Demise of the Pay Phone Industry

Assessing the Welfare Implications

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I. Introduction

In many ways, technology is the essence of growth. New developments and products allow us to do things we could not do before, arguably raising the standard of living and enhancing our lives. Technological developments add to and improve what we already have, thereby increasing the welfare of society. While this is true in some cases, there are also examples, both historic and present, where technological developments imply negative welfare consequences for at least *some* part of society. The relative size of that part differs from case to case, as does the relative harm in each situation. This paper outlines some of the historic examples of decreased welfare due to technological improvements, and employs a specific detailed example to demonstrate the phenomenon more fully.

The specific case about which this paper is concerned is that of the disappearing pay phone, or public telephone. Pay phones have been in use since the late nineteenth century (Oslin, 1992). They have remained an essential communications device throughout the development of society and the economy over the last one hundred years. Cellular phones emerged in 1983 (Hausman, 1997) and were subsequently adopted at varying rates. Inevitably, with this invention, the demand for pay phones decreased. In turn, profits decreased, leading phone companies to eradicate millions of pay phones throughout the United States. Many people prefer to use pay phones, but this is becoming increasingly inconvenient and impractical. Telephone-using consumers that prefer pay phones to cellular phones may be ill-fated as pay phones continue to disappear.

A few researchers have addressed the idea that technology can induce negative welfare effects, although none of the following cases directly address the pay phone problem. Theodore Schultz (1961) published on the topic of redistributing losses from economic progress, focusing on the farming industry. As technology makes farms more efficient, fewer hands are needed on each farm and fewer individual farms are necessary, explains Schultz. The only way to resolve the incipient employment problem is for farmers to leave the rural areas and pursue jobs elsewhere. However, "farm people are trapped by the low salvage value of their particular skills in other occupations," says Schultz (555). The government approach to these issues focuses on evening out the booms and recessions inherent to the farming industry by using fiscal and monetary policies, while paying unemployment benefits as well (556). The biggest problem with this system is that farmers cannot distinguish "between losses in earnings from their own effort (their labor and management) and changes in the return to land and to other forms of capital they employ in farming caused by economics progress" (557). Meanwhile, consumers realize lower priced farm goods because output increases with technology. Schultz presents an alternative policy that aims to balance the gains and losses between consumers and producers (respectively) that accompany economic progress and technology improvements in the agriculture sector. He suggests incentives to lure younger farmers away from agriculture because older farmers are less able to adapt their skills for a career change. Along with these incentives, he proposes programs to ease the transition away from farms for those who choose to leave. Schultz also addresses and invalidates the fact that farm people experiencing these difficulties on the supply-side of agriculture simultaneously experience gains as consumers: "farm people can lose more as producers than they gain as consumers from this process" (557). This early look at the negative consequences of technology is not modeled. However, Schultz's work has since been built upon by Schmitz and Seckler (1970), among others.

Schmitz and Seckler (1970) studied the introduction of the tomato harvester to modern agriculture in California in the early 1960s. They write: "'Technological displacement'…remains the source of some of our greatest social problems" (569). As farming techniques improve with technology, many workers become unemployed. Schmitz and Seckler follow through on the idea that "the broad social costs of technological innovation can be mapped into the framework of economic analysis" and present a quantitative model of the tomato harvester's impact on society (569). They come to the following conclusion:

> …the social costs accompanying such innovations as the tomato harvester… would be substantially reduced [and] interventions… would allow social costs and benefits to fall more or less randomly on the population as a whole and thus, in a sense, cancel each other. If this were to occur, 'everyone' would be better off with technological change. That is, to us, the moral of the tomato harvester (576).

Schmitz and Seckler tally up the net losses (lost wages of unemployed workers) and the net gains (reduced production costs and lower price of tomatoes for consumers) and find that the gains outweigh the losses. If the producers and consumers were to take their gains and distribute some among the unemployed workers, "'everyone' would be better off" (576), so society gains as a result of the tomato harvester's inception. This model works in a limited way. It is impossible to consider all the "costs" besides lost wages that the displaced workers face. Additionally, the fact that the technological advancement is a producer concern makes this case qualitatively different than the pay phone problem, where technological change is happening on the consumer side.

Both of these cases illustrate scenarios in which economists have attempted to analyze the welfare effects of technology, yet none of them parallel the pay phone problem. The core of the pay phone problem is that a new technology emerged (cellular phones), and customers who prefer pay phones are in an unfortunate position because the pay phone customer base is losing critical mass and the industry is no longer profitable. The concept of the digital divide parallels this problem in ways that the other examples do not.

The digital divide refers to the gap between those who have access to Internet technology and those who do not. More specifically,

> The *global divide* refers to the divergence of Internet access between industrialized and developing societies. The *social divide* concerns the gap between the information rich and poor in each nation. And finally within the online community, the *democratic divide* signifies the difference between those who do, and do not, use the panoply of digital resources to engage, mobilize, and participate in public life (Norris, 2001, 4).

The fact that some people do not have access to the Internet is a growing welfare problem because the Internet is an increasingly valuable resource, and "[t]he contrasts worldwide are sharp: [m]ore than half of all Americans now surf the Internet compared with .1 percent of Nigerians" (Norris, 2001, 15). "While the technology may exist to deliver any information anywhere in the world, many people lack the money to pay for it, the equipment to access it, the skills to use it, or even the knowledge that any of this might be useful to them in the first place" (Cranor & Greenstein, xii). Contemporary discourse concerning the digital divide identifies it as a worldwide emergency: "The Internet threatens to magnify the existing socioeconomic disparities, between those with access and those without, to levels unseen and untenable. Therefore, urgent actions are needed at the local, national, and international levels to bridge the global digital divide" (Ishaq, 2001). The "disparities" that Ishaq refers to, are conceived on a sociological level, where people who have access to the vast resources of the Internet are increasingly better off because of the Internet's increasing value as an efficient tool with social, educational, economic, and entertainment facets. Discourse has failed to establish whether the individuals that do not have Internet access are simply, relatively worse-off compared to those with Internet access, or whether they are additionally, worse-off in an absolute sense, compared to themselves in past time periods.

The examples of Schultz and Schmitz & Seckler certainly show reasons to be concerned about welfare, but in reality, users of the old technology in these cases can choose to continue using it until they decide otherwise, leaving them no worse-off than before the new technology came. The pay phone problem is different in that users of the old technology (pay phones) are unable to continue using it because of its gradual extinction. Since the spread of cellular technology, the pay phone-using customer base has been declining so much that the phone companies have started to remove pay phones. Users of the old technology will either have to buy a cell phone or be willing to walk farther to find a pay phone when they want to use one.

Although the literature does not discuss it specifically, the digital divide concept parallels this problem in a specific way. The Internet has created new, more efficient, ways to do many things. College applicants can now apply online instead of sending in the paper-based applications of the past. Travelers now buy airplane tickets online, day or night, from the comfort of their homes, instead of telephoning the airline or visiting the travel agent. Many job-seekers do all their searching on the Internet, a constantly updated resource, and no longer rely on newspapers or other printed advertisements.

Customers can now order pizza or buy movie tickets on the Internet! It is conceivable that in the future, the "old" ways of doing things will no longer be available. Once enough people (a critical mass) switch over to using the Internet for all of these things, those who prefer the old ways or do not have access to the Internet will be worse-off in an absolute sense, as the previous ways of doing things will be unavailable. Every home will need an Internet connection, just as every individual may need a cellular telephone. The costs of connecting to the Internet and subscribing to cellular telephone service are consistently decreasing, but the consumers who prefer the old way of doing things, or cannot afford these costs, may be at a welfare disadvantage because of their preferences.

II. The Pay Phone Industry

Pay phones, or public telephones, are the means by which any person can make a telephone call by inserting coin currency. Since the 1880s (Noguchi, 2002 and Oslin, 1992), pay phones have typically been located in highly trafficked public spaces. Today, consumers put money into the phone and are subsequently connected to a dial tone. The local phone company (let us call the generic local phone company LC) owns the pay phone equipment and the phone lines in the area. LC provides connections to other telephones served by their phone lines and to any telephone served by another company's telephone lines, via agreements with long distance phone companies. Let us call the generic long distance phone company LD.

LC periodically collects the money from each pay phone site, using some of this money to pay for maintenance of phones and telephone wires in the area. The pay phone industry is atypical in that it exhibits decreasing marginal costs (Ottalagana, 2003). There are high fixed costs associated with setting up each phone booth and installing new telephone wires. Additionally, many phone booths have to be replaced after only 2 or 3 years of operation, due to the physical wear and tear that threatens many of these public devices (Ottalagana, 2003). Because of the high fixed costs associated with setting up each phone booth, a firm would rather have high call volume at a fewer number of sites, than set up pay phones all over the region and have the same number of calls dispersed throughout them (Ottalagana, 2003).

Although the vast majority of pay phones are owned and operated by local phone companies (like Verizon), some are owned and operated by independent companies (Noguchi, 2002). The structure for these independent companies is slightly more complicated because they must have agreements with the local company as well as with long distance carriers. Smaller, independent companies are often at a disadvantage and are less likely to establish profitable pay phone enterprises, due to the extra agreements and line-leasing costs (Ottalagana, 2003). This adversity is still observed, although it is now illegal for "the incumbent pay-phone provider, such as Verizon, [to] have a financial advantage over independents. Specifically, Verizon cannot charge the independents more to connect to its network than it costs to provide the service" (Woller, 2001). Although laws like this one have proliferated over the past two decades, the monopolistic nature of the phone industry, especially at a local level, remains largely undisputed.

The reason that competition between local phone companies only exists to a very small degree is that telephone lines are expensive to install and, therefore, only one set of telephone wires runs to every phone. Because one company, in particular, owns the lines to each location, the customer at a specific site (a home or office, for example) has little choice but to subscribe to that phone company. Just as an individual can set up his own personal telephone, he can orchestrate having a pay phone on his property (a store or restaurant, for example). The following scenario, while providing additional information about the pay phone industry, illustrates reasons that bar individuals from setting up pay phones independently. If someone wants to own and operate a pay phone, he or she must be certified by the state in which the phone is to be located. This ensures that the phone will offer an operator service and a 911 service at no charge to customers, each of which will require a monthly premium (Ottalagana, 2003). Additionally, the telephone lines leading up to the phone must be leased from the local company. This can be expensive because that phone company has a monopoly on the wires to the phone's location. The cost of the pay telephone is also substantial. For an independent proprietor to go through this process, he would have to anticipate very high revenues from his payphone. This can happen, although sometimes individuals set up pay phones as a service to others. For example, a business owner might install a pay phone for his employees to use, not as a revenue-making device (Ottalagana, 2003).

The monopolistic nature of the local phone business has been under scrutiny for much of the 20th century. The Mann-Elkins Act of 1910 came "in response to complaints that AT&T was engaging in monopolistic practices" and provided for increased government regulation to combat this problem (Crandall & Waverman, 1995, 40). The

Federal Communications Act of 1934 created the Federal Communications Commission (FCC) to oversee *interstate* communication, without giving jurisdiction over *intrastate* communication. Over the years, the FCC has sought to improve competition in the phone industry, but "the dual system of regulating telephone service at the state and federal levels has always been accompanied by a certain degree of tension between the state regulators and the FCC" (Crandall & Waverman, 1995, 41). This history of the industry puts the current pay phone problem in a context of longstanding regulatory and monopolistic difficulties. The Telecommunications Act of 1996 addressed competition in the pay phone industry directly, by completely deregulating pay phone pricing in hopes of promoting competition among pay phone companies (Consumers Union, June 4, 1998). Until then, prices for local calls were regulated by the states (Consumers Union, Oct. 2, 1997). Letting pay phone companies determine their own pricing schemes had the theoretical prospect of making the business more competitive, but so far, it has not worked. Within two years of price deregulation, most pay phone companies raised the price of a local call from $0.25 to $0.35 (Consumers Union, June 4, 1998). By 2001 the price had reached $0.50 in many areas (Noguchi, 2002). Consumers were outraged as the price swelled. This price increase may be a deciding factor in favor of buying a cell phone for those not yet decided.

Although the phone industry is clearly not competitive at the local level, Robert E. Hall explains that long-distance phone companies have crossed the threshold:

> With respect to the issue of competition and the Telecommunications Act's desire to create more effective competition, one very important thing to say is that we already have a lot of competition. Competition does work in telecommunications. We have a very effective competitive long-distance market in which relatively little intervention occurs… We have growing

> effective competition in local toll markets (Sidak, 1999, 12, quoting Robert E. Hall).

It is possible that the regulatory system could promote competition at the local level in the future, including competition in the pay phone industry. Such a change might allow the problem of overpriced, underused pay phones to resolve itself. If demand for pay phones truly exists, the laws of supply and demand predict that pay phones would be supplied at a near-optimal level under competition. (See the Appendix for a model of the pay phone industry under competition, including a short welfare analysis).

Even under competition, the consumer side of this quandary illuminates some other complexities. Since deregulation of prices, and because pay phones are geographically dispersed, each pay phone is its own monopoly. When a consumer wants to make a call, and finds a pay phone, he is subject to the prices of that phone. His only alternative is to keep walking, in hopes of finding a lower-priced phone nearby, although there is no guarantee he'll find a phone anywhere nearby, and the possibility exists that he's already found the lowest-priced phone in the area. He has incomplete information about the product he wishes to purchase, and this is known to cause breakdowns in a competitive market equilibrium.

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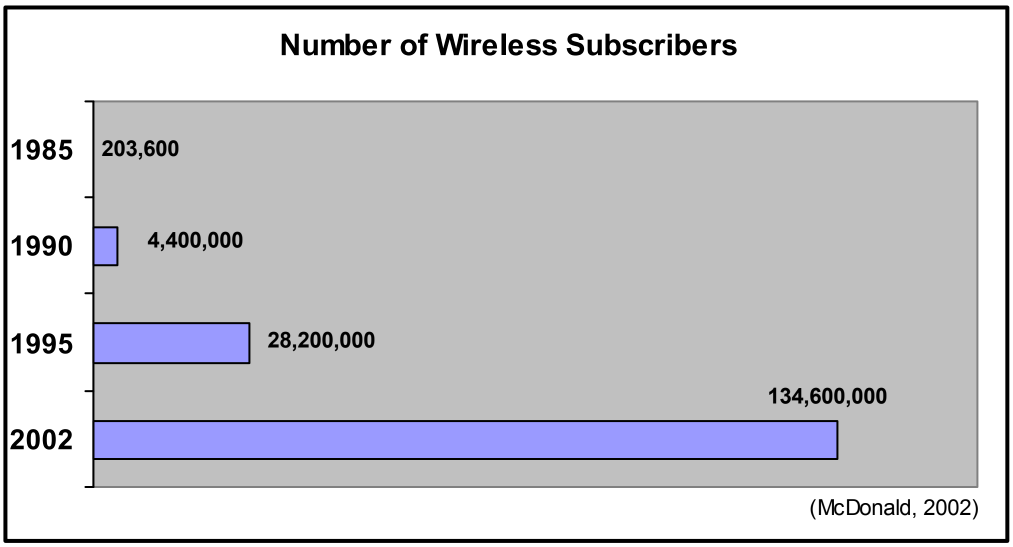
There are four primary reasons that pay phones have recently become less profitable, although the increased use of cellular phones accounts for much of the problem. While cellular technology was conceived in the 1940s, it was not until the 1970s that trial phones were available (Bellis, 2003). In 1982 "the slow-moving FCC finally authorized commercial cellular service for the USA" (Bellis, 2003). As technology improved in the 80s and 90s, cellular phones became smaller and more manageable in size. Additionally, the cost of subscribing to cellular service has decreased with technology improvements. Studies have shown that individuals of both genders, of all income levels, and of most races are represented (Katz & Aakhus, 2002) in the growing customer base that now exceeds 50% penetration in the United States.[1] In economic terms, the proliferation of cellular phones has caused demand for pay phones to decline. The following chart shows that cell phone use increased more than 30-fold from 1990-2002.



In the same years that cellular phones gained enormous popularity, the number of operating pay phones declined. In the mid-1990s there was a high of 2.7 million payphones across the United States (Noguchi, 2002). "In 1998, there were 2.6 million pay phones in the country. Three years later, the number was 2.2 million" (Larson, 2002). By December 2002 only 1.9 million remain (Noguchi, 2002). Every major pay phone provider, including AT&T, Qwest, Verizon, and BellSouth has discontinued the operation of some pay phones (Larson, 2002 and Woller, 2001). Although certain pay

[1] This is my estimate, based on extrapolation from various sources.

phones, or in some cases, the entire pay-phone-portion of their businesses are no longer profitable, these companies are well diversified. Hence, adjustments in the pay phone industry are not causing these large companies to go out of business.

Because of the relative substitutability of cell phones and pay phones, the inverse correlation is not a coincidence. Others have noticed this phenomenon, and have written news articles with titles like, "Public pay phone use down as wireless use grows" (Woller, 2001), and "Requiem for the Pay Phone: As Cell Phone Use Increases, an Icon Gradually Dies" (Noguchi, 2002). Whether or not fewer pay phones is a problem, society knows it is a fact.

A second negative influence on the pay phone business is a cooperative problem between the local and long-distance companies. In the 1990s, phone cards and "dial-around calls" gained popularity. These types of calls are always "toll-free" and do not require consumers to deposit money for LC to collect. Instead, the consumer dials into a different, (long-distance) phone company (like AT&T) and pays by credit card, or makes a collect call. In this situation, the consumer uses LC's phone and phone lines, yet compensates the company (LD) they've dialed into. Aware of this problem, the government implemented a program, as part of the 1996 Telecommunications Act, in which LC bills LD 24 cents for each dial-around-call (Pappas, 2002 and Van, 2002). This was an attempt to even out the revenues and compensate LC for the use of equipment and telephone lines. Unfortunately, this system has not worked. The local company bills LD, who, in turn, often disagrees (or claims to disagree) with the amount billed, and does not end up paying the entire bill. The Chicago Tribune estimates that this amount goes unpaid as much as 40% of the time (Van, 2002). LC's only option is to file a lawsuit, which costs more than the amount of money LD is failing to pay (Ottalagana, 2003). In the face of decreased demand, pay phone companies struggle to maintain revenue, because inter-company strife is able to eclipse the law, and because of the unfortunate effects of the way dial-around calls work.

Another source of pay phones disappearing stems directly from a provision of the 1996 Telecommunications Act. Prior to this time, many phone companies continued to operate pay phones that were not profitable because they were able to subsidize that part of the business with excess revenue from other sources, such as local telephone service for homes and businesses. In order to even out the playing field between pay phone companies of different sizes and degrees of diversity, this Act banned all "cross-subsides" (Patrick, 2001). Subsequently, companies began to "disconnect and remove payphones based on standalone profitability" (Public Utility Law Project). This regulation effectively made it impossible for companies to decide for themselves whether or not to subsidize certain pay phones, even though they were willingly providing a public service. "The hope was that by preventing payphone costs from being spread to all users, and allowing the price of payphone calls to go up, competition would be encouraged, and eventually market forces would be a more efficient substitute for regulated payphone service" (Public Utility Law Project). It is impossible to know whether this logic would have worked under the absence of cellular phones, but time has already told the story. The provisions of the 1996 Act did not work, and it is inconceivable to implement a program in which phone companies are *forced* to provide the public service out of their own pockets.

Although the aforementioned causes of the declining profitability in the pay phone business are more commonly named, some people point to a different source. Kagan (2001) titled his *Newsbytes* piece, "Payphone Business Killed Itself." His account of the "suicide" is hyperbolic, but true, in an unfortunate sense:

> The business was deregulated. New service providers popped up on the scene. So did cheaper, less reliable phones. Phones were everywhere, but increasingly they were out of order or at best, poor quality. Customers started losing money in phones that didn't work, and getting a refund from the new service providers was nearly impossible. Costs of payphone service spun out of control. Service providers charged obscene rates and often customers didn't even know how much they were getting ripped off till they got their phone bill months later. To make matters worse, the phones themselves were dirty, crusty, germ covered things nobody wanted to touch with a ten-foot pole.

Patrick (2001) also writes about poor signage, deferred maintenance, sky-high prices, and difficulty finding working phones. Indeed, this decay was happening at the same time that cellular technology was taking off. It is likely that all of these factors influenced one another in the reality that has played out over the past several years. The result is a transformation in the way that society communicates and a potentially significant welfare problem.

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As it stands, there are certain measures taking place to keep pay phones around, one program, on the part of the federal government, and other trial schemes implemented by the phone companies themselves. Although the government's program is currently underused (PULP, 2003), it probably has the most potential to be successful. The law (Section 276 of the 1996 Telecom Act) provides for state governments to take on the responsibility of establishing and maintaining "public interest pay phones," known as PIPs (Pennsylvania Public Utility Commission). States have implemented programs in which individuals or businesses can make requests for PIP designation. In New York State, a qualifying phone "fulfills a public policy objective in health, safety, or public welfare" and "would not otherwise exist as a result of the operation of the competitive marketplace" (NYSPSC, 1998). The state must compensate pay phone companies for maintaining qualifying public interest pay phones. PIPs are usually found in airports, shopping centers, train stations and other common public spaces.

As many pay phone companies remove phones nation-wide, some companies have tried to implement programs to preserve them. Mid America Pay Phones of Omaha, Nebraska constantly evaluates their pay phones to make sure each is profitable. If it turns out that one is not, Mid America gives the nearby businesses a chance to subsidize the phone's existence. If agreed upon, that entity pays Mid America and the phone stays; if not, the phone goes (Larson, 2002).

Verizon Communications Inc. tried new pay phone pricing plans in 2002 in parts of Virginia and Florida. A standard call of unlimited length costs 50 cents, but this trial program implemented a one-minute call for 10 cents and a three-minute call for 25 cents, in addition to the 50-cent option. The idea behind this trial is to segment the market by phone call length, assuming demand for shorter, less expensive phone calls exists (Phone Plus Magazine, January 30, 2002).

In a joint venture with POPA Media, Barry Shapiro of Budtel Associates implemented another sort of plan to save pay phones in Philadelphia, PA. A 4-minute call from one of his phones costs nothing to the consumer. His phones pay for themselves with advertising. A 12-inch screen in each phone booth constantly runs ads (Pappas, 2002).

As pay phone companies struggle to say in business, incentives to create ways that may rectify the downward spiral are more prevalent for some companies than others. These profit maximizing firms may be less likely to dabble in experimental pay phone strategies, and instead, eliminate that part of the business. Therefore, the government-established PIP program may be the most auspicious sign that pay phones will remain.

III. Model

The goal of this model is to set up a general equilibrium framework in which to analyze the welfare implications of technological advancement in the cellular phone industry. As described in the previous section, adoption of cellular phones has been detrimental to the pay phone industry. This section explores the ways that the pay phone and cellular phone markets function separately, and the way they interact, considering welfare effects in each market, and finally, the net effects on society. The simplest short run model of part A is expanded to the long run in part B. Part C implements simple functional forms and Part D assess the potential of the model to help understand welfare implications.

A. General Model—The Short Run

Consumers choose how many pay phone calls (B_i) and cellular phone calls (C_i) to make by maximizing utility subject to a budget constraint:

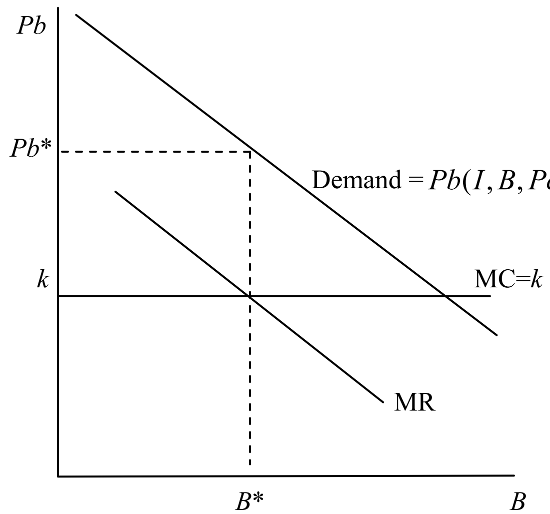
$$\max\ U_i(C_i, B_{i,} N) \text{ subject to } I_i = Pc \cdot C_i + Pb \cdot B_i$$

The number of pay phones (*N*) contributes to utility because of the assumption that if more pay phones are distributed throughout a region, consumers walk less far to find a phone, on average, than they would if fewer phones existed. Traditionally, utility also depends on the amount of all other goods consumed. However, the phone-call-part of a consumer's basket is a small fraction of total consumption, and can be considered relatively constant over all consumers, in relation to total consumption. This model is interested in the choices between *B* and *C* that are made within that small fraction of total consumption, and therefore is able to ignore 'all other goods' as a component of utility. Accordingly, the term "income," represented by *I*, refers to the fraction of disposable income spent on phone calls. This model assumes identical income for every consumer.

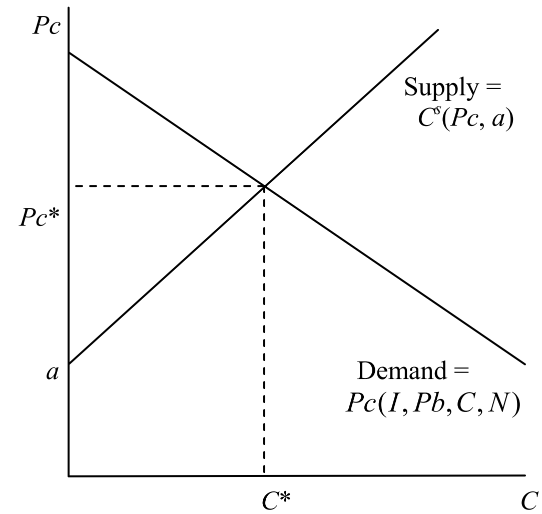
Assuming an interior solution exists, maximizing utility subject to the budget constraint yields individual demand for pay phone calls, $B_i^d(I_i, Pb, Pc, N)$, and for cellular phone calls, $C_i^d(I_i, Pb, Pc, N)$. Summing demand over all consumers reveals market demand functions: $B^d(I, Pb, Pc, N)$ and $C^d(I, Pb, Pc, N)$. These market demand functions can be rewritten as inverse demand functions, and will be used in this form for much of the following analysis: $Pb(I, B, Pc, N)$ and $Pc(I, Pb, C, N)$

The following graphs depict the markets for pay phone calls and cellular phone calls, as they will be described:

Pay Phone Call Market (monopolistic)



Cellular Phone Call Market (competitive)



The cellular phone market is assumed to be competitive. Supply is a function of the price of cellular phone calls (*Pc*) and a technology parameter (*a*): $C^s(Pc, a)$. For simplicity, supply of cellular phone calls is assumed to be linear. Equilibrium in the cellular phone call market is determined by equating supply and demand in the traditional way:

$$C^s(Pc, a) = C^d(I, Pb, Pc, N)$$

The price and quantity that satisfy this equation are the equilibrium values, $Pc^*(I, Pb, a, N)$ and $C^*(I, Pb, Pc, a, N)$. Both of these are expressed in terms of *Pb*, the price of a pay phone call. Therefore, this equilibrium depends on what happens in the market for pay phones.

The monopolist in the pay phone market is a price-setter. Because this initial model is limited to the short run, defined by the period in which the number of pay telephones is fixed, *N* is treated as exogenous. The welfare conclusions of Part A do not incorporate any potential consequences of changing *N*, although Part B expands this model to the long run. Since this model uses inverse demand, the monopolist sets price by maximizing profits with respect to *B*, the number of phone calls. Profit is equal to revenue (price of a call times number of calls) minus fixed costs (*FN*), which are proportional to the number of pay phones, minus variable costs (*kB*), which are proportional to the number of calls:

$$\max\ \pi = Pb(I, Pc, B, N) \cdot B - FN - kB$$

Although marginal costs in the pay phone industry are typically decreasing, this model assumes constant marginal costs (MC = *k*). In order to satisfy the first order condition, $\frac{\partial \pi}{\partial B} = 0$, the firm chooses $B^*(I, Pc, k, N)$ so that marginal cost equals marginal revenue:

$$\text{MC} = \text{MR}$$

$$k = \frac{d}{dB}\left(Pb(I, Pc, B, N) \cdot B\right)$$

Consumers make $B^*(I, Pc, k, N)$ calls at the monopolist's price of $Pb^*(I, Pc, k, N)$.

The equilibrium prices in the pay phone market, $Pb^*(I, Pc(I, Pb, a, N), k, N)$, and the cellular phone market, $Pc^*(I, Pb(I, Pc, k, N), a, N)$, are given in terms of each other. Since the number of pay phones fixed, *N* can be thought of as a parameter, along with *I*, *k*, and *a*. Solving this system of two equations and two unknowns establishes values for $Pb^{**}(I, Pc, a, k, N)$ and $Pc^{**}(I, Pb, a, k, N)$, where an extra * is added to denote a simultaneous equilibrium. In each market separately, equilibrium values for $B^{**}(I, Pc, Pb, N, k, a)$ and $C^{**}(I, Pc, Pb, N, k, a)$ are obtained by plugging in *Pb*** and *Pc***.

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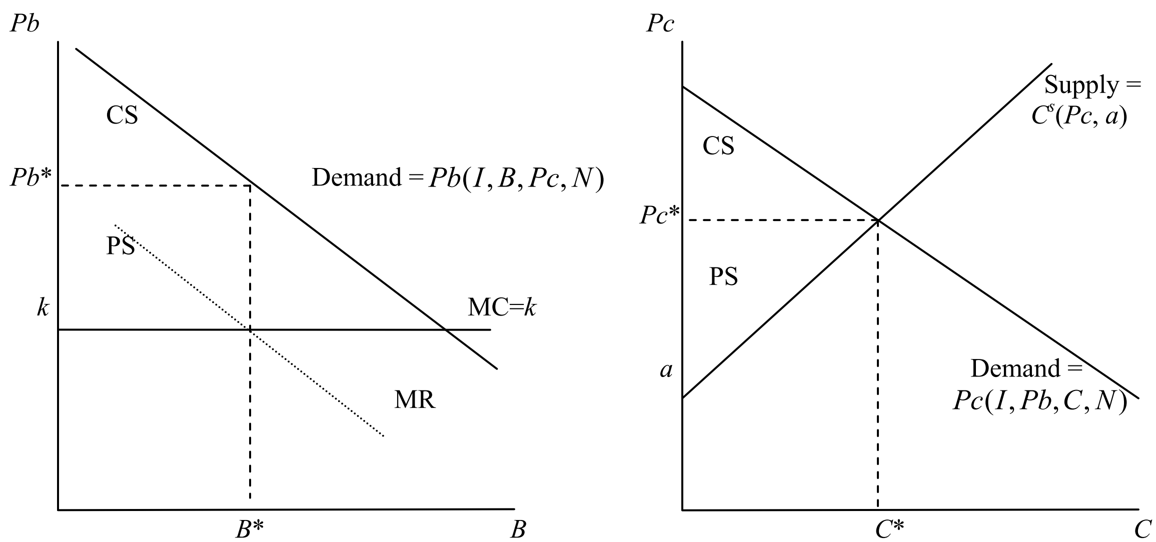
The most obvious way to assess welfare changes as these markets fluctuate is by comparing consumer surplus (CS) and producer surplus (PS) before and after the fluctuations. The difference between CS and CS' represents a welfare change on the part of consumers, where as welfare changes on the supply side are characterized by the difference between PS and PS'. The way to evaluate the net welfare of society is to compare (CS + PS) and (CS' + PS'), the sum of consumer and producer surpluses before and after the market fluctuations. The following graphs include labels for the CS and PS regions:

Consumer Surplus and Producer Surplus in the Markets for Phone Calls

Pay Phone Call Market — Cellular Phone Call Market



Additionally, these regions can be quantified with integrals. Surpluses in the cellular phone call market are assessed as follows:

$$CS = \int_0^{C^*} \left[Pc(I, C, Pb, N) - Pc^* \right] \qquad PS = \int_0^{C^*} \left[Pc^* - C^s(Pc, a) \right]$$

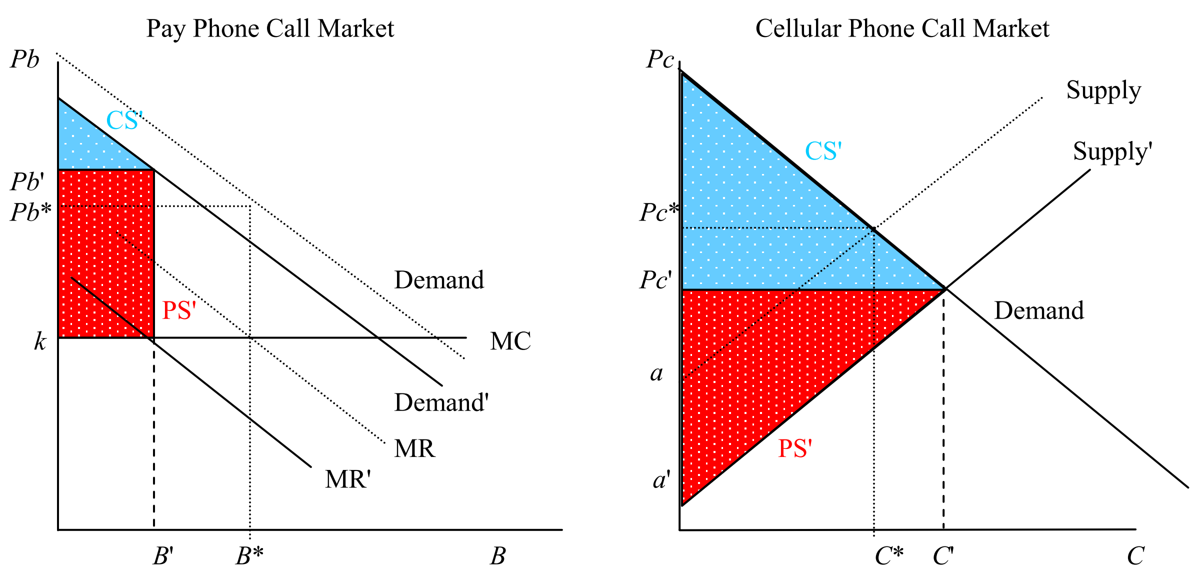
Surpluses in the pay phone market are calculated similarly:

$$CS = \int_0^{B^*} \left[Pb(I, Pc, B, N) - Pb^* \right] \qquad PS = \int_0^{B^*} \left[Pb^* - k \right]$$

In the monopolist's case, PS is equal to revenue minus variable costs, a rectangular region.

Since this model is concerned with welfare changes accompanying improvements in cellular technology, subsequent analysis will focus on this trend. A decrease in the technology parameter, *a*, corresponds to these technological advances. This is equivalent to shifting supply outwards. As shown below, the number of cellular phone calls, *C*, increases with this shift and the price of cellular phone calls, *Pc*, decreases. Consumer surplus in the market for cellular phone calls is unambiguously larger than before. The change in PS may be positive or negative, which means that it is impossible to be sure about the *net* welfare change in the cellular phone call market, represented by the difference between (CS + PS) and (CS' + PS').

Consumer Surplus and Producer Surplus after Technology Improvements in the Cellular Phone Call Market (an Outward Shift in Supply)



Demand for pay phone calls, $Pb(I, B, Pc, N)$, is a function of *Pc*, meaning that as *Pc* decreases with the outward shift in cellular phone call supply, demand also shifts. The premises behind the model suggest that decreased price of cellular phone calls leads demand for pay phone calls to shift inward. As demand shifts inward, it is likely, but not guaranteed, that MR also shifts inward. Making these two changes in the market for pay phone calls produces the above graph. CS' and PS' are smaller than CS and PS, as is the net surplus. Increased price of pay phone calls (*Pb*') and decreased number of pay phone calls (*B*') characterize the new equilibrium. This makes sense in a practical capacity. As cellular phone calls become less expensive, consumers switch over to making more phone calls with cellular phones. Producers of pay phone calls must raise prices to compensate for decreased demand. This leaves pay-phone-call consumers and producers unambiguously worse off.

The remaining question concerns the *overall* welfare implications of the supply shift corresponding to improvements in cellular technology. This shift decreased net welfare in the pay phone call market and led to ambiguous net welfare effects in the cellular phone call market. Without a quantitative structure, it is impossible to know more from this model. In reality, it seems that the switch to using cellular phones happens seamlessly for many people. It is possible that although pay phone consumers in this model are worse off, society, as a whole, is better off.

B. General Model—The Long Run

The primary limitation of the model in Part A is the restricted time frame. The number of pay phones, *N*, is an essential component of consumer utility. Consequently, allowing *N* to vary changes the welfare analysis. Considering that technological advances in cellular phones leads to a decreased demand for pay phone calls, it is likely that pay phone owners would not only raise the price of a call, as seen in Part A, but also remove certain underused pay phones in order to avoid the enormous capital expenses associated with maintaining a pay telephone. As *N* decreases, there are negative welfare implications for individuals who use pay phones because each phone call requires a farther walk to reach a phone, inconveniencing consumers. Conceptually, allowing producers to vary *N* leads to a decrease in welfare. The following long-run model is unable to provide a concrete conclusion in support of this notion.

Identical to the model in Part A, consumers choose how many pay phone calls and cell phone calls to make, maximizing utility subject to a budget constraint:

$$\max\ U_i(C_i, B_{i,} N) \text{ subject to } I_i = Pc \cdot C_i + Pb \cdot B_i$$

This maximization determines individual demand for pay phone calls and individual demand for cell phone calls, which can each be summed over all consumers (and translated into inverse form) to yield the following market demand functions: $Pb(I, B, Pc, N)$ and $Pc(I, Pb, C, N)$.

Equilibrium in the market for cellular phone calls is identical to the model in Part A, where setting demand equal to supply determines the equilibrium price of cellular phone calls, $Pc^*(I, Pb, a, N)$. In the long run, *N* and *Pb* are both determined by the pay phone monopolist, who maximizes the following profit function, where *F* is the fixed price of installing a pay telephone and *k* is the constant value of marginal costs:

$$\max\ \pi = Pb(I, B, Pc, N) \cdot B - FN - kB$$

The pay phone monopolist now maximizes profit with respect to price (by choosing *B*) *and* number of phones. The first order conditions are:

$$\frac{\partial \pi}{\partial B} = 0 \qquad \frac{\partial \pi}{\partial N} = 0$$

Solving these two equations for *B* and *N*, respectively, yields equilibrium functions for $B^*(I, Pc, k, N)$ and $N^*(F, I, Pc, k, B)$ in terms of parameters and other variables, including each other. These two equations, together with $Pc^*(I, Pb, a, N)$, make a trio of equations with three unknowns:

$B^*(I, Pc(I, Pb, a, N), k, N(F, I, Pc, k, B))$

$N^*(F, I, Pc(I, Pb, a, N), k, B(I, Pc, k, N))$

$Pc^*(I, Pb(I, Pc, B, N), a, N(F, I, Pc, k, B))$

Simultaneously solving this system gives values for $B^{**}(I, Pc, k, N)$, $N^{**}(F, I, Pc, k, B)$, and $Pc^{**}(I, Pb, a, N)$. As technology improves, supply of cellular phone calls shifts out. The corresponding decrease in *a* changes all three of the simultaneous equilibrium values.

Just as in Part A, integrals can be used to calculate CS and PS in order to assess the welfare changes. The same two-dimensional spaces are aggregated, treating *N*** as the fixed number of pay phones in the long run.

For the cell phone call market:

$$CS = \int_0^{C^*} \left[Pc(I, C, Pb, N^{**}) - Pc^* \right] \qquad PS = \int_0^{C^*} \left[Pc^* - C^s(Pc, a) \right]$$

And for the pay phone call market:

$$CS = \int_0^{B^*} \left[Pb(I, Pc, B, N^{**}) - Pb^* \right] \qquad PS = \int_0^{B^*} \left[Pb^* - k \right]$$

Again, without a quantitative structure it is hard to concretely assess welfare changes. It is likely that pay phone users will be worse-off in the long run, when producers are permitted to remove payphones in response to decreased demand. Predominately cellular-phone-using customers may or may not experience a change in welfare, depending upon how they value the option to use a pay telephone. Because cellular technology is not yet able to guarantee service everywhere, and because cellular phones run on batteries, consumers who use cellular phones on a regular basis, may value the option to use pay phones in emergency situations. If this scenario holds, any cellular-phone-using consumer would experience a decrease in welfare as *N* decreases. The overall picture is complicated and increasingly ambiguous about the net welfare effect on society as cellular technology improves. The next section tries to clarify this muddle by being more explicit about functional forms.

C. Implementing Simple Functional Forms

Consumers choose how many calls to make from a pay phone (B_i) and how many calls to make from a cell phone (C_i), maximizing utility subject to the budget constraint.

$$\max\ U_i(C_i, B_{i,} N) = z_i N B_i + (1 - Z_i) C_i \text{ subject to } I_i = Pc \cdot C_i + Pb \cdot B_i$$

Consumer *i*'s preferences for using pay phones versus cellular phones are represented by a parameter, z_i. As previously explained, this model is able to ignore 'all other goods' as a component of utility.

The linear nature of this utility function leads optimal consumer choices to occur at corner solutions. This is not unrealistic, as most of today's phone-call consumers use either pay phones *or* cellular phones, instead of switching between the two. Whether consumer i will choose pay phones or cellular phones in this model depends on the parameter, z_i. A consumer is perfectly indifferent between pay phone calls and cell phone calls if:

$$z_i N \frac{I}{Pb} = (1 - z_i) \frac{I}{Pc}$$

A consumer spends all I on B (pay phone calls) if the value of z_i makes the following equation true.

$$z_i N \frac{I}{Pb} > (1 - z_i) \frac{I}{Pc}$$

The same consumer makes only cellular phone calls if this inequality is reversed. The price ratio causing consumers to be indifferent is:

$$\frac{Pb}{Pc} = \frac{z_i \cdot N}{1 - z_i}$$

Assuming that the consumers' z_i parameters are uniformly distributed between 0 and 1, and indexed so that $z_i > z_j$ if and only if $i > j$, there exists a "critical individual," who is indifferent, where $z_i = \dot{z}$ and $\dot{z}(Pb, Pc, N)$ satisfies the following price ratio:

$$\frac{Pb}{Pc} = \frac{\dot{z} \cdot N}{1 - \dot{z}}$$

which can be rewritten:

$$\dot{z}(Pb, Pc, N) = \frac{\frac{Pb}{Pc}}{\frac{Pb}{Pc} + N}$$

Integrating the optimal number of pay phone calls consumed per person, $\frac{I}{Pb}$, over the area from $\dot{z}$ to 1 (consumers who use only pay phones), and substituting in for $\dot{z}$ yields the following market demand for pay phone calls:

$$B(I, Pb, Pc, N) = \frac{I \cdot N}{Pb\left(\frac{Pb}{Pc} + N\right)}$$

This model will use the corresponding inverse demand function:

$$Pb(I, B, Pc, N) = \sqrt{\left(\frac{I \cdot N \cdot Pc}{2}\right)^2 + \frac{I \cdot N \cdot Pc}{B}} - \frac{N \cdot Pc}{2}$$

Similarly, demand for cellular phone calls is obtained by integrating the optimal number of cellular phone calls per person, $\frac{I}{Pc}$, over the area from 0 to $\dot{z}$ (consumers who only use cellular phones) and substituting in for $\dot{z}$:

$$C(I, Pb, Pc, N) = \frac{I \cdot Pb}{\frac{Pb}{Pc} + N}$$

The corresponding inverse demand function is:

$$Pc(I, B, C, N) = \frac{C \cdot Pb}{I \cdot Pb - C \cdot N}$$

Equilibrium in the market for cellular phone calls occurs when demand equals supply. As in Parts A and B, supply depends on the technology parameter, *a*, and is assumed to be linear:

$$C^s(Pc, a) = Pc - a$$

Setting supply equal to demand and solving for *Pc** results in a quadratic function, for which only one root is positive:

$$C^s(Pc, a) = C(I, Pb, Pc, N)$$

$$Pc - a = \frac{I \cdot Pb}{\frac{Pb}{Pc} + N}$$

$$Pc^*(a,N,Pb,I) = \frac{aN - Pb + IPb + \sqrt{4aNPb + (-aN + Pb - IPb)^2}}{2N}$$

On the pay phone supply side, the monopolist again maximizes profit with respect to *B* and *N*. Profit is revenue minus fixed costs (which are incurred for each pay phone, *N*) minus variable costs (which are incurred for each phone call, *B*). This time, the equation for pay-phone-call demand can replace $Pb(I, Pc, B, N)$:

$$\max\ \pi = B \cdot \left(\sqrt{\left(\frac{I \cdot N \cdot Pc}{2}\right)^2 + \frac{I \cdot N \cdot Pc}{B}} - \frac{N \cdot Pc}{2} \right) - FN - kB$$

The monopolist chooses *B* and *N* in order to satisfy the following first order conditions:

$$\frac{\partial \pi}{\partial B} = 0 \qquad\qquad \frac{\partial \pi}{\partial N} = 0$$

The equilibrium equations for $B^*(I,k,Pc,N)$ and $N^*(I,F,B,Pc,N)$ are:

$$B^*(I,k,Pc,N) = \frac{2\left(-2FkN + INPc - FN^2Pc + \sqrt{(IN^2Pc)(-4Fk + IPc - 2FNPc + F^2IN^2Pc)}\right)}{4k^2 + 4kNPc + N^2Pc^2 - (INPc)^2}$$

$$N^*(I,F,Pc,B) = \frac{16F^2 + 16BFPc + (2BPc)^2 - (2BIPc)^2 + 4(2F + BPc)\sqrt{4F^2 + 4BFPc + (BPc)^2 - (BIPc)^2}}{2(-4BF^2IPc - 4B^2FIPc^2 - B^3IPc^3 + (BIPc)^3}$$

Together with the cellular phone call market equilibrium equation,

$$Pc^*(a,N,Pb(I,B,Pc,N),I) = \frac{aN - Pb + IPb + \sqrt{4aNPb + (-aN + Pb - IPb)^2}}{2N}$$, these

three equations characterize a simultaneous equilibrium for the two markets and can theoretically be solved to find values for $B^{**}(I,Pc,k,N)$, $N^{**}(F,I,Pc,B)$, and $Pc^{**}(I,Pb,a,N)$.[2]

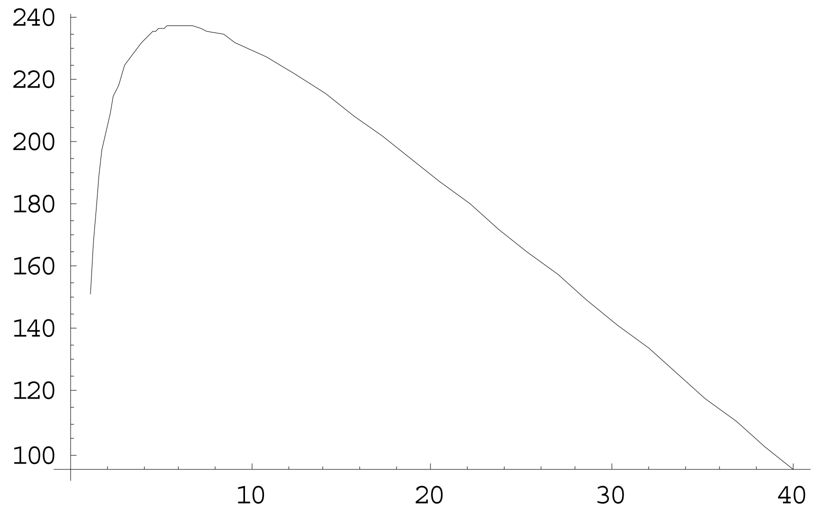
[2] Although Mathematica has the capability to solve systems of equations, this system is too complicated to be solved in any reasonable amount of time. In fact, the two-variable system, treating *N* as exogenous, is also too complicated for Mathematica to solve in any reasonable amount of time.

A decrease in *a*, corresponding to improvements in cellular technology, changes all three of the simultaneous equilibrium values. Again, regarding N^{**} as the fixed number of pay phones in the long run, welfare effects are understood, in a two-dimensional sense, by the difference in consumer and producer surpluses before and after a decrease in *a*. The same integrals from Part B apply. Implementing functional forms has the theoretical prospect of being able to explore the welfare consequences this paper aims to discover. However, the problem proved intractable in this case. The next section examines the validity of the present technique by assigning values to the parameters.

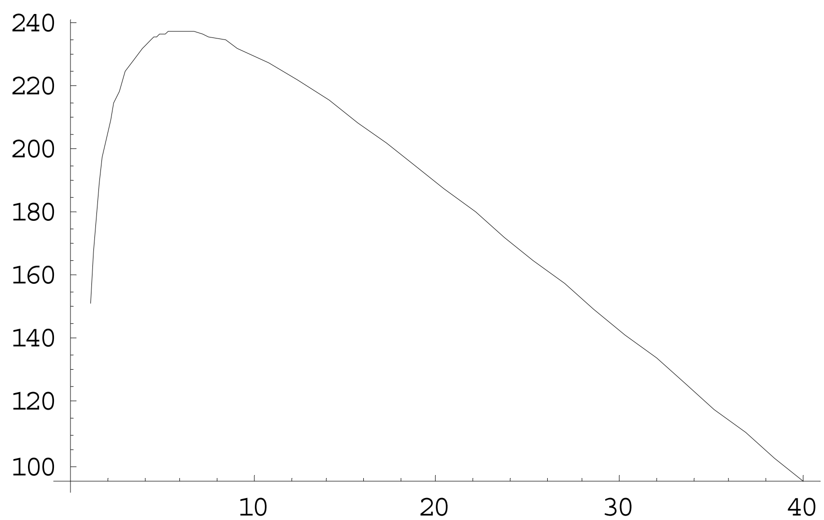
D. Potential of this Model

The model variations presented in Parts A-C, although logically sound, do not present ways to assess welfare concerns concretely. The purpose of this final section is to demonstrate the potential of this model to function as it was meant to. One essential component of the model is the monopolist's ability to maximize profits. This assumes a dome-shaped profit function. Assigning values to all of the parameters and variables, it is possible to graph profits with respect to *B* and *N*, the two variables the monopolist chooses. The graphs below demonstrate the feasibility of this element of the model. These curves are not always dome-shaped because the shape depends on the ratios between the values assigned to the parameters.

Profit with respect to *B*, where *N*=100, *I*=800, *k*=5, *F*=5, and *Pc*=30



Profit with respect to N, where *B*=100, *I*=800, *k*=5, *F*=5, and *Pc*=30



This paper has barely touched on the idea that welfare changes may differ for groups with different income levels. However, the model has potential to help analyze this hypothesis. Income disparities can be represented by evaluating and comparing the model's conclusions for $I=I_L$ and $I=I_H$, where L $\neq$H. Although the model has potential to provide more information than was presented in Parts A-C, this section has accomplished what it meant to, by establishing a general equilibrium framework in which to analyze the welfare implications of technological change in the cellular phone industry.

IV. Conclusion

As society evolves new technologies constantly replace existing ones. This process assumes a certain amount of substitutability in order to function. Cellular phones have transcended pay phones for many consumers. Others prefer and continue to use pay phones. Conceptually, however, every individual who switches from using pay phones to cellular phones contributes to a negative externality affecting all pay phone users. Pay phone companies can only continue to operate pay phones if they get enough business. As individuals switch to using cellular phones, pay phone profits decline and companies are forced quit the industry. As discussed in Section II, the government has attempted to alleviate this problem, but such efforts have not furnished a solution. The declining number of pay telephones and their increasingly decrepit condition makes it difficult for pay-phone-using consumers to continue to rely on them. In this sense, the problem cycles around. The fact that pay phones are increasingly unreliable causes individuals to switch to using cellular phones, which further damages the pay phone industry.

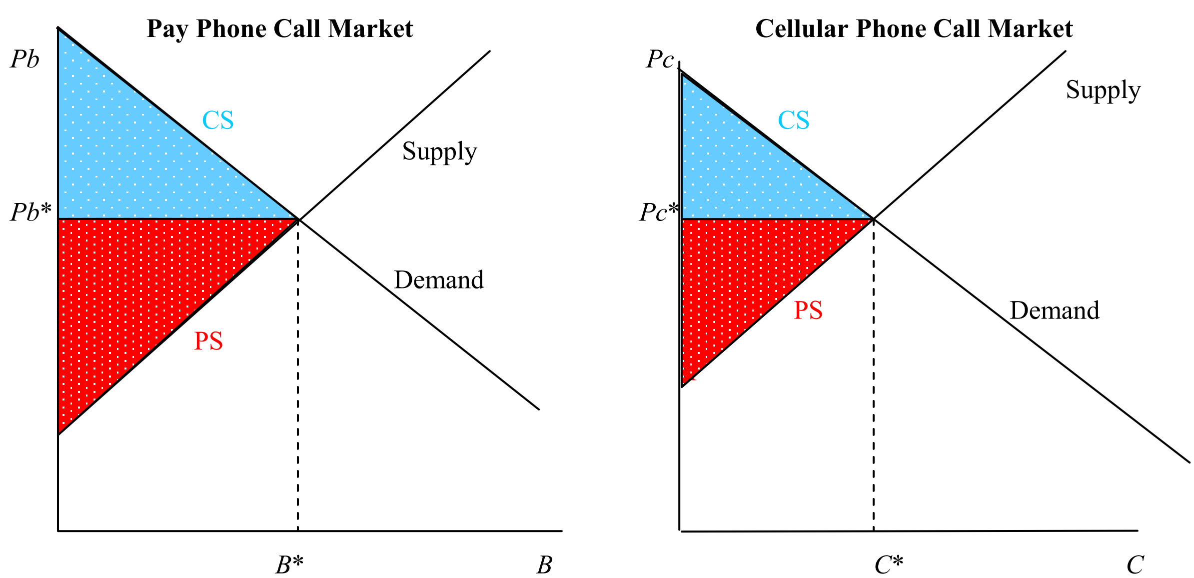
Research shows that cellular phones are not ready to completely replace pay phones. Cellular telephone coverage is not yet as pervasive as it needs to be, meaning that phones tend to “cut out” in certain geographical pockets that are not yet connected to the growing network. Pay telephones are necessary in the case of emergency and for individuals who cannot afford cellular phones. Additionally, a number of households do not have telephone service installed. "As of November 1994, telephone penetration in the United States was 93.8 percent" (Compaine, 2001, 15). Since then, the number of American homes without a telephone has declined, but the fact that people do not have household telephones emphasizes the importance of pay phones.

As the model presented in Section III was inconclusive, the overall implications for society arising from technological improvements in the cellular phone industry are also unclear. Given the assumptions, there is no doubt that pay phone customers are worse-off with the decreasing number of phones available and that cellular phone customers are better-off as prices of cellular phone calls decrease. The concept of adding together these welfare changes with welfare changes on the part of producers gives a way to understand society's overall situation. It may be that welfare increases to cellular phone market participants outweigh the losses to pay phone firms and their customers, but it also may be the other way around. Perhaps the net effects differ by region, depending on variables that are specific to different fractions of society. The inconclusive nature of this paper does not change the fact that it has raised interesting concerns about a complicated issue.

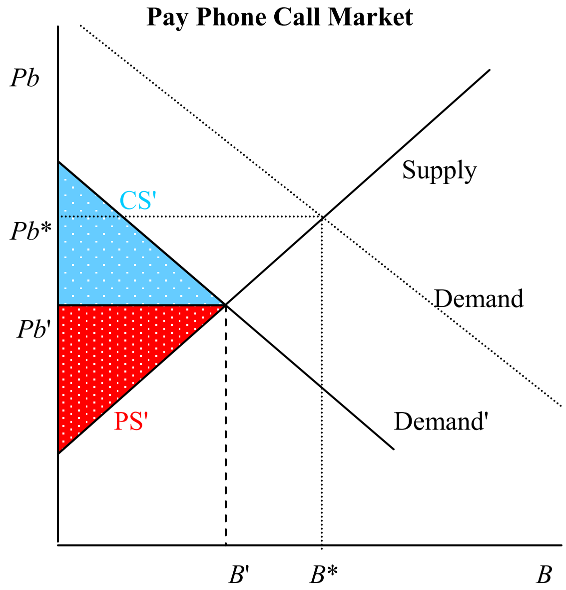
Appendix: A Competitive Pay Phone Industry

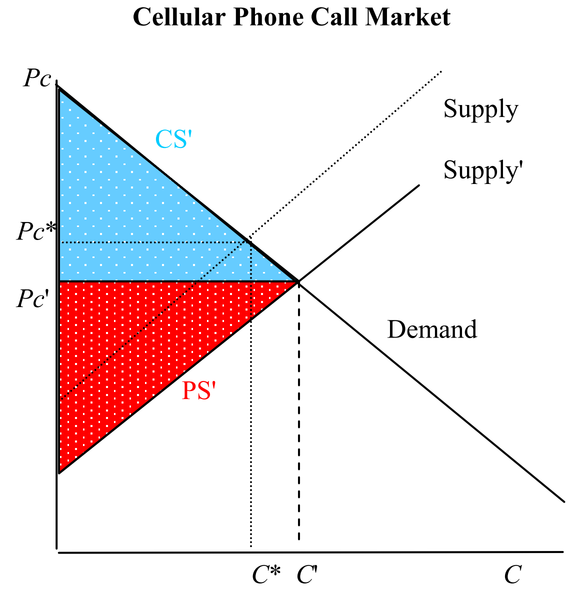
The model presented in this paper assumed a monopolistic structure in the market for pay phone calls, which is a realistic conjecture based on the way the industry operates. Earlier, section II indicated that lack of competition is one of the main industry problems and that encouraging competition should be an objective of regulatory action. This appendix explores the prospect of a competitive market for pay phone calls, in order so assess whether there would be welfare advantages.

The following set of graphs depicts the two markets in their original state.



The next two graphs show the markets for pay phone calls and cellular phone calls after improvements in technology. Technological improvements in the market for cellular phone calls shift the supply curve outwards. Because demand for pay phones depends on the price of cellular phone calls, this shift in supply affects the pay phone market by shifting demand inwards. The graphs for the cellular phone call market are the same ones presented in Section III.





Comparisons between these two sets of graphs shows that consumer and producer surpluses in the pay phone call market both decrease as cellular technology improves. The cellular phone call market experiences the same increase in welfare described in Section III. This application of the model rejects the popular belief that regulatory action to encourage competition in the market for pay phones would help welfare.

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