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February 19, 2013

Dear Ms. Veach:

Thank you for the opportunity to peer review the Connect America Cost Model (CACM). Attached to this letter is your original request to me.

Let me relate my research experience that is relevant to this review. I received my PhD from the Business and Public Policy Department of the Wharton School, University of Pennsylvania in 2000, and my dissertation research focused on the buildout of broadband networks. I worked for two years at Bell Laboratories, Lucent Technologies, Murray Hill, NJ in the Technology Management and Economics Research department of the Mathematics Science Research Center. My work there centered on models of buildout of fiber-optic networks. I have spent 13 years as assistant and then associate professor of economics at Wesleyan University, Middletown, CT. I have continued to do economics research on various aspects of broadband Internet regulation. I am currently co-editor of *Information Economics and Policy*, an economics journal specializing in these and related topics.

To prepare this peer review, I have spent a good deal of time reading the model documentation (CAF2 Model Overview by CostQuest Associates), several background reports, and experimenting with running scenarios on the model. I have also read "The Broadband Availability Gap," OBI Technical Paper No. 1, April 2010, hereafter abbreviated OBI1.

The CACM is a very large and complex model with an enormous number of economic and engineering parameters. Given the time available, I have had to

narrow down my review to certain model elements where I think I can make the best contribution. This review is organized in several sections:

I begin with a discussion of an article that I co-authored with Gerald Faulhaber (Faulhaber and Hogendorn 2000, hereafter abbreviated FH) in which we studied the buildout of broadband networks. This discussion gives an idea of how I think about the relevant economic issues.

I then compare the CACM with the FH model. Primarily I discuss the demand-side, including assumptions on take-rate, pricing, and changes in demand.

Next I discuss how competition and technology change through time and how this can be captured using dynamic models. This draws on my PhD thesis and on my experience at Bell Laboratories. I compare the CACM to other dynamic models I have worked on. This includes issues of preemptive behavior by service providers, terminal values and time horizons, and technology roadmapping to anticipate technological change.

Finally I discuss some issues relating to economies of scope between broadband Internet and voice and video. These relate to brownfield versus greenfield and accounting for revenue and equipment related to here other services.

1. The Faulhaber-Hogendorn Model

In the late 1990s, while I was a PhD student at the Wharton School, University of Pennsylvania, I worked with my dissertation advisor Gerald Faulhaber on a model of broadband network buildout. It was published in 2000 in the *Journal of Industrial Economics.*

The main point of this model is that when service providers enter a market, they incur a fixed cost of "network scope" which determines the areas of

homes passed by the network. This is equivalent to "capex" in the CACM. After having committed to capex, service providers compete, receiving an operating profit equal to revenue (price × take rate × homes passed) and incurring costs (equivalent to "opex" in CACM).

As a result of this structure, service providers will not commit capex to a location unless they expect an operating profit greater than or equal to the capex. Operating profit per household is approximately the same at all population densities, but capex per household is much higher in less dense areas. Thus, FH derive an equilibrium in which there are up to 3 competing service providers in the most dense areas, 2 in medium density areas, 1 in low density areas, and 0 in the least dense areas.

The FH model features an oligopoly market structure without price regulation. Thus, prices are higher in the monopoly area where there is only one service provider than in the areas with facilities-based competition. Higher prices in the monopoly area have both good and bad effects on social efficiency. On the bad side, the higher price results in a lower take rate. On the good side, the higher operating profit allows for facilities to be built into lower density areas. The areas that receive no service in the FH model have such low density that even monopoly operating profits are not high enough to cover the high capex costs.

2. Comparison of CACM to FH

Both the CACM and FH cover the same basic question, namely the revenues versus costs of a broadband buildout. The CACM has a vastly more accurate method of measuring costs, using both much more detail at the engineering level and a far more precise method of modeling geographic locations. Indeed, the CACM is more accurate in its treatment of the road network than any other model I am aware of, and I hope this will lead to a lot fewer "surprises" when construction actually takes place.

Service Areas Covered. On the demand side, the CACM is used primarily for those areas which do not have broadband service according to the National Broadband Map (NBM). The FH model makes clear that the boundary between the no-service area and the monopoly service area is changeable, depending on the level of demand. For a run of the CACM, this boundary is taken as fixed based on current inputs from the NBM. This leads to concern that some of the areas modeled by the CACM would become profitable in the future if demand grows. The CACM documentation that I reviewed indicates a 20-year levelized ARPU and take-rate, so it does not address this problem. The demand modeling described in OBI1 does have the ability to analyze whether certain areas will become profitable in the near future.

Monopoly Pricing. The CACM default ARPU inputs are "typical" prices for broadband in America. But the areas being dealt with will only have one provider whereas the "typical" area has facilities-based competition. Economic theory would predict that a monopoly area would have higher prices, and thus higher ARPU and lower take rate, than an area with competition. It may be that the service providers receiving Connect America funding are under either explicit regulation or implicit regulatory pressure to charge the same prices as in areas with competition. Or it may be that many of these service providers also serve areas where there is competition and need to maintain uniform pricing either for marketing purposes or to avoid angering customers. But whatever the reasons, when the model is used the issue of monopoly market structure should be addressed. There should be an explicit justification for why a monopoly would charge anything other than the profit-maximizing monopoly price.

Take Rate. In FH, the highest take rate we considered (again at "typical" ARPU) is 67%. A recent ITIF report (Bennett, Stewart, and Atkinson 2013) cited a 65% American take rate based on FCC data (50% in rural areas) and take-rates in the rest of the world that are below 83% everywhere except Iceland and Korea based on OECD data. All of these are measures for broadband Internet only, and would likely increase if we also considered video

service. The default take-rate in the CACM is 90%, which seems too high based on any of the above measures.

3. Dynamic Issues

In an environment where demand is growing, service providers may anticipate the growth and prepare for it in a strategic way. In an extension to FH, Hogendorn (2000), I showed that a service provider should preemptively build into the valuable monopoly area in order to secure it for itself rather than a competitor. This race to become the monopolist means that service begins earlier in time in less-dense areas because of the anticipated monopoly profit from serving them. However, the least-dense areas, where capex costs are too high relative to operating profit even at maximum demand, never receive coverage because there is no profit to preempt.

Building Ahead of Demand. The preemption logic suggests that if there will be any increase in demand that makes an area viable, then a service provider may enter that area while an "investment gap" still exists because it anticipates future profits. The CACM is well-placed to test this. If the CACM shows that areas that already have service have a gap to profitability, then it is possible that firms have built ahead of demand in order to achieve first-mover status. Since the areas under evaluation are very low density, I would expect that any preemptive investment would come from the existing telco trying to beat to market a potential fixed wireless competitor.

Levelized Demand. This type of dynamic model calls into question the assumption of 20 years of levelized revenues and costs that is used in the CACM. If in fact demand is growing over the time period, then private investment might occur even without Connect America funding.

To give a sense of how this could result in misleading model output, consider one of the most dense areas that currently has no service. Using the CACM's methods, this area would receive Connect America funding and by

assumption this would result in 20 years of service to the area's residents. But if demand is growing and private investment would occur in year 5, then the Connect America funding really only buys 5 years of service, not 20.

Terminal Operating Profit. The CACM does not include any terminal value at the end of the 20 year period. In fact, customers in year 20 would presumably continue buying service "forever," so a more natural assumption would be that the operating profit stream continues forever, properly discounted of course. (As noted in OBP1, there might be additional capex at some point due to technological change or depreciation of the existing equipment.) This terminal operating profit issue is important for two reasons. First, without a terminal operating profit, the apparent investment gap is greater than it really is. Second, the example above of beginning service in year 5 is much more plausible with a terminal operating profit. In the current CACM, a year-5 capex would give lower net profit because only 15 years of operating profit would be counted. With a terminal operating profit, a year-5 start date would show a higher net profit if demand is growing.

Technology Roadmapping. Another dynamic issue concerns changes in technology over time. Over a 20-year time period, there will be significant changes in the technologies used to provide broadband access. The version of CACM I worked with concentrated on one DSL technology, though it also allows a fiber to the home (FTTH) option. While DSL may be the best technology to meet demand today, it is almost certain that service providers in more dense areas will be making upgrades to their DSL plant over the 20-year time horizon. Thus, the investment gap is likely to re-emerge relative to the generation of equipment likely to be in use in high-density areas of the USA. It may, therefore, make sense to explore the FTTH option more extensively, at least in the higher-density areas subject to Connect America funding.

4. Economies of Scope with Video and Voice

Brownfield Versus Greenfield. A final set of issues concerns the ability of the upgraded network to offer video and voice as well as broadband Internet. The proposed improvements can reuse many existing network elements, so the CACM includes a brownfield option. I am not sure why the greenfield option would ever be applicable unless there are instances where there is truly no infrastructure in a particular service area. It is certainly very useful, however, for considering the possibility of competitive entry.

Video. The CAF2 model overview explicitly states that video equipment is not included in the CACM. This seems entirely appropriate since the funding is for Internet not video. On the other hand, ARPU also excludes video, even though most of the costs of the video will be attributable to the same facilities as the broadband Internet. Thus there should be a video ARPU assumption to help offset the costs of these shared facilities. This approach was taken explicitly in OBI1.

Voice. A similar issue of shared facilities pertains to voice. On slide 88 of the CAF2 model overview, it is stated that "When the opex inputs were calculated by the coalition, they were calculated on a greenfield basis." But some of this so-called greenfield opex would have been spent anyway on the telephone elements being replaced, so this method seems to overestimate the opex cost attributable to broadband.

5. Conclusion

Most of the above concerns with the CACM are really concerns with the default inputs discussed in its documentation. It appears to me that the CACM or a related model is capable of handling more complex parameter inputs based on OBI1. In that paper, demand grows over time according to a Gompertz curve and is adjusted by local demographics. Other inputs like

terminal value can be adjusted, and it is possible to study issues of dynamic entry, again by changing parameters.

Overall, the CACM is a very impressive engineering model, with tremendous degree of accuracy at the geographical level. It is capable of dealing with most of the economic issues I have raised simply by adjusting inputs in the appropriate way, and indeed some of these adjustments already appear to have been tried in OBP1.

Sincerely,

Christiaan Hogendorn

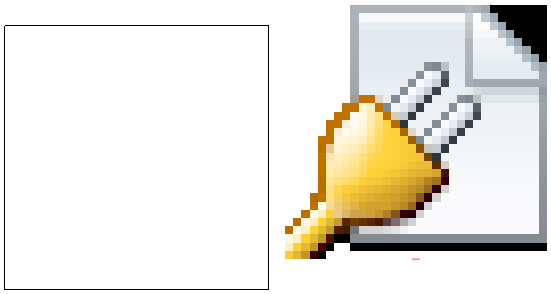
References

Bennett, R., Stewart, L, & Atkinson, R. (2013). *The Whole Picture: Where America's Broadband Networks Really Stand*. ITIF.

Faulhaber, G. R., & Hogendorn, C. (2000). "The Market Structure of Broadband Telecommunications." *Journal of Industrial Economics,* 48(3), 305-329.

Federal Communications Commission (2010). "The Broadband Availability Gap," OBI Technical Paper No. 1.

Hogendorn, C. (2000). "The Feasibility of Competition in Broadband Networks," Chapter 1 in *Unbundled Infrastructure Firms: Competition and Continuing Regulation,* PhD Dissertation, University of Pennsylvania.



UNITED STATES GOVERNMENT

memorandum

WIRELINE COMPETITION BUREAU

DATE: December 27, 2012

TO: Christiaan Hogendorn

FROM: Julie A. Veach
Chief, Wireline Competition Bureau

SUBJECT: Peer Review of Connect America Phase II Cost Model

The Federal Communications Commission (Commission) is in the process of developing a cost model for use in the Connect America Fund proceeding (WC Docket No. 10-90, et al.).[1] Through this memorandum, I request that you perform a peer review of the model in question, the Connect America Cost Model.[2]

The Commission is currently implementing Connect America Phase II, a program with the goal of deploying modern, scalable, broadband-capable infrastructure to areas of the nation where high costs have left consumers unserved by broadband, while preserving ubiquitous voice service and minimizing the burden on all consumers to support the funding mechanism for the program.[3] The Wireline Competition Bureau (Bureau) has been directed by the Commission to adopt an engineering-based cost model, which will estimate the forward-looking cost of deploying and operating a modern wireline voice and broadband-capable network at the census block (or smaller) level.[4] The model will

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1 See *Connect America Fund,* WC Docket No. 10-90, et al., Report and Order and Further Notice of Proposed Rulemaking, 26 FCC Rcd 17663 (2011) (*USF/ICC Transformation Order*). To access the order, *see* http://transition.fcc.gov/Daily_Releases/Daily_Business/2012/db0206/FCC-11-161A1.pdf.

2 For a description of the model, *see* http://transition.fcc.gov/wcb/tapd/universal_service/caf/CAF2-Part1.pdf and http://transition.fcc.gov/wcb/tapd/universal_service/caf/CAF2-Part2.pdf.

3 *USF/ICC Transformation Order*, 26 FCC Rcd at 17673-75, 17725-38, paras. 23-28, 156-93.

4 *See id.* at 17735, para. 187; *see also Request for Connect America Fund Cost Models*, WC Docket Nos.

ultimately be used to determine support amounts that will be offered to incumbent price cap carriers in specified areas. The Bureau is directed to "ensure that the model design maximizes the number of locations that will receive robust, scalable broadband within the budgeted amounts. Specifically, the model should direct funds to support 4 Mbps/1 Mbps broadband service to all supported locations, subject only to [a] waiver process for upstream speed . . . and should ensure that the most locations possible receive a 6 Mbps/1.5 Mbps or faster service at the end of the five year term, consistent with the CAF Phase II budget."[5]

The Universal Service Administrative Company (USAC) is the entity that is making the model available to the public. USAC has procured the services of a contractor, CostQuest, to provide the model and to assist with its public hosting, execution and support. The model and accompanying documentation (including description of process for obtaining access to them) can be accessed online at http://www.fcc.gov/encyclopedia/caf-phase-ii-models. Access to the model is subject to a second level protective order, and requires the execution and return to us and CostQuest (as appropriate) of the requisite confidentiality, licensing and non-disclosure agreements (respectively Appendices A, B and C of the attached Third Supplemental Protective Order, also found at http://www.fcc.gov/document/connect-america-phase-ii-third-supplemental-protective-order). Login and other information about accessing the model is available from USAC's contractor, CostQuest (James Stegeman, President (jstegeman@costquest.com; (513) 941-9009), or Mark Guttman, Vice President of Operations (mguttman@costquest.com; (513) 662-2124 x102).

The current version of the model provides the ability to calculate costs using a variety of different inputs and assumptions, allowing the Bureau to choose among different network deployments to serve funded locations (*e.g.*, FTTP or fiber-fed DSL), different assumptions about the amount of existing facilities assumed to exist (e.g., green-field or brown-field deployments, the mix of aerial, buried or underground plant), as well as different assumptions about unit costs for capital and operating expenses.[6] The cost model is based on geospatial information systems (GIS) data on the nation's roads and implements a road-based spanning tree to minimize the distance covered by the network, limiting coverage to road types that are used for residential and business locations. The model employs actual locations of existing central offices. Contemporary wireline systems engineering standards are incorporated to ensure that the modeled network accurately captures the number of routers located at the edge of the cloud, quantities of

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10-90, 05-337, Public Notice, 26 FCC Rcd 16836 (Wireline Comp. Bur. 2011), http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-11-2026A1.pdf . For a virtual workshop on issues associated with the development of the cost model, *see* http://www.fcc.gov/blog/wcb-cost-model-virtual-workshop-2012. For the announcement of the workshop questions, *see* http://www.fcc.gov/document/wcb-releases-additional-discussion-topics-connect-america-phase-ll.

5 *USF/ICC Transformation Order*, 26 FCC Rcd at 17735, para. 187.

6 *Id.*

feeder and distribution cable, customer aggregation points, and other network elements. The contractor supplying this model to USAC previously provided related models for submission in the record of this proceeding.[7] Subsequent versions of the model likely will include updates and enhancements such as the use of 2010 Census data, a 2010 commercial business data set (which includes geocoded business addresses), updated network coverage data from the National Broadband Map/State Broadband Initiative, updated wire center boundaries, and network topologies refreshed to reflect new demand data. It is expected that voice costs, on a per subscriber basis, will be added and that the brown field model will include operating expenses and replacement capital expenses for facilities assumed to be already deployed. In addition, it is expected that audit reports for outside plant by wire center and for middle-mile connectivity will be provided. Version two of the model will incorporate some of these updates and is scheduled to be available in the near future.

Before a federal agency may rely on influential scientific information such as this cost model in creating rules, the material must be peer reviewed to enhance the quality and credibility of the government's scientific information.[8] Guidance from the Office of Management and Budget (OMB) requires agencies to provide peer reviewers with "instructions regarding the objective of the peer review and the specific advice sought."[9] The objective of this peer review is to establish whether the Connect America Cost Model can reasonably be used to estimate the forward-looking cost of deploying and operating a modern voice and broadband-capable network. Specifically, we seek your advice on the following issues, from both a theoretical and empirical perspective: (1) whether the methodology and assumptions employed are reasonable and technically correct; (2) whether the methodology and assumptions are consistent with accepted practices in the fields of economics, engineering, GIS, and costing; and (3) whether the model is logically consistent. Please note that the standards for evaluation are not necessarily the same as those one might apply in evaluating studies for publication in a professional journal. For example, it is not necessary that the study present new or novel theoretical results or empirical techniques. Consistent with the requirements of the OMB Bulletin, we are not asking you to "provide advice on policy" or to evaluate any policy implications that might arise from use of this cost model.[10]

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7 *See* Letter from Jonathan Banks, USTelecom, to Marlene H. Dortch, Secretary, FCC, WC Docket Nos. 10-90 and 05-337 (filed Feb. 13, 2012) (attaching updated documentation of the CostQuest Broadband Access Tool or CQBAT model). This submission updated the ABC Coalition's prior proposal for a forward-looking cost model, which had been submitted prior to the release of the *USF/ICC Transformation Order*. Letter from Robert W. Quinn, Jr., AT&T, Steve Davis, CenturyLink, Michael T Skrivan, FairPoint, Kathleen Q. Abernathy, Frontier, Kathleen Grillo, Verizon, and Michael D. Rhoda, Windstream, to Marlene H. Dortch, Secretary, FCC, WC Docket No. 10-90 et al. (filed July 29, 2011).

8 *See* OMB Peer Review Bulletin, 70 Fed. Reg. 2664 (2005), http://www.ssa.gov/515/PeerReviewsFedRegNoticeForFinalBulletin.pdf.

9 *Id.* at 2668, http://www.ssa.gov/515/PeerReviewsFedRegNoticeForFinalBulletin.pdf#page=5.

10 The OMB Bulletin states in relevant part: "Peer reviewers can make an important contribution by distinguishing scientific facts from professional judgments. Furthermore, where appropriate, reviewers

Guidance from OMB further requires that "[r]eviewers shall be informed of applicable access, objectivity, reproducibility and other quality standards under the Federal laws governing information access and quality."[11] The OMB also requires that "peer reviewers ensure that scientific uncertainties are clearly identified and characterized."[12] Finally, please be aware of two other aspects of the peer review process. First, the peer review will not be anonymous. Reviewers are identified and reviews placed in the public record. Past peer reviews conducted for the FCC can be found at: http://www.fcc.gov/omd/dataquality/peer-agenda.html.

Second, the OMB Bulletin requires us to assess whether potential peer reviewers have any potential conflicts of interest.[13] In particular, a "conflict of interest" would exist if you have "any financial or other interest that conflicts with the service of an individual . . . because it could impair the individual's objectivity or could create an unfair competitive advantage for a person or organization."[14] To assist our determination of whether there are any potential conflicts, please indicate whether you have participated in this rulemaking proceeding in any capacity. For your convenience, a list of parties who have participated in the proceeding is attached. A search of the Commission's Electronic Comment Filing System (ECFS) will also be useful in identifying potential conflicts.

I request that you provide a written report of your review, findings, and recommendations with regard to this influential scientific information by January 25, 2013. In recognition of the fact that this peer review requires substantially more effort than is typical, we will award you an honorarium of $1,000 on completion of this work.

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should be asked to provide advice on the reasonableness of judgments made from the scientific evidence. However, the charge should make clear that the reviewers are not to provide advice on the policy…." *Id*. at 2669, http://www.ssa.gov/515/PeerReviewsFedRegNoticeForFinalBulletin.pdf#page=6.

11 *See id.* at 2675, http://www.ssa.gov/515/PeerReviewsFedRegNoticeForFinalBulletin.pdf#page=12 . These standards are discussed in greater detail in OMB's "Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by Federal Agencies," 67 Fed. Reg. 8452 (2002).

12 OMB Peer Review Bulletin. 70 Fed. Reg. at 2669, http://www.ssa.gov/515/PeerReviewsFedRegNoticeForFinalBulletin.pdf#page=6. The Bulletin further states that since not all uncertainties have an equal effect on the conclusions drawn, reviewers should ensure that the potential implications of the uncertainties for the technical conclusions drawn are clear. In addition, peer reviewers might be asked to consider value-of-information analyses that identify whether more research is likely to decrease key uncertainties. Value-of-information analysis was suggested for this purpose in the report of the Presidential/Congressional Commission on Risk Assessment and Risk Management. A description of additional research that would appreciably influence the conclusions of the assessment can help an agency assess and target subsequent efforts. *Id.*

13 *Id*. at 2670, http://www.ssa.gov/515/PeerReviewsFedRegNoticeForFinalBulletin.pdf#page=7.

14 *Id*.