A SURVEY OF COST MODELS IN TELECOMMUNICATIONS
Prepared for the
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One of My Biases About Cost Studies

“Any reader with a knowledge of accounting or economics knows that the idea of a true cost is a delusion -- costs must be established for the purpose at hand.”

Allison Kennedy in “ABC Basics,” Management Accounting, June 1996, p.24

Network Cost System @ AT&T Long Lines, 1978-80

• Ramsey pricing project required marginal cost estimates
• FCC seeking FDC-based prices for MTS
  – 288 rate elements
  – Didn’t want to see any more NCS output
  – MTS demand model: quarterly development reviews with FCC staff economists
• Data tapes by taxi: Armonk to White Plains

Scale Economy Studies circa OCC Entry

• Denny, Fuss, Everson & Waverman (Canada) 1979: 1.46
• Meyer et al. @ CRA (US, long distance) 1979: 1.1-1.5
• Nadiri & Schankerman (US, Bell System) 1979: 1.75 & 2.12
• Christensen, Cummings & Schoech (US, Bell System) 1983: 1.3-1.7
Proper Cost Functions

- Non-negative
- Linearly homogeneous in input prices
- Concave in input prices
- Nondecreasing in input prices

Anti-Trust Case Cost Issues

- New network cost model undertaken --- engineering process
  - Guided by Dale Jorgenson
  - Reported in Skoog
  - Case settled before model finished
- Econometric studies of cost subadditivity
  - Evans & Heckman (1983) estimated translog cost function and rejected natural monopoly hypothesis
  - Charnes, Cooper & Sueyoshi (1988) performed a goal-programming/constrained-regression analysis and accepted hypothesis
  - Waverman (1989) reviewed above studies and found lots of negative marginal costs in both

Anti-Trust Case Cost Issues -- Continued

"On the basis of this evidence, one would not, however, rush to the FCC or the Canadian Radio, Television, and Telecommunications Commission and argue that this econometric evidence supports divestiture between local and toll services but further supports the existence of a single firm in the toll market. The weight of the evidence of all these studies is simply not strong enough, since changing the level of aggregation, the functional form, the constraints imposed, or the objective function dramatically alters the results. The message is simply that the data available are insufficient to enable researchers to discriminate between alternative hypotheses. Moreover, I also share the doubts of Fuss, who argued that the evidence cannot adequately disentangle the effects of two factors that both reduce unit costs -- economies of scale and technological advance."  ---  Leonard Waverman, 1989

Anti-Trust Case Cost Issues - Continued

- Roller (1990) estimated quadratic cost function constrained to be “proper” in relevant output region; accepted natural monopoly hypothesis
- Diewert & Wales (1991) reviewed Evans & Heckman and found their cost function not to be nondecreasing in outputs
- Waverman (1989 OpCit) “My view is that the subadditivity test for aggregate AT&T data is so sensitive to data and to econometric technique that it cannot be relied on for making policy.”
RAND Model, 1990

• Purpose was to develop marginal cost estimation methodology, à la EPRI
• Small engineering process model of loop plant, switching and interoffice facilities
• Estimated average incremental cost of adding and operating capacity to serve increase in demand in established area
  – Augment feeder, switching and interoffice trunks
  – Assume all distribution needed already in place; i.e., fixed

RAND, Continued

• Developed model for three representative California communities, using GTEC and PacBell network practices and data
  – Process was in several ways a model of openness
    • CPUC staff involved all the way
    • Public reviews conducted
    • Model equations and code published
  – Utilized some proprietary data, but disguised
• Example: Total investment in switching

\[
C = g + C_l \cdot \text{lines} + C_t \cdot \text{trunks} + C_a \cdot \text{attempts} + C_u \cdot \text{CCS}
\]

\[
g = \$150,000 - 400,000 \\
C_l = \$80 - 125 \\
C_t = \$200 - 350 \\
C_a = \$1 - 3 \\
C_u = \$8 - 26
\]

RAND, Continued

• A coherent economic scenario
  – Regarded firm as going concern for financial analysis
    • Had a specific planning horizon
    • Provided for replacement investment
  – Took growth into account
    – Discussed assumed relationship between nominal and real magnitudes
  • Explained how methodology was appropriate for cost concept being estimated; i.e., what was fixed -- what was incremental
  • Examined implications of investment lumpiness
    – for pricing
    – for fill factors

NRRI Symposia (1990)

Marginal Cost Techniques for Telephone Services

Two Fundamental Insights

1. "There is no one correct measure of marginal costs that is applicable to all policy objectives of a commission, company or court. This fact is not much comfort for a commissioner or policy maker desiring a single cost estimate on which to base all policy decisions. However, long-run incremental costs measured over a company’s planning horizon may minimize strategic behavior on the part of participants to a regulatory proceeding because the cost of capacity is included."

2. "Engineering process models are superior to econometric and optimization models when marginal-cost information is desired on a functional basis (that is, switching) or for a service such as local."
### Some RAND Results, 1988 Prices

**Average Incremental Costs of Access and Usage**  
(Dollars per year)

<table>
<thead>
<tr>
<th></th>
<th>Small Urban (10K)</th>
<th>“Average” (20K)</th>
<th>Large Urban (40K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access</td>
<td>152 - 169</td>
<td>67 - 80</td>
<td>53 - 66</td>
</tr>
<tr>
<td>Usage</td>
<td>5 - 10</td>
<td>13 - 24</td>
<td>14 - 27</td>
</tr>
<tr>
<td>Business</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access</td>
<td>111 - 126</td>
<td>62 - 75</td>
<td>46 - 59</td>
</tr>
<tr>
<td>Usage</td>
<td>7 - 15</td>
<td>14 - 27</td>
<td>21 - 39</td>
</tr>
</tbody>
</table>

### Some RAND Results, 1988 Prices, continued

**Local Exchange Fixed Costs**  
(Dollars per year per line)

<table>
<thead>
<tr>
<th></th>
<th>Small Urban</th>
<th>“Average”</th>
<th>Large Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loop</td>
<td>164 - 165</td>
<td>60 - 61</td>
<td>45</td>
</tr>
<tr>
<td>Switch</td>
<td>5 - 11</td>
<td>5 - 10</td>
<td>5 - 9</td>
</tr>
<tr>
<td>IOF</td>
<td>7 - 8</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Land &amp; buildings</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

### A Departure from Duality Theory

Duncan (1990) included call-completion probability in objective function, to represent situation faced by firms that experience random fluctuations in demand but must stand ready to serve all demand.

- Firm typically does not operate on efficient frontier of production possibilities sets
  - Duality theory breaks down
  - Independence of demand functions and cost functions also lost
- Reformulated production theory shows how negative relationships between cost and lines can be obtained, but Duncan got far fewer than E&H or CC&S, using a GTE data set

### The Recent Spate of LEC Cost Models

- Hatfield Model, July, 1994
- US West Model, Oct. 28, 1994
- Benchmark Cost Model, Sept. 12, 1995
- Hatfield Model Version 2.2, Release 1, May 16, 1996
- Cost Proxy Model, May 21, 1996
- Benchmark Cost Model 2, July 5, 1996
- Strategic Policy Research Model, Nov. 17, 1996
- Benchmark Cost Proxy Model, Jan. 31, 1997
- SPR, Revised Model, Feb. 18, 1997
- Hatfield Model Version 3.1, Feb. 28, 1997
- Benchmark Cost Proxy Model, Version 1.1, Mar. 24, 1997
The Hatfield Model

• First in the field
• A “scorched earth” or “blank slate” model
  “The model we developed is based on a “greenfield” assumption: the entire network is as it would be if it were built from scratch. No consideration was given to the total number and ownership of local exchange carriers or other aspects of the regulatory and commercial history of the local exchange telephone industry.” (p.7)
  - Instantaneous, all-at-once replacement of entire domestic LEC network
  - 4200 switches in place of 19,000
• Claimed to be TSLRIC; is not
TC(U,V,W,X,Y,Z) - TC(ø,V,W,X,Y,Z)
• Note: investment per line costs turn up in high density zones

Hatfield Model 2.2.1

• Incorporated BCM loop module, with modifications
  – added business lines and multiple residence lines
  – Increased distribution structure costs in rural areas
  – Added drops, etc.
  – Shared structure costs with other utilities
• Accepted current LEC switch locations, but built new switching cost module
• Used OSP unit costs from BCM, but with higher discounts for DLC and with higher fill factors
• Network Operations Expense driven by lines; other expenses driven by investment
• Added modules
  – Interoffice transport
  – Signaling network
  – Operator positions
• Calculated costs for 11 unbundled network elements, plus public telephone
• Like BCM, was very sensitive to fill factors, capital costs, depreciation rates and structure multipliers
• Routine results reported by six density zones

Hatfield Model 2.2.2

• Loop module now called BCM-PLUS
  – Uses 1995 Census data
  – Varies, by density, number of equal-length distribution cables per CBG
  – Adds 20% to loop distance for terrain obstacles
  – Introduces Serving Area Interfaces
  – Sets default structure sharing at 1/3, 1/3, 1/3
• Subtracts $16 per line from switching cost for trunk ports whose cost is not there to begin with

US West Model

• Applied RAND loop plant module to 220,506 CBGs
  – Assigned CBGs to nearest wire center
  – Used NECA tariff for WC locations
  – Built OSP for each CBG on stand-alone basis
  – Used RAND unit cost data
• Was a cost index model only; i.e., a fund allocator
  – Identified high cost areas
  – Relative costs correlated highly with 1992 unseparated NTS revenue requirements
The Benchmark Cost Model

- Greatly revised version of US West Model
  - Shared feeder
  - Added switching and expenses
  - Totally new price list for inputs
- Now sponsored by MCI, NYNEX, Sprint & US West
- Still focused on USF
- Used annual cost factors (2) to calculate return on investment, depreciation, taxes and operating expenses
- Refused to characterize costs as TSLRIC
- Basic loop architecture used in subsequent BCM and Hatfield Models
  - Tree and branch algorithm
  - Took surface soil conditions into account

Cost Proxy Model

- Developed by INDETEC for PacBell for CA/US
- Used grid cell as basic geographic unit
- Used samples from PacBell’s network for loop plant
- Used SCIS for Switching
- Did activity analysis for expenses, but expressed all expenses on per-line basis

Putting Things in Perspective

### Monthly Cost per Line for Residence BUS

<table>
<thead>
<tr>
<th></th>
<th>BCM</th>
<th>H2.2.1</th>
<th>CPM</th>
<th>BCM2</th>
<th>H2.2.2</th>
<th>BCPM</th>
<th>H3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACF1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CA</td>
<td>18.05</td>
<td>13.09</td>
<td>16.22*</td>
<td>26.72</td>
<td>24.50</td>
<td>15.30*</td>
<td>16.25*</td>
</tr>
<tr>
<td>TX</td>
<td>25.14</td>
<td>18.23</td>
<td>33.94</td>
<td>29.98</td>
<td>17.58*</td>
<td>32.45*</td>
<td>18.94*</td>
</tr>
</tbody>
</table>

*Mercer Direct Testimony

Problems with Models

- No coherent economic scenario (recall RAND)
  - Instantaneous, all-at-once installation of new network to serve 100% of current market (New entrant is anonymous, efficient and omnipotent?)
  - Growth is ignored
  - When in future do numbers apply?
  - Real vs. nominal dollars
- Don’t estimate any particular economic cost concept
  - Not TSLRIC (F-SJB/US didn’t specify)
  - Stand-alone cost of narrowband network, with costs for business services and toll usage removed by factors
  - Replete with cost allocations
- Producing estimates widely at variance with recent actuals
  - Investment per line for RBOCs as a whole, and monthly cost per line, including expenses
    | H2.2.2 | BCM2  | CPM  | '95 ARMIS |
    | $769   | $960  | $1057| $1609     |
    | $18.58 | $41.12| $29.14|           |
U. S. West Model

Hatfield Model, Table 2

<table>
<thead>
<tr>
<th>Population Density zone</th>
<th>Cost per line per month, wireline</th>
<th>Subsidy per line per month</th>
<th>Total number of residential access lines</th>
<th>Basic universal service subsidy for cost zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>$65.63</td>
<td>$47.63</td>
<td>4,866,708</td>
<td>$2,781,655,624</td>
</tr>
<tr>
<td>10-100</td>
<td>$66.39</td>
<td>$18.39</td>
<td>16,565,081</td>
<td>$3,655,922,175</td>
</tr>
<tr>
<td>100-500</td>
<td>$147.4</td>
<td>($3.26)</td>
<td>16,473,132</td>
<td>($644,428,924)</td>
</tr>
<tr>
<td>500-1,000</td>
<td>$1408</td>
<td>($3.92)</td>
<td>12,112,035</td>
<td>($592,790,156)</td>
</tr>
<tr>
<td>1,000-5,000</td>
<td>$14.19</td>
<td>($3.81)</td>
<td>34,150,858</td>
<td>($1,961,377,228)</td>
</tr>
<tr>
<td>&gt;5,000</td>
<td>$18.32</td>
<td>-$72</td>
<td>7,335,214</td>
<td>$28,167,222</td>
</tr>
<tr>
<td>Total</td>
<td>$3,689,808,643</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Hatfield Model, Table 4

<table>
<thead>
<tr>
<th>Population density range per sq km</th>
<th>Total Lines</th>
<th>Residential lines</th>
<th>Investment per line wireline</th>
<th>Investment per line wireless</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>5,864,232</td>
<td>4,866,708</td>
<td>$3,351</td>
<td>$1,557</td>
</tr>
<tr>
<td>10-100</td>
<td>20,105,709</td>
<td>16,565,081</td>
<td>$1,925</td>
<td>$1,422</td>
</tr>
<tr>
<td>100-500</td>
<td>23,407,335</td>
<td>16,473,132</td>
<td>$764</td>
<td>-</td>
</tr>
<tr>
<td>500-1,000</td>
<td>17,200,110</td>
<td>12,112,035</td>
<td>$726</td>
<td>-</td>
</tr>
<tr>
<td>1,000-5,000</td>
<td>48,496,905</td>
<td>34,150,858</td>
<td>$738</td>
<td>-</td>
</tr>
<tr>
<td>Greater than 5000</td>
<td>18,338,035</td>
<td>7,335,214</td>
<td>$1,001</td>
<td>-</td>
</tr>
</tbody>
</table>

Benchmark Cost Proxy Model

- Joint effort of Pacific Bell, Sprint & U.S. West
- Outgrowth of “Best of Breed” process
- Combined some features of BCM2 and CPM
  - Grid cells and census blocks
  - More density zones
- Revised capital cost calculations
- Estimated new switch cost curve from sample data provided by several LECs’ SCIS runs
- Estimated all expenses on per-line basis, using forward-looking estimates collected from several LECs
Hatfield Model, Version 3  
(Prepared before filed)

- CBG assignment to switch by NPA-NXX
- Business & residence line data from PNR database
- Fixes to loop plant so network will work
- New switching cost module
- Adding some omitted General Support investment
- More density zones at upper levels
- Including data on multiple tenant dwellings and high-rise buildings

Model Issues
- What is/are the relevant cost concept(s) to model?
- One model for access charges, unbundled network elements and universal service?
- How do TELRICs relate to TSLRICs?
- What constitutes adequate validation?
- What explains wide gap between actuals and estimates?
  - All-at-once installation
  - All digital switching
  - Declining switch prices
  - Reduced switch maintenance
  - Lots more optical fiber
  - Reduced cable maintenance
  - Under depreciated plant
  - Alleged waste and inefficiency
  - Model errors
- Normally, when an economic model mispredicts real world outcomes, the real world is given the benefit of the doubt

Conclusion
- Recall Waverman Quotes
- Now, what are you willing to bet on these models:
  - Your company?
  - Your state’s ILEC & CLEC industry?
  - The whole US ILEC & CLEC industry?
  - Somebody else’s ox?

Other Models -- Slighted
- SPR Model
  - Top-down; econometric
  - Pooled NECA USF data
  - Two network elements’ cost estimated
    - loops 72% higher than FCC proxy
    - switching 34% higher than upper end of FCC proxy range
- Telecom Economic Cost Model
  - Takes market share into account
  - More parameters set at wire center level (WC is basic geographic unit)
- Sharma Model (UK)
  - Average Incremental Cost of three representative conurbations: rural, suburban, inner city
  - Reed-like serving area
  - Does growth right
Benchmark Cost Model 2

- Included all cost elements of BUS
- Added business lines
- Revised distribution plant in sparse areas
- Eliminated use of structure cost factors
- New switch cost model in five size ranges
- Some expenses investment related, some line related
- Added terrain slope variable