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BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

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In the Matter of the Pricing Proceeding for Interconnection, Unbundled Elemetns, Transport and Termination, and Resale for GTE NORTHWEST INCORPORATED	)))))	DOCKET NO. UT-960371

ATTACHMENT

TO

DIRECT TESTIMONY

OF

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March 27, 1997

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ECONOMIC EVALUATION OF THE HATFIELD MODEL RELEASE 3.1

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Table of Contents

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Executive Summary

The Hatfield Model Release 3.1 is an engineering model of cost developed by Hatfield Associates, Inc. of Boulder, Colorado. It was created at its inception for the purpose of estimating the size of forward-looking universal service support funds.[1] The Hatfield Model Release 3.1, is being promoted by AT&T and MCI as a model that accurately predicts the economic, forward-looking total element long run incremental cost (TELRIC), relevant for setting the prices of unbundled network elements or measuring the economic subsidy for universal service support. Prior to the introduction of the Hatfield Model Release 3.1 in the third week of February 1997, the Hatfield Model Version 2.2 Release 2 and the Hatfield Model Release 3.0 had been promoted by the same sponsors. It is unclear whether AT&T and MCI will sponsor this latest release in all of the upcoming state and federal proceedings.

In many ways, Release 3.1 of the Hatfield Model ("Hatfield Model" or "Model") represents a substantial change to previous Hatfield models-- the programming code is different and more efficient and the loop distribution component (which accounts for 40 to 50 percent of the total cost of network elements) has been substantially changed. Much of the demographic data and default values of the user adjustable input variables have been modified. Curiously,

[1] Hatfield Associates, Inc., *The Cost of Basic Universal Service*, prepared for MCI Telecommunications Corporation, July 1994.

however, the overall results have hardly changed. Estimated total cost of switched network elements calculated by Release 3.1 for GTE are only 8% higher and loop costs only 5% higher in the state of Washington. These results are based on the default input values of Version 2, Release 2.2 and Release 3.1. Even more surprising, estimates of the distribution element are very similar between Release 3.1 and previous releases of the Hatfield Model.

Based on our evaluation, we have concluded that the Hatfield Model Release 3.1 is fundamentally flawed, and should *not* be used as the basis for setting prices for interconnection or unbundled network elements or for quantifying the subsidy of local exchange service to universal service. The problems with the Model go well beyond using the right user-adjustable inputs. While correct input prices and values for other inputs, e.g., fill factors, are very important—both common sense and economic theory dictates that incorrect input prices will produce incorrect costs for network elements—the problems with the Hatfield Model run deeper. Even if all inputs were valid, the Model would still produce incorrect estimates of the "incremental costs that incumbents actually expect to incur in making network elements available to new entrants."[2]

Furthermore, our evaluation indicates that the model's latest round of adjustments falls far short of correcting any of the basic problems associated with earlier versions of the model. In fact, none of the fundamental problems concerning the model's structural validity and outside verification have been remedied.

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[2] Federal Communications Commission, *Implementation of the Local Competition Provisions in the Telecommunications Act of 1996*, First Report and Order ("FCC Order"), CC Docket 96-98, August 1, 1996, ¶685.

The Hatfield Model is result driven and generates unrealistically low costs and rates. As will be presented in our paper, its estimated rate for basic residential service is typically about one half of an Incumbent Local Exchange Carrier's (ILEC's) actual costs, and also lower by about the same amount relative to residential service rates estimated by other cost models. At the Hatfield Models' estimated rates, no rational Alternative Local Exchange Carrier (ALEC) would even consider entering the market as a reseller of network services, even at very generous wholesale discount rates of 10-25 percent. Instead, market entrants would find it far more profitable to purchase all of the ILEC's unbundled elements and then repackage them for sale. Consequently, facilities based market entry would be significantly discouraged.

Particular shortcomings of the Hatfield Model fall into two major areas. First, the Model ignores market realities that a typical ILEC faces; it is completely independent of past ILEC investment decisions and simulates a network far different from the actual ILEC's network. Moreover, estimates of the Model have never been compared to actual observable data to see how well its predictions comport with reality.

Second, in addition to the lack of realism, the Hatfield Model fails to utilize sound economic methods to accomplish its purpose of predicting the cost of unbundled network elements. Particular shortcomings of the Model include the following:

- The Hatfield Model assumes that the ILEC's present facilities and assets—end offices, interoffice trunks, tandem switches, switching ports, feeder and distribution facilities—will be scrapped.[3] In its place the Model conceptualizes an entirely new network

[3] The Model's only likeness to reality in this regard is in building networks based on existing wire-center locations - often employing inaccurate data that either omit from or add to the existing wire-centers.

utilizing the most streamlined loop structures, one that claims to use the most efficient technology at the lowest possible cost utilizing the most streamlined loop structures[4]. The Model endows firms with perfect hindsight which provides cost savings not available to any real company operating in a forward-looking environment. Indeed, it models a firm where there is no uncertainty, no technological change, and no growth, thus ignoring the very concerns that are paramount in the telecommunications environment today.

- The Model's predictions do not agree with those of other industry models that are based on *firm specific* data. The Model still incorrectly identifies GTE and other ILEC serving areas. It grossly underestimates, in some cases by factors of 2, actual plant needed to serve areas. Moreover, it builds plant in other firms' serving areas, erroneously identifies other ILECs' wire centers as GTE's, and similarly identifies GTE's wire centers as belonging to other ILECs.

- The Model's input price assumptions (e.g., wire center equipment prices and switch prices) are consistently lower than what ILECs actually pay. For example, a comparison of actual GTE California switch contracts shows that the Model's switch costs per line predictions are roughly 60% of actual GTE contract prices .[5] Many of these assumptions are user adjustable while some are either hard wired data or intrinsic modeling components of the cost function and cannot to be adjusted.

- The Model claims to consider only "forward-looking technology" which reflects "forward-looking cost". This concept, however, is used only as a way of justifying lower costs. On the expense side, its methodology is for the most part backward

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[4] Even an engineering witness for the Model has admitted that it is "highly unusual in a real world situation that you would construct a total network on day one." (Before the California Public Utility Commission, Deposition of Robert Mercer, Joseph P. Riolo, and Terry Murray, R.93-04-003, I.93-04-002, March 7-8, 1997, p.12 "California Deposition").

[5] We calculated this figure by regressing the ratio of Hatfield calculated switch cost (Ch) over GTE calculated switch costs (CG) on the number of lines. This percentage is only valid for switches larger than 12,000 lines. For smaller switches the percentage error is even greater.

looking—entirely predicated on past demand and past costs as published in ARMIS.[6] On the investment side, it builds plant incapable of meeting the present demand and even more incapable of meeting the future demand. The understatement of investments and costs is done only in the name of eradicating stranded infrastructure—although the infrastructure it attempts to eradicate is exactly the infrastructure, except for a very small percentage, that is in use today and will be for the foreseeable future.

- The Model is entirely static. Growth is not properly factored in, and the Hatfield modelers generally assume that the cost of building and maintaining spare capacity for future expansion should not be considered. However, the rapid increase in the need to create new area codes, increased Internet usage and the popularity of second and third residential phone lines all point to a necessity for expansions in the local loop plant everywhere, in the present time and in the future. These facilities must be built by existing ILECs. The Model simply ignores these actual costs, market realities and demand considerations and therefore, fails to estimate a real "forward-looking cost."

- The Model subjects ILECs to cost reducing effects by using the latest technology available. At the same time their equipment depreciates at agency-prescribed rates. Moreover, their cost-of-capital is the same as for regulated utilities, and they are guaranteed the full level of demand that a monopoly carrier would enjoy. This is in direct contradiction with economic theory of competitive markets.

- The Model employs artificial jurisdictional cost allocations to determine its cost factors. One problem caused by this methodology is that costs incurred by a home office in one state of a firm operating in many states show up as revenue rather than cost flows with the consequence that the expenses calculated by the Model can be negative. This biases the costs in that state downward.

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[6] Where the model does depart from historical data (switching, circuit equipment, and network operations expenses), the adjustments always reduce estimated costs.

- The Model's assumptions that all volumes currently served by local exchange carriers will be served by a brand new entrant and that a brand new infrastructure instantly materializes are inconsistent with both reality and sound economics. Accordingly, costs based on such a model will *not* be representative of the costs ILECs incur providing services and unbundled network components.

- The Model's method of equating the lowest observed expense-to-investment ratios in the industry to individual firms' forward-looking expense factor is unjustified. Because it ignores economic tradeoffs and scale differences between firms (i.e., it assumes an identical isoquant curve for all firms across the industry), such a "pick and choose" approach runs the risk of creating networks that cannot handle any firm's current traffic and service demands.

- The Model's method of calibrating expenses and common costs by use of constant volume and price insensitive cost factors is econometrically and statistically unsound. Moreover, determination of the common cost factor is based on a single year of AT&T's costs, not ILEC costs. The Model then allocates its estimate of common costs uniformly over network elements. This approach both contradicts Consensus Costing Principle No. 5 (which treats the recovery of common costs as a pricing problem) and is theoretically unsound.

- Finally, the Model simply fails to provide external or internal justification of its validity, thereby precluding even the slimmest basis for regulators to trust its outputs. Externally, its predictions of presently necessary investments and costs do not comport with real data. Internally, it fails all consistency checks on necessary features of mathematical structure capable of representing the minimum cost of producing telecommunications services using the most efficient forward-looking technology.

We caution that the debate over the merits of this Model is more than academic. Basing prices on costs that no real-world provider could even hope to achieve without service degradation or outright network failure would stifle, not promote, facilities-based competition Therefore, we recommend that the Model not be adopted.

SECTION I Introduction Model Description and External Validity Checks

A. Introduction

The Hatfield Model Release 3.1 is a cost proxy model which purports to calculate Total Element Long Run Incremental Cost (TELRIC) as an estimate of forward-looking economic cost of unbundled network elements. In a separate calculation, the Model attempts to estimate the cost of universal service. Hatfield Model Release 3.1 (Hatfield Model or Model) is the fourth and latest edition in a series of Hatfield Models. It was filed with the FCC Joint Board on February 28, 1997 – only two weeks upon filing Hatfield Release 3.0 with the same authority.

In many ways, the Model represents a substantial change to previous Hatfield models. Programming code has changed significantly from that of earlier versions and the model executes now more efficiently. Model algorithms, and most notably the loop distribution component (which accounts for 40 to 50 percent of the total cost of network elements), have been substantially revised. The methods of estimating lines on a per CBG level and the allocation of CBGs to wirecenters have been revised as well.

The model's fundamental structure, however, remains unaltered, and therefore retains most of the modeling and economic errors that we have pointed out in previous versions, through the different editions of the model.

Curiously, however, all the revisions that were made had little or no effect on the Model's TELRICs. Even more surprising, estimated distribution costs were very similar between Release 3.1, Release 3.0 and Version 2.2 Release 2. Table 1 illustrates these points for GTE Northwest –Washington State.

Table 1

Hatfield Cost Estimates By Releases

	HM R. 3.1	HM R. 3.0	HM V. 2.2, R. 2	% change V. 2.2, R. 2 to R. 3.1	% change R. 3.0 to R. 3.1
	(1)	(2)	(3)	(4) [(1)/(3)-1]	(5) [(1)/(2)-1]
GTE Northwest – Washington					
Total Loop	$ 14.58	$ 15.40	$ 13.92	4.7%	-5.3%
Total Elements	$ 20.85	$ 19.75	$ 19.30	8.0%	5.6%
Loop Distribution	$ 7.99	$ 7.41	$ 8.86	-9.8%	7.8%

The findings contained in this paper are primarily based on documentation that was included with the Model's software[7], examination of the Model's algorithm and our experience with previous versions and releases of the Model. The incomplete documentation of the Model's hundreds, and possibly thousands, of algorithms requires an intensive review of all macro codes, database queries and Excel formulas to gain a true understanding of its workings.

Despite, or perhaps because of the complexity of the programming and the vastness of real and discretionary input data used to run the Model, its output is entirely unreliable. This

[7] "Hatfield Model Release 3.1, Automation Descriptions and User Guide and "Hatfield Model Release 3.1, Model Description", Hatfield Associates, Inc., Boulder, CO, February 28, 1997.

paper will demonstrate that the Hatfield Model does *not* provide reasonable estimates of the costs of local exchange company network elements, neither for ILECs in general nor for any particular ILEC, because the Model (1) is based on a hypothetical and an unrealistic local exchange network system, (2) departs from fundamental economics in a number of significant ways, (3) produces results that are inconsistent with what is actually observed and (4) implies an unrealistic version of both regulated and competitive markets.

Our analyses emphasize the Model's deficiencies in cost estimating methods, and examine its external (statistical) and internal (theoretical) validity. The results of our external validity tests in Part B of this section set forth clear evidence that the Model is not valid. Furthermore, our evaluation of its internal makings will show that there is no basis to support the output of the Model.

Due to the short amount of time that has been accorded to evaluate this enormously complicated model, this evaluation is far from being exhaustive. Experience with a predecessor (Hatfield Version 2.2, Release 2.2) predicts that a great deal more will be learned as the model is presented and tested in regulatory arenas during the upcoming months. Nevertheless, all indications of our initial analysis of the Model are that it is unfit to accomplish its intended goal of estimating the cost of unbundled network elements.

B. External Validity Checks

Perhaps the most fundamental test of a model is whether its results can be validated by comparison to external measures of the same costs. The Hatfield Model is not a valid economic cost model because it either fails this external validity check required of any cost model or the checks were never performed. By external validity we mean the simple comparison of the predictions of the model to actual occurrences in the real world. For example, a cost model that predicts a particular cost per line is invalidated if the actual cost turns out to be substantially different most of the time. Ordinarily, this verification is done as part of the estimation of the model.

A cost model is selected from a set of reasonable cost models by choosing the one that best reproduces actual data. For an econometric model, one collects from a firm (or from a set of similar firms) data on all of its costs, all of its input prices, the levels of its outputs, and the levels of each of its factors of production. Using economic theory as a guide, the analyst statistically determines a cost function and a set of input, or factor demand functions whose predictions for costs and inputs for each combination of outputs, fixed factors and input prices, come closest to the observed costs and factors for those same combinations. To use a model that has not been externally validated is much like allowing a new type of plane, a type that has never even been test flown, to carry passengers.

The Hatfield proponents admit the desirability of external validation but claim such validation is impossible. They specifically respond to this criticism by claiming that to use historical or even current data is to use embedded costs, claiming further that using embedded costs and therefore historical cost data is precluded by the desire to estimate "forward-looking" costs. Such an assertion demonstrates a lack of understanding about cost modeling, and the relationship between forward-looking costs and embedded costs. To the contrary, for many types of costs, current levels can serve as an excellent starting point for forecasts of forward-looking costs.[8] Indeed, the Hatfield Model proponents have consistently argued that its loop costs are based on technology that has been in place for years and that current engineering practices are followed.[9] In these circumstances, observation of actual costs (and the loop facilities themselves) can be considerably more reliable than cost estimates based on a "blue print" that has never formed the basis for a functioning network.

The difficulty of basing costs on an abstract representation of a network is exacerbated by the fact that engineering decisions involve a considerable degree of judgment, with different engineers making different decisions in similar situations.[10] In effect, the Hatfield Model proponents would substitute the judgment of a small handful of engineers for the collective record of efficient decisions recorded in the cost structure of the current network.

Forward looking costs merely refer to the minimum cost of producing current and anticipated flows of outputs, e.g., subscriber lines, minutes of use, toll minutes, using the best technology currently employed today and using inputs purchased or valued at current prices. Embedded costs refer to any or a combination of three things: 1) using book value of capital or the unrecovered part of past investments in a depreciation account as a measure of the capital input or investment, 2) using the prices at which inputs were purchased historically as current prices, or 3) basing the relationship between observed costs, outputs, inputs, and input prices on outmoded technologies. An example of the latter might be to have an accurate cost model for the relationship between costs and its drivers for a firm that had only old electromechanical

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[8] In fact, in discussing the issue of sharing structures, Dr. Mercer opined that the current situation is instructive. (Deposition Transcript, p. 294)

[9] Model Description, p. 24.

[10] Mr. Riolo, Deposition Transcription, pp. 19-20.

switches. Using such a model would be inappropriate for ILECs whose network facilities are all digital or nearly so. However, no one proposes tearing down the entire network of any LEC and building it up again using a substantially different or lower cost technology.

Consider a simple example of a firm that produces a single output, y, using one fixed factor, K, and one variable factor X, whose price is p_x. Suppose that costs, and the drivers, output, capital, and the price of the input were observed over time and for a number of similar firms. Suppose that a Hatfield type model were proposed to predict costs for a combination of the drivers that had never been observed in that particular combination before. The Hatfield proponents would assert that their model could not be validated because of the fact that the particular combination of drivers had never been seen before. This is wrong. Validation of the model could be done in the following simple manner: use the Hatfield Model to predict the costs for the combinations that can be observed and compare its predictions to the actual observed costs that attended those combinations. If the model predicts these well and if the new combination of drivers is not too far out of the range of the observed combinations of drivers, then one has a reasonable confidence that the model will predict the new cost for the new combination.[11]

Other less direct tests are also available. For example, if, instead of the cost, one were to observe the level of the input X, the model could be used to predict the level of X for each

[11] Economists routinely employ such models to study the cost characteristics of a firm or industry. For example, Professor David Kaserman, testifying on behalf of AT&T in GTE arbitrations, cited an econometric study of telephone company historical costs in support of his assertion that local exchange service in not a natural monopoly. (See Richard Shin and John S. Ying, "Unnatural Monopolies in Local Telephone," *Rand Journal of Economics*, Vol. 23, 1992, pp. 171-183.)

combination of observed X and cost drivers. If the predicted X's did not agree with those observed, the model's validity would be seriously compromised, if not completely destroyed.

An indirect test of this type for the Model would be to compare the actual sheath miles of cable and/or cable pair miles with what Hatfield predicts, or to see if it predicts the right number and type of switches or switching facilities. In any case, the claim that a forward looking model cannot be externally validated is without merit because it is has been and continues to be done by econometricians and statisticians.

No one can have any confidence in a model without compelling validation tests to support it. The fact that the Hatfield Model may not be able to be externally validated has less to do with the question of embeddedness versus forward looking than it does with an incomplete modeling approach which makes the Model not only difficult to use, but difficult to test in an economically meaningful fashion. Without testing, without external validation, the Model is simply a speculative construct, totally hypothetical, and is not a basis to determine the costs of a real functioning firm.

As our own partial test, we offer two comparisons using: 1) Hatfield Model predictions of the amount of sheath-miles of feeder and distribution cables needed for a random sample of GTEC wire centers with actual street miles in those wire centers as a proxy for sheath miles (Table 2), 2) dollar amount investments and expenses predicted for GTE Northwest—Washington State by the Model with amounts reported to ARMIS by the same companies (Table 3).

Table 2 illustrates the extent to which the Hatfield Model's forward-looking feeder and distribution loop investment predictions fall short of actual investment necessary to meet current demands. The lack of necessary structural investments of the loop, and possibly other network elements, explains, to a great extent, why model predicted investments are much lower than investments reported in ARMIS.

The measure of the magnitude of feeder and distribution investment used in our analysis is sheath-miles. Actual sheath miles were estimated based on the lengths of streets in wire centers' service areas. The Model calculates sheath-miles in its process of building loop networks.

Table 2

Comparison of Total Loop Length
Actual GTE vs. Hatfield Model 3.1

Hatfield Area Adjusted to Match Actual

State	Wire Center	Feeder and Distribution Sheath Miles[1] Actual[1]	Feeder and Distribution Sheath Miles[1] per Hatfield	Ratio of Cable Investment Hatfield/GTE
(1)	(2)	(3)	(4)	(5) (4)/(3)
California	Arrowhead	262.4	141.2	0.54
California	Banning	510.8	387.96	0.76
California	Pinyon	110.5	162.69	1.02
California	Carpinteria	159.9	96.78	0.88

1 Actual Sheath Miles are estimated by actual street miles.

Source: Actual data: U.S. Streets Data Technology Inc., U.S. Streets 95 CD-Rom.
Hatfield data: State specific Workfile "Feeder Investment" worksheet, Hatfield Model, Release 3.1

As the comparison shows, the Model significantly underestimates the feeder and distribution cable sheath-miles and by substantial amounts in three of the four wirecenters that were studied. The same analysis conducted in other states using randomly selected wire centers confirmed that the Model attributes less than necessary feeder and distribution cable lengths to wire centers.

Comparing total cable sheath miles per wirecenter estimated by the Model to estimates that were produced by Version 2.2, Release 2 reveals an increase in total cable sheath mileage of 353% for Arrowhead, 192% for Banning, 274% for Carpinteria and 230% for Pinyon. Interestingly, estimated TELRICs for California increase only by 8%, defying common sense that a large increase in cable length would produce significantly higher TELRICs due to increased placement costs, cable costs, conduit costs, and structure costs.

In our second validation analysis we compare the amount of dollar investments and expenses predicted by the Hatfield Model to those reported in ARMIS reports 43-03, 43-04, 43-07 and 43-08 (ARMIS) by GTE Northwest—Washington State. The difference between investments or expenses recorded in ARMIS and its counterparts—predictions made by the Model—should serve as proxy for the stranded costs. Our analysis shows that the Model essentially designates inordinate portions of ILECs' investment and expense costs as being economically stranded.[12] In general, the Model produces costs that are only about 40 to 50 percent of current costs—an outcome that defies common sense and sound economics.

[12] The difference between current booked costs and a correct estimate of forward-looking costs represents costs that would not be recovered at prices based completely on forward-looking costs, and, therefore are stranded in this sense.

In the case of general support investment for GTE Northwest in the state of Washington, shown in Table 3 below, the Model designates 83% of what is reported by ARMIS as being stranded. Network investment, which makes up the greatest portion of the total cost, is 51% stranded according to the Hatfield Model.

Table 3

Actual versus Hatfield Release 3.1 Comparison
GTE Northwest–Washington State
($ million)

Cost Category (1)	Actual (2)	Model (3)	Model/Actual (4) (3)/(2)
Network Investment	1,549	767	49.49%
General Support Investment	255	43	16.72%
Total Investment	1,814	809	44.62%
Network Expenses	44	20	44.89%
Support Expenses	70	27	39.45%
Corporate Expenses	77	19	24.19%
Total Expenses	190	66	34.53%

Our comparison of different components of network costs as reported by ILECs (i.e. GTE companies) in their ARMIS reports to those estimated by the Hatfield Model shows irreconcilable differences between the Hatfield Model's results and available *actual* data. Similar comparisons based on GTE and RBOC companies in other states corroborate the above analysis for GTE Northwest—Washington State.

While forward-looking costs and current costs will not necessarily match dollar-for-dollar, an important question is whether a model that produces forward-looking costs that are only one-half of current costs is credible. The answer to this question is an overwhelming

"No." Technological change and competition will undoubtedly make an ILEC more efficient. However, the idea that it can operate at current levels at about half the cost is extremely unlikely.

To give this comparison some context, recall that when the FCC established price caps for AT&T in 1989, it estimated that AT&T could reduce its costs by 3% per year. It would require 23 *years* at this rate of cost reduction for a firm to shed 50% of its costs. In contrast, proponents of the Hatfield Model are, in effect, arguing that incumbent telephone companies can shed such costs overnight.

The main cause of such a large discrepancy between observed data and the Model's predictions is the fact that the Model produces estimates of network element costs based on an *abstract* representation of network service costs. Left to its own devices the Model constructs insufficient amounts of facilities to be able to serve the demand that exists in the real world.

Another insight into a cost model's validity or lack thereof can be gained through comparison of the results to those produced by other models, and the extent to which the model satisfies internal validity checks. Internal validity will be discussed in Section III where the structural deficiencies of the Model are addressed.

More evidence of the Model's lack of external validity is provided by other cost models. We have observed that the cost estimates produced by the Hatfield Model, Release 3.1 are far below those produced by any other cost model. A recent edition of Telecommunications Reports compared residential universal service costs produced by three proxy models: the Hatfield model 2.2.2, the Cost Proxy Model (CPM), and the Benchmark Cost Model 2 (BCM2). CPM is sponsored by Pacific Telesis (and adopted by the California Public Utilities

Commission in its Universal Service Proceeding) and BCM2 is sponsored by U.S. West and the Sprint Corporation. Contrasting the estimated TELRICs of Hatfield Release 3.1 to this comparison revealed that the costs predicted by the Hatfield Model are substantially lower than those predicted by the other two models. CPM and BCM2 produce relatively similar cost results with BCM2 costs being 10.9% lower, nationally. The Hatfield model's cost estimates, however, are 20 to 62 percent lower than CPM estimates.[13]

The inability to satisfy external validity checks is a sufficient condition to discredit models even with a *plausible* premise; the Hatfield Model lacks a plausible premise and also fails the external validity checks. The basic premise on which the Model is built on—that one can estimate the actual cost of TS/TELRIC by modeling hypothetical local exchange networks without regard to actual ILEC network configurations and costs—is very speculative at best, a shot in the dark. But its faulty premise is not the only cause of its failure as a cost estimator.

One might create a model that accurately estimates costs, albeit one needs to be extremely fortuitous, based on hypothetical networks. The Hatfield Model is not so lucky. Not only does the Hatfield Model lack a plausible premise, its modeling design creates an overall bias that understates costs.

[13] Telecommunications Reports, October 28, 1996, p.19.

Section II Economic Modeling Deficiencies

Our assessment of the Hatfield Model starts with a review of its underlying economic theory. Next, we consider the results of detailed analyses on the reasonableness of the Model's major parts. We conclude this section with a discussion on proper methods of generating econometric or statistical estimation of expense factors.

A. Economic Theory

The Hatfield Model documentation characterizes the model as "scorched node"—it starts with the existing locations of wire centers, then builds a brand new system instantaneously from the ground up. This definition of "scorched node" is inconsistent with the approach adopted by this Commission, which retains the existing locations of outside plant facilities as well as wire centers. Further, the version of "scorched node" contained in the Hatfield Model is extreme. While proponents of this approach claim that it approximates the textbook definition of long-run cost, it is quite at odds with how real businesses incur costs, especially capital-intensive firms that expand their facilities by adding capacity in discrete modules.[14] In 1991, 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 cost 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

[14] 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.

> 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 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).[15]

Additionally the Hatfield Model's scorched node view of the world ignores the fact that in an industry experiencing rapid technological change, which clearly characterizes telecommunications, no company would set prices based upon such costs. Basing prices on the Hatfield view of the world would never recover costs. Professor Kahn and Dr. Tardiff 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 call "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

[15] 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.

> 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.[16]

Another problem with the Hatfield Model's scorched node approach to cost modeling is the implicit assumption that ILECs lose one hundred percent of their demand for telephone services on day one.[17] In effect, ILECs would hand over their entire business to each 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. But the assumption is counterfactual; real firms grow 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.

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[16] 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.

[17] In fact, when questioned about whether MCI or AT&T used the Hatfield model to plan their own local service networks, Mr. Stephen Siwek, a witness sponsoring the Hatfield Model, answered as follows: "I would also point out that the suggestion implicit in your question that this would be a useful thing to do strikes me as a bit, frankly, ridiculous because MCI would have to assume that it instantly can serve all of the demand in the state of Pennsylvania. And that assumption is simply not realistic." Pennsylvania Public Utility Commission Dockets A-310203F0002, A-310213F0002, A-310236F0002, and A-310258F0002, February 26, 1997, Tr. 1364.

In fact, the Hatfield Model's experts admitted that its scorched node assumptions do *not* describe how a network is engineered. For example, Mr. Riolo, the outside plant advisor for the Hatfield Model, indicated that: "It would be highly unusual in a real world situation that you would build a network on day one."[18] Similarly, Dr. Mercer, one of the developers of the Hatfield Model, agreed that switching capacity is added over time to accommodate growing demand.[19] Strangely, the Model's defenders rationalize these departures from reality by distinguishing between a cost model and an engineering model.[20] They never explain how it is possible for a cost model to produce the correct results when it departs so substantially from the design decisions that cause the firm to incur its costs. It would be a random coincidence if a model based on design decisions fundamentally at odds with the real world approximated the costs a firm expects to incur in producing unbundled elements.

The Model's failure to incorporate demand growth and underestimation of the true economic cost of network investment are primary deficiencies resulting from static characteristics of the model. It inadequately accounts for growth in demand and, in doing so, it mis-characterizes the spare capacity which results from optimal timing of laying discrete plant, instead labeling it as inefficient over-capacity. Consequently, Hatfield proponents typically concentrate and insist on fill factors that are too high. 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

[18] Mr. Riolo, Deposition Transcript, p. 12.

[19] Dr. Mercer, Deposition Transcript, p. 442.

[20] Ms. Murray, Deposition Transcript, p. 16.

the *Review of Economic Studies*, David Starrett shows that the cost minimizing firm in a dynamic situation trades off some spare capacity against the economies of scale in construction. The firm minimizes cost by choosing the lengths of the intervals between which it invests. During periods between investments there will always be spare capacity so it is often optimal and cost minimizing to have substantial 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.

In an advanced economics graduate textbook, authors Professors Avinash Dixit and Robert Pindyck write on the theory of investment decisions of firms, stressing the irreversibility of most investment decision and the ever present uncertainty of the economic environment in which those decisions are made.[21]

> The theory of how firms make intertemporal choices gives us rules for determining the firm's desired or optimal capital stock at each point in time. The demand for gross investment during any one time period can then be calculated: gross investment equals the desired capital stock at the end of the period, minus the actual capital stock at the beginning, plus the depreciation that occurs during the period. Any shocks that occur, for example, demand shifts or interest rate changes, alter the desired capital stock. In practice, the effects of such shocks on investment have been found to be more gradual and spread out over many future periods. Economists rationalized this by positing the existence of adjustment costs—costs of changing the capital stock too rapidly—and modifying their theories of investment to account for such costs.

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[21] Avinash K. Dixit and Robert S. Pindyck *Investment Under Uncertainty*, Princeton University Press, Princeton, New Jersey, 1994, Chapter 10, Incremental Investment and Capacity Choice, p. 381.

> In fact we need something stronger than the mere existence of adjustment costs to explain why a firm's investment choices might respond gradually to a shock. Specifically, we need costs that are a strict convex function of the rate of investment. In other words, it would have to be the case that the marginal cost of investment is an increasing function of the rate of investment. Then the optimal rate of investment is determined at the point where the marginal cost of speeding up the adjustment of capital to its desired level is just equal to the marginal benefit of doing so.

In the case of ILEC investments in feeder and distribution facilities, the marginal cost of investment is indeed an increasing function of the rate of investment. Therefore, ILECs would prefer a relatively slow rate of investment, i.e. build facilities in modular fashion thereby spreading out effects of demand shocks on investment over many future periods. For ILECs, at the optimal investment decision point, the marginal cost of speeding up the adjustment of capital (adding incremental facilities) would be high if the marginal benefit for installing incremental facilities is high—as would be in the case when the fill capacity of feeder or distribution facilities is continually close to being exhausted.

As a result of ignoring the economic principles referenced and discussed above, the Model's proponents ignore the high likelihood that competition will further increase the real cost of capital because of the increased riskiness of an industry moving rapidly into competition, and (2) the increasing economic depreciation rates required to recover investment in plant and equipment. To appreciate the current and evolving climate of the telecommunications industry which is characterized by increased in and shorter economic lives of equipment, one only needs to consider the ramifications on competition that the boom in direct satellite communications and other technological innovations will bring to the local exchange market. For example, *U.S.*

News & World Report reported in an article in its March 3, 1997 issue that Teledesic, backed by Bill Gates and a "cellular phone tycoon," plans to use 840 satellites to provide broadband connections which work best over fiber-optic cables. Besides Teledesic there are many more companies which plan to use satellites to provide broadband services.[22] Entry of these companies with new technologies in the telecommunications market will accelerate the economic depreciation of ILECs' plants and increase the risks associated with providing local exchange services.

Failure to recover sunk investment has severe economic consequences, for the rate and level of capital recovery not only signals firms how to use their existing equipment but also dictate whether or not they should replace equipment, as it becomes obsolete, with the next generation. Indeed, by ignoring dynamics altogether, the Model fails to be forward looking even in concept.

According to the Hatfield Model, a firm is subject to the cost reducing effects of using the latest technology, but the Model inadequately reflects the effects of such cost reductions in its estimated economic cost of investments. Unfortunately, as discussed by Dr. Hausman,[23] competitive markets are inconsistent with low depreciation rates, guaranteed demand and guaranteed returns.

[22] *U.S. News and Report*, in the same article, lists the following companies with plans to provide satellite based telecommunications service: Spaceway, ICO Global Communications, Odyssey, Globalstar, Iridium, Orbcomm. Many of these companies are backed by high-tech and telecommunications companies such as Hughes electronics, Motorola, Raytheon, Lockheed Martin, and Sprint.

[23] Hausman, Jerry A. (1996) Reply Affidavit Before the Federal Communications Commission In the Matter of Implementation of Local Competition Provisions in the Telecommunications Act of 1996 CC docket No. 96-98.

B. Modeling Problems

It is unclear how the Hatfield Model proponents would like to classify their model—whether to call it an engineering model or a costing model or even a hybrid model. The Model Description explains that the Hatfield Model "builds an engineering model of a local exchange network with sufficient capacity to meet total demand, and to maintain a high level of service quality."[24] It is apparent that the model does in fact build loop structure according to a set of engineering rules as partly described in its documentation. However, when questioned about some of the unrealistic engineering assumptions of the Model, its proponents characterize the model as something other than an engineering model.[25] How one classifies a model is moot; it is important, however, that the model is based on a *correct* set of methodologies and assumptions.

It has been well recognized for some time that there are three general methods of calculating cost: an accounting method, a statistical method, or an engineering method.[26] Also there could be a hybrid method combining the methods mentioned above.

The fact is, the costing carried out by the Hatfield Model is predicated largely on its engineering assumptions. For example, the Hatfield Model's engineering assumptions dictate the amount of distribution and feeder cables, the number of SAIs to connect these distribution and feeder cables, the number and size of switches housed in each wire center, the number of DS-0's (a 64kbp voice-equivalent circuit) required for transport facilities, etc., in order to

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[24] "Hatfield Release 3.1, Model Description", Hatfield Associates, Boulder, CO, page 4

[25] For example, Mr. Joseph Riolo, an engineering witness for AT&T and MCI, testified that "[The Hatfield Model] is not an engineering design type of model…Hatfield doesn't design the outside plant, but rather my understanding is it costs the outside plant." California Deposition, p.19.

[26] See for example *Economics of Overhead Costs* by J. Maurice Clark, Chapter 11, 1923, University of Chicago Press.

calculate cost for ILECs. Therefore, it is crucial that, in order to produce correct cost estimates, the Hatfield Model gets its engineering assumptions right. As we have indicated before and will further show, much of Model's engineering assumptions are unrealistic and wrong.

The Hatfield Model reports cost estimates for several network components: (1) Network Interface Device, (2) Loop Distribution, (3) Loop Concentrator/Multiplexer, (4) Loop Feeder, (5) End Office Switching, (6) Common Transport, (7) Dedicated Transport, (8) Direct Transport, (9) Tandem Switching, (10) Signaling Links, (11) Signaling Transfer Points, (12) Service Control Point, and (13) Operator Systems. Because components (2) and (5) constitute a substantial proportion of the total cost (about 75 percent for GTE Northwest—Washington State) and typically have been subject to more extensive examination in arbitration proceedings than the other components, our review focuses on these components.

1. Loops

For the most part, the Hatfield Model's development of loop costs relies on an Access database that consists of an array of different databases. Specifically, the newest model obtains its fundamental inputs from a database developed by PNR and Associates, containing PNR survey information, Dun & Bradstreet business establishment information, and the Donnelley Marketing household database. Furthermore, the Model employs 1990 actual census data and 1995 census estimates provided by Claritas, the Local Exchange Routing Guide by Bellcore and results obtained from the BCM-PLUS Model.

The Hatfield Model starts with the current locations of the ILEC's wire centers. The model then constructs loop plant (feeder, distribution, and associated structures) from the wire center locations to the customer premises by assigning CBGs to wire centers through means of assigning the CBGs to the wire center that serves the greatest number of phone numbers.

This assignment does not necessarily assign the households within the CBG to the wire center that actually serves them. For example, for GTE serving areas in many different states, we have found that the Hatfield Model assigns substantial percentages of households to the wrong wire center.

Moreover, in most states it does not even use the correct set of wire centers. For GTE California for example, we have observed that Release 3.1 omits 12 wire centers among 278 and includes 2 wire centers that do not belong to GTE. Of the 264 wire centers that were matching, 67% contained line estimates that were off by more than 10% from the actual line count. Similar results were found in analog studies for other GTE serving areas. As a result of these errors, the network represented by the Hatfield Model significantly departs from the ILECs' actual network.

The Hatfield Model's proponents may argue that the Model has assigned households more efficiently than the ILECs have. A more likely explanation is that the extremely abstract representation of the network—a featureless plain[27]—ignores real world constraints, such as physical barriers, e.g., freeways, stadiums, rivers, lakes, and hills, between a CBG and its closest wire center. The Model also ignores possible non-physical right-of-way barriers.

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[27] The only distinguishing characteristics are a number of surface soil conditions used to estimate the cost of installation and support structures.

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 could instantly install all of the switching capacity it needs at once, the Hatfield Model produces costs that are substantially lower than the forward-looking local switching costs that real telephone providers actually incur.

The Model creators developed a relationship between switching cost per line and the size of the switch by piecing together information from various sources to create four line size/cost per line data points. For the three lower points, line size is taken from 1995 ARMIS data and costs per line are from a Northern Business Information report. Information on the largest switch size is based on conversations with unidentified switch vendors.

The Model creators then fitted a logarithmic curve to these three data points using least-square regression. To reflect the different growth rates in average line size per switch for small and large ILECs, the model uses two different intercept terms, namely one at $ 242.73 for large ILECs and one at $416.11 for small ILECs.

The Model's approach in determining the switch cost function suffers from a mismatch between the data sources it employs: The Model matches a 1995 forecasted price with an average embedded switch size and assumes that the average *installed* switch is of the same size as the average *new* switch--an assumption that is not necessarily valid.

Comparison of the Model's switch cost assumptions to actual GTE switching cost data in California is instructive. GTE provided data on 53 competitive switch contracts during the period 1989 to 1994. Statistical analysis on the data gave a best fit relationship of

$$C_G = C/L = \$97.30 + \$781{,}599/L,$$

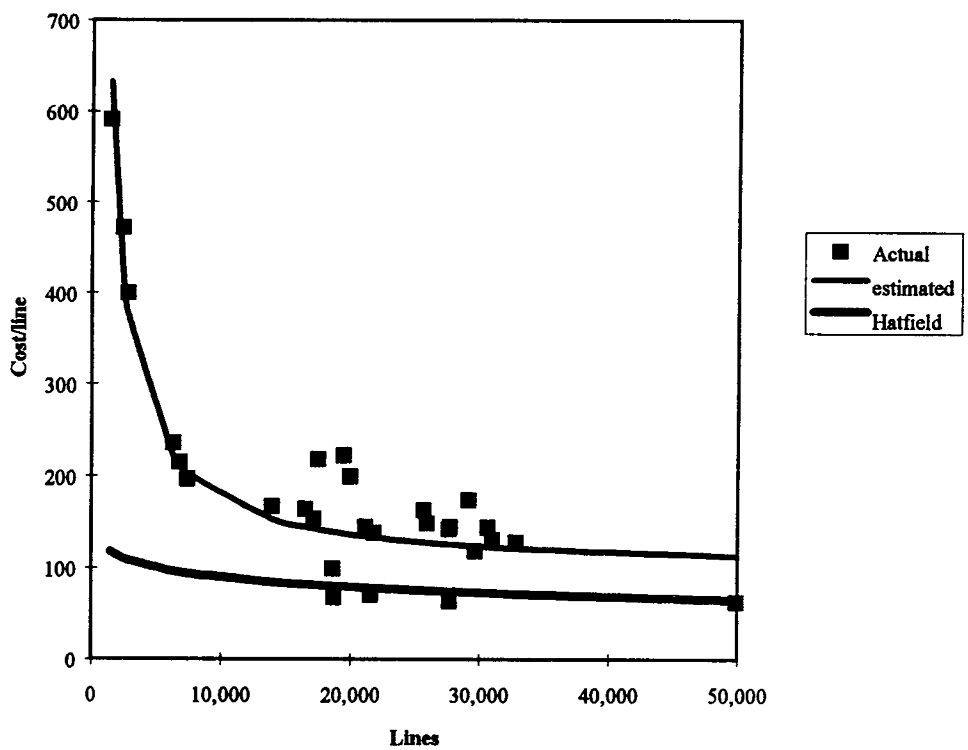
where C=cost of switch and L=number of lines. Variables such as year, type of switch, host/remote were insignificant.

Hatfield's reported analog of this function is:

$$C_H = C/L = 242.73 - 14.922 \ln(L)$$

Chart 1 graphically illustrates the large difference between the cost function used by the Model with that of GTE's actual cost function.

Chart 1



More fundamentally, the Hatfield Model ignores the fact that ILECs buy additional lines for installed switches as well as new lines for new switches. The additional lines for installed switches actually cost more, as the McGraw-Hill switch cost study used by the Hatfield model describes:

> The add-on market provides significant revenue potential for switch 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 (new) line sale in exchange for the increased revenue in the after-market, where prices are less likely to be set by competitive bidding.[35]

The local switching component of the Hatfield Model 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 ILECs apparently command. The fact that ILECs 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.

C. Converting Investments and Expenses into Annual and Monthly Costs

The various manifestations of the Hatfield model are essentially models of the investment and expense components of an ILECs' cost structure. These components are summed together

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

and 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.

In the case of investments, once the artificially low "forward-looking" network investment costs are calculated, the Model converts these investments into annual amounts over the economic life of the investment.

The model makes two errors in this calculation. First, it bases the return and tax gross-up calculation on the net plant in the middle of the year, rather than the beginning of the year. For example, to calculate return and taxes for the first year, the model uses net investment after six month's worth of depreciation, rather than the (correct) initial investment. In addition, the Model uses a pre-tax, rather than an after-tax, discount rate in calculating present values and annualized amounts. These errors are repeated in the calculation process of capital costs in every year of relevant depreciable life of a plant, resulting in an understatement of cost.

For a plant with a particular depreciation life (e.g., 20 years), the model follows the following steps in calculating a factor that converts the investment into a constant annual equivalent.

- Calculate the following series for the life of the investment: depreciation, return, plus income taxes. The return plus taxes component is calculated on a net base that is the average of the beginning and end of period net investments. For example, for the first year of a 20-year investment, the base is 97.5 percent of the initial value (100%

+ 95%)/2 and for the 20th year, the base is 2.5 percent of the initial value. The particular formula is:

$$annual\ value_t = depreciation + return_t = \frac{1}{Life} + pre - tax\ RoR\ (1 - \frac{t - 0.5}{Life})$$

In the formula above, the pre-tax RoR is calculated by:

$$pre - tax\ RoR = \frac{\%\ Equity \times ROE}{(1 - Tax\ Rate)} + \%\ Debt \times Debt\ Interest\ Rate$$

For example, the Hatfield default values are the following:

* % Equity: 55%
* ROE: 11.9%
* Tax Rate: 40%
* % Debt: 45%
* Interest rate: 7.7%

Therefore, the pre-tax rate of return (RoR), which includes both return and the tax gross-up, is 14.37%.

- Calculate two present values for the series in the first step—the first present value has the first annual payment at the end of the first year and the second present value has the series beginning at the beginning of the first year. Note that the two present values differ by (1 + discount rate). The Hatfield model then takes a simple average of the two present values. The Hatfield model's discount rate is the following.

$$Discount\ Rate = \%\ Equity \times ROE + \%\ Debt \times Debt\ Interest\ Rate$$

- Calculate the levelized payment of the average of the previous steps in two ways—assume that the payment is made at the beginning and end of each year, respectively.

The factor used to convert investment into annual amounts is simply the average of the two payments. Again the two payment estimates differ by (1 + discount rate). These factors apply to investments with integer lives.

- When the life is between two integers (e.g., 20.45 years), Release 3.1 takes a weighted average of the higher and lower integer lives. For example, for a 20.45 year life, the model averages 45 percent of the 21 year factor and 55 percent of the 20 year factor.

The Hatfield factors for integer lives can be calculated in a single step. Calculate the single payment for the Hatfield annual series using the conventional end-of-period formula for both the present value and levelizing steps. The Hatfield factor is the following.

$$Hatfield\ Factor = \frac{(1+\frac{r}{2})^2}{(1+r)} PMT(NPV)$$

The Hatfield approach differs from the standard finance text book treatment,[36] which would consider the initial investment to occur at the beginning of the first year and the annual depreciation, return, and tax components to occur at the end of each year of the life of the investment. In addition, (1) the annual amounts are based on the beginning-of-period net investments and (2) the discount rate is the after-tax rate of return. The after-tax discount rate is the following:

$$After-tax\ discount\ rate = pre-tax\ RoR \times (1 - tax\ rate)$$

The series of annual values (for the life of the investment) is the following.

[36] *Principles of Corporate Finance*, Fourth Edition, Chapter 5, 1991, McGraw-Hill.

$$annual\ value_t = depreciation + return_t = \frac{1}{Life} + pre - tax\ RoR\ (1 - \frac{t-1}{Life})$$

It turns out that the present value of the annual values is the following:

$$PV = \frac{Investment - PV(depreciation\ tax\ benefit)}{(1 - tax\ rate)}$$

The annual depreciation tax benefit is simply tax rate/Life.[37].

The present value is then levelized, using the end-of-period payment function and the after-tax discount rate.

The following schedule compares the Hatfield factors with the correct factors. The correct factors are generally greater than the Hatfield factors, especially for assets with short lives. Also note that the Hatfield factors have the counter-intuitive property that the factor *increases* between 19 and 20 years.

[37] The Hatfield Models implicitly assumes that tax depreciation is straight-line. Using accelerated depreciation would reduce the annual factor.

Depreciation Life	Hatfield Release 3.1 Factors	Corrected Factors	Ratio
(1)	(2)	(3)	(4) [(3)/(2)]-1
1	1.07430738	1.143733333	6.5%
2	0.574885487	0.609285395	6.0%
3	0.409172164	0.431794755	5.5%
4	0.326883398	0.343541753	5.1%
5	0.277961577	0.290981929	4.7%
6	0.245720171	0.256266694	4.3%
7	0.223007263	0.231746288	3.9%
8	0.206246432	0.213595524	3.6%
9	0.193450384	0.199689029	3.2%
10	0.183426408	0.188751349	2.9%
11	0.175415219	0.179970632	2.6%
12	0.168910381	0.172805467	2.3%
13	0.163561074	0.16688088	2.0%
14	0.159116537	0.161928898	1.8%
15	0.155392727	0.157752894	1.5%
16	0.152251488	0.154205297	1.3%
17	0.149587067	0.151173172	1.1%
18	0.14731713	0.148568608	0.8%
19	0.145376611	0.14632214	0.7%
20	0.145649747	0.144378144	0.9%
21	0.142285296	0.142691547	0.3%
22	0.141057721	0.141225439	0.1%
23	0.140002114	0.1399493	0.0%
24	0.139094664	0.138837677	-0.2%
25	0.138315375	0.137869177	-0.3%
26	0.137647339	0.137025686	-0.5%
27	0.13707617	0.136291773	-0.6%
28	0.13658956	0.13565421	-0.7%
29	0.136176924	0.135101597	-0.8%
30	0.135829119	0.134624064	-0.9%
31	0.135538217	0.134213022	-1.0%

1. Cost of Capital

The Hatfield Model's 10.01 percent default value for cost of capital is too low for two reasons. First, the FCC's approved rate of return remains at 11.25 percent. Second, the whole premise behind the Model'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 and unbundled network elements.

As a very simple example, consider the following scenario of increasing the uncertainty of an investment. An investor may invest $K now in a regulated firm and receive a guaranteed return of 0.11 next year. The expected future value of such an investment is 1.11*$K. Alternatively, the same investor can invest the same amount in a firm entering competition and receive the competitive return with probability 0.7 or only receive 0.65 of his or her original investment. The expected future value of this alternative is

$$0.7*(1+r)*K+(1-0.7)*0.65*K,$$

where r is the rate of return.

What rate of return will make the investor indifferent between the certain 0.11 return and the uncertain case? Assuming the investor is risk neutral, the required return can be calculated by equating the expected value of the uncertain outcome with the outcome of the certain case. Simple algebra shows that the required rate is 0.307, fully three times higher than the certain case. (Let f be the fraction recovered in the case of a loss, let r_c be the rate of return for the certain case, and let ρ be the probability of making a positive return, then $r = \frac{1+r_c}{\rho} - \frac{(1-\rho)f}{\rho} - 1$.) We note in passing the complications introduced by moving to more periods or considering a distribution of possible losses makes the problem harder. Such considerations were the basis of Dr. Hausman's May 30, 1996 affidavit before the FCC.

2. Depreciation Rates

The Hatfield Model uses relatively long depreciation lives 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. For example, Schmalensee and Rohlfs reported that AT&T's depreciation rate is 18.5 percent.[38] Even AT&T's 1994 book depreciation rate of about 11 percent is higher than the rates used in the Hatfield Model. 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.

3. Common Costs

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

In its Version 2.2 Release 1, the Hatfield Model 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. In AT&T arbitration hearings with GTE in 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.[39] In Releases 3.0 and 3.1 this factor changed to 10.4%. According to Dr. Mercer this change resulted from "re-analyzing the factor."[40] He presented as additional support the assertion that the value given to the factor was consistent with ratios of overhead costs to total costs seen in the auto industry and the airline industry. Finally, the developers of the Hatfield Model have admitted they took the number from AT&T.[41]

Regardless of how the number was generated, the treatment of common costs as an across the board increase in attributable cost is incorrect. Were common costs so attributable they would, in fact, not be common costs. By definition costs that can be attributed are not common costs. Beyond that, however, common costs[42] are not easily identified; they are costs over and above the costs attributable to specific elements in an economically meaningful fashion.

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[39] 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).

[40] Generic Costing and Pricing Workshop, Olympia, WA, February 17, 1997 page 223

[41] "AT&T's Responses to Recorded Requests and Supplemental Response to Data Requests from Pacific Bell", OANAD Proceeding, R.93-04-003/I.93-04-002, March 17, 1997.

[42] Here we use the term common costs to include shared costs and joint costs.

Common costs for an ILEC should be its total costs minus the sum of all of its TELRICS. If the Model was calculating the TELRICS correctly it could simply subtract the sum of an ILEC's TELRICS from its total cost reported in ARMIS to arrive at the amount of common costs for that ILEC.

Overlooked in the debate over what should be the input value of the common cost factor is the issue of the Hatfield Model's mistaken notion that common costs are mostly corporate overhead costs of the president's desk variety, rather than other unattributable operating expenses and investment-related costs. From the Model's point of view, common costs include 67XX accounts reported in ARMIS which are expenses associated with corporate activities such as accounting and finance, procurement, information management, executive compensation and other general and administrative expenses. These 67XX expenses are, by their nature, variable in the short term. Arbitrarily reducing these costs to appeal to the forward looking concept is a mistake.

FCC staff has stated the following on what costs constitute forward-looking economic costs.[43]

> *Use of Forward-looking Economic Costs as a Basis for Pricing.* In dynamic competitive markets, firms base their actions on the relationship between market-determined prices and forward-looking economic costs. We define forward-looking economic costs as the costs that would be incurred if a new element or service were provided, or that could be avoided if an existing element or service were not provided, assuming that all input choices of the firm can be freely

[43] *The use of Computer Models for Estimating Forward-Looking Economic Costs*, FCC Staff, Jan 1 1997 at para 9.

> varied. This is often referred to as long-run economic cost. This "long run" approach ensures that rates recover not only those operating costs that vary in the short run, but also fixed investment costs that, while not variable in the short term, are necessary inputs directly attributable to providing the element or service.

Corporate and operational expenses certainly meet these criteria.

There are more fundamental shortcomings in the Hatfield Model's methodology of estimating common costs. First, the Hatfield regression approach is based on a classic error in logic, the fallacy of division[44]. 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 assuming a fixed ratio of overhead costs to attributable costs, Hatfield assumes a linear relationship between directly attributable costs and common costs. Such a relationship is pure nonsense because it implicitly assumes that the stand alone costs of producing each service or element is totally volume insensitive.

The assumption 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 Model's linear structure, the TELRICs are also the stand-alone costs. 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

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

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, ILECS, specifically.

The Hatfield Model 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 0.12.

There are a number of problems with the Hatfield Model's regression analysis, any one of which renders all of its analyses useless. We begin with its approach. The Model 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. CC=a +bDC, that a reduction of $100 dollars in DC due to resale will result in a reduction of CC of b*100. This is the fallacy of division that we 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, the authors of the

Hatfield Model ran a regression of each man's height on its weight, it would obtain a positive coefficient on weight, just as they 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 Model'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 Model'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. This error is a common source for stereotypical characterizations of ethnic, religious and gender groups that lead to various sorts of discrimination. In Attachment Section B, a graphical depiction of this error and its likely consequences are shown.

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 II, Section C, we 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 the Hatfield Model's underlying model one must be willing to believe that the cost of supplying service to 10,000 extra customers is zero. Moreover, the Hatfield Model's formulation has the additional odd feature that, if volumes increase, 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. Therefore were the Model's methods believed one need also believe that competition will fail and the current industry will be replaced by a group of natural monopolists.

The Model also suffers from problems in its choice of a sample, a single cross section of firms in a single year. The Model's limited sample is incapable of either supporting or refuting the analyses based on it. 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.[45]

Compounding the sample problem with the Model's analysis is its choice of methodology. Having shown that its group relationship cannot be applied to specific members of the group. We now show that the Model's method of obtaining the group relationship is also flawed. Regression analysis, like many other technical methods operates validly only in specific environments.

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[45] 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.

Statisticians and econometricians state the characteristics of 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 Model'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, when the citizens became wealthier, had more children and generated more garbage, more storks appeared in Holland to scavenge on the increased supply of garbage.. 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, 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. The Model's group regression is of exactly this type.

Common costs neither cause nor are 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.[46] The consequence is a simultaneous equation bias.

For an example of how misleading a regression with a simultaneous equations bias can be we can 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 we alluded to above, and as a consequence the prediction was fallacious.[47]

4. Annual Expenses

Like its predecessors, the Hatfield Model, Release 3.1 develops expense estimates based upon ratios of *booked* expenses to investment. For this purpose, the model uses ARMIS data to develop expense to investment factors. These factors are used to compute the expenses necessary for different network elements and their components. TELRIC of a network component multiplied by its corresponding expense factor yields the expense costs of that network element. Expense factors related to various components of many network elements are based on the amount of investment in that component—ARMIS expense divided by ARMIS

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

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

investment. When certain expenses are deemed more sensitive to the number of customers, expense factors take the form of ARMIS expense divided by ARMIS reported number of lines.

This way of calculating expense is an example of what's called, in statistical or econometric parlance, causal forecasting. When the Hatfield Model calculates an expense factor for a wire center building by dividing a 1995 ARMIS reported expense associated with buildings by 1995 ARMIS reported investments in wire center buildings, it is estimating a single parameter of a single equation regression model with one explanatory variable. In the case of the building expense, building investment is the sole explanatory variable. The equation is of the form E=aI, where E=expense, I=investment, and a=expense factor. It is essentially a specification of a simple regression term, one that does not include an intercept term nor other explanatory variables such as lines or, in the case of the building expense example, such as the percentage of buildings leased. This single variable regression approach is simply inadequate for a variety of reasons. First, in implementation, the value of the coefficient is estimated as a ratio of ARMIS expense to ARMIS investment or to ARMIS reported lines. Thus the expense part of Model is calibrated or estimated using only one observation. This is pure statistical error. Second, the single variable regression specification is an assumption, one that can be tested statistically. For example, it is quite likely that a regression with intercept of the form E=b+c*Lines would be a better model of expenses. This model can be tested to see if b=0, if it is then the Hatfield specification(though not the estimation of the factor using only one observation) is correct, if it is not, then Hatfield is wrong. Note that the assumption that b is negative in the expense on investment factor estimates, leads to an understatement of expenses.

The approach of using expense factors can be appropriate if (1) proper forward-looking adjustments are made and/or (2) they are applied reasonably consistently with how they were developed, the approach can be problematic if such care is not exercised. Operating expense ratios based on historical investment can be poor approximations of the forward-looking relationship.[48] 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 potential pitfalls of using annual factors. By employing the unrealistic assumption that a LEC can buy switching at the initial prices, the model assumes that annual costs would be lower as well. In fact, the very report that the model relies on to develop the switching cost model suggests that such an additional cost may increase when switch vendors discount the prices of initial, but not additional, lines. On the other hand, had a properly developed factor been used with a reasonable estimate of forward-looking investment, the estimated maintenance expense would be reasonable.

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.

[48] During the recent deposition, Dr. Mercer and Ms. Murray identified two problematic aspects of the Hatfield model's factor approach: (1) that they produce a great deal of uncertainty in expense estimation (Deposition Transcript, p. 64) and while the are constant for an ILEC in the model, they should vary with the size of the ILEC (California Depositions, p. 139)

Moreover, the assumption that ILECs forward-looking network operations expenses can be well approximated by applying a factor of 50 percent to its current booked expenses is arbitrary and unjustified.[49] It appears that the Model has assumed that under forward-looking operations, both the ILECs' investment costs and expenses would be lower. If, in contrast, competition and loss of scale economies causes certain expenses to *rise*, it is not at all clear that simply applying a factor of 50 percent to current booked expenses would adequately represent ILECs' forward-looking expenses.

Finally, a somewhat subtle, yet very serious error exists in the way the model computes expense factors. The Hatfield Model forecasts expenses, E, at time t+1 with the parameter a (expense factor) calculated at time t. It ignores that the equation used to predict E at time t+1 is based on a different independent variable than that used to estimate the parameter a in the first place. The investment used to estimate the parameter a is the ARMIS reported investment and presumably includes embedded costs. At time t+1, the Model uses the independent variable of TELRIC calculated in the framework of the model. Again, the ARMIS reported investment costs and the forward-looking costs computed by the Model are not inter-changeable variables. As the model estimated TELRIC understates the value of the independent variable this misspecification biases the forecast of expenses downward.

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[49] In fact, Hatfield 3.1's reduction of the historical factor by 50 percent is a clear example of its selective use of evidence to artificially reduce the cost of network elements. The adjustment was based on evidence presented by Richard Scholl in California (February 14, 1997 Workshop in this proceeding, p. 234). Examination of the source document reveals that Mr. Scholl compared Hatfield model results to his results with respect to 10 cost categories. Network operations was the *only* category where the Hatfield model produced a higher cost. Significantly, no adjustments have been made to other historical factors where the Hatfield model costs were lower than Mr. Scholl's.

D. Proper Factor Estimation Method

To conclude Section II we address the subject of econometric or statistical estimation of expense factors. Before doing so we note that the problem with the factor approach from an econometric point of view is that each of the factors must be constrained so that total costs satisfy the required cost conditions above. While homogeneity is easy enough to enforce, the requirement that costs be increasing in all outputs and that variable cost be decreasing in all fixed factors can be difficult to impose without limiting the types of substitution the cost function can exhibit. For example, forcing the individual factors to increase as outputs will do this however there is nothing theoretical that requires any particular factor to either increase or decrease in output except that in the aggregate the cost function itself must. Rather than deal with that problem here, we abstract from those problems to suggest some simple, practical methods of estimating the factors.

For simplicity sake let us assume there is only one factor of interest, one of either the expense to dollar investment type or of the expense to physical quantity type. Extension to a complete set will be analogous to extending single equation regression or time series methods to multiple regression relations e.g., Seemingly Unrelated Regressions, Three-Stage-Least Squares or Vector-Auto Regressions.

If input prices change at roughly the same rate along with outputs, the factors might change smoothly as well. If so, a time series type of adjustment model might be able to predict future or forward looking factors from data on past factors, input price changes, output changes and fixed factor changes. Under the conditions just mentioned one might totally differentiate

$F_1(y, w, K, t)$ with respect to time to obtain $F_1(\dot{y}, \dot{w}, \dot{K}, t) = a_1(t)\dot{y} + a_2(t)\dot{w} + a_3(t)\dot{K} + a_4(t)$, this might lead us to expect a time series relationship for $F_1(y, w, K, t)$ of the form

$$F_1(y, w, K, t) = a_1(t)y + a_2(t)w + a_3(t)K + a_4(t)$$

or in regression form

$$F_t = a_1(t)y_t + a_2(t)w_t + a_3(t)K_t + a_4(t) + \varepsilon_t.$$

Where the $a_j(t) = \sum_{i=1}^{I_j} a_j^i(t)L^i$ is a time varying polynomial lag operator. Such a specification is general enough to represent any form of interest. For example, time varying parameters regression, state-space regression, ARIMA, or simple regression.

A forward-looking expense factor might be estimated by such a time varying parameters regression model. Indeed, there is no reason why it might not equally well be represented by an ARIMA or by an auto-regressive-distributed lag or by a distributed lag. Thus one might be able to reduce the problem of estimating forward-looking expense factors to a simple time series problem. Indeed, one could imagine properly cleaned up ARMIS data might be used as a basis for estimating these factors. The reason such an approach would be forward looking even though it is based on historical data is that the factor used is not a mere average of past factors but a prediction of a future factor that adjusts for anticipated and historical changes in input prices, through its dependence on input prices, on technology, through its dependence on time, and so on. If one were lucky, and all variables followed a simple time series, the factors might have simple ARIMA representations, eliminating the need to collect direct data on input prices and the like.

The drawback to such an outcome would be that details of substitution could not be investigated. However, for estimation of forward looking costs using investment predictions derived from engineering process models that would be adequate. To complete the program all factors would, of course need to be estimated jointly.

Taking this last idea a step further, one might consider a panel of factors, that is a pooled cross section time series of factors for different firms in different time periods. With luck, change might be regular enough that all the data needed might be publicly available. One could then predict or forecast the forward looking factors according to the regression results. Obviously this idea needs to be fleshed out and some research done to check it.[50] However, it does show promise given the success of time series methods for predicting Total Factor Productivities.

[50] We are currently carrying out such an analysis, but the analysis is not yet finished.

Section III Structural Deficiencies

In this section, we address the most fundamental of the many theoretical or structural problems accompanying the Hatfield Model. By design, the Hatfield Model is *not* a valid cost model because it fails internal and external consistency checks required of any cost model. Whether estimating costs using a pure econometric approach, a pure engineering approach or some hybrid approach, common practice model building requires internal and external validation of a model. Our internal checks demonstrate that the Hatfield Model is theoretically incapable of representing the minimum cost of producing telecommunications services using the most efficient forward looking technology. Our external checks produce similar conclusions and confirm that the model produces results with no credibility.

A. Valid Cost Models

Like its predecessors, the newest version of the Hatfield model is not a valid economic cost model because it fails the internal validity check required of any cost model. This is more than just a theoretical point. Failure to satisfy these checks means that the Hatfield Model cannot represent the minimum cost of producing outputs using the most efficient forward looking technology. In Attachment Section A, we show this and also show that any numbers the Hatfield model produces purporting to be TS/TELRICs are biased in an unknown direction, meaning that they are not even correct on average. 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 Model impossible to fix without a complete overhaul, starting with the basic conceptual approach and ending with data requirements.

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.

B. Internal Validity Checks

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.[51] Rather than a complete listing of them, we

[51] Varian, Hal R. *Microeconomic Analysis, Third Edition*, New York: Norton, 1992.

will discuss two that the Hatfield Model clearly violates. The first is linear homogeneity in input 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 through the front-end user interface by 10%, using their default GTE/Contel California data as benchmark. A valid cost structure should yield an increase in TS/TELRICs of exactly 10%.[52] The results of this first test are presented below in Table 6, and can be seen to yield increases of roughly 7.7%—a number 23% lower than it should be.

[52] This result is proven in Attachment Section A 2.

Table 6

Comparison of Hatfield Model Release 3.1 TSLRIC Results
GTE/Contel of California, Inc.

	GTE Base Case (1)	Costs with All Input Prices Increased 10% (2)	% Change (3) [(2)-(1)]/(1)	% of Total Cost of Network Elements (Base) (4)
NID	$ 0.64	$ 0.70	9.34%	3.69%
Loop Distribution (all)	$ 6.23	$ 6.82	9.44%	35.82%
Loop Concentration (all)	$ 2.56	$ 2.81	9.41%	14.74%
Loop Feeder (all)	$ 2.64	$ 2.89	9.45%	15.17%
Total Loop (all)	$ 12.08	$ 13.22	9.43%	69.43%
Total Cost of Network Elements	$ 902,184,448.39	$ 972,283,610.68	7.77%	100.00%

The test clearly indicates that the Hatfield Model does not fulfill the linear homogeneity test.

A theoretical explanation of the necessary failure of both versions of the model to satisfy linear homogeneity and the derivative property is presented in Attachment Section A. In that presentation, we show that the Model's dependence on the use of constant expense factors to account for expenses is the root cause of its problem. By employing expense per pair-mile of cable as it does for installation and structure expenses it necessarily violates linear homogeneity.

For example, by assuming constant expense per dollar of investment factor as it does for most of the rest of expenses, it almost certainly violates the derivative property of cost functions. 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 book, cannot represent the minimum cost of producing services using the most efficient forward looking technology.

Conclusion

There are numerous reasons not to use the Hatfield Model Release 3.1 to determine TS/TELRICs and none to support their use. One of the most vexing problems is the Hatfield Model has never been tested against real data as might be expected of any model of any type. Trying to use a model in spite of this fact is a little like asking paying customers to fly on a plane which has never before flown or even tested.

As an added insight to the problem of using a model that has not been verified with 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 earns each year. The model is simply based on assumptions about how much a person should be earning 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 Models are doing to ILECs.

Beyond lack of external verification and empirical validity, explicit economic and conceptual flaws were identified that make the Model unlikely to produce any useable numbers. The Model is static rather than dynamic which gives rise to, among other things, fill factors that are too high. An equally troubling aspect of the Model is their fundamental assumptions that the telecommunication industry will not face increased market uncertainty and that LECs have had, and will continue to have, perfect foresight of all market conditions.

The Models do not even satisfy the minimum criteria required of properly constructed cost models—that increasing all prices by a common proportion must increase TS/TELRICs by exactly the same amount. In addition, there are other fundamental flaws in the Hatfield Models that we have identified: (1) they model the cost of no realistic local service provider and certainly not the incumbent LECs who will actually sell the unbundled elements and (2) particular inputs and processes appear to systematically understate the costs of network elements.

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 over-investment. For example, the Model claims that about half of the LEC's current plant represents over-investment.

Apart from the fact that this label is entirely meaningless, since the Models call over-investment anything with which they do not agree, and that the Models' estimate of the so-called gap is fatally flawed by the theoretical and measurement problems, it defies common sense to believe that over-investment of this degree could take place.[53] Regulators (both at the federal

[53] 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.

and state level) would have to have been quite derelict in their public responsibilities for such this event to have occurred, an unlikely event given the scrutiny the telecommunications industry receives.

Attachment

In this Attachment we demonstrate that the Hatfield Model violates the derivative property and that it produces biased TS/TELRICs. We begin with a brief discussion of the factor approach to cost model building and Hatfield Model's misuse and misunderstanding of it.

Section A

A majority of the technical errors in the Hatfield model arise from its authors' dependence on the use of charge factors to handle everything from expenses to common costs. In this section we will give a justification for a form of the charge factor approach and then use this as a basis from which to analyze the Hatfield model. A mathematical function $C(y, w, K)$ is said to be a cost function if it represents the minimum cost of producing a set of outputs y, such as subscriber lines, minutes of use and the like (we will treat fill factors later), when the prices for a set of inputs x are w, e.g. wages, materials, et cetera, using physical units of machinery, switches, conduit and so on usually referred to as capital, K. Formally,

$$C(y, w, K) = \min_{x} \{w^T x | F(y, x, K) \leq 1\}$$

where F(y,x,K) is a traditional distance function and the locus of points $\{(y, w, K) | F(y, x, K) = 1\}$ represent the most efficient combinations of inputs, that is, the best practice engineering method of combining inputs and outputs.

As a consequence of being the minimum cost of producing y using K, when input prices are w, a cost function satisfies the following mathematical properties, which can be found in any graduate microeconomic theory text:

1. It is non-decreasing in y

2. It is non-decreasing in w

3. It is non-increasing in K

4. It is convex in w

5. It is linear homogeneous in w

6. The inputs demand functions are given by $x(y, w, K) = \frac{\partial C(y, w, K)}{\partial w}$

7. There is one and only one distance function generating $C(y, w, K)$; equivalently there is one and only one technology consistent with C.

8. In addition, conditions 5 and 6 together imply that the input demand functions $x(y, w, K)$ are zero degree homogeneous in input prices w.

1. The Charge Factor Approach

Below we delineate how to generate a cost function in the charge factor form that seems popular with accountants and which is the prevalent form in which public utilities model costs. Let $x = \{x_1, x_2, \cdots, x_m\}$ where the x_i represent mutually exclusive subsets of inputs, then a cost function can always be written as

$$\begin{aligned} C(y, w, K) &= w_1^T x_1(y, w, K) + w_2^T x_2(y, w, K) + \cdots + w_m^T x_m(y, w, K) \\ &= E_1(y, w, K) + w_2^T x_2(y, w, K) + E_3(y, w, K) + E_4(y, w, K) + \cdots + E_m(y, w, K) \end{aligned}$$

Where $E_i(y, w, K)$ is the optimal (cost minimizing) expenditure on the ith group of inputs. Note that as a consequence of conditions 5, 6 and 8 above, we have:

9. The group expenditure or cost functions are first degree homogeneous in w.

Assume that x_2 is a scalar quantity such as installed lines, then the above equations can be rewritten as

$$C(y,w,K)=\left(\frac{E_1(y,w,K)}{x_2(y,w,K)}\right)x_2(y,w,K)+w_2x_2(y,w,K)+\left(\frac{E_3(y,w,K)}{E_4(y,w,K)}\right)E_4(y,w,K)+E_4(y,w,K)+$$
$$+E_m(y,w,K)$$
$$=\left(\frac{E_1(y,w,K)}{x_2(y,w,K)}+w_2\right)x_2(y,w,K)+\left(\frac{E_3(y,w,K)}{E_4(y,w,K)}+1\right)E_4(y,w,K)+\cdots+E_m(y,w,K)$$
$$=F_1(y,w,K)x_2(y,w,K)+F_4(y,w,K)E_4(y,w,K)+\cdots+E_m(y,w,K)$$

Where we have introduced charge factors F_1 and F_4 defined as

$$F_1(y,w,K)=\left(\frac{E_1(y,w,K)}{x_2(y,w,K)}+w_2\right)$$
$$F_4(y,w,K)=\left(\frac{E_3(y,w,K)}{E_4(y,w,K)}+1\right)$$

As a consequence of 8 and 9 above we have that $F_1(y,w,K)$ is first degree homogeneous in w and $F_4(y,w,K)$ is zero homogeneous in w. Any cost function therefore can be represented in the charge factor form provided the factors and the terms to which they are applied satisfy the conditions above.

2. Biases in Hatfield' Model's Factor Approach

Let x_{ci} be the physical quantity of input i in input group c and let p_{ci} be its price. Let E_{ci} be expenditure on x_{ci} and let E_{si} be the expenditure on other inputs associated with x_{ci}, that is expenses.

a. The Hatfield Model Violates the Derivative Property

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

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

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.[54] Thus, the derivative of C with respect to p_{ci} should give x_{ci}. Symbolically this is,

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

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

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

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

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

b. Hatfield violates linear homogeneity

This follows from checking condition 9 above. By that condition, factors that are ratios of expenses to physical quantities must be homogeneous of degree one. However, Hatfield assumes the expense to cable factor is constant. Constants do not change and so do not double when all input prices change, thus they fail homogeneity.

c. 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:

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

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

[54]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.

The cost minimizing cost function is

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

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

For the Hatfield Model,

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

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

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

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.

d. 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 $y_1,\ldots y_n$, with m inputs which have prices $w_1,\ldots,w_m$ be denoted $C(y_1,\ldots y_n, w_1,\ldots,w_m)$. The TS/TELRIC for service 1 is given by

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

Where $C(0,y_2,\ldots y_n,\ w_1,\ldots,w_m)$ 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 $C(y_1,\ldots y_n, w_1,\ldots,w_m)$ and $C(0,y_2,\ldots y_n, w_1,\ldots,w_m)$ 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

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

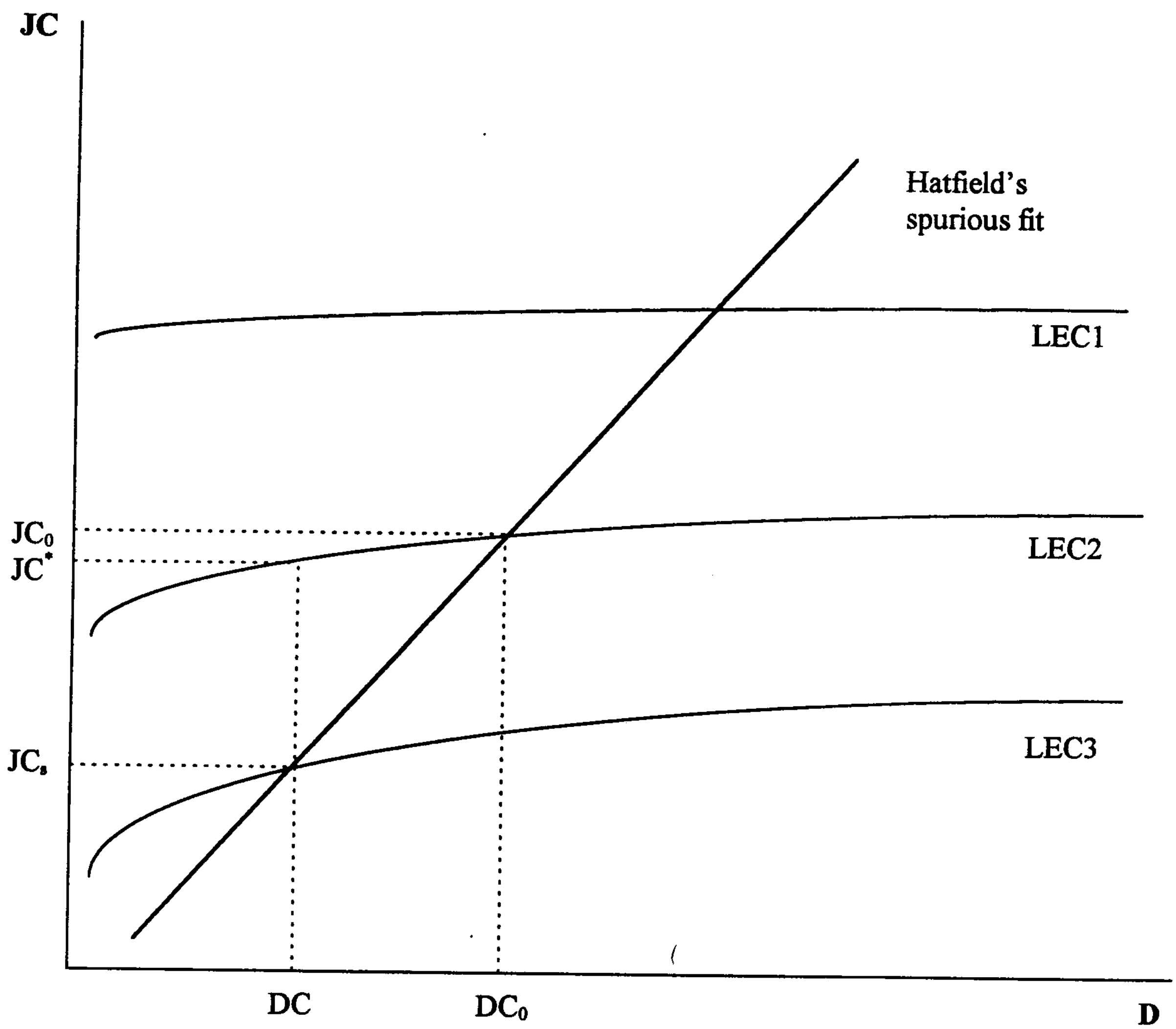
or

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

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

Section B Graphical illustration of 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 we 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
JC0
JC*
LEC2
JCs
LEC3
DC
DC0
D

Section C 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 we 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:

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

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

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

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 $(y_1, 0, \ldots, 0)$.

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

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

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

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

Simplifying and solving for the standalone cost gives:

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

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.

REFERENCES

Dixit, Avinash K. and Pindyck, Robert S. (1994), *Investment Under Uncertainty*, Princeton University Press, Princeton, New Jersey.

Clark, J. Maurice (1923), *Economics of Overhead Costs by J. Maurice Clark*, University of Chicago Press.

Duncan, Gregory M. (1990), "The Effect of Probabilistic Demand Structures on The Structure of Cost Functions," *Journal of Risk and Uncertainty* 3, 3, 211-220.

Emmerson, Richard D.(1991), "Theoretical Foundation of Network Costs," in W. Pollard, editor, *Marginal Cost Techniques for Telephone Services*, National Regulatory Research Institute, pp. 145-189.

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

Greene, William H. (1993), *Econometric Analysis* 2nd Edition, Macmillan Publishing Company. New York.

Hausman, Jerry A. (1996), Reply Affidavit Before the Federal Communications Commission In the Matter of Implementation of Local Competition Provisions in the Telecommunications Act of 1996 CC docket No. 96-98.

Starrett, David (1978), 'Marginal Cost Pricing of Recursive Lumpy Investments', *Review of Economic Studies* pp. 215-227.

Varian, Hal R. (1992), *Microeconomic Analysis, Third Edition*, New York: Norton.