Spectrum Allocation Alternatives[1]

Industrial Policy Versus Fiscal Policy
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Abstract

Various proposals have been put forth on the issue of allocations spectrum. Such processes as lotteries and comparative hearings have been used in the past. This paper considers methods such as auctions and amortized bid fees that place a clear economic value on the property. The paper reviews the basic economic models, develops one for the specific case of electromagnetic spectrum, and demonstrates how this applies to Personal Communications Services. The results of this analysis are twofold; first, that the LECs have an insurmountable barrier to entry and resulting bottleneck with their monopolistic rents in that they can bid irrational rates to maintain the rents; second, U.S. industrial competitiveness in this industry can be destroyed for a generation if the Government establishes an inequitable "tax" on the entrepreneurs and risk takers. The paper concludes with several alternative suggestions that allow the U.S. to achieve the overall policy goal while obtaining fair and equitable rents from the providers of service.

1.0 Introduction

The U.S. Government has a long history, through the FCC and through the Commerce department of assigning and managing spectrum for the purpose of assigning it to operators of telecommunications services. The assignments have for the most part been done on the basis of petition, lottery, or comparative hearings. There is no history in the United States of selling the spectrum in any process. At the current time, several countries, New Zealand being one, have begun the process of auctioning. The New Zealand auction is one that theoretically is the most cost effective and reflects the true market value of the property.

The U.S. Government has changed its position of gaining revenues from auctions and is now proposing an auction process. In the more recent NPRM Comments on PCS the majority of companies supported lotteries or comparative hearings. A few companies, the author's being one, supported auctions. In the author's filings, there were several microeconomic arguments that justified auctions as being the most efficient. [2]Namely that they would, if properly run, clear the market in the most efficient fashion. However, the position taken in that document also stated that the auctions had to be fair and equitable. The equitable nature is no longer valid if monopoly players are allowed to bid because their bid reservation prices include the fair market value plus the monopoly rent that they can maintain. In this paper we develop this microeconomic argument in detail, and provide examples where this has actually occurred.

This paper then begs the question of what is best for the U.S. from a public policy perspective. Specifically, monopolists can outbid any other player and retain their monopoly power. If that power is entrenched with an outdated technology and using inefficient economic factors of production, protected by the aegis of the monopoly position , then, it is argued, they can bid at a much lower rate than would occur in a true competition and eliminate all competitors due to their bottleneck power. The result is a destruction of value in the national economy. It also results in a diminution of national competitiveness by entrenching an inefficient producer whose control is based upon its monopolistic power.

The issue of allocating frequency spectrum on the basis of auctions or some equivalent capital raising mechanism is in essence both a fiscal policy as well as an industrial policy. We examine these in the context of PCS.

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[1]This paper Presented at the MIT Industrial Liaison Program Seminar on Universal Personal Communications, MIT, Cambridge, MA 02139, March 30, 1993.

[2]TTI NPRM Filings and Comments. In this filing TTI, and the author specifically, support the position of auctions if they were fair and equitable, as a means of valuing the asset, and clearing the market.

1.1 The Product and it Commodicization

Personal Communications Services, PCS, are a set of service offerings that are nothing more, than at a minimum, toll grade quality voice and data services, provided in a fully competitive fashion, and providing as a base a platform for technological innovation. As such, PCS can be considered commodicizable, namely creating a service that is indistinguishable from any other. The approach is to make telecommunications first oats and then to allow the development of oatmeal and oat bran muffins. It is implied that the commodity nature must first be developed.

In order to address the publics concerns, it is argued that the product must be at its base level transparent to the user. This in a fashion preserves the concept of universal service by allowing the commidicization to make all systems at base level both compatible and consistent.

1.2 Policy Issues and Factors

There are two main policy objectives that have been implied in the discussions on PCS. They relate to the nature of the service and ensuring the overall public benefit is satisfied, and they relate to obtaining fair and equitable value for the access to the bandwidth provided. The policy objectives may be stated as follows:

> ***Service Objective***
> *The service should be, at a minimum, of toll grade quality, supporting both voice and data, and provided in a national seamless interoperable network, provided on the most cost effective basis available.*
> ***Valuation Objective***
> *The bandwidth should be valued at a fair market basis assuming that all bidders can bid on a fair and equitable basis, with their reservation prices reflecting their individual abilities to meet the Service Objective through innovative technologies and efficient management.*

As stated earlier, these two policy elements are intertwined with both Fiscal Policy and Industrial Policy. The Service Policy Objective is in essence an objective aimed at an industrial policy that creates new and innovative services and technologies that will allow the United States to retain and expand its position as a world leader in technology, especially telecommunications. The second Policy Objective, that of Valuation, is at first glance a Fiscal policy aimed a obtaining revenue for the Federal coffers but more importantly it is also an Industrial Policy. It has the potential effect of either stimulating the first objective or of suppressing it. Intertwined in this paper is the issues associated with the balancing act between these two policies.[3]

2.0 Economic Analyses

The provision of telecommunications services can be done either in a wire based or wireless fashion. The economic structure, from the perspective of the supply function, can vary dramatically. It has been shown elsewhere that there is a fundamental paradigm shift in the old LEC architecture and the new PCS

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[3]See the works by Solow and Arrow and Kurz. Both address the issue of how costs of capital becomes a dominant factor in developing the balance of Fiscal and the equivalent of Industrial Policy as it relates to Growth. In addition, Thurow and Muroyama and Stever provide a presentation of how this is handled in other countries, especially Japan. The United States has never developed an Industrial Policy directly and has used the Fiscal Policy, via Investment Tax Credits, R&D Tax Credits, and Capital Gains Tax as an indirect means to influence Industrial Policy. These have been positive incentives, specifically the reduction of tax burden for technological and industrial risk takers. This proposal for auctions is the First Negative Incentive, namely having the risk takers pay for the right to take a risk in a new market. The issue posed in this paper is that such a risk should be balanced.

architecture.[4] One is centralized and hierarchical and the other is a fully distributed architecture that takes advantage of the new processing capabilities of distributed systems. In this section we review the economic models of these businesses and then demonstrate that having and economic model that one can determine the bidding reservation price of that system.

2.1 Supply Models

The supply function for the provision of the service can be developed for the existing LEC provider as well as the PCS wireless provider. The supply function, we argue, has undergone dramatic change resulting from the entry of new technology. The original supply function as viewed by the LEC in a monopolistic environment had scale and scope economies. However, it was based and is still based upon nineteenth century technological Architectures. The new technologies of PCS, for example, are based upon late twentieth and early twenty first century fully distributed technology. [5]This difference, we shall demonstrate, yields a different economic structure.

Case 1: LEC Wire Based

The LEC currently has invested about $1,800 of capital per subscriber with 20% of that in inside plant and 80% in outside plant. The LEC currently uses cost based rate based pricing for their services. Thus, the LEC has a expense plus depreciation supply model that does not reflect any market or technology economies. More importantly, the LEC has a profit defined as:[6]

Profit = RoR (Accumulated Capital - Accumulated Depreciation)

where RoR is the PUC accepted rate of return. To maximize their profit, therefore, it is prima facie required to maximize the capital plant. Thus there are de minimis needs to reduce capital through capital innovation.
If we assume 15 year depreciation as an average, then the depreciation per customer per year is $120. That is $10 per month. At longer schedules this will decrease, but given the nature of the technology and its change, this is a more realistic schedule. If we further look at a typical LEC such as NYNEX, we find that it has approximately 26,000 management employees for 13 million access lines (namely one per 500) and 52,000 craft or union employees for the same number (or one per 250). This is a total of 88,000 employees for this number of access lines.

If we use comparable salaries, we find that a fully loaded management year costs $96,000, and a fully loaded craft year is $72,000. These include salaries plus direct overheads. They do not include the extra cost of R&D etc. Recall, also, that the revenue per residential access line is approximately $37.50 per month, for a total of $5.8 billion per year.[7] This is 50% of the total revenue, the remainder being business circuits. We must then allocate expense accordingly. The other expenses are Bellcore, of $200 million per year, NYNEX

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[4]McGarty, Wireless and McGarty, Architectures.

[5]See the papers by McGarty; Architecture's, Wireless and Access. These recent papers discuss the issues of Architectures, paradigms and world views. They clearly develop the deconstructionist and hermeneutic arguments for the understanding of the 19th Century Architectures of the LECs.

[6]Brenner or Spulber. Both references describe the rate of return regulation.

[7]McGarty, Wireless, MIT, 1993.

S&T of $100 million per year and other outside expenses of $300 million per year. On an allocated basis this is $300 million divided by 13 million per year, or $25 per year or $2 per month.[8] Therefore, we have:

Cost Per Line = Depreciation + Fully Loaded Salary + Other Costs

where:

Depreciation = $10 per line per month
Fully Loaded Salary = 0.5($16/month-management + $24/month -craft)
Other Costs = $2
Cost Per Line = $10+$20+$2 = $32/month

This then yields a cost function as a function of demand. Specifically, if we define C(q) as the cost as a function of demand q, then we have in general,

$$C(q) = F_0 + F_1(q)$$

where F_0 is the fixed costs and F_1 the variable costs.[9] The Marginal cost will be defined as:

$$\frac{dF_1}{dq} = MC$$

We shall assume variable costs throughout this paper.

Case 2: PCS Wireless

Technology has changed dramatically in the past five years. The two current ways of providing voice service are via wireline twisted pair telephone service and through cellular voice service.[10] New technological innovations have allowed the wireless PCS services to be provided by another form of technology. This technology takes advantage of a distributed telecommunications architecture and places as much "silicon" in the field as possible. It also performs as much processing as possible so as to minimize the functions required by the LEC interconnect.

We shall use the example of CDMA technology to demonstrate how this new technological infrastructure can enable the new market. We shall briefly describe the CDMA system and then proceed to the financial implications of using this new technology. The CDMA system described is that of QUALCOMM [11]. Fundamentally the system is characterized in the following fashion:

(i) An air interface of a CDMA signal is provided by a cell or cell re-rad over the air to the portable. The signal is encoded in a direct sequence CDMA spread spectrum code. Thus a 9.6 Kbps signal is spread, or multiplied by a unique code at the rate of 1.25 Mbps. The codes are orthogonal. Namely, if two or more

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[8]Huber presents an excellent summary of the network capital and expenses in the 1987 time frame. Not a great deal has changed in that period. Weinhaus and Oettinger update this study and provide detail on a per access line basis.

[9]Note that we are using the long run cost factors. See Pindyck and Rubenfield or Kahn.

[10]See the works by Lee. The author has provided several key bodies of analysis that provide insight into the history and current status of cellular.

[11]See the works by Gilhousen for the QUALCOMM approach. Also see the paper by Pickholtz et al for a differing approach to CDMA. The latter approach is Broadband CDMA compared to mid-band.

codes are combined, then if they are multiplied by the desired code, the residual of the other signal appears as a low level noise signal. Thus CDMA is frequently interference limited no random noise limited.
(ii) A cell controller is used to ensure hand off between other cell controllers. The cell controller has a capacity that depends upon the bandwidth, the interference level, the size of the cell and other factors. Typically a cell controller has the capacity of 500 to 1,000 trunks. Note that this is given in trunks and not portables. If a portable is busy 5% of the time then this means a cell controller with 1,000 trunks can handle 20,000 portables. The cell controller is a highly intelligent distributed processing node. The CDMA codes assure signal orthogonality and inherently manage the interference. The cell controller assures a soft hand-off between the other cells in the grid. In addition, the cell controller establishes the relationship between the call and the switch. Namely the cell controller passes an intelligent and digitally "packed" set of voice channels.
(iii) The cell-controller hands the switch a DS-3 formatted voice signal, with a SS-7 signaling channel, on a SONET interface. As far as the switch is concerned, the call may have originated from a Class 5 or Class 4 switch. As we have discussed before, the Class 5 LEC functionality is not required. What is required is the Class 4 toll-tandem switching capability. The only need for Class 5 functionality is that needed for billing.
(iv) The re-rads are clustered around the cell controller. A re rad is used to manage the coverage issue, whereas the cell controlled is used for the capacity issue. The re-rads are an order of magnitude less expensive than the cell controller. The re-rads are interconnected to the cell controller via a microwave path, at 40 GHz, or over CATV or a bypass carrier.

When looked at in this fashion, the use of CDMA dramatically reduces the needs from a LEC environment. All that is needed is the ability to backward access to the Local user, namely a customer of the LEC. Thus the access fee should be reduced.

A simple calculation will show how this new technology dramatically reduces the capital per subscriber.

- Assume that there are 1,000 square miles of coverage and 48,000 subscribers.
- Assume that a cell controller or a re-rad handles a 3 mi. radius or about a 30 mi. cell coverage area. This implies that 3 cell controllers and 30 re-rads will cover the area.
- Assume that the cell-controller is equipped to handle 800 trunks per cell controller. Assume that the peak usage ratio is 5%. Thus each cell controller can handle 16,000 subscribers, 800 instantaneously active in the busy hour.
- Assume that the cell controller are about $1 million each and that the re-rads, with microwave back haul are at $50 thousand each. The total capital is $4.5 million. This the is about $100 of capital per subscriber.

Now this can be compared to the capital per subscriber in the LEC and cellular environments. In the LEC world the capital per subscriber is almost $1,800. This is split between switch and transport as follows; $400 for the switch and $1,400 for transport. Namely, the LEC is outside plant dominated. Moreover, under rate of return regulation, the LEC makes most of its profit off of its outside plant. In the cellular world the capital per subscriber is $750. This includes the cells and the MTSO, Mobile Telephone Switching Office. It does not include access to the LEC Class 5 switch.

Now we can also determine the unit costs of PCS as we have done for the LEC. This is as follows:
Let:

A= The access fee per line per month. If we are charged $0.11 per minute as is the case in New York, and at an average usage of 500 minutes per month, which compares with the Telco usage, then access fees are:[12]

A = $55 per user per month

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[12] De Sola Pool provides information on time usage in the Telecommunications Reference.

D= Depreciation. As we indicated, the depreciation is on a base of $100. Assume a five year depreciation and this equal approximately $2 per month per customer. Thus;
D = $2 per month per user
E= Operating expenses. From prior studies this has been shown to be approximately $180 per year per user of;
E = $15 per month per user
Thus;
C = $2 + $15 + $55 = $72

Note that this is dominated by the access fee. If access were not there then the cost function for PCS would be significantly below that of the LEC. The access fee is nothing more than a tax on the Local user that has the long distance carrier supporting the LEC. LEC charges do not reflect the true cost and in turn the true monopolistic inefficiencies.

2.2 Reservation Prices and Valuations

Let us now take these two models and determine what the value is for each of these business. This is at the heart of the dynamics of and allocation process based upon a bidding or auction mechanism. Let us create a NPV, net present value function that uses revenue, expenses and depreciation. [13] If m is the cost of capital or the effective discount rate at the defined risk level, than the NPV can be defined as;[14]

$$V(N) = \sum_{n=0}^{N} \frac{R(n) - E(n) - D(n)}{(1+m)^n}$$

We can define this NPV on a per customer basis. We further use a time horizon of N years for the measurement of the NPV. We shall use the life of a PCS license, assuming fifteen years.
Now we can expand this concept one step is we assume that there is some form of tax, foe example an auction fee or a franchise fee. Let us assume that there is a "tax" due to some form of U.S. Government allocation process. Call that tax, T. This then reduces the NPV as shown in the following.

$$V^*(N) = \sum_{n=0}^{N} \frac{R(n) - E(n) - D(n) - T(n)}{(1+m)^n}$$

Now we can further add to the tax, the access fee. Let A be the access fee. Then the PCS carrier faces the following NPV function;

$$V_{PCS}(N) = \sum_{n=0}^{N} \frac{R(n) - E(n) - D(n) - T(n) - A(n)}{(1+m)^n}$$

In Contrast the LEC has the value;

$$V_{LEC}(N) = \sum_{n=0}^{N} \frac{R(n) - E(n) - D(n)}{(1+m)^n}$$

It should be immediately clear that the LEC, even if it is more economically efficient can reduce the net present value per customer of the PCS company by four means;

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[13]It should be noted that this should be revenue, expenses and capital. We shall assume that we can use depreciation since there may be a leasing function available. This is truly an inaccurate method for NPV but it allows a first order comparision of LEC and PCS on a per subscriber basis. A more detailed model has been developed by the author and presented elsewhere, see McGarty, CMU, 1992.

[14]McGarty, Business Plans. See the details on the definition of NPV and its evaluation. In the proper sense it does not include depreciation but capital.

(i) **Access Fees:** The LEC can burden the PCS company with and access fee, such as the $55 per month number in New York, that makes the PCS company, in any circumstance non-competitive.[15]
(ii) **Auction "Tax"**; The "Tax" can be structured in such a fashion, as is currently being lobbied by the RBOCs in Congress, as a large up front payment,, that increases the risk and further reduces the NPV for the PCS company.[16]
(iii) **Increased Risk**: The cost of capital, m, can be different for the two companies. Specifically, if m_{LEC} is the LEC cost of capital, generally a very low cost due to its existence and capital raising capacity, and if m_{PCS} is the cost of capital for the PCS entrant, then we find;[17]

$$m_{PCS} >> m_{LEC}$$

Specifically:

$$V_{PCS}(N) = \sum_{n=0}^{N} \frac{R(n) - E(n) - D(n) - T(n) - A(n)}{(1 + m_{PCS})^n}$$

for the PCS entity, and;

$$V_{LEC}(N) = \sum_{n=0}^{N} \frac{R(n) - E(n) - D(n)}{(1 + m_{LEC})^n}$$

for the LEC.

Thus, the LEC, can through its entrenched position, increase the risk level and, in turn, reduce the NPV, indirectly, through the cost of capital.

(iv) **Monopoly Rents**: The LEC, as a monopoly, has what is termed monopoly rents resulting from its monopolistic control over the property. This rent, as we shall discuss in the next section, acts in a bidding process, as a price escalator. Namely the LEC, if in the bidding process, can bid an amount that is consistent with its NPV, plus the amount equal to its existing monopoly rent. Namely; if MR_{LEC} is the LEC monopoly rent, as defined in the next section, then the NPV_{LEC} is;

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[15]McGarty, Wireless (MIT, 1993). The author details the impact of access fees on PCS and details the potential for violation under Robinson Patman. It is not clear if there is any violation per se but the issue of internal transfer pricing of switch access at possible rates less than long term average costs and having the IECs and other CAPs effectively underwrite these costs are in question. Another factor that delimits access indirectly is that of number availability through the North American Numbering Plan (NAM), see Brenner, p. 19. The NANP can also be an access barrier to entry to any potential competitor. It is controlled by Bellcore, the R&D arm of the RBOCs. Bellcore is generally difficult to deal with and as has been seen in the cellular world the ability of Bellcore to manipulate the numbering plan can add additional costs and market delays. It is an issue that the Commission must address if it truly seeks competitive options.

[16]Clearly this is a Fiscal Policy element that impacts the Industrial Policy element. The author suggest a balanced of risk sharing. This approach is a modification of the policies developed by Solow in the area of Growth Theory and have been positioned in a similar fashion by Arrow.

[17]See the reference by Kolbe where he develops the details on rates of return and the cost of Capital for utilities.

$$V_{LEC}(N) = \sum_{n=0}^{N} \frac{R(n) - E(n) - D(n)}{(1 + m_{LEC})^n} + MR_{LEC}$$

$$\gg V_{PCS}(N) = \sum_{n=0}^{N} \frac{R(n) - E(n) - D(n) - T(n) - A(n)}{(1 + m_{PCS})^n}$$

Note, that the LEC now has four factors that increase its value for bidding for a wireless property. The LEC has such strong market power that it could, in a collusive fashion, between and amongst themselves, dominate the new PCS market. All one has to do is look at the current Cellular markets and see that they dominate by almost 70% all current cellular properties and if one adds AT&T, it is almost 90% of the major markets.

3.0 Monopolistic and Competitive Implications

In the preceding section we developed a model for the provision of wireless services. We have shown that there are no economies of scale and scope in the use of the new wireless technology. Furthermore, we have developed a model that allows the buyer of frequency to determine its value in a fully competitive market. That latter assumption of full and complete competition is a critical assumption that we examine in this section. We focus firsts on reviewing the monopolistic model versus the competitive model. This will be essential to understand the monopoly rents that accrue to the monopolist. These rents then allow the monopolist to raise their reservation price and bid at a disproportionaly higher rate. We then show what are the minimum conditions for a fully competitive market process. Those conditions will be later reflected in the development of policy alternatives.

3.1 Microeconomic Models

We provide a brief overview of the microeconomic models in order to show the impact of the results presented in the last section. Figure 1 depicts the market for this type of telecommunications services. We define P9q) as the demand curve, and define MD as the marginal demand. We define MR as the marginal revenue, where MR is given by;

$$MR(q) = \frac{\partial R}{\partial q} = \frac{\partial(pq)}{\partial q} = q\frac{\partial p}{\partial q} + p = p - qP'$$

That is the marginal revenue is always the demand curve less the factor associated with price and prices sensitivity. Therefore, the MR, marginal revenue always lies below the demand curve.. The marginal cost curve, MC, is the supply oriented curve. It is as shown. Recall from the last section, we have developed a simplistic model of the marginal cost curve for both LEC and PCS businesses.
Recall, also, that the profit maximization stable points for a competitive market and a monopolistic market are as follows:[18]

Competitive:

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[18]As is shown in Pindyck and Rubinfeld or Henderson and Quandt, Profit is given by the following:

$$\Pi = R - C = pq - C(q)$$

and that profit is maximized by the value of q that meets the following condition;

$$\frac{\partial \Pi}{\partial q} = 0 = \frac{\partial(pq)}{\partial q} + \frac{\partial C(q)}{\partial q}$$

or the MC.

MC(q)=p(q); defines the q_m *point on the demand curve.*

Monopoly:

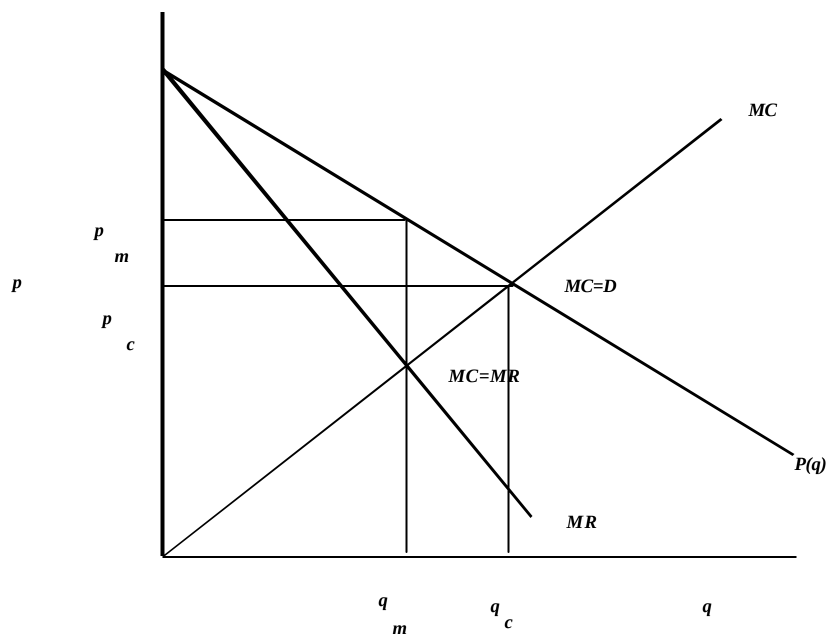
MC(q)=MR(q); defines the q_m *point on the demand curve.*

Therefore, the monopoly player can charge a higher price, p_M, as compared to a competitive play, charging, p_C. We show this in Figure 1. Note also that the monopoly player has a greater profit. Specifically, it can be shown that the price of a monopoly player is $P_{MONOPOLY}$ as compared to the price of a competitive player, $P_{COMPETITIVE}$, and that they are related as:[19]

$$P_{MONOPOLY} = \frac{P_{COMPETITIVE}}{1+\frac{1}{\frac{\partial D}{\partial q}}}$$

Since the elasticity of demand is negative, the price of the monopolist is greater. Moreover, in the PCS and LEC environment, the LEC if it retains its monopoly position can retain the excess monopoly rates and thus retain monopoly profits, which are competitive profits plus the monopoly rent. In Figure 1 we first note that the monopoly demand point, q_m is where MC=MR. The price depends on where this demand quantity intersects with the demand curve, p(q). However, in the competitive case, the market equilibrium is where the demand curve equals the MC curve.

Figure 1: Microeconomic Analysis of Monopoly vs Competitive Markets



3.2 Monopoly Rents and Competition

Monopoly rents are the excess profits that accrue to a monopoly player, such as an RBOC acting as a LEC, in the absence of competition. This "rent" is a premium resulting from their single market dominance, and results in an increase in the NPV of the property if this rent can be retained through continuing monopoly

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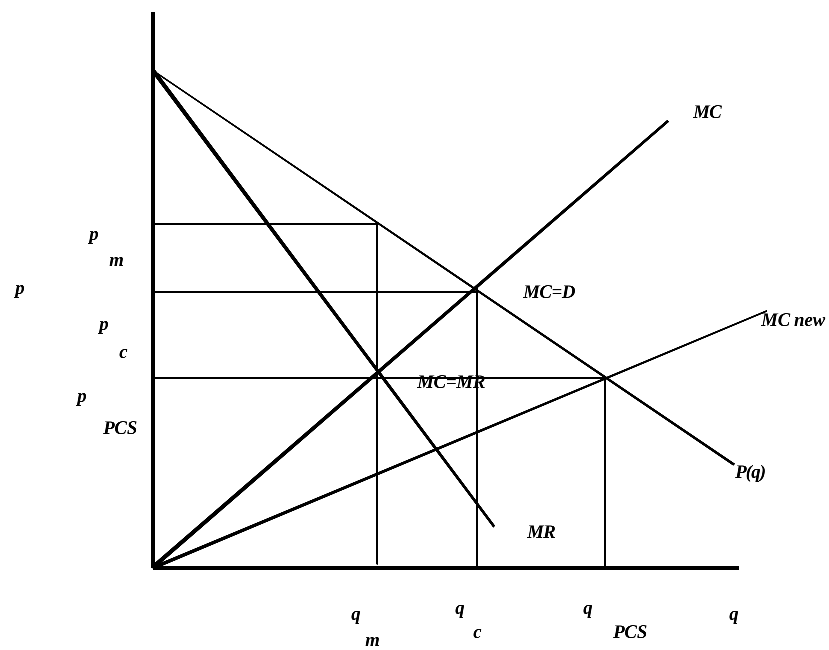
[19]Pindyck and Rubinfeld, p. 343. This shows the added monopoly power in pricing of the LEC in a potentially competitive market.

control. In Figure 2 we depict the microeconomic situation with a monopoly and a competitive environment,. Here we show the competitive price at p_C and the monopoly price as shown before. Moreover, in Figure 2 we show that the competitor now has a marginal costs curve below that of the monopolist as shown for PCS. The effect is dramatically increased demand at a dramatically lowered cost to the consumer. This is a Pareto efficient case.[20] However, this assumes that the Taxes and Access fees were not present. If these fees and taxes are added, then the new marginal costs may, as we have shown, exceed the marginal costs of the monopoly. This is and artificial cost increase, driven by Government fiat and not market forces. It is an artificial manipulation of the market mechanism that further entrenches the monopolist.

Figure 2: Competitive Environment with New Technology



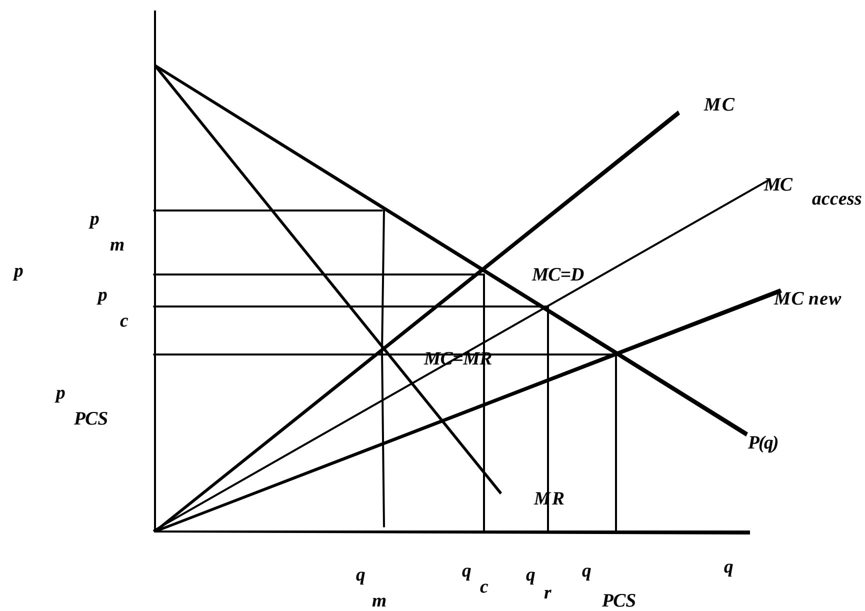
The deadweight loss is defined as the value of the dotted triangle that appears between the p and MC curve.[21] It is in effect the monopoly rent.

We can now determine the effects on competition with the addition of access fees. The same argument will hold with regard to the addition of the "Tax" fees. Figure 3 depicts the results with access added. Specifically, we show the case of the access fee added. This reduces demand, increases costs, and further puts the new entrant in a non-competitive position with respect to the entrenched monopolist.

[20]Henderson and Quandt, p. 286. Also termed Pareto Optimal, this implies, "if production or distribution cannot be reorganized to increase the utility to one or more individuals without decreasing the utility to others. "

[21]See Tirole or Pindyck and Rubinfeld.

Figure 3: Competitive Environment with New Technology and Access Fees



3.3 Fully Competitive Conditions

Innovation in technology can be supported or destroyed by Government actions as we have just demonstrated. It can be shown that if a new technology is introduced that will reduce the MC, marginal cost, from c_{old} to c_{new}, where $c_{old} >> c_{new}$, then the value to the monopolist in not allowing this change to occur can be shown to be:[22]

$$V_m = (1/r) \int_{c_{new}}^{c_{old}} D(p_m(c))\, dc$$

where D is the demand function, and r is the cost of money. The valuation is made at the price point of optimization. Thus there is a further incentive by the LECs to hinder new technologies. This has been shown to be the case in two specific recent examples. Consider first the attempt by Bellcore to position PCS as nothing more than a slight extension of the wireless phone.[23] The Bellcore position is that all wireless users should use older technology and use the existing telephone network to act as a backbone in support of the telecommunications infrastructure.[24] What this does is drive up the costs and further entrench the

[22]Tirole, p. 391. The author develops this relationship in the context of the "Social Planner" model. It also represents the bidders excess prices that an LEC may bid to keep the competition out of a market.

[23]Cox. This paper summarizes the attempts by Bellcore to delimit technology innovation. There is a blatant attack on CDMA technology because it frees the wireless provider from the LEC network.

[24]In a recent FCC report, see Reed, the Commission Staff indicated that in its analysis there was limited scale economies but significant scope economies. The scope was based on cable and LECs having infrastructure. In McGarty, Wireless, the author demonstrated why the argument is specious in the context of the CATV entities. As regards to the LECs, that argument is also invalid because it assumes a technological solution consistent with the Bellcore approach of many microcells, being nothing more than extensions of wireless phones in the home, the cordless phone. This is a specious argument since it is based upon the Bellcore technology which begs the answer of continued reliance and support of the monopoly LEC.

monopolist. It also reduces the chances for technology innovation. The second example was in the RBOC battles over a new generation access technology for cellular. This was and still is the CDMA versus the TDMA battle. It is in essence an attempt to maintain the high costs of infrastructure and in order to maintain the high barrier to entry despite the ability of technology to reduce it.

4.0 Allocation Options and Optimization

The options available for allocation of frequencies all must reflect the overall two major policy objectives of providing seamless interoperable national service and in providing a competitive based market valued price for the access to the spectrum. This than means that we must balance competition with cost.

4.1 Allocation Alternatives

The issue of lottery versus a competitive bid is clearly at the heart of establishing a truly competitive market. The following observations drive the process.

> (i) A clear and measurable value exist for each frequency allocation based upon the perceived market and the expected costs. The value is based upon perceived revenue flows, based upon price and price alone, and price is based upon operational efficiencies in both labor and capital. Therefore, the most labor and capital efficient player can pay the highest price for the system, assuming a fair and equitable competition. This is in the best interests of the consumer.
> (ii) It is recognized that in any competitive market, no matter how many contenders, the top three contenders are the dominant players in the market.[25] Their dominance is based upon their ability to sell the product and this ability is based on quality and price. Assuming equal quality, price alone is the determinant in a commodiczable market. Thus value and in turn the bid reservation price is a purely competitive factor.
> (iii) Value is not diluted by more players, this is a result of the three dominant players observation.
> (iv) Qualified contenders for the frequency bands are required, since those not qualified may bid high and thus not allow true providers to enter. Thus to be qualified means that the contender must be both competent and committed. Competence is based on experience, demonstrated by such things as Experimental Trials or Technology contributions. Commitment is reflected in a commitment to operate in a short period of time or suffer loss of the license.

Based upon these observations, and based upon the Goal established for the PCN services, the argument proceeds as follows:[26]

THE GOAL OF THE ESTABLISHMENT OF NEW PCN SERVICES IS TO PROVIDE TO THE PUBLIC, SEAMLESS AND INTEROPERABLE WIRELESS TELECOMMUNICATIONS SERVICES THAT USE THE MOST INNOVATIVE TECHNOLOGY AND TECHNIQUES AND PROVIDED IN AS COMPETITIVE ENVIRONMENT AS POSSIBLE, TO ENSURE THE MAXIMUM BENEFIT TO THE CONSUMER IN THE SHORTEST TIME.

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[25] See Porter, Competitive Advantage, 1985, Free Press, pp. 221-228. Porter demonstrates that a stable market configuration follows a semi logarithmic distribution where each competitor's share is a constant proportion of the next higher ranking competitor. Furthermore, and most importantly, it is shown that a market in a commodity, will generally have three dominant players in the ratio of 4:2:1 of share. The evidence for this seems to be overwhelming. This does not however indicate that a market cannot support five or more players.

[26] TTI, NPRM Comments.

We develop the argument in favor of modified auctions as follows. Competitive bidding provides a basis to allow the true value of the asset to be measured and returned to the owner of the asset, in this case the public. Further, competitive bidding, though its revenue generation ability, can establish a fund from which the Government can and should initially establish and support the underlying industry technical support so critical for the success of this business. In addition, competitive bidding in the only true way for the Government to ascertain the best and most endurable players in this field. From the point of view of best, the process, if rationally pursued, allows each contender to take their pool of capital asset and apply them to each bid in such a fashion that is closest to or equal to their reservation price, such prices reflecting the true value of the asset.

Their reservation price is based upon three factors; their expected rate of return, their anticipated revenue growth, and their expected operational capabilities. The rate of return is clearly an individual factor, but based on comparable market rates for the level of risk, it is anticipated that each rational investor, will, in the large, converge on similar rates of return. The revenue goal is based upon the anticipated price that the competition can offer and their expected relative price to their competitors. Assuming that a competitor is equally efficient, then the demand is relatively well understood by all parties. Also, we assume that all bidders face the same initial costs, and the differences result only from execution ex post facto. [27]Thus, from a competitive bid aspect, rates of return and revenue are equal to all competitors. The only differentiating determinant is the operational costs. The better the operator, the lower the operating costs, and the higher the reservation price. Thus, this process, namely competitive bidding, drives out inefficient players, in a rational bidding environment, ab initio. It is the most efficient process from a public policy perspective having full Pareto optimality.[28] This then leads to the issue of closed versus open bids.
In contrast, the Lottery process has been experienced before in the initial stages of Cellular. It suffers from clear and well understood difficulties, such difficulties publicly acknowledged by all those involved. Lotteries have generally no entry cost. Thus the asset is not valued and the entrant is not vetted. Lotteries have the chronic problem of speculation and the resale of assets with no public benefit. Lotteries also do not recognize the efforts of those who can operate at the lowest costs, thus providing, in a truly competitive environment, the lowest price. Therefore, this option is clearly unacceptable from a public policy perspective.

An open bidding process tends to be the most efficient. It provides feedback to all the bidders on price and such process clearly demonstrates the true value for the property. Open bidding allows all other players in the bid to have information on all other players valuations and to adjust their values accordingly. However, it can be shown that certain forms of closed bids, such as "Second Price Auctions" with sealed bids are as efficient in clearing the market for true valuation. This OPTION is the most appropriate, however, its effect can be achieved with a modified form of closed bidding.

The closed bid, as was shown, can if properly constructed, result in efficient bidding. Although this is a second choice, its is recommended that this be selected since it is logistically the most efficient.

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[27]This is a critical factor. As we have argued the LECs have disproportionate market power and control. As such, this must be mitigated against if there is to be a fair and equitable bidding process.

[28] See Shubik [1988], A Game Theoretic Approach to Political Economy, MIT Press, 1988, pp. 377-378; The author of this work refers to the large body of literature on the auctions and bidding processes. See Fudenberg and Tirole [1991], Game Theory, MIT Press, 1991, pp. 10-11, and pp. 219-224; In this reference, the concept of a Second Price Auction is analytically discussed and it is shown that in such an auction, wherein the highest bidder pays the price bid by the second highest bidder, then each bidder bids their perceived value for the property. This is exactly the strategy that the Commission desires. There is a wider body of literature on auctions and bidding that clearly demonstrate the efficacy and efficiency in clearing markets and maximizing the public good.

Holding all of the bids at the same time, forces all of the bidders to select a single bid price for a property and to value all properties based upon the reservation methodology with market information only. This can be shown to be the most efficient form of bidding process in reflecting true valuation. This OPTION is recommended.

This bidding process adds another factor into the bid. Specifically it adds the "feeding frenzy" factor of escalating and oscillatory bids, based on fluctuating a posterior information available to all bidders. Large oscillations in valuations can occur and these may and have been shown in other cases to result in over-valuations and the failure of properties due to over payment and failure to meet required financial returns. This process is typical in real estate bidding and it is well know to microeconomics to cause the high volatility in these markets. It is recommended that this OPTION not be followed.
If sealed bids are used, one location is best. If open bidding is used, logistically one location could cause chaos. Multiple locations for open bidding is the best logistical choice.[29] From an operational perspective sealed bids are more efficient. As has been presented, such a process can also be shown to be economically the most efficient.

Thus it is clear that the proposed auction process is one that is a ***Sealed and Simultaneous Bidding Process which is done for all Licenses at the same time and with Regions that are acceptable.***

4.2 Optimal Allocation Options

As we have just argued, an allocation process that values the property in a true market fashion is Pareto Optimal. However, the essence of the argument was that all of the bidders were bidding on the basis that was fair and equitable. Specifically, it assumes that all bidders face the same basis for the supply curve. This, unfortunately, is not the case. As we have already argued, the RBOCs, plus GTE, face a different curve. They have monopoly power that provides them with four price advantages; monopoly rents, inequitable access fees, market leads and thus lower cost of capital, and no existing "tax "base. In addition, they face building this in an incremental fashion, and having control over the total market at the current time. The process of allocation, even in an auction format, must take these into account.
There result two possible options for the process. They are as follows:

(i) RBOC/GTE Exclusion: This would be a total exclusion to allow the other players to bid on a non monopoly basis.
(ii) RBOC/GTE Restrictions: This would develop a set of restrictions or increase the bid prices to off set the monopoly rent advantage. Possibly, it would entail the "taxing" of their existing properties.

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[29]In the TTI NPRM Filing the following recommendation was made: "***IT IS RECOMMENDED THAT THE COMMISSION HAVE COMPETITIVE BIDDING, AND DOES NOT CONSIDER LOTTERIES OF ANY FORM, AND THAT THE COMPETITIVE BIDDING BE DONE IN A SIMULTANEOUS FASHION, AND IN A MANNER THAT ALLOWS MAXIMUM COMPETITIVENESS AMONGST ALL OF THE CONTENDERS. SPECIFICALLY, THE OPTIMAL CHOICE IS A FULL OPEN BIDDING PROCESS BUT BARRING THE COMPLEXITIES OF SUCH A PROCESS THE SECOND OPTIMAL RECOMMENDATION IS THE CLOSED, SEALED BID PROCESS, SIMULTANEOUSLY, FOR ALL AREAS SELECTED, WITH QUALIFIED BIDDERS. A QUALIFIED BIDDER SHALL BE ONE WHO HAS CLEARLY DEMONSTRATED BOTH DEVELOPMENTAL COMMITMENT THROUGH AN EXPERIMENTAL TRIAL OR TECHNOLOGY DEVELOPMENT, AS WELL AS DEMONSTRATING FINANCIAL RESOURCES ADEQUATE TO EXECUTE THE BID PAYMENT.***"

We have also argued that if the auction process is efficient and if it clears the market, then it is Pareto efficient. The second concern is how best to maximize the Governments return. Consider a bidding process that entails an up front payment. The following scenarios are possible:

Scenario 1: RBOC participation.

In this case the RBOC have the monopoly advantage. They clearly will dominate the bid and present a chilling effect to any other bidder. Lacking a large group of bidders, the RBOCs may be able to get the bandwidth at reduced rates. The net result is a dramatically lowered price, reflecting inefficiencies in bidding and allowing the RBOCs, by the monopoly power and chilling effect to gain bandwidth at prices well below their reservation price and continue their monopoly.

Scenario 2: No RBOC but Up Front Payment

In this case we assume that monopoly rent protection is eliminated but that all bidders face a large cost of capital from the perceived risk of the existing monopolies in other bands as well as the from the needs to raise large amounts of capital in the open markets. The dynamics in this process will result in a dramatically lowered bid price, a single up-front payment, and may not even clear the market. If the market is not cleared, then the overall public policy objective of a national PCS service is unattainable.

Scenario 3: No RBOC and Risk Sharing through Bid Amortization

In this case we assume no RBOC but that there is a bidding process that works as follows;

> *(i) The auction process as described in the last section is enacted. Namely, sealed simultaneous bids, on a regional basis or on the basis of a set of national consortia.*
> *(ii) The bid is awarded on the basis of top three maximum bid in terms of dollars per population unit per region. Namely, bids of say $10 per PoP.*
> *(iii) The payment of the bid is made over a period of time based upon a fixed percent of the revenue generated from the system by the license holder, until the bid amount has been paid off. For example, a set percent, say 5%, of the revenue is paid each year until the total auction bid is amortized.*
> *(iv) The commitment to bid amortization is transferred upon sale or transfer of the property.*

In this case we have a value per PoP which is given by:

$$V_{PCS}(N) = \sum_{n=0}^{N} \frac{R(n) - E(n) - D(n) - T(n) - A(n)}{(1 + m_{PCS})^n}$$

where T is the amortization of the bid price. Namely, any bidder will offer a value per PoP based upon the perceived values entered into the NPV equation for the business. Clearly, from the Governments perspective, the value is maximized for the bid price, specifically;

$$BID_{PCS} = \sum_{n=1}^{N} \frac{T(n)}{(1 + m_{PCS})^n} = \sum_{n=1} \frac{P^* R(n)}{(1 + m_{PCS})^n}$$

where P* is the annual revenue amortization rate of the initial Bid value.[30]
The Bid Value then is risk shared. The Government, in this scenario, is motivated to ensure that competition thrives, that the competitors are dealt with fairly by the monopoly players, and that the consumer is best served. If that is the case, the Government gets a payback quicker and the NPV of the BID is greater.

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[30]The issue of the discount factor is critical. Arrow and Kurz raise the issue of the difference in a public and private discount factor. Further they argue that from a public policy perspective that this discount may be different from infrastructure elements than others. It is clear that this is a Game Theoretic issue when it comes to bidding. The seller, namely the Government may or may not have a rational estimate of this discount factor. It will be essential from both an Industrial Policy Perspective and a Fiscal Policy perspective that a rational and mutually satisfactory approach be taken. From the business risk perspective, this rate is well understood, and the bidders will compete with their own rates.

Thus the proposed Optimal Bid Strategy is as follows:

> ***A Sealed Simultaneous Bid of a Bid Price on the basis of Value per PoP per Region, amortized at a Rate P* per year as a percent of Gross Revenue. Furthermore, it is suggested that all users of comparable frequencies, when their license comes up for renewal, also be required to rebid the license on a similar basis.***

5.0 Policy Implications

Having established a model for the business, having reviewed and placed in context the issues of fully competitive markets and having determined a selection of allocations options, there result a set of possible policy implications. This section presents a set of these options that are based on the realities of technology, the market, and the ability to raise capital in a still uncertain business area. It is clear that the ability to raise capital in a fully competitive market is dramatically different that raising capital against an entrenched monopolistic player with bottleneck control. This paper assumes that competition and innovation are essential and that commoditizaion of the service is achievable. Based upon these factors the policies developed allow for balanced and full competition.

Technological Innovativeness

Technological Competitiveness is enhanced by allowing the maximum numbers of players into PCS subject to the overall policy guidelines. Limiting the players indirectly such as through a monopoly bidding process will delimit national competitiveness. It is clear as we have demonstrated that e regulated monopoly is neither incentivized not conditioned to build and create new and competitive technologies.[31] In fact, the rate of return mentality rewards lack innovation and capital intensivensss. The new technologies such as those of QUALCOMM may never see the light of day if they are not allowed to evolved in the competitive process.

Anticompetitive Factors

The Government, through the selection of the type of auction and the entrants into the auction may, in effect, be creating an environment that may create a chilling effect on non monopolistic bidders. These bidders may not be able to freely and competitively, in a fair and equitable fashion, present their bids and be able to obtain the same economic returns. Clearly, it has been demonstrated by the RBOCs and GTE in the LEC and Cellular markets that they have in combination, in such markets as Boston, controlled both wire and wireless services (NYNEX and Southwest Bell), and have overtly monopolized the residential telecommunications Local access, and that if they are permitted to bid for PCS bandwidth, perforce of that monopolistic position may be able to bid in a fashion that may preclude other competitors, and as such this may have a detrimental effect in interstate communications and commerce, and as such may possibly be viewed as in violation of antitrust laws.

The issue, then, is; can the U.S. Government act in a fashion supporting the LECs interests and create an environment that lacks competition?[32] Admittedly the monopoly structure was acceptable with the old

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[31]See the references by Murowaya and those by Thurow, pp. 160-190. The relationship between this effort and what MITI does in Japan is striking. Here the U.S. is taxing entrepreneurs for the development of infrastructure. In addition the U.S. may be supporting an unbearable burden of a monopoly player that further adds to risk. In Japan, the MITI Industrial Policy works differently. The current proposed approach is the extreme in capital, allowing the smaller entities to pay for the right while still bearing the burden of dealing with entrenched competitors.

[32]Hovencamp, Antitrust (1977), pp. 740-742. Under the doctrine developed in Noerr, 365 U.S. 127, 81 S.Ct. 523, 5 L.Ed 2nd 464 (1961), the LECs can petition the Government in their monopolistic interests. However, the question is one of acting in such a direct and overt fashion that could place the Government in the role

technology that clearly showed economies of scale and scope. [33]The new technologies, as has been shown, do not have scale and scope. Thus the monopolist positions of the LEC are such as to merely eliminate the existence of any future competitor. The question is; what role is the Government playing in this process? In fact, can the Government, by recognizing the monopolistic nature of the market, recognizing the change that technology can and should play in developing competition, create a risk sharing allocation procedure that is Pareto Optimal?[34]

Consumer Choice

By allowing for the maximum amount of competition it will allow for the most creative solution and provision of new services to the consumer. Innovation is clearly attributed to the smaller entrepreneurial companies. All one has to do is look at the LECs and see how lithe they have done with ISDN to understand what would result if they had monopoly control over PCS.

Market Competition

Market competition has positive and negative effects. It drives prices down and leads to innovation. Clearly the competition in the IEC market has benefited the consumer. It has also benefited AT&T. AT&T has evolved into a leaner and more competitive company. It avoided the problems of IBM and faced the issues of focus and competence early. The LECs are just beginning the recognize these issues with large downsizings and slow and almost glacial innovation. The competition that could come from the PCS markets will help to reinvigorate the Local Exchange with lower prices, improved efficiencies and better services.

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of market maker and controller to the detriment of both the potential competitors and the consumers. Also in Areeda & Kaplow, pp. 413-414, the case of California Motor Transport Co. v. Trucking Unlimited 404 U.S. 508 (1972) placed a limit on the level of that influence. That level was one of fair and proper representations and the ability to obtain recourse under such circumstances. The question herein is one that asks if the LEC can fairly represent the continuation of the monopoly structure both de facto and de jure.

[33]Hovencamp (1985) pp. 32-36 discusses the issues of natural monopoly as having both scale and scope plus the limited amount of sunk costs and the ability to transfer assets. Under Clayton Section 7, the authority to regulate the monopoly has been given to the FCC. In Brenner, p. 91, "the Commission in... 84 F.C.C. 2d 445 (1981) determined that congressional intent underlying the act was to ensure universal service by limiting the market power of dominant carriers. Title II regulation of non dominant carriers could well contradict Congress's goals...". The issue before the Commission is in effect the issue of the structural elimination of market dominance by means of technological innovation supported by a de facto Fiscal Policy via the Auction process. It is argued that under Sherman, with the issue of natural monopoly in serious question, and under Clayton and Robinson Patman with regard to pricing, specifically the fact that access fees are internally transferred at less than long term average costs, that it will be necessary for the Congress and the Commission to review the issues of authority to permit the LECs to even be active bidders in the process of new spectrum allocation.

[34]It should be noted that this is comparable to the evolution of the railroads and the airlines. Ironically it was during the Administration of Franklin D. Roosevelt that the railroad found competition from the airlines. The Administration in that period could have taken the position that the Government should protect the quasi monopoly structure of this "Transportation" industry and should not encourage the new interlopers. After all, it was the depression and as railroads lost business employees would loose jobs. Roosevelt, instead, fostered this new industry, using highly competitive Postal and Mail Delivery contracts. The net result was that the US Government during this administration fostered the technology that was to become a dominant element in the export trade of the United States for the Past sixty years. The same opportunity presents itself to the current administration. Instead of "Taxing" the risk takers or instead of immortalizing the monopolists, the Administration can empower the entrepreneurs to create the technology base for the next fifty years.

Investment and Innovation

Competition in this technological area is based on technological innovation. Technological innovation is diffusive into product innovation and these products will lead to user empowerment. The key to PCS is its ability to extend the nature of telecommunications to a full wireless environment that will lead to a plethora of new service and product offerings. These in turn will create new opportunities for entrepreneurs and job creation. PCS can potentially have the same effect as the PC did in the computer area. However, innovation requires investment. Investment is undertaken subject to risk and return. The current proposal taxes on the front end as well as on the back end. If we view the initial payment as a tax, and alternative would be to use that as a tax credit in some other area. This is an alternative proposal of balancing Fiscal and Industrial demands.

6.0 Conclusions

The issue of allocation spectrum to balance policy objective of service availability and valuing the assets allocated must be further balanced in terms of the public's interest in ensuring the overall competitiveness of the US. technology and business base. This paper has shown that there is a fundamental technological change occurring in telecommunications and that this change will significantly alter the way the services are provided to the consumer. Furthermore, this paper shows that the way this change is to occur is directly linked to the manner in which the Government will allocate the spectrum.

Specifically, the LECs have dominant monopoly power in all markets through the Local exchange that is wire based or via their subsidiaries which are wireless. Almost 70% of the total markets are already RBOC dominated and they are present in 100% of all markets with both wire and wireless services. The LECs have monopoly rents and access fees that are barriers to entry to other competitors. Especially in a bidding process where that monopoly power may be applied to exclude competitors and retain monopoly power the LECs can continue.

The Government is faced with a critical decision. In this paper we have recognized two clear policy goals as articulated by many in Government. First that the services that PCS provides are done so as to deliver a seamless interoperable toll grade quality national services. Second, that the value of the spectrum be recognized and that the taxpayer per compensated for that value. We agree that these are essential goals. Their implementation is at issue.

It is shown in this paper that the entrepreneurial risk taker faces the task of valuing the PCS business in a quantitative and rational manner. The risks are reflected in the cost of capital and the vagaries of the payout of compensation for access to the frequency. This paper recommends a proposal that will balance risk with return and will optimize the roles of new competitive market entrants and ensure the development of new technologies. The proposal in this paper has clearly shown that it can create an environment of United States Leadership in this new technological area if and only if competition is allowed to enter on a fair and equitable basis.[35]

[35] Gilder, Telecosm.

References

1. Areeda, P., L. Kaplow, Antitrust Analysis, Little Brown and Co (Boston), 1988.
2. Arrow, K.J., M. Kurz, Public Investment, The Rate of Return, and Optimal Fiscal Policy, Hopkins Press (Baltimore), 1970.
3. Blackwood, M.A., A. Girschick, Theory of Games and Statistical Decisions, Wiley (New York), 1954.
4. Brenner, D.L., Law and Regulation of Common Carriers in the Communications Industry, Westview (Boulder, CO), 1992.
5. Cox, D.C., A Radio System Proposal for Widespread Low Power Tetherless Communications, IEEE Trans
6. Comm, Vol. 39, No 2, Feb. 1991, pp 324-335.
7. de Sola Pool, I., Technologies Without Barriers, Harvard University Press (Cambridge, MA), 1990.
8. de Sola Pool, I., The Social Impact of the Telephone, MIT Press (Cambridge, MA), 1977.
9. Dertouzos, M.L., J. Moses, The Computer Age, MIT Press (Cambridge, MA), 1979.
10. Dugan, D.J., R. Stannard, Barriers to Marginal Cost Pricing in Regulated Telecommunications, Public Utilities Fortn., vol. 116, No 11, pp 43-50, Nov 1985.
11. Fisher, F.M., Antitrust and Regulation, MIT Press (Cambridge, MA), 1985.
12. Freeman, R.L., Telecommunications System Engineering, Wiley (New York), 1989.
13. Freidel, F., Franklin D. Roosevelt, Little Brown (Boston), 1990.
14. Fudenberg, D., J. Tirole, Game Theory, MIT Press (Cambridge, MA), 1991.
15. Gilder, G., Telecosm, Forbes, ASAP, March, 1993.
16. Gilhousen, K.S., et al, Increased Capacity Using CDMA for Mobile Satellite Communications, IEEE JSAC, Vol. 8, No 4, May 1990, pp 503-514.
17. Gilhousen, K.S., et al, On the Capacity of a Cellular CDMA System, IEEE Trans Veh Tech, Vol. 40, No 2, May 1991, pp 303-312.
18. Henderson, J.M., R.E. Quandt, Microeconomic Theory, McGraw Hill (New York), 1980.
19. Hovenkamp, H., Antitrust, West Publishing (St Paul, MN), 1977.
20. Hovenkamp, H., Antitrust, West Publishing (St Paul, MN), 1986.
21. Hovenkamp, H., Economics and Federal Antitrust Law, West (St Paul, MN), 1985.
22. Huber, P.W., The Geodesic Network, U.S. Department of Justice, Washington, DC, January, 1987.
23. Kahn, A.E., The Economics of Regulation, MIT Press (Cambridge, MA), 1989.
24. Kolbe, A.L. et al, The Cost of Capital: Estimating the Rate of Return for Public Utilities, MIT Press (Cambridge, MA), 1984.
25. Lee, C.Y., New Cellular Schemes for Spectral Efficiency, IEEE Trans Vehic Tech, Vol 36, No 4, November 1987, pp 188-192.
26. Lee, C.Y., Overview of Cellular CDMA, IEEE Trans Veh Tech, Vol 40, No 2, May, 1991, pp. 291-302.
27. Lee, C.Y., Spectrum Efficiency in Cellular, IEEE Trans Vehic Tech, Vol 38, No 2, May 1989, pp 6975.
28. Lee, C.Y., Mobile Cellular Telecommunications Systems, McGraw Hill (New York), 1989.
29. Lehman, D.E., D.L. Weisman, Access Charges for Private Networks,Interconnecting with Public Systems, Twentieth Telecommunication Policy Research Conference, September, 1992.
30. McGarty, T.P., Local Area Wideband Data Communications Networks, EASCON, 1982.
31. McGarty, T.P., R. Veith, Hybrid Cable and Telephone Networks, IEEE CompCon, 1983.
32. McGarty, T.P., S.J. McGarty, Impacts of Consumer Demands on CATV Local Loop Communications, IEEE ICC, 1983.
33. McGarty, T.P., G.J. Clancy, Cable Based Metro Area Networks, IEEE Journal on Selected Areas in Communications (JSAC), Vol 1, No 5, pp 816-831, Nov 1983.
34. McGarty, T.P., Business Plans, J. Wiley (New York), 1989.
35. McGarty, T.P., Alternative Networking Architectures; Pricing,policy and Competition, Information Infrastructures for the1990s, Harvard University, J.F. Kennedy School of Government, Nov. 1990.
36. McGarty, T.P., S.J. McGarty, Information Architectures and Infrastructures; Value Creation and Transfer, 19th Annual Telecommunications Policy Research Conference, Solomon's Is, MD, September, 1991.
37. McGarty, T.P., Communications Networks: A Morphological and Taxonomical Analysis, Columbia University, CITI Conference,October, 1991.

38. McGarty, T.P., Wireless Communications Economics, Carnegie Mellon University, Advanced Telecommunications Institute, June, 1992.
39. McGarty, T.P., Communications Network Morphological and Taxonomical Policy Implications, Telecommunications Policy Research Conference, Solomon's Island, MD, September, 1992.
40. McGarty, T.P., Multimedia Communications in Medicine, IEEE JSAC, November, 1992.
41. McGarty, T.P., S.J McGarty, Architectures et Structures de L'Information, Reseaux, No 56, pp. 119-156, December, 1992, Paris.
42. McGarty, T. P., Economic Structural Analysis of Wireless Communications Systems, Advanced Telecommunications Institute Policy Paper, Carnegie Mellon University, February, 1993.
43. McGarty, T.P., Access to the Local Loop, Kennedy School of Government, Harvard University, Infrastructures in Massachusetts, March, 1993.
44. McGarty, T.P., Wireless Access to the Local Loop, MIT Universal Personal Communications Symposium, March, 1993.
45. MCI, NPRM Filing on PCS, November 8, 1992, FCC, Washington, D.C.
46. Muroyama, J.H., H.G. Stever, Globalization of Technology, National Academy Press (Washington), 1988.
47. Noam, E. M., Network Tipping and the Tragedy of the Common Network, J.F. Kennedy School of Government, Harvard University, Working Paper, October, 1990.
48. Pickholtz, R.L., et al, Spread Spectrum for Mobile Communications, IEEE Trans Vehc Tech, Vol 40, No 2, May 1991, pp313-322.
49. Pindyck, R.S., D.L Rubinfeld, Microeconomics, Macmillan (New York), 1992.
50. Porter., M., Competitive Advantage, Free Press (New York), 1985.
51. Reed, D., Putting it all Together: The Cost Structure of Personal Communications Services, OPP FCC Report Working Paper No. 28, November, 1992.
52. Shubik, M., A Game Theoretic Approach to Political Economy, MIT Press (Cambridge, MA), 1987.
53. Shubik, M., Game Theory in the Social Sciences, MIT Press (Cambridge, MA), 1984.
54. Solow, R.M., Growth Theory, Oxford Press (New York), 1970.
55. Spulber, D.F., Regulation and Markets, MIT Press (Cambridge, MA), 1990.
56. Stallings, W., ISDN and Broadband ISDN, MacMillan (New York), 1992.
57. Telmarc Telecommunications Inc., NPRM Response, FCC Gen Docket 92-333, November 9, 1992.
58. Telmarc Telecommunications Inc., Pioneers Preference, FCC Gen Docket 90-314, PP 76, May 4, 1992.
59. Telmarc Telecommunications Inc., Pioneers Preference, Reply to Comments, FCC Gen Docket 90-314, PP 76, June 25, 1992.
60. Thurow, L.C., The Management Challenge, MIT Press (Cambridge), 1985.
61. Tirole,J., The Theory of Industrial Organization, MIT Press (Cambridge, MA), 1988.
62. Weinhaus, C.L., A.G. Oettinger., Behind the Telephone Debates, Ablex (Norwood, NJ), 1988.
63. Winograd, T., F. Flores, Understanding Computers and Cognition, Addison Wesley (Reading, MA), 1987.