta E / \partial t_i$, and dividing by the marginal change in tax revenue with respect to the tax rate, $\partial TR / \partial t_i$:

$$\left(\frac{\partial \Delta E / \partial t_i}{\partial TR / \partial t_i} \right) \approx \frac{\eta_i \left(1 - \frac{m_i}{p_i} \right) + \eta_i \frac{t_i}{p_i} + \left[\eta_i \frac{t_i m_i}{p_i^2} - .5 \eta_i \frac{t_i^2}{p_i^2} \right] \frac{\partial p_i}{\partial t_i}}{1 - \eta_i \frac{t_i}{p_i} \frac{\partial p_i}{\partial t_i}} \tag{10}.$$

Using equation (10) together with the assumption that $\partial p_i / \partial t_i = 1$ along with the fact that $t_i / p_i = 0.1452$ for the median state when federal taxation is included, Equation (10) is estimated to be 0.709[88]. When the marginal efficiency loss is

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[86] Under various competitive assumptions that businesses pass along the increased cost of inputs in their final product prices, the estimates in this paper would remain approximately the same. However, as I discuss subsequently, the pass through assumptions can be affected by oligopoly models of final product demand. So as not to unduly complicate the models, I assume unitary pass through of the wireless taxation to final product demand and assume that the same price elasticities hold for business and residential customers. Thus, business demand can be interpreted as a derived demand for wireless that arises from final product demand from consumers.

[87] Hausman (1998) and Hausman and Shelanski (1999) discuss the Internet subsidy program for schools and libraries.

[88] If instead of the assumption that $(\partial p_i / \partial t_i = 1)$, I use a differentiated product oligopoly markup model assumption along with constant elasticity demand curves, the marginal efficiency loss could be higher than 0.71. Other oligopoly models, especially models based on linear demand curves could find $(\partial p_i / \partial t_i < 1)$. For a further discussion of these matters see e.g. Hausman and Leonard (1999). However, the introduction of 4–5 new wireless competitors in addition to the two cellular incumbents in each market will lead to increased competition, leading to the conclusion that the entire tax will be passed on to customers. When I did a similar analysis for the introduction of the 'E-rate' tax on long distance in Hausman (1998), the chief economist at the FCC at that time claimed that the long distance companies might not pass on the increased tax to their customers. However, experience demonstrates that the long distance companies did pass on the entire tax, often using a separate line item on the bill to call customer attention to the tax.

calculated using the exact calculation based on Equation (9) using the approach of equation (10) instead of the traditional approximation, the marginal efficiency loss is estimated to be 0.724. For all further calculations, the exact approach is used rather than the approximation of Equation (10).

Thus, for increased taxation the efficiency loss to the economy is approximately $0.72 for each $1 of additional tax revenue. For states such as California and New York with tax rates near 20 percent (which rise to 25 percent when current federal taxation is included), the marginal efficiency loss is about $0.93 for each $1 of tax revenue raised from wireless service. Thus, the marginal efficiency loss is quite high since for each dollar raised by an increase in wireless taxes, $0.72 to $0.93 of efficiency loss is created for the economy, beyond the tax revenue raised[89].

Three reasons exist for this high amount of efficiency loss to the economy from wireless taxation, which can be seen by an examination of equations (8) and (10): (1) the elasticity η_i is relatively high, (2) m_i/p_i is relatively low since gross margins are high in wireless which is to be expected given the large fixed costs of wireless networks, and (3) t_i/p_i is relatively high in the range of 14 percent-25 percent.

6.2. Comparison with alternative taxes

Rather than taxing telecommunications usage to fund the subsidy for universal service landline telephone subsidies and Internet access subsidies for schools and libraries, Congress could have used general tax revenue. Similarly, states can levy taxes on incomes or expenditures (sales taxes) to fund their various social programs. While no generally agreed to number exists for the value of the marginal efficiency loss to the economy from increasing overall taxes, the range of estimates is reasonably close. The generally used estimates are all below about $0.40 of marginal efficiency loss per dollar of additional revenue raised[90]. Thus, they are all significantly less than the $0.72 to $1.14 efficiency loss per additional dollar of tax revenue raised by the FCC and by the state and local authorities. Thus, considerably less expensive means to raise tax revenues, in terms of economic efficiency losses, exist for the federal government and for the states in terms of increasing income taxes or other broad-based taxes, rather than targeting the use of wireless services. Government taxation of mobile telephone imposes an especially high efficiency loss on the economy given the demand and cost factors that exist for mobile telephone. Governments would be much better off to use a broad based tax such as an income tax or find alternative goods to tax with lower demand elasticities of a lower proportion of fixed costs to total costs.

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[89] Since the numerator is homogeneous of degree one in the price elasticity and the denominator will decrease with a higher elasticity, the marginal efficiency loss would increase significantly if the higher elasticity of −0.71, which I discussed above, were used. Indeed the estimate of $0.724 increases to $1.14 for the marginal dollar of tax revenue.

[90] See Hausman (2000a) for the sources of these estimates.

In this section the outcome of three government regulatory and taxation policies for mobile telephone has been considered. All three policies had a significant and large negative effect on consumer welfare. While mobile telephone is a telecommunications service from a sector of the economy that has traditionally been heavily regulated, a clear lesson is believed to be that regulation should be removed from mobile telephone[91]. Regulation of a dynamic technology is notoriously difficult, and U.S. regulation of mobile telephone has provided a very good example. Sufficient competition now exists in the U.S. and most other countries so that regulation of mobile telephone is unnecessary. However, regulators find it notoriously difficult to 'let go' since they seemingly have little faith in the operations of markets. In the U.S. it took an act of Congress to deregulate mobile. While economics students learn that in the absence of market failure consumers benefit from market outcomes, regulators either favor competitors' interests over consumer welfare because of political considerations or do not believe in economics. One leaves it to the reader to decide.

7. Conclusion

Successful new telecommunications services create very large gains in consumer welfare. Mobile telephone is an example of an extremely successful new telecommunication service that already has changed how people live and work. In any large urban area, it is difficult to walk more than a block or two without seeing someone using a mobile telephone. Mobile telephone penetration has surpassed landline telephone penetration in Scandinavia and Japan, and it will do so in a number of other European and North American countries in the next few years. Thus, the initial technology invented by Bell Labs and advanced by numerous companies since, has led to an innovative product of great usefulness. With the possible future combination of wireless telephones and PDAs with the Internet, the usefulness may increase by even more. Indeed, the future of landline telephone may be called into question by the availability of mobile telephones.

Government decisions have played a significant role in the past and future of mobile telephones. Government decisions did permit competition in mobile, in contrast to the single provider model of landline telephone. However, at least in the U.S., the FCC delayed the introduction of cellular telephones, costing consumers tens or even hundreds of billions of dollars in lost consumer welfare. Again in the U.S., it was the Congress that forced the regulatory agencies to auction off spectrum rather than use beauty contests, and used political influence to allocate scarce spectrum. Further, Congress caused cellular prices to be deregulated in the U.S. Thus, the lesson that one draws from the experience is that consumers and the mobile industry, in terms of lower prices and greater

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[91] Regulation may be needed to minimize spectrum interference, but economic regulation is unnecessary and generally harmful in this situation.

investment, would have been better off, and would be better off in the future, with de-regulation of mobile telephone. Competition among 4 to 5 providers should be sufficient to protect consumers. In many industries with 4 to 5 providers that arise because of large fixed and sunk costs, no responsible economist would call for price or access regulation. Yet, telecommunications regulators, perhaps because of their experience in regulation of landline telephone, seem to continue to regulate an industry that does not need regulation. Competition is typically superior to regulation in situations similar to the mobile industry, and regulators seem to want to engage in competitor protection policies. Instead, regulators should consider consumer welfare and allow competition to take care of consumers.

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