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GTE FLORIDA INCORPORATED

DIRECT TESTIMONY OF GREGORY M. DUNCAN

DOCKET NO. 961537-TP

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is Gregory Michael Duncan. My business address is 555 South Flower Street, Suite 4100, Los Angeles, Ca 90071.

Q. BY WHOM ARE YOU EMPLOYED? WHAT IS YOUR POSITION?

A. I am employed by National Economic Research Associates as Vice President. Before that, I worked for GTE Laboratories, Inc., with the Department of Economics and Statistics where I was a Staff Scientist; a position reserved for a small number of independent researchers with responsibility for developing, proposing and conducting research as well as supervising the research of other economists and statisticians at GTE Labs. I received a M.A. in Statistics in 1974 and a Ph.D. in Economics in 1976, both from the University of California, Berkeley. Beginning in 1975, I taught in the Economics Department and Statistics Program at Northwestern University in Evanston, IL, where I was an Assistant Professor of Economics and of Statistics. There, my teaching included demand and production theory, econometrics and statistics. I also conducted research on demand and production that appeared in refereed journals. I left Northwestern in 1979 to join the faculty at Washington State University. There, I served as Professor of Economics and of Statistics. My research

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continued in demand, production theory and applications as well as in other topics. During that period, I was one of the first Associate Editors of the academic journal *Economic Theory*. I have published many referred papers in cost, production, and demand analysis, including the results of the research that supported other testimony before a number of regulatory commissions. During my career, I have spent a good part of my time working on the analysis of cost data and have been fortunate enough to be able to contribute much of it to the academic literature on costs and production. My papers in this area appear in the *International Economic Review*, *Proceedings of the National Academy of Sciences*, *Econometrica*, and the *Journal of Risk and Uncertainty*. In addition, under my supervision, a number of Ph.D. students at Northwestern University, Washington State University and Boston University wrote dissertations that utilized modern cost and production methods. The results of some of these dissertations have also been published as contributions to the economic profession's understanding of costs. My particular expertise includes the formulation, specification, estimation and testing of cost models. And, as a consequence, I was asked to teach and have taught numerous graduate-level courses that covered directly and indirectly all aspects of cost analysis.

Q. DO YOU ADOPT THE ATTACHED REPORT (MARKED AS GMD-1) AS YOUR DIRECT TESTIMONY ON BEHALF OF GTE FLORIDA INCORPORATED IN THIS PROCEEDING?

A. Yes, I do.

Q. **DOES THIS CONCLUDE YOUR TESTIMONY?**

A. Yes it does.

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ECONOMIC EVALUATION OF VERSION 2.2 OF THE HATFIELD MODEL

by

Gregory M. Duncan

and

Timothy J. Tardiff

September 14, 1996

EXECUTIVE SUMMARY

Version 2.2 of the Hatfield Model is fundamentally flawed, and therefore does not provide reasonable estimates of the costs of incumbent local exchange carrier (ILEC) network elements. Particular shortcomings of the model fall into two major areas. First, the model has never been directly empirically validated. By this we mean that the predictions of the model have never been compared to actual observable data to see how well the model predictions comport with reality. Second, the model fails direct internal consistency checks of its validity, indirect comparisons of its validity by comparison of its results to cost models that do depend on real data, and is based on a set of restrictive assumptions whose lack of realism would try the confidence of even the most partisan proponent. Particular shortcomings of the model include the following.

- The model is based on static notions of cost rather than the dynamic notions that are relevant to regulations that seek to emulate the workings of dynamic competitive markets.
- There is no attempt at empirical validation of the model or its predictions.
- Its predictions fail explicit internal consistency requirements that are a necessary feature of structures capable of representing the minimum cost of producing telecommunications services using the most efficient forward-looking technology[1].
- Its predictions do not agree with other industry models that are based on firm specific data.
- The assumption that all volumes currently served by local exchange carriers will be served by a brand new entrant that instantly materializes is inconsistent with both reality and sound economics. Accordingly, costs based on such a model will *not* be representative of the costs incumbent LECs incur providing services and unbundled networks components.

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[1] By the most efficient forward looking technology, we mean the least cost technology taking the installed network as a base and building from that using the least cost technology available for producing the services required.

- The inputs (e.g., central office equipment prices) are consistently lower than what local exchange companies actually pay.

This report evaluates a number of additional, specific shortcomings of the model, including (1) the use of Census Block Groups to represent distribution plant, (2) the misuse of utilization (fill) factors, (3) the understatement of local switching costs, and (4) the understatement of the cost-of-capital and the rates of depreciation that will prevail under competitive conditions when network elements are offered on an unbundled basis. The cumulative impact of these various effects is that the Hatfield model understates the cost of loop plant and local switching by about one-third. Stated on a per line basis, the Hatfield model understates loop and local switching costs by about $9.00 per month.

Of course, the ultimate concern is how network elements are unbundled in a way that promotes competition. Basing prices on costs that no real-world provider could hope to meet is *anti-competitive*, because it would stifle, not promote, the most effective type of competition—facilities-based. In addition, requiring incumbent LECs to sell inputs at non-compensatory rates would have the deleterious effects of forcing whatever customers that may remain with the LEC to subsidize the below-cost input prices and/or severely handicapping firms that represent a substantial proportion of this dynamic industry.

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Ignored in most "greenfield" or "scorched node" arguments is that to actually use them one would have to tear up useful plant. None of these methods take into account either the direct or indirect costs of such a strategy.

I. INTRODUCTION

In its May 16, 1996 comments and May 30, 1996 reply comments in the Federal Communications Commission's (FCC) Local Competition Investigation, AT&T introduced Version 2.2 of the Hatfield model.[2] On June 14, 1996, AT&T and MCI filed the same model in the unbundling proceeding in California.[3] The purpose of this paper is to demonstrate that the Hatfield model does *not* provide reasonable estimates of the costs of local exchange company (LEC) network elements, either for LECs in general or any particular LEC, because the model (1) departs from fundamental economics in a number of significant ways, (2) contains a number of inaccuracies in execution that depart from reality, (3) produces results that are inconsistent with what can actually be observed, and (4) implies a fantasy version of both regulation and functioning markets.[4]

Particular shortcomings of the model include the following:

- The model is based on static notions of cost rather than the dynamic notions that are relevant to regulations that seek to emulate the workings of dynamic competitive markets.

- There is no attempt at empirical validation of the model or its predictions.

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[2] The Hatfield model is somewhat of a moving target. For example, MCI introduced a different ("greenfield") version of the model in its May 16 comments (Hatfield Associates, Inc., "The Cost of Basic Network Elements: Theory, Modeling, and Policy Implications"). Versions of the model have received extensive attention in ongoing universal service and unbundling proceedings in California.

[3] We understand that the model has been filed in a number of other states as well.

[4] Given the recent release of the Hatfield model and the constant changes made by the proponents, our evaluation is preliminary in nature, and will undoubtedly uncover more errors. As we understand it, working versions of Version 2.2 Release 1 only became available in late June. We received a working version of Version 2.2 Release 2 on August 26. The model is extremely complex and has limited and incomplete documentation. As a thorough evaluation is necessarily time-consuming, one was not possible within the time period available for our evaluation. Consequently, as new discoveries are made, they are added to the text as appendices. One must also ask how many more releases are in the offering. As an indication of how complex the program is we note the following facts. The number of pages is 4,210. The number of cells is 2,720,973. The number of cells that are physically changeable is 1,431,335. The number of cells that are intended for user input is 370; and the number of cells that contain a formula is 1,413,043. Most of the inputs are undefined so that a knowledgeable user would need to guess at the appropriate definition.

- Its predictions fail explicit internal consistency requirements that are a necessary feature of structures capable of representing the minimum cost of producing telecommunications services using the most efficient forward-looking technology.
- Its predictions do not agree with other industry models that are based on firm specific data.
- The assumption that all volumes currently served by local exchange carriers will be served by a brand new entrant that instantly materializes is inconsistent with both reality and sound economics. Accordingly, costs based on such a model will *not* be representative of the costs incumbent LECs incur providing services and unbundled networks components.
- The inputs (e.g., central office equipment prices) are consistently lower than what local exchange companies actually pay.

II. External Validity

We begin with the most vexing of the many problems accompanying the Hatfield Model. That is its lack of independent or external verification. Whether estimating costs using a pure econometric approach, a pure engineering approach or some hybrid approach, common practice requires validating a model by comparison to real world phenomena.

Ideally, a model such as the Hatfield Model would be calibrated or estimated using cost data from a source similar to those desired to be predicted. For example, the typical cost model would attempt to minimize differences in its predictions and real world data. If TS/TELRICs were readily available and observable for a number of firms over a period of time, then the model would be calibrated using all of the data from a subset of the firms, presumably a group of firms representative of the group whose TS/TELRICs we wish to predict. The model developed during this phase would then be subjected to a validation test, that being a comparison of the predictions of the model for firms left out of the calibration subset to the actual TS/TELRICs of those firms. For example if there were data on five or six firms one might hold out the data for two of them and calibrate the cost model on the basis of the other four. Then the model would be used to predict the TS/TELRICs for the two firms held out. The validity of the model would be judged by comparing the predictions of the model with the data that obtained in the real world for the firms in the validation data set using a variety of well known and widely accepted criteria.

This ideal procedure is not always followed, of course. Data are precious and expensive; so often other types of validation are used where the whole data set can be employed in the calibration or estimation phase. Again the methods are well known and need not concern us here because the Hatfield model is not based on sampling data nor has it ever been validated to our knowledge. Consequently, its validity or lack thereof must be judged on other grounds. These include the realism of the model's assumptions. comparison of the results to those produced by other models. and the extent to which the model satisfies internal validity checks. The model will be shown to fail miserably in these other criteria. leaving absolutely no basis supporting the model.

One particular feature of the structure of the Hatfield model needs special verification, that is its assumption that the cost function is additive in element cost components[5]. This assumption is particularly troublesome because it assumes away the existence of joint and common costs without testing to see whether or not there really are. Ordinarily, such features of a model are subjected to statistical testing to validate the structure. Indeed, Baumol, Willig and Ordover base their claim that pricing at TELRIC is economically valid on a mistaken belief that the Hatfield Model proves that the costs are indeed separable, whereas it merely assumes that fact as part of its construction so necessarily reproduces such a result when run. The fact of the matter is that this crucial aspect of the Hatfield Model has never been tested at all, neither have any other features of the model.

Another reason for needing formal external validation is the fact that the model is written in EXCEL which is a language ill suited for modeling. While easy to use, it is difficult to debug in the best of circumstances. Particularly disturbing here is there are thousands of

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[5] If a cost function $C(y_1,...,y_n)$ can be written as $C(y_1,...,y_n)=C_1(y_1)+...+C_n(y_n)$ it is said to be additive. This is the only structure consistent with TELRIC pricing. This is because there are no joint or common costs. The TSLRICs are simply the components, e.g. $TSLRIC_1 = C_1(y_1)$.

lines of undocumented code. Moreover, the auditing feature that allows some minimal tracing of the code are turned off by the Hatfield authors and password protected preventing the feature to be turned back on. Consequently, the only way to figure out if all the formulas are correct is to see if the model correctly comports with reality.

The rest of the paper is divided into two parts. The first part concentrates on the realism of the assumptions and comparison of Hatfield Model outputs to those of other cost models. The second part demonstrates that the Hatfield Model is theoretically incapable of representing the minimum cost of producing telecommunications services using the most efficient forward looking technology.

III. ECONOMIC THEORY

The Hatfield model documentation characterizes the model as "scorched node"—it starts with the existing locations of central offices, then builds a brand new system instantaneously from the ground up. While proponents of this approach claim that it approximates the textbook definition of long-run cost, it is grossly at odds with how real businesses incur costs, especially capital-intensive firms that expand their facilities by adding capacity in discrete modules.[6] Almost five years ago, Professor Alfred Kahn advised the FCC of the need to employ a realistic and practical perspective.

> In strict economic terms, the concept of long-run marginal costs relates to a hypothetical situation in which all inputs are variable, and a supplier confronts the possibility of installing entirely new facilities, in effect from the ground up. And the "marginal" relates to the incremental cost of a single unit of output. The concept of long-run incremental cost, in contrast, is more pragmatic: it takes a firm's past history as given, does not assume that it is writing on a blank slate, but recognizes that it will ordinarily be planning the installation of new capacity, at whatever that additional investment will cost given its current

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[6] Even the theoretical definition must be conditioned by reality. For example, Professor Varian has noted: "Long run and short run are of course relative concepts. Which factors are considered variable and which are considered fixed depends on the particular problem being analyzed. You must consider over what time period you wish to analyze the firm's behavior and then ask what factors can the firm adjust during that time period." Hal R. Varian, *Microeconomic Analysis, Third Edition*, New York: Norton, 1992, p. 66.

situation, and it spreads the costs over either the total output of that additional capacity—in that sense it is a kind of average incremental cost—or over the additional output that is likely to be induced by a price reduction under consideration (or curtailed in response to a price increase.)[7]

An additional difficulty with the Hatfield scorched view of the world is that it ignores the fact that in an industry with technological change, which clearly characterizes telecommunications, no company would set prices based upon such costs. The reason is that when technology advances, a new entrant taking advantage of latest technologies would drive prices down. Basing prices on the Hatfield view of the world would never recover costs. Professor Kahn and Dr. Tardiff recently noted this phenomenon as follows:

> In a world of continuous technological progress, it would be irrational for firms constantly to update their facilities in order completely to incorporate today's lowest-cost technology, as though starting from scratch: investments made today, totally embodying today's most modern technology, would instantaneously be outdated tomorrow and, in consequence, never earn a return sufficient to justify the investments in the first place. For this reason, as Professor William J. Fellner pointed out many years ago, firms even in competitive industries would systematically practice what they calls "anticipatory retardation," adopting the most modern technology only when the progressively declining real costs had fallen sufficiently below currently prevailing prices as to offer them a reasonable expectation of earning a return on those investments over their entire economic life. In consequence even perfectly competitive prices would not be set at the level of these (totally) current costs—unless, to put it another way, the calculated costs of the new plant included an extremely high rate of return and of depreciation, in reflection of the exposure of any such investments to costs and prices progressively declining in real terms over their life.[8]

[7] Affidavit of Alfred E. Kahn, Before the Federal Communications Commission, In the Matter of Expanded Interconnection with Local Telephone Company Facilities, CC Docket No. 91-141, August 6, 1991.

[8] Declaration of Alfred E. Kahn and Timothy J. Tardiff, Before the Federal Communications Commission, In the Matter of Implementation of the Local Competition Provisions in the Telecommunications Act of 1996, CC Docket No. 96-98, May 30, 1996. (footnote omitted). Professor Jerry Hausman's reply affidavit, filed in this docket on the same day, makes a similar point in the context of depreciation. Professor Hausman's findings will be discussed later when depreciation issues are addressed.

The Hatfield model's scorched approach to cost modeling essentially assumes that a LEC's loses one hundred percent of its demand for telephone services on day one. In effect, the succession of incumbent LECs would hand over their entire business to the newcomer, which in turn would instantly size its plant to perfectly accommodate this demand, taking advantage of all the economies that come with serving the demand with perfectly sized facilities obtained at the maximum volume discounts. It would be nice if the world worked this way, because we would all like to pay less for what we consume. Unfortunately, it does not. A real firm grows to meet demand as it materializes. As such, it adds capacity taking into account the trade-off between the lower per unit costs of bigger modules (e.g., larger cable sizes) and the costs of carrying the unused capacity that deploying larger modules would entail.

In short, the Hatfield model creates a contradictory world in which both full competition and the scale economies that would ordinarily dictate a monopoly structure coexist:

- Only a single firm can enjoy the economies of scale from deploying larger modules and the high capacity utilization from efficient inventory management.

- The firm is subject to the cost reducing effects of using the latest technology, while at the same time its equipment depreciates at regulatory-prescribed rates and its cost-of-capital is the same as for regulated utilities and it is guaranteed the full level of demand that a monopoly carrier would enjoy. Unfortunately, as discussed by Dr. Hausman, competitive markets are inconsistent low depreciation rates, guaranteed demand and guaranteed returns.

IV. SPECIFIC COMPONENTS OF HATFIELD MODEL

The Hatfield model reports results for several networks components: (1) loops, (2) local switching, (3) signaling, (4) transport, and (5) operator systems. Because the first two components constitute a substantial proportion of the total cost and have been subject to more extensive examination in the California proceedings than the other components, our review focuses on these components.

A. Loops

For the most part, the Hatfield model's development of loop costs relies on an incompletely documented revision to the Benchmark Cost Model (BCM Plus). The original model (BCM1) has been filed with the FCC by MCI, NYNEX, Sprint, and U.S. West. BCM1 identified geographic areas where costs of basic residential access service are relatively high or low cost. The sponsors describe their model as follows.

> The BCM does not define the actual cost of any telephone company, nor the embedded cost that a company might experience in providing telephone service today. Rather the BCM provides a benchmark measurement of the relative costs of serving customers residing in given areas, i.e., the CBGs [Census Block Groups].[9]

What is noteworthy about this description of purpose is that the costs that the BCM produces are not the actual costs of any particular company. Despite this acknowledgment by the BCM's sponsors, the proponents of the Hatfield model incorrectly propose to use parts of the BCM, albeit revised, to produce actual prices for the incumbent LEC's unbundled elements.

The BCM starts with the current locations of the LEC's central offices. The model constructs loop plant (feeder, distribution, and associated structures) from the central office locations to the households in the CBG by means of specific engineering rules, e.g., the lines served by a particular central office are the result of assigning CBGs to the closest wirecenters.

This assignment does not necessarily assign the households within the CBG to the wire center that actually serves them. For example, in California, Pacific Bell and GTE have found that the BCM assigns substantial percentages of households to the wrong wirecenter. As a result, the network represented by the BCM departs from the LEC's actual network. The Hatfield model's proponents may argue that the BCM has assigned households more efficiently than the LECs have. A more likely explanation is that the extremely abstract representation of

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[9] MCI Telecommunications Corporation, NYNEX Corporation, Sprint Corporation, and US West Inc., "Benchmark Cost Model," Submitted to the FCC, CC Docket No. 80-286, September 12, 1995, p. 3.

the network—a featureless plain[10]—ignores real world constraints, such as physical barriers, e.g., rivers, lakes, and hills, between a CBG and its closest central office.

Because the BCM assumes that loop facilities are installed instantaneously, the model selects the largest available cable sizes to serve a given static volume. In contrast, because real networks evolve as demand grows and changes, firms face a trade-off between deploying larger cable sizes (and enjoying the economies of scale that result at or near full capacity) versus using smaller sizes, thus reducing the carrying costs of the extra inventory that large cable sizes entail. In this regard, the BCM may underestimate loop cost, because it could assign larger/less costly facilities (on a per-unit basis) than an efficient firm would deploy. Such "savings" are illusory, not real. What has been left out of the BCM is the carrying charges on the unused capacity that the larger cable sizes would require for several years, until actual demand materializes.

A number of calculations built into the BCM can produce inaccurate estimates of efficient loop costs.

1. Installation and Structure Costs

For loop plant, both feeder and distribution, BCM1 calculates the investment costs of installation and structures by multiplying the cost of cable by factors that represent the installation labor cost and support structure investments. While properly developed factors can give reasonable representations of average installation and structure costs if current conditions are similar to those from which the factors were based, problems can arise when conditions change. In particular, changes in the cost of cable pass through directly into changes in the cost of installation and structures. In other words, the model would predict that two otherwise identical areas would have different installation and structure costs if they were served by companies that paid different amounts for their cable. Similarly, the model would predict that

[10] The only distinguishing characteristics are a number of topological factors used to estimate the cost of installation and support structures.

cost of installation and structures would decrease when a company is able to secure a better discount on the cost of the cable itself.

Hatfield's BCM Plus separately estimates the cost of structures, thus potentially overcoming the conceptual flaw in BCM1. Of course, the accuracy of the estimates depend heavily on the use of correct input prices for structures. We understand that for at least one such structure—manhole structures—the default prices contained in the model are considerably lower than at least one LEC actually pays. This type of inaccuracy is of more than academic interest; installation and structures can account for upwards of 80 percent of loop costs. In fact, a reasonable sanity check on the structure cost inputs would be to ascertain whether the share of loop costs accounted for by structures reasonably approximates real world experience.

2. Modeling Distribution Facilities

The BCM constructs feeder plant from the central office to the edge of the CBG. All loop plant within a CBG is assumed to be distribution plant. The BCM assumes that CBGs are square in shape and that households are uniformly distributed over the area of the CBG, neither of which is true of real CBGs. The BCM also uses an abstract representation of the distribution plant within a CBG. CBGs in the same density class have the same number of distribution cables of length equal to 62.5 percent of the square-root of the area of the CBG.[11]

The abstract representation of distribution plant can produce results that differ from reality, i.e., loop lengths can be inaccurate, cable sizes can be incorrect, and the number of cables within a CBG can differ from the number of cables assigned by the BCM.

First, as the sponsors of the BCM acknowledge, in sparsely populated areas, the uniform distribution assumption can cause substantial errors in cost estimation.[12] The basic problem is that the average loop length depends on the distribution of households within an area. When

[11] The model assumes that CBGs are square. Therefore, the square root of the area is the side of the square.

[12] BCM, p. 38.

the assumed distribution differs from the actual, an average based on the former will be inaccurate.

Second, although the BCM documentation describes CBGs as containing on average 400 households, there is, in fact, considerable variation in the number of households within a CBG. The consequence is that CBGs with a large number of households exceed the size of the distribution areas that at least one LEC, Pacific Bell, employs. In turn, the BCM allows larger copper cable sizes than the LEC actually employs. In particular, Pacific's maximum feeder cable is 3,600 pairs (GTE's maximum size is 3,000 pairs), compared to the 4,200 maximum in the BCM. For distribution cable, the corresponding values are 1,800 and 3,600 for Pacific and the BCM, respectively. If support structure can accommodate larger cables, there are economies in larger cable sizes. Because Pacific has found that its support structures cannot accommodate the largest cables assumed by the BCM, the BCM's default assumptions would understate the true cost of Pacific's loop plant.

Third, the use of the same number of distribution cables in a density class can cause substantial bias.[13] In fact, GTE examined the impacts of doubling the number of distribution cables from four to eight, accounting for installation and structural costs the way they are actually incurred. The estimated increase in cost was 49 percent.

Finally, the representation of the interface between the distribution cable and the subscriber (the drop wire and subscriber terminal) is not described in the Hatfield model documentation. The cost assumed for drop wire may be inconsistent with drop wire lengths that are compatible with the number of distribution cables employed in the model. For example, under a particular geometric representation of the distribution cables and drop wire, four distribution cables (as used in BCM1) implies an average drop wire length would be about 25 percent of the distribution cable length. In contrast, GTE estimates that the cost employed in the Hatfield model implies a drop distance of only about 25 feet, which is considerably shorter

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[13] BCM1 used exactly four distribution cables per CBG. BCM Plus apparently varies the number of cables by density class, although no documentation on the actual numbers has been provided.

than 25 percent of the average length of distribution cable. For example, for a low density CBG of one square mile, one-quarter of the BCM1's distribution cable length is 3/16 of a mile. GTE estimates that the drop wire investment for this length to be about $1,700 in California.[14] This is equivalent to a monthly cost of $32, which is about 55 percent of the Hatfield model's loop cost in the lowest density group (0 - 5 households per square mile) in California.

The abstract nature of the BCM's distribution model has practical importance. In the network cost elements produced by Release 2, distribution plant accounted for 39 percent of the total cost of switched network elements in California. Percentages are similar in other states, e.g., distribution plant accounts for 42 percent of Hatfield's total cost for switched network elements in Texas.

3. Fill Factors[15]

Because telephone capacity is modular, i.e., it comes in sizes greater than a single unit, there is more capacity in place than volumes in service. Capacity exceeds volume even when the most efficient engineering practices are followed. The ratio of volume in service to capacity is the fill factor.

The spare capacity represented by a fill factor less than 1.0 is a *current* economic cost of providing service. In a previous evaluation of the BCM, Pacific Bell's cost experts in reviewed that model.[16] As part of that review of the BCM engineering rules, Pacific's experts compared

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[14] Despite the likelihood that changing the number of distribution cables (as well as an apparent change in the average distribution cable length) would change the drop length, no change in the default values for drop wire have been made in the latest version of the Hatfield model.

[15] A theoretical discussion of these issues appears in Richard D. Emmerson, "Theoretical Foundation of Network Costs," in W. Pollard, editor, *Marginal Cost Techniques for Telephone Services*, National Regulatory Research Institute, 1991, pp. 145-189. See also Gregory M. Duncan, "The Effect of Probabilistic Demand Structures on The Structure of Cost Functions", *Journal of Risk and Uncertainty* (1990), 3, 3, 211-220.

[16] Timothy J. Tardiff, "Evaluation of the Benchmark Cost Model," prepared on behalf of Pacific Bell, for filing with the California Public Utilities Commission, Rulemaking/Investigation on the Commission's Own Motion into Universal Service and to Comply with Mandates of Assembly Bill 3643, R.95-01-020/I.95-01-021, December 1, 1995.

the model's fill factors with the actual fill factors that would result from the best engineering practices. In general, the fill factors for feeder plant in the BCM were moderately higher than best practice and the fill factors for distribution plant in high density areas were substantially higher than best practice. Distribution fill factors are relatively low because of the high cost of adding capacity after the support structure has been built. Accordingly, capacity for an indefinitely long planning horizon is installed initially and utilization of that capacity is low as a result.

Unfortunately, Version 2.2 of the Hatfield model has increased the already somewhat high distribution fill factors in the original BCM, as shown in the table below. This would cause the underestimation of loop costs to be even greater.

	BCM		**Hatfield**	
Density Zone	Feeder	Distribution	Feeder	Distribution
1	0.65	0.25	0.65	0.50
2	0.75	0.35	0.75	0.55
3	0.80	0.45	0.80	0.60
4	0.80	0.55	0.80	0.65
5	0.80	0.65	0.80	0.70
6	0.80	0.75	0.80	0.75

The Hatfield model's use of unrealistically high fill factors causes costs to be understated because the fill factor, in part, determines how much cable is needed. The Hatfield model appears to be based on the belief that competitive firms would have minimal spare capacity. In this regard, the FCC's finding on spare capacity in interstate long-distance, which was one of the bases for granting AT&T non-dominant status, contradicts this apparent belief:

> AT&T asserts, and no one disputes, that MCI and Sprint alone can absorb overnight as much as fifteen percent of AT&T's total 1993 switched demand at no incremental capacity cost; that within 90 days MCI, Sprint, LDDS/Wiltel, using their existing equipment, could absorb almost one-third of AT&T's total switched capacity; or that within twelve months, AT&T's largest competitors could absorb almost two thirds of total switched traffic for a combined investment of $660 million. Thus, AT&T's competitors possess the ability to accommodate a substantial number of new customers on their networks with little or no investment immediately, and relatively modest investment in the short term. We therefore conclude that AT&T's competitors have sufficient excess capacity available to constrain AT&T's pricing behavior.[17]

To cast the FCC findings in terms relevant to the current discussion, note that MCI and Sprint combined are roughly one-half of AT&T's size. Overnight they can absorb 15 percent of AT&T's capacity. This implies that MCI and Sprint have at least 30 percent spare capacity that could be deployed overnight.

The implication of these findings is that, if anything, competition may require more, rather than less spare capacity to be flexible enough to respond the to vicissitudes of the market. Failure to recover in current revenues the current cost of business caused by the spare capacity necessary to operate in the competitive environment would be detrimental to the shareholders of such companies, perhaps even forcing some of them out of business.

B. Switching

Version 2.2 of the Hatfield model systematically understates the cost of local switching. By selectively using heavily discounted prices for new switches and by assuming that a local service provider would instantly install all of the switching capacity it needs at once, the Hatfield model produces results that are substantially lower than the forward-looking local switching costs that real telephone providers actually incur.

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[17] Federal Communication Commission. In the Matter of Motion of AT&T Corp. to be Reclassified as a Non-Dominant Carrier, FCC 95-427, October 15, 1995, paragraph 59.

Hatfield developed a relationship between switching cost per line and the size of the switch by piecing together information from various sources. In particular, the algorithm is driven by three data points constructed as follows.[18]

- Small switch: the cost per line ($241 for 1994) was taken from the Northern Business Information report on the average cost of *new* lines for independent companies. Hatfield associated the average *installed* switch size of 2,782 lines for small LECs (LEC industry less RBOCs), calculated from statistics on lines and switches reported to the FCC for 1993.

- Medium switch: the cost per line ($104 for 1994) was taken from the Northern Business Information report on the average cost of *new* lines for RBOCs. Hatfield associated the average *installed* switch size of 11,200 for RBOCs, calculated from statistics on lines and switches reported to the FCC for 1993.

- Large switch: cost per line of $75 for a 80,000 line switch, "obtained from switch manufacturers."

Hatfield then drew straight lines between the three points to determine a relationship between switch price and switch size.

Hatfield's approach suffers from two problems. First, there is a mismatch between the data sources they employs. Note, for example, they matches a 1994 forecasted price with a 1993 average embedded switch size. In addition, while Hatfield uses independents (excluding GTE) for the small switch price. GTE is included in the calculation of the switch size. Finally, the approach assumes that the *average* installed switch is of the same size as the average *new* switch, an assumption that is not necessarily valid.

Second, and more fundamental, the Hatfield model ignores the fact that LECs buy additional lines for installed switches as well as new lines for new switches. These additional lines cost more, as the study that Hatfield used for his switch prices describes.

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[18] The switching cost function is described in some detail in the documentation for Release 1. The prices for the three switch sizes appear to be lower in Release 2. No justification for the lower prices has been provided.

The add-on market continues to retain revenue potential for the suppliers, particularly as the margins on new switches remain below the margins for the add-on market. A digital line shipped and in place will generate hundreds of dollars in add-on software and hardware revenue during the life of the switch. Suppliers can afford to lose a few dollars on the initial line sale in exchange for the increased revenue in the aftermarket, when prices are less likely to be set by competitive bidding.[19]

The local switching component of the Hatfield model graphically illustrates the fallacy of its scorched view of cost studies. In order for the approach to produce realistic costs (ignoring the data problems identified earlier), a new entrant would have to serve customers with initial lines only and also have the volumes to command the discounts that existing LECs apparently command. The fact that LECs expand their switches as demand grows and the existence of a lucrative aftermarket for this expansion demonstrate that the "instant LECs" posited by the Hatfield model are inconsistent with reality.

The documentation for Release 1 describes a single number for end-office switching: investment per line. Yet, the model produces two cost estimate: ports and usage. It appears that the model assigns exactly 30 percent of end office switching costs to ports and the remaining 70 percent to usage. The resulting costs are then divided by external estimates of the number of lines and minutes served by end offices in a service territory. We are aware of no justification for the assignment of end office costs to lines and usage.

C. Converting Investments to Annual and Monthly Costs

The various manifestations of the Hatfield model are essentially models of the *investment* component of an LEC's cost structure. These investments are converted into annual and monthly amounts by (1) annualizing the investments through the use of cost-of-capital and depreciation rates and (2) estimating out-of-pocket operating expenses through the use of historical expense to investment ratios.

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[19] Northern Business Information, *US Central Office Equipment Market—1994*, McGraw-Hill, p. 71.

1. The Hatfield Model Underestimates the Cost of Capital

The 10 percent return in Release 2. although higher than that used in the earlier release, is too low for two reasons. First. the FCC's approved rate of return remains at 11.25 percent. Second, the whole premise behind Hatfield's cost estimates is that they emulate the effects of competition. One of these effects is to raise the riskiness, and therefore the cost of capital, of competing firms (incumbents as well as entrants). This, in turn, increases the annual capital cost for local exchange services.

2. The Hatfield Model's Depreciation Rates Are Lower Than Economic Depreciation

The Hatfield model uses long depreciation rates in estimating the annual costs of network investments. While such long investment lives may have been appropriate for a regulated monopoly provider. the competitive environment fostered by the Telecommunications Act is a different world. The forces of competition itself, as well as the technological change that permeates this industry, invalidate the use of the old long depreciation lives. In fact, Professor Hausman's May 30, 1996 reply affidavit demonstrates that accounting for the increased risk and uncertainty of competition increases the annual cost related to investments by a multiple of at least 3.

Release 2 of Version 2.2 of the Hatfield model lists asset lives by type of facility, e.g., end office switches have a life of 14.3 years in the model. In order to compare these depreciation lives with external sources, we have calculated a weighted (by monthly cost) of about 17 years, which is equivalent to an annual depreciation rate of 5.9 percent. This rate is somewhat lower than the 1994 book depreciation of 7.16 percent for RBOCs, let alone the higher true economic depreciation rate.[20]

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[20] Federal Communications Commission. Statistics of Communications common Carriers, 1994/1995 Edition, Table 2.9.

Of course economic depreciation rates are much higher. For example, Schmalensee and Rohlfs reported that AT&T's depreciation rate is 18.5 percent.[21] Even AT&T's 1994 book depreciation rate of about 11 percent is much higher than the rates used in the Hatfield model.

3. The Operating Expense Estimates in the Hatfield Report Are Questionable

The Hatfield Report develops expense estimates based upon ratios of *booked* expenses to investment. This approach is problematic. Operating expense ratios based on historical investment may be a poor approximation of the forward-looking relationship. Consider, for example, an expense whose costs are unrelated to the underlying technology. As capital equipment becomes more (or less) productive, the expense to capital ratio changes, even though the absolute level of unit expenses does not.

The central office switching example discussed earlier illustrates the pitfalls of using annual factors. By employing the unrealistic assumption that an LEC can buy switching at the initial prices, the model assumes that annual cost (which we understand include the generic upgrades) would be lower as well. In fact, the very report that Hatfield relies on to develop the switch model suggests that such additional costs may increase when switch vendors discount initial prices.

The factor approach also suffers from the general problem that any decrease in an investment will cause a proportionate decrease in expenses. For example, if one LEC, for whatever reason, obtained a higher discount on its equipment, the model implies that it would enjoy lower out-of-pocket expenses, an implication that defies common sense.

V. COMPARISONS WITH EXTERNAL SOURCES

Version 2.2 of the Hatfield model produces estimates of network element costs, based on the abstract representations of network service costs. In contrast, the LECs have information

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[21] Richard Schmalensee and Jeffrey H. Rohlfs, "Productivity Gains Resulting From Interstate Price Caps for AT&T," National Economic Research Associates, September 1992.

on their current forward-looking costs of doing business. Because the prices for unbundled network elements obtained from the LECs must at least recover their costs, such a comparison is extremely informative.

Pacific Bell has provided the California Public Utilities Commission with results from its Cost Proxy Model (CPM) in the context of universal service.[22] Based upon our participation in the California unbundling and universal service proceedings, we understand that the CPM is designed to replicate the forward looking costs of Pacific's operations, because the model represents the engineering rules and cost-of-equipment Pacific actually uses.

To compare the output of the two models, we calculate the monthly cost for loops and local switching , which are common to both models. The results are $14.24 and $23.12 for the Hatfield model and the CPM, respectively. In short, the Hatfield model produces costs that are about 62 percent as high as Pacific's.[23] In light of the various shortcomings we discussed previously which would tend to understate the costs produced by the Hatfield model, the CPM's results are clearly the more plausible.

VI. Internal Consistency

A. The Hatfield Model Is Not A Valid Cost Model

The Hatfield model is not a valid economic cost model because it fails the internal and external consistency checks required of any cost model. This is more than just a theoretical point. Failure to satisfy these checks means that the Hatfield cannot represent the minimum cost of producing outputs using the most efficient forward looking technology. In Attachment I, we show this and also show that any numbers the Hatfield model produces purporting to be

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[22] Pacific Bell and INDETEC International, The Cost Proxy Model, California Universal Service Subsidy, 1996.

[23] The loop costs produced by Release 2 of the Hatfield model are 25 percent higher than those produced by Release 1. In contrast, in Texas, loop costs increased by only about one percent between releases. In both states, locals switching costs hardly changed.

TS/TELRICs are biased in an unknown direction. This makes them useless for even the minimal task of providing upper and or lower bounds for prices. Further, we will show that the underlying approach is so flawed as to render the Hatfield model impossible to fix without a complete overhaul, starting with the basic conceptual approach and ending with data requirements.

B. Cost models and TS/TELRIC calculations

The primary purpose of a cost model is to answer the question "What is the minimum cost of producing a stream of outputs using the most efficient forward looking technology and facing a perhaps uncertain stream of input prices?" To use a cost model to calculate a TS/TELRIC for a product, one calculates the minimum cost of doing business as usual and subtracts from that the minimum cost of doing business if a product line were dropped from production. Both components of this difference should be dynamic cost functions, not costs calculated only for the year in question, but costs calculated over the optimal planning horizon of the firm. Single period static cost functions are totally inappropriate.

C. Valid cost models

A valid cost model shows the relationship between the minimum cost of producing a flow of services using the most efficient technology, given a set of expected input prices, starting today and flowing into the future as far as the firm's optimal planning horizon. Specifically, for input prices and output levels in each year of the planning period, it shows the minimum present discounted value of producing those levels of outputs.

As a consequence of this minimization, costs functions and cost models necessarily satisfy a set of mathematical properties which can be found in a first year graduate textbook such as 'Microeconomic Analysis' by Hal Varian. Rather than a complete listing of them, we will discuss two that the Hatfield model clearly violates. The first is linear homogeneity in prices; this means if all prices are increased proportionately, then total costs will increase by the same proportion. The second is the derivative property. An easily understood form of the derivative property is this: the percentage increase in total costs as a consequence of a one hundred percent increase in the price of an input, i.e.. labor . loops, wire, and the like, will be exactly equal to the share of total costs directly attributable to that input. So if cable of a certain grade comprises 10% of total costs and its price rises 100%, then total costs should rise 10% as a consequence.

To test the linear homogeneity assumption we increased all the input prices in the Hatfield model by 10% using their default GTE California data as a base case. A valid cost structure should yield an increase in TS/TELRICs of 10% as well[24]. The results can be seen in Table 2, and can be seen to yield increases of roughly 13%—a number 30% higher than it should be.

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[24] This result is proved in Attachment I.

Table 2: Comparison of Hatfield TSLRIC Results
GTE California

	GTE Base Case	Costs with All Input Prices Increased 10%	Percent Change	Percent of Total Cost of Network Elements (Base)
Loop Distribution	$6.7455593	$7.7168590	14.3991%	42.43%
Loop Concentrator/Multiplexer	$1.7516408	$1.9674141	12.3183%	11.02%
Loop Feeder	$2.6270746	$3.0163648	14.8184%	16.53%
Local Switching	$1.1026042	$1.2219772	10.8265%	22.12%
Other				7.91%
Operator Systems	$6,876,152	$7,637,209	11.0681%	
common Transport	$0.0027286	$0.0030552	11.9700%	
Dedicated Transport	$4.0673481	$4.5524163	11.9259%	
Signaling Link Transport	$52.2779075	$57.9206566	10.7938%	
Signaling Transfer Points	$0.0000769	$0.0000852	10.7938%	
Service Control Points	$0.0010559	$0.0011698	10.7938%	
Tandem Switching	$0.0018684	$0.0020685	10.7066%	
Total Cost of Network Elements	$730,471,465	$827,067,353	13.2238%	

In the attachment we show that to the extent the Hatfield Model maintained the multiplicative structure of its past versions one should expect the derivative property of cost functions to be violated as well. Regardless of the source or reason for the error, the fact that the model produces wrong results is incontrovertible. And to emphasize the consequences of the error we once again point out that any cost function or cost model that fails even one of the criteria required of a cost function, whether as stated above or found in a text, cannot represent the minimum cost of producing services using the most efficient forward looking technology.

VII. THE HATFIELD MODEL IS BASED ON INAPPROPRIATE STATIC NOTIONS

Because the Hatfield model is a static rather than a dynamic model, it mishandles growth and underestimates the true forward-looking cost of capital. It totally ignores growth and in doing so, it mischaracterizes that spare capacity which results from optimal timing of laying discrete plant, instead labeling it as inefficient over-capacity. A consequence of this is Hatfield's concentration on and insistence that fill factors are too low. In fact, at least since the mid 1970's it has been well known that in a dynamic context, the problem of optimally investing in discrete plant when there is growth has a component not found in static situations. In his 1978 paper in the *Review of Economic Studies*, David Starret shows that the cost minimizing firm in a dynamic situation trades off some spare capacity against the economies of scale in construction. The firm cost minimizes by choosing the lengths of the intervals between which it invests. During periods between investments there will always be spare capacity and it is often optimal and cost minimizing to always have spare capacity. Moreover, the mathematical structures that might be appropriate in a static situation may not be in the dynamic one. To determine whether or not they are appropriate requires the kind of empirical testing that the Hatfield model has not undergone.

Second, it underestimates real cost of capital by ignoring the effects on the cost of capital that attend (a) the increased riskiness of an industry moving rapidly into competition and (b) the increased economic depreciation rates required recover investment in current plant and equipment. Failure to recover sunk investment has severe economic consequences; for the rate and level of the recovery of capital not only tell firms which activities to direct the use of their existing equipment but also dictate whether or not there is an incentive to replace equipment, as it becomes obsolescent, with the next generation. Indeed, by ignoring dynamics altogether, it fails to be forward looking even in concept.

VIII. Concluding Remarks

There are many reasons not to use the Hatfield model to determine TS/TELRICs and none to support its use. Primary among these is that it has never been tested against real data as might be expected of any model of any type. Trying to use it in spite of this is a little like asking paying customers to fly on a plane the type of which has never before flown or even tested. As an added insight to the problem of using a model that it has not been verified on actual data consider the following example. Suppose that the IRS decides to simplify its analysis of all of the paper work associated with reporting and verifying tax payers' income. To make the process easier, the IRS decides to create a model that estimates how much income from employment and investment a person makes each year. The model is simply based on assumptions about how much a person should be making based on the tax payer's age and the number of years of schooling that the person has completed. To use this model, the IRS enters the person's age and number of years of schooling and lets the model derive an estimate of income which is used in place of any reported income. Despite valid criticisms of consumer groups and without taking the time to validate what the model predicts with actual income data, the IRS then uses this model to estimate a tax payer's income and taxes the person accordingly. We would hope everyone recognizes this as a ludicrous idea but this is an exact analogy of what the Hatfield model is doing to incumbent local exchange carriers.

Beyond lack of external verification and empirical validity, explicit economic and conceptual flaws were identified that make it unlikely the model could produce any useable numbers. The model is static rather than dynamic which gives rise to, among other things, fill factors that are too high. The model does not even satisfy the minimum criteria required of properly constructed cost models—that increasing all prices an common proportion must increase TS/TELRICs by exactly the same amount. In addition, are the other fundamental flaws in the Hatfield model that we identified (1) it models the cost of no realistic local service provider and certainly not the incumbent LECs who will actually sell the unbundled elements it attempts to cost and (2) particular inputs and processes appear to systematically understate the costs of network elements. Indeed, at the same time that AT&T reported to the FCC that it would cost $1,240 per customer if AT&T provided local service to 20 percent of the market (likely the least costly part of the market), it and MCI are supporting models that produce investment costs of only $840 per line.[25]

Like any model, the Hatfield model is best interpreted in the context of why it was built and what objectives it is intended to foster. The architects and sponsors of the Hatfield model are quite clear in their purpose—they want to buy elements from the LECs, most prominently switched access, at rates far below current rates and even below the costs of the LECs require to produce these elements. While we would all like to pay lower prices, markets only permit this when those prices are commensurate with the costs of production.

The Hatfield model developers defend their costs by arguing that any difference between the costs of their model and costs reported by the LECs (either accounting costs that are required by law and by regulators or the cost produced by LEC incremental cost models) represent the costs of overinvestment. For example, the report describing the "greenfield" version of the Hatfield model that was attached to MCI's opening comments claims that about half of the LEC's current plant represents overinvestment. Apart from the facts that this label is entirely circular and Hatfield's estimate of the so-called gap is fatally flawed by the theoretical and measurement problems with the Hatfield models, it defies common sense to believe that the overinvestment of this degree could take place.[26] Regulators (both at the federal and state level) would have to have been quite derelict in their public responsibilities in order for this event to have occurred, an unlikely event given the scrutiny this industry receives. Perhaps even more telling, employees and representatives of the IXCs and other companies purchasing inputs from the LECs would have had to have been asleep at the switch to allow their companies to pay allegedly bloated prices for inputs for years without insisting on immediate correction of the

[25] The FCC's April 19, 1996 Notice of Proposed Rulemaking listed the costs AT&T reported it would incur. The Hatfield investment per line is calculated from the "greenfield" version of the model.

[26] Some of the gap between book investment and forward looking investment could represent the effect of the decline in prices for facilities such as end office switches. The fact that current prices recover some of these costs is entirely consistent with the economic fact that with technological change, no firm could survive by charging prices that completely reflect the decline in new equipment prices.

situation. Of course, the more important concern is how network elements are unbundled in a way that promotes competition. Basing prices on costs that no real-world provider could hope to meet is *anti-competitive*, because it would stifle, not promote the most effective type of competition—facilities-based. In addition, requiring incumbent LECs to sell inputs at non-compensatory rates would have the deleterious effects of forcing whatever captive customers that may remain to subsidize the below-cost input prices and/or severely handicapping firms that represent a substantial proportion of this dynamic industry.

ATTACHMENT I:

In this Attachment we demonstrate that the Hatfield Model violates the derivative property and that it produces biased TS/TELRICs.

Let i=1,...,n index the types of cable. let p_{ci} be the price per foot of the ith type of cable, let L_{ci} be the miles of the ith type of cable. let E^{o}_{si} be the base year expense of structure and installation for cable of type i and let E^{o}_{ci} be the base year expense of cable of type i. let E_{si} be the cost minimizing expenditure for expenses associated with cable of type i and let E_{ci} be the cost minimizing expenditure on cable of type i. and let y be the output for which a TS/TELRIC is desired.

A. The Hatfield Model Violates the Derivative Property

The loop cost part of the Hatfield model may be represented as

$$C = \sum_{i=1}^{n} \left(p_{ci} L_{ci}\right)\left[1 + \left(\frac{E^{o}_{si}}{E^{o}_{ci}}\right)\right].$$

The derivative property of cost functions requires that the derivative of a cost function with respect to an input price give the optimal amount of the input.[27] Thus. the derivative of C with respect to p_{ci} should give L_{ci}. Symbolically this is,

$$\frac{\partial C}{\partial p_{ci}} = L_{ci}.$$

Unfortunately, direct calculation of the partial derivative of the Hatfield model yields

[27]We use the level form of the derivative property here rather than the proportional or logarithmic derivative form we used in the text, because the level form has easier mathematics.

$$\frac{\partial C}{\partial p_{ci}} = L_{ci}\left[1+\left(\frac{E^{\circ}_{si}}{E^{\circ}_{ci}}\right)\right]$$

which is an over statement of L_{ci} by a factor of

$$\left[1+\left(\frac{E^{\circ}_{si}}{E^{\circ}_{ci}}\right)\right].$$

B. Hatfield TS/TELRICs Are Biased

For simplicity, assume only expenditures on cable. and expenses. The results are exactly the same with switching and expenses except the notation is more elaborate and difficult to follow. The Hatfield Model gives a cost function of the following form:

$$C^{*} = \sum_{i=1}^{n}(p_{ci}L_{ci})\left[1+\left(\frac{E^{\circ}_{si}}{E^{\circ}_{ci}}\right)\right]$$
$$= \sum_{i=1}^{n}(E_{ci})\left[1+\left(\frac{E^{\circ}_{si}}{E^{\circ}_{ci}}\right)\right].$$

The cost minimizing cost function is

$$C = \sum_{i=1}^{n}(E_{ci} + E_{si}).$$

Use the difference calculus to obtain Hatfield TS/TELRIC and the true TS/TELRIC.

For the Hatfield Model,

$$\Delta C^{*} = \sum_{i=1}^{n}(\Delta E_{ci})\left[1+\left(\frac{E^{\circ}_{si}}{E^{\circ}_{ci}}\right)\right],$$

for the true model

$$\Delta C = \sum_{i=1}^{n}\left(\Delta E_{ci} + \Delta E_{si}\right).$$

Taking the difference between the terms gives

$$\Delta C - \Delta C^{*} = \sum_{i=1}^{n}\left(\Delta E_{ci} + \Delta E_{si} - \left(\Delta E_{ci}\right)\left[1+\left(\frac{E_{si}^{o}}{E_{ci}^{o}}\right)\right]\right)$$

$$= \sum_{i=1}^{n}\left(\Delta E_{si} - \left(\Delta E_{ci}\right)\left(\frac{E_{si}^{o}}{E_{ci}^{o}}\right)\right)$$

$$= \sum_{i=1}^{n} E_{si}^{o}\left(\frac{\Delta E_{si}}{E_{si}^{o}} - \frac{\Delta E_{ci}}{E_{ci}^{o}}\right).$$

Dividing by Δy, multiplying and dividing by y and rearranging terms gives

$$\frac{\Delta C - \Delta C^{*}}{\Delta y} = \sum_{i=1}^{n}\frac{E_{si}^{o}}{y}\left(\frac{\Delta E_{si}}{E_{si}^{o}}\frac{y}{\Delta y} - \frac{\Delta E_{ci}}{E_{ci}^{o}}\frac{y}{\Delta y}\right)$$

which is the bias in the incremental costs. The bias is then a weighted sum of the differences between installation and structure expenditure elasticities and the cable expenditure elasticities.

C. Valid TS/TELRICs Must Be Linear Homogeneous in Input Prices

As discussed above, total cost functions must be first degree (or linear) homogeneous in input prices. This means if all input prices are increased by the same percent, say 10%, than total costs will increase by the same percent, in this case 10%. In this section we show that TS/TELRICs must satisfy the same requirements. We state the result as a Lemma

TS/TELRICs are linear homogeneous in input prices.

Proof:

Let the total cost of providing n services at levels $y_1,...y_n$, with m inputs which have prices $w_1,...,w_m$ be denoted $C(y_1,...y_n, w_1,...,w_m)$. The TS/TELRIC for service 1 is given by

$$TS/TELRIC_1(y_1,...y_n,w_1,....,w_m) = C(y_1,...y_n,w_1,...,w_m) - C(0,y_2,...y_n,w_1,...,w_m).$$

Where $C(0,y_2,...y_n, w_1,....,w_m)$ is the minimum cost of dropping the production of service one entirely while keeping the levels of all other outputs at their previous values. Thus, both $C(y_1,...y_n, w_1,...,w_m)$ and $C(0,y_2,...y_n, w_1,....,w_m)$ satisfy the linear homogeneity requirements,

$$\lambda C(y_1,\cdots,y_n,w_1,\cdots,w_m) = C(y_1,\cdots,y_n,\lambda w_1,\cdots,\lambda w_m)$$
$$\lambda C(0,y_2,\cdots,y_n,w_1,\cdots,w_m) = C(0,y_2,\cdots,y_n,\lambda w_1,\cdots,\lambda w_m)$$

Thus, by subtraction

$$\lambda C(y_1,\cdots,y_n,w_1,\cdots,w_m) - \lambda C(0,y_2,\cdots,y_n,w_1,\cdots,w_m)$$
$$= C(y_1,\cdots,y_n,\lambda w_1,\cdots,\lambda w_m) - C(0,y_2,\cdots,y_n,\lambda w_1,\cdots,\lambda w_m)$$

or

$$\lambda TSLRIC(y_1,\cdots,y_n,w_1,\cdots,w_m) = TSLRIC(y_1,\cdots,y_n,\lambda w_1,\cdots,\lambda w_m).$$

Which says, in words, that proportionally increasing all input prices will increase TS/TELRICs by the same proportion.

D. HATFIELD'S JOINT COST ANALYSIS

In version 2.2 Release 1 Hatfield presents a regression analysis of common costs (support costs) regressed on direct costs (total costs as measured by total revenues minus support costs) to support a 10% factor to adjust for common costs. In release 2, the reference to the analysis is dropped and a 10% factor merely asserted. However, in ATT arbitration with GTE California, Dr. Mercer, one of the sponsors of the model, defended the 10% factor using the regression analysis contained in the old and presumably superseded manual and documentation for Release 1[28]. As a consequence we include here a critique of that method.

Hatfield's analysis cannot be used to determine either the amount or fraction of common or support cost. First, the Hatfield approach is based on a classic error in logic, the fallacy of division[29]. The fallacy of division ascribes properties that hold for a group to each member of the group. Second, underlying its analysis is an implicit assumption about telecommunications firms that is certainly false; by positing a linear relationship between directly attributable costs and common costs it implicitly assumes that the stand alone costs of producing each service or element is totally volume insensitive. This assumption simply does

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[28] Interestingly, Dr. Lee Selwyn presented the results of a similar analysis in the same arbitration to estimate the amount of avoided common cost and found a 18%-21% number. The difference in analysis seems to be in choice of firms to include and the year sampled (1994 for Selwyn 1995 for Mercer).

[29] Shim, J.K. and Joel Spiegel, *Dictionary of Economics*, John Wiley and Sons, Inc. New York

not withstand scrutiny. It has two implications: first, it implies the stand alone cost of providing loops for 20 customers is the same as the cost of providing them for 10,000; second, it implies that eventually telecommunications services will be provided by a set of natural monopolies one for each element or service. Given the Hatfield model's linear structure, the TELRICs are also the stand-alone costs. Thus this result says that if the Hatfield model adequately represents such a firm, its TELRICs should be volume insensitive as well. Thus if the regression were to be believed then it gives hard evidence that the Hatfield model does not model a real firm. This is somewhat of a non-issue since the regression analysis is worthless. Third, its data set, a single year of data on a subset of local exchange carriers, is incapable of determining the answer to the question it poses or the validity of its approach because it doesn't contain multiple observations on each firm to predict what happens to a specific firm when its direct costs vary. Fourth, it utilizes the wrong statistical technique, regression analysis, to identify a group relationship which it then mistakenly applies to the members of the group, GTE, specifically.

Hatfield suggests the following procedure to account for common costs. Using a sample of firms in a single year, it regresses an estimate of common costs (CC) on an estimate of direct costs (DC) (Hatfield Documentation of May 16, 1996 Version 2.2 Release 1, p. 51). It finds that the regression has a statistically insignificant value, and that the coefficient on direct costs is .10. This fraction is then used to gross up the direct costs to account for common costs.

There are a number of problems with Hatfield's analysis, any one of which renders all of its analysis useless. I begin with its approach. Hatfield would determine a relationship between direct and common costs that holds between firms, and then apply that relationship to each firm. Hatfield suggests that since a direct statistical relationship between CC and DC exists across firms. e.g. JC=a +bDC. that a reduction of $100 dollars in DC due to resale will result in a reduction of JC of b*100. This is the fallacy of division that I referred to above. To take the implications of this from the abstract to the specific and intuitive level, an analogy is in order.

A strong positive correlation exists between height(H) and weight(W) of males. This means that men who are taller tend to be heavier. If, for a sample of men, Hatfield ran a regression of each man's height on its weight, it would obtain a positive coefficient on weight, just as Hatfield found a positive relationship between direct and joint costs. For purposes of illustration, let us assume that it found that H=(1/30)W. Thus a man weighing 150# would be predicted to be 5' tall, a man weighing 180# would be predicted to be 6' tall. Applying Hatfield's approach to the height and weight analogy, it would assert a person going on a diet and losing 10# would get 4" shorter (4"=12"×(1/30)×10). The problem with Hatfield's approach is that it took a group relationship, one that holds only for the group, and applied it to each member of the group. This is called a fallacy of division. This logical error is common and has severe consequences. For example, it the common source for stereotypical characterizations of ethnic. religious and gender groups that lead to various sorts of discrimination. In the next section, I present a graphical representation of this error and its likely consequences.

Related to this is the question is there any reason to believe that the group relationship might, nonetheless. hold individually. The answer is no. In the appendix I show that the only case where the common costs bear a direct linear relationship to joint costs is one where marginal costs are zero. This means that to believe Hatfield's underlying model one must be willing to believe that supplying service to 10,000 extra customers is zero! Moreover, Hatfield's formulation has the additional odd feature that if it is believed, then eventually the volume sensitive costs of joint production, which increase as volume increases, will exceed the volume insensitive costs of independent production. Consequently, production will take place independently using a technology having volume insensitive costs. Necessarily this means only one firm is needed to produce arbitrarily large amounts of any one service or element, so that were Hatfield believed one need also believe that competition will fail and the current industry will be replaced by a group of natural monopolists. I am sure no one believes this scenario, but that is what is implicit in Hatfield's structure---accepting Hatfield's structure implies accepting the scenario that follows from it.

The third problem is that its choice of a sample, a single cross section of firms in a single year, is incapable of either supporting or refuting its claims. To determine whether or not its group relationship could be applied to a member of the group, it would need to use a panel of data, that is, multiple observations on each firm over time. It would need to do a pooled time-series cross-section analysis and test the hypothesis that the between firm relationship is the same as the within-firm, a single cross-section cannot provide information on within firm relationships because there is only one observation on each firm, whereas many more than the number of coefficients estimated are needed[30]. Moreover, regression analysis of the type it attempted will give the wrong result. I now turn to this problem.

A fourth problem with Hatfield's analysis is its choice of methodology. Having shown that its group relationship cannot be applied to specific members of the group, I will now show that Hatfield's method of obtaining the group relationship is also flawed. Regression analysis like many other technical devices operates validly only in specific environments. Statisticians and econometricians present the environments where regression analysis is valid in the form of assumptions. For example, a statistician might say a regression will give you the right answer provided none of the following occur. A conscientious practitioner of econometrics then checks the specific situation he or she is working in to make sure none of the required assumptions are violated. She might, for example, check to make sure that the independent variable, in Hatfield's case, direct costs, is uncorrelated with the error in the equation. If the independent variables are found to be correlated with the error, then regression analysis will lead to spurious results. Examples of spurious results include the finding that as birth rates increased in Holland so too did the number of storks, leading to a conclusion that storks brought babies. In fact, as people got wealthier and had more children and more garbage—storks are scavengers. So the relationship is spurious, there is none between storks and babies, instead there is one between income and babies and income, through consumption and garbage,

[30] An elementary but more complete explanation can be found in Greene, William H. (1993) *Econometric Analysis* 2nd Edition, Macmillan Publishing Company, New York. p. 444-480.

to the number of storks. The alleged relationship comes because both relations are positively related to income. However, a good trash collection policy or birth control policy would sever the relationship. Hatfield's group regression is of exactly this type. common costs are neither caused nor caused by direct costs: instead both are caused by the interaction of production with market forces. Specifically, a firm chooses inputs to minimize the total costs of production, thus the amount of direct and common costs are jointly determined. It can be found in any basic econometrics text that regression analysis is wrong when the dependent variable, here common costs and the independent variable, here direct costs, are jointly determined[31]. The consequence is a simultaneous equations bias. To give an example of how misleading a regression with a simultaneous equations bias can be we need to go back 50 years to the end of WWII (since then competent econometricians have known better than to make such errors). Then, the National Bureau of Economic Research issued a forecast and a prediction that as a consequence of the end of WWII and the return of the servicemen, the economy would be thrust back into a severe depression. That never happened. Milton Friedman, a Nobel Prize winner in Economics, and arguably also one of the great statisticians of that period, showed that the NBER had committed the very error I alluded to above, and as a consequence the prediction was fallacious[32].

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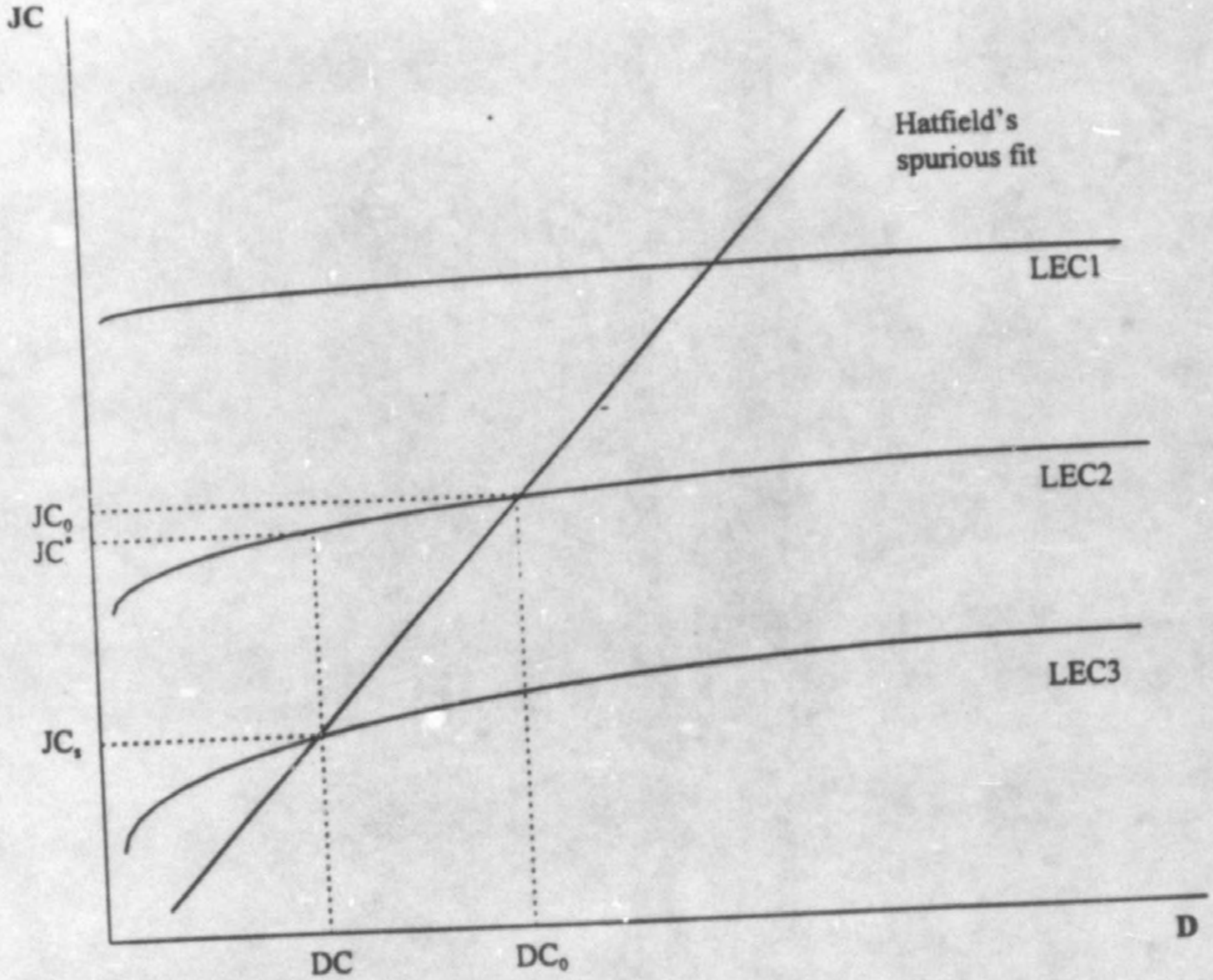
[31] Greene, William H. (1993) *Econometric Analysis* 2nd Edition, Macmillan Publishing Company. New York p. 579.

[32] Friedman, Milton (1957) *A Theory of the Consumption Function*, Princeton University Press. Princeton NJ

1. Graphical illustration of Hatfield's Fallacy of Division

Graphically, the error and its consequences can be clearly seen. Referring to the graph below let LEC1 be the graph of the true relationship between the direct costs (DC) of LEC1 and its joint costs (JC). Define LEC2 and LEC3 analogously. The three points where the straight line labeled Hatfield's spurious regression intersect the lines LEC1, LEC2, and LEC3 correspond to the observed values of joint and direct costs observed for each firm. Hatfield's regression runs a line through these three points. Hatfield then uses this relationship to predict the avoided joint costs for a particular firm. Here I use LEC2 as an illustration. If DC falls from DC0 to DC*, the joint costs for LEC2 fall from JC_0 to JC^* -- moving along the true relationship LEC2 from point A to B. Hatfield would predict that JC would fall from JC_0 to JCs, that is, moving from A to C. So Hatfield's model will far over predict the avoided joint cost.


JC
Hatfield's
spurious fit
LEC1
LEC2
JC0
JC*
LEC3
JCs
D
DC
DC0

2. Hatfield's Formulation Has Incredible Implications:

In this part of the appendix, we show that the only industries that Hatfield's formulation can be applied are those where the stand alone costs are volume insensitive. For purposes of demonstration I show this is true for the first service, it can be shown to be true for all services.

$TSLRIC_i(y_1,\ldots,y_n) = C(y_1,\ldots,y_n) - C(y_1,\ldots,y_{i-1},0,y_{i+1},\ldots,y_n)$

Direct cost can be defined

$$DC = \sum_{i=1}^{I} TSLRIC_i$$

Joint cost can be defined as

$$\begin{aligned} JC &= C - DC \\ &= C - \sum_{i=1}^{I} TSLRIC_i \end{aligned}$$

Hatfield model supposes that $JC = a + b \times DC$. This may be written as

$$C - \sum_{i=1}^{I} TSLRIC_i = a + b \times \sum_{i=1}^{I} TSLRIC_i .$$

The following algebra shows that if this is true then the standalone costs of producing services or elements is totally volume insensitive. Such an assertion is on its face certainly incorrect.

Lemma:

If $C - \sum_{i=1}^{I} TSLRIC_i = a + b \times \sum_{i=1}^{I} TSLRIC_i$ then for each service or element, i, the standalone cost of production is volume insensitive.

Proof:

$$
\begin{aligned}
C &= a + (b+1) \times \sum_{i=1}^{n} TSLRIC_i \\
&= a + (b+1) \\
&\quad \times [C(y_1,\ldots,y_n) - C(0, y_2,\ldots,y_n) \\
&\quad + C(y_1,\ldots,y_n) - C(y_1,0,y_3,\ldots,y_n) \\
&\quad + C(y_1,\ldots,y_n) - C(y_1,\ldots,y_{i-1},0,y_{i+1},\ldots,y_n) \\
&\quad \vdots \\
&\quad + C(y_1,\ldots,y_n) - C(y_1,\ldots,y_{n-1},0)]
\end{aligned}
$$

$$
\begin{aligned}
C(y_1,\ldots,y_n) = a + (b+1) \times n \times C(y_1,\ldots,y_n) \\
-(b+1) \times [C(0, y_2,\ldots,y_n) \\
+C(y_1,0,y_3,\ldots,y_n) \\
+C(y_1,\ldots,y_{i-1},0,y_{i+1},\ldots,y_n) \\
\vdots \\
+C(y_1,\ldots,y_{n-1},0)]
\end{aligned}
$$

$$
\begin{aligned}
C(y_1,\ldots,y_n) = \frac{(b+1)}{(b+1)n-1} \times [C(0, y_2,\ldots,y_n) \\
+C(y_1,0,y_3,\ldots,y_n) \\
+C(y_1,\ldots,y_{i-1},0,y_{i+1},\ldots,y_n) \\
\vdots \\
+C(y_1,\ldots,y_{n-1},0)] \\
-\frac{a(b+1)}{(b+1)n-1}
\end{aligned}
$$

Without loss of generality, we demonstrate the result for the first service. The standalone cost of service 1 is given by $C(y_1,0,\ldots,0)$. We now evaluate the result above at $(y_1,0,\ldots,0)$.

$$C(y_1,0,\ldots,0) = \frac{(b+1)}{(b+1)n-1} \times [C(0,0,\ldots,0) + C(y_1,0,0,\ldots,0) + C(y_1,0,0,\ldots,0) \vdots + C(y_1,0,\ldots,0)] - \frac{a(b+1)}{(b+1)n-1}$$

$$C(y_1,0,\ldots,0) = \frac{(b+1)}{(b+1)n-1} \times C(0,0,\ldots,0) + \frac{(b+1)(n-1)}{(b+1)n-1} C(y_1,0,0,\ldots,0) - \frac{a(b+1)}{(b+1)n-1}$$

$$C(y_1,0,\ldots,0)\left[1 - \frac{(b+1)(n-1)}{(b+1)n-1}\right] = \frac{(b+1)}{n(b+1)-1} \times C(0,0,\ldots,0) - \frac{a(b+1)}{n(b+1)-1}$$

$$C(y_1,0,\ldots,0)\left[1 - \frac{(b+1)(n-1)}{n(b+1)-1}\right] = \frac{(b+1)}{n(b+1)-1} \times C(0,0,\ldots,0) - \frac{a(b+1)}{n(b+1)-1}.$$

Simplifying and solving for the standalone cost gives:

$$C(y_1,0,....0) = \frac{(b+1)(C(0,0,....,0)-a)}{b}.$$

Note that the right hand side of the equation does not depend on the level of service y_1. Thus the stand-alone cost of providing a service does not depend on the level of the service provided. This means the cost of a new entrant would be the same whether it proposes to serve one customer or a million. Clearly, this is not a cost relationship that is relevant to telecommunications.

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January 24, 1997

Re: Docket No. 961537-TP
Petition by American Communications Services, Inc., and its local exchange operating subsidiaries, for Arbitration with GTE Florida Incorporated pursuant to the Telecommunications Act of 1996

Dear Ms. Bayo:

Please find enclosed for filing an original and fifteen copies of the direct testimony of Kirby D. Cantrell, Michael J. Doane, Gregory M. Duncan, Donald W. McLeod, Beverly Y. Menard, William E. Munsell, Bert I. Steele, and Dennis B. Trimble on behalf of GTE Florida Incorporated in the above matter. Service has been made as indicated on the Certificate of Service. If there are any questions regarding this matter, please contact me at (813) 483-2615.

Very truly yours,

Cantrell - 00930-97
Doane - 00931-97
Duncan - 00932-97
McLeod - 00933-97
Menard - 00934-97
Munsell - 00935-97
Steel - 00936-97
Trimble 00937-97

Anthony P. Gillman
APG:tas
Enclosures

CERTIFICATE OF SERVICE

I HEREBY CERTIFY that copies of the direct testimony of Kirby D. Cantrell, Michael J. Doane, Gregory M. Duncan, Donald W. McLeod, Beverly Y. Menard, William E. Munsell, Bert I. Steele, and Dennis B. Trimble on behalf of GTE Florida Incorporated in Docket No. 961537-TP were sent via overnight delivery on January 23, 1997, to the parties listed below.

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