Assessing the Consequences of Additional FCC Regulation of Business Broadband: An Empirical Analysis

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By Hal Singer[1]

Executive Summary

This paper seeks to model the likely impact of the FCC's recent effort to preserve and extend its special access rules on broadband deployment, as telcos transition from TDM-based copper networks to IP-based fiber networks to serve business broadband customers. The deployment impact of expanded special access rules can be measured as the difference between (1) how many buildings would have been lit with fiber by telcos in the absence of the rules and (2) how many buildings will be lit with fiber by telcos in the presence of the rules. With an estimate of the cost per building, the deployment impact can be converted into an investment impact. And with estimates of broadband-specific multipliers, the fiber-to-the-building network investment impact can be converted into job and output effects.

The investment model developed here combines geospatial fiber-cost modeling with unlit-building Ethernet revenue modeling to construct building-specific net-cash flow curves. The model is used to build a business case for extending connections from existing telco network facilities to new buildings where telcos do not have fiber to serve business customers. Charlotte, North Carolina was chosen as the subject for the geospatial cost modeling because the density of its establishments is representative of the typical U.S. city. Charlotte very closely matches the national average number of total establishments (84,643 versus 83,530 average), the average number of large establishments (5,527 versus 5,291 average), and large establishments per square mile (1.1 versus 1.0 average). AT&T and Level 3 have the most lit buildings in Charlotte (636 and 541, respectively). Across all providers, there are 726 unique lit buildings, which represent 12 percent of the total buildings with 20 or more employees (6,257) in Charlotte.

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The model shows that a significant number of buildings in Charlotte would qualify for investment in the absence of any expanded special access regulation. The model then measures the extent to which regulation—including price-cap and/or wholesale requirements (that reduce expected revenues)—erode the ILEC business case for fiber extension. Because the ILEC business case is sensitive to changes in expected revenue or operating expenses, regulation results in a reduction in the number of buildings that can be profitably lit with fiber and a corresponding reduction in investment. The predicted investment effects in Charlotte are scaled to measure the impact of special access regulation nationally. The investment effect measured here does not include the regulatory impact on CLEC and cable fiber-to-the-building network investment, which economic theory predicts would also decline.[2]

The major findings of the paper are as follows:

- Monthly Ethernet prices (per unit) of a leading broadband business provider declined between seven and seventeen percent from December 2013 to June 2015, indicating that the business broadband markets are competitively supplied. Regulatory intervention in competitive markets to push prices downward is likely to generate costs (dynamic inefficiency from less investment and innovation, allocative inefficiency from prices that do not cover marginal costs) in excess of benefits (static welfare gains from lower prices).

- Nearly 30 competitive broadband providers have lit at least 1,000 buildings each with fiber. Collectively, these competitors serve over 267,000 buildings with fiber, laying over 650,000 route miles of fiber, or 2.42 route miles per building. By comparison, AT&T's fiber network reached 500,000 route miles by January 2016.

- From 2010 to 2015, the four major pure-play fiber service providers—Zayo, Level 3, Lightower, and TW Telecom—lit over 40,000 buildings, laid approximately 60,000 miles of metro fiber, and invested approximately $6 billion in fiber infrastructure.

- Level 3's CFO, Sunit Patel, offered a cost-per-building estimate of between $50,000 and $100,000. Based on our cost model for Charlotte, we estimate an average cost per building of $76,000, which is close to the midpoint of Mr. Patel's range ($75,000). Others have estimated

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2. Cable operators have indicated in filings and letters with the Commission that mispriced resale opportunities for CLECs will undermine cable's incentive to invest their own facilities, further undermining deployment. *See* Reply Comments of NCTA, In the Matter of Special Access for Price Cap Local Exchange Carriers, WC Dkt. No. 05-25, RM-10593, Feb. 19, 2016, at 4 ("Given the substantial consumer benefits that have resulted from this facilities-based competition, the most important task for the Commission in this proceeding is to ensure that it preserves incentives for continuing and expanding facilities-based competitive entry and investment."). *See also* NCTA Letter to Marlene Dortch, Re: Special Access, WC Dkt. No. 05-25, Mar. 22, 2016 ("The Commission should reject policy proposals that would undermine the incentives for continued investment in new facilities by regulating incumbent LEC special access rates in geographic areas where cable operators and others have invested, or are likely to invest, in facilities to serve business customers. Proposals from certain competitive LECs to regulate rates in any building with fewer than four facilities-based providers would essentially compel rate regulation of all business services on a nationwide basis, which would result in substantial harm by discouraging all providers (incumbents and competitors) from investing in new facilities.").

higher costs, but those estimates are upwardly biased because they do not reflect the typical urban business environment.

- Based on our cost-per-building estimate in Charlotte, the aggregate capital expenditure needed to wire all unlit buildings in the United States would be between $52 and $75 billion based on Vertical Systems and FiberLocator business-fiber penetration data, respectively. Although it is highly unlikely that 100 percent business-fiber penetration is achievable, this calculation is meant to indicate the maximum upside for the U.S. economy.

- For purposes of measuring the impact on fiber penetration, our study is limited to Ethernet over dedicated fiber, which is the equivalent architecture to the special-access (private) dedicated lines that have traditionally served medium-to-large businesses. In the absence of any new regulation (the "Baseline Case"), an ILEC is predicted to increase business-fiber penetration in Charlotte from 10 to 20 percent over the coming years, an increase of 589 lit buildings, 18.6 metro fiber route miles, and $47.5 million in investment.

- Next, we model a scenario where special-access price regulation extends to the ILECs' fiber networks. Assuming this scenario reduces an ILEC's expected Ethernet revenue by 30 percent—the typical price effect associated with prior episodes of price-cap regulation and unbundling—the model predicts that ILEC will increase business-fiber penetration from 10 to 14 percent (compared to 20 percent in the Baseline Case), an increase of only 265 lit buildings, 10.8 metro fiber route miles, and $21.4 million in investment. Thus, the special access obligations under this scenario result in a 55 percent reduction in an ILEC's CapEx relative to the Baseline Case.

- Extrapolating the results from Charlotte to the nation suggests that, in the absence of any regulation, ILECs would increase business-fiber penetration by ten percentage points over the coming years—the same percentage point increase predicted in Charlotte—lighting an additional 122,400 buildings with fiber, adding 4,900 new fiber route miles, resulting in $9.9 billion in additional investment. In contrast, when the special-access price regulations extend to fiber networks, ILECs would increase penetration by only four percentage points, lighting an additional 55,100 buildings with fiber, adding only 2,200 new fiber route miles, resulting in $4.4 billion in additional investment. Thus, expansion of special access price regulation to Ethernet services is predicted to reduce ILEC fiber-based penetration by 67,300 buildings nationwide—a result that is hard to reconcile with the FCC's mandate to encourage broadband deployment.

- We present a range of sensitivity analyses for this regulatory scenario. For example, if the special access price regulation reduces Ethernet revenues by only 27 percent (compared to 30 percent in the Baseline Case), investment falls by $5.0 billion in Charlotte (as opposed to $5.4 billion). Relative to the Baseline Case, nominal investment levels are most sensitive to the assumed payback period.

- Based on original empirical analysis and the economics literature, reviewed in Part V, the estimated impact of unbundling on incumbent investment appears to range from approximately 6 to 49 percent. Thus, the likely investment effect under the most plausible scenarios predicted by the investment model (55 percent) fits is closer to the high end of the range of observed effects in the literature.

- Several researchers have used a jobs multiplier of approximately 20 jobs per million dollars of broadband investment. I adopt that figure here to estimate the initial job impact associated with the FCC's special access rules. Because the multipliers are stated in terms of annual effects, I spread the predicted investment loss equally across five years, consistent with the short-run horizon (roughly five years) of the investment model. Before considering spillover effects, the FCC's expanded special access rules could eliminate 43,560 jobs annually over a five-year period. Similarly, using a fiber-construction output multiplier of 3.12, expansion of the special access rules is expected to reduce economic output by 3.4 billion per year over a five-year period.

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I. Introduction

The Federal Communications Commission (FCC) is exploring a multi-pronged regulatory agenda that seeks to manage the inner workings of one segment of the broadband Internet access market aimed at business customers ("business broadband market"). Although this regulated segment of the larger business broadband market is largely quarantined to relatively slow connections running over a fading technology (copper), the agency's recent efforts threaten to expand its foothold into a much larger and growing segment of the business broadband market, allowing the agency to regulate high-speed Ethernet services running over fiber lines.[3]

The segment of the business broadband market currently regulated by the FCC is referred to as "special access" services. As its name suggests, the FCC compels incumbent local exchange carriers (ILECs) to provide access at regulated rates to their copper-based lines used to serve businesses, including wholesale access to competitive providers, such as resellers,[4] mobile operators,[5] and middle-mile providers.[6] (Cable operators serving the same businesses are not subject to these special-access requirements.) Competitive providers can exploit two regulated entry paths: (1) purchase an ILEC's DS-1 or DS-3 service for resale at a term- or volume-based discount from the tariffed retail rate; or (2) purchase an ILEC's unbundled network elements (for example, a copper loop) at regulated rates, which in turn can be combined and used to provide DS-1 or DS-3 service.[7] Like mandatory access or mandatory unbundling, special access allows competitive providers to obtain an ILEC's network elements or services on a wholesale basis, at terms and conditions that are superior to those that would be achieved under a voluntary access arrangement.

Over the last decade, since the FCC granted forbearance from regulating Ethernet services, special-access obligations have been limited to an ILEC's time-division multiplexing (TDM)-based services running on copper networks, which are typically used to provision DS-1 and DS-3 connections to business customers.[8] Relative to these TDM-based services running on copper networks, fiber-based connections give business customers greater flexibility, as they can be configured to accommodate any desired bandwidth (typically over 10 Mbps). Because business customers increasingly demand greater speed[9] and flexibility,[10] fiber connections

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3. Unlike TDM-based DS-1 and DS-3 service, Ethernet service is not tariffed.

4. Competitive local exchange carriers rely on special access to supply or supplement capacity for resale to their own business customers. For a review of the history of special access regulation, see Larry Downes, The Losing Case for Special Access Regulation, Georgetown Center for Business and Public Policy Paper, Nov. 2015, *available at* http://cbpp.georgetown.edu/sites/cbpp.georgetown.edu/files/Larry_Downes_PolicyPaper_SpecialAccess%2012.14.15.pdf.

5. Mobile operators rely on special access to provide backhaul for mobile voice and data traffic.

6. Middle-mile providers rely on special access to provide last-mile connections for their business customers.

7. FCC, Special Access Data Collection—Glossary of Terms, *available at* https://www.fcc.gov/general/special-access-data-collection-glossary-terms.

8. DS-1 and DS-3 connections offer users (in this case, employees of a firm) bandwidth of 1.5 Mbps and 45 Mbps, respectively.

9. For example, Comcast advertises that its "Business Ethernet Network Services can seamlessly network you with 10 Mbps, 100 Mbps, 1 Gbps, or 10 Gbps Ethernet User-to-Network Interfaces (UNI) that are Certified MEF Compliant." Comcast Business Ethernet Network Services, *available at* http://business.comcast.com/ethernet/products/network-services (accessed Dec. 30, 2015).

offering IP-based services are displacing TDM-based services.[11] One analyst conservatively projects that access providers could discontinue selling DS-1 and DS-3 lines in seven years at the current rate of substitution.[12] Recent regulatory developments threaten to expand the scope of special-access obligations considerably, including into areas of the business broadband market for which the FCC granted forbearance and other regulatory relief less than a decade ago.[13]

In December 2012, the FCC released an order calling for the mandatory collection of data from entities that provide or purchase special access services.[14] Rather than limit its inquiry to TDM-based services, however, the FCC sought information on "the full array of traditional special access services, including DS1s and DS3s, and

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10. Danielle Young, U.S. Ethernet WAN Access Enables Digital Business Strategies, Gartner Group, Oct. 6, 2015 ("Compared to broadband, T1 or T3 access, fiber-based Ethernet access is more reliable and agile. Ethernet can support higher bandwidths at lower cost.") [hereafter *Gartner Group*].

11. Roger Entner, *Special access—How government preference for some may mean higher prices for all*, FIERCE WIRELESS, Oct. 21, 2015 ("Zayo's data shows a *massive shift to Ethernet connections*, which are both faster and cheaper than DS1/DS3, and where the marketplace is essentially even as new entrants and incumbents are building capacity at the same time.") (emphasis added), *available at* http://www.fiercewireless.com/story/entner-special-access-how-government-preference-some-may-mean-higher-prices/2015-10-21; Vertical Systems, Mid-Year 2015 U.S. Carrier Ethernet Leaderboard, Aug. 24, 2015 ("Primary drivers for growth [in the Ethernet segment] are *massive migration from TDM to Ethernet services*, robust demand for higher speed Ethernet private lines and rising requirements for connectivity to public and private Clouds.") (emphasis added), *available at* http://www.verticalsystems.com/vsglb/mid-year-2015-u-s-carrier-ethernet-leaderboard/. See also Report of Dennis Carlton, Mark Israel, Allan Shampine & Hal Sider, In the Matter of Investigation of Certain Price Cap Local Exchange Carrier Business Data Services Tariff Pricing Plans, WC Dkt. No. 15-247, Jan. 7, 2016, ¶ 19 (noting that between January 2013 and October 2015, AT&T's sales of TDM DS-1 services to non-affiliates declined rapidly).

12. Entner, *supra* ("If we take Zayo's data and project out the current decline rate then they will have stopped selling DS1s in three and a half years and DS3s in less than seven years. But these projections are deceiving, and likely too conservative, as declines are accelerating as the DS1/DS3 technology becomes increasingly obsolete.").

13. In 2003, the FCC relieved ILECs of most obligations to lease advanced fiber-to-the-home (FTTH) network facilities to competitors at a regulated, cost-based price. In the Matter of Review of the Section 251 Unbundling Obligations of Incumbent Local Exchange Carriers, CC Dkt. No. 01-338 (released Aug. 21, 2003). However, until December 2015, ILECs were still required to provide unbundled access to a voice grade equivalent channel and high capacity loops utilizing TDM technology, such as DS-1s and DS-3s. *Id*. at 11. In 2006, the FCC granted Verizon's petition for forbearance from Title II for certain business broadband services, including "packet-switched broadband services, such as Frame Relay and Asynchronous Transfer Mode Cell Relay (ATM) as well as non-time division multiplexing-based (non-TDM-based) optical networking, optical hubbing, and optical transmission services." Joint Statement of Chairman Kevin J. Martin and Commissioner Deborah Taylor Tate, Petition of the Verizon Telephone Companies for Forbearance under 47 U.S.C. § 160(c) from Title II and Computer Inquiry Rules with Respect to Their Broadband Services, WC Dkt. No. 04-440 (released Mar. 21, 2006). In 2007, the FCC granted similar relief to AT&T. In Petition of AT&T Inc. for Forbearance Under 47 U.S.C. § 160(c) from Title II and Computer Inquiry Rules with Respect to Its Broadband Services, Memorandum Opinion and Order, WC Dkt. No. 06-125 (released Oct. 12, 2007).

14. In the Matter of Special Access for Price Cap Local Exchange Carriers, WC Dkt. No. 05-25, Report and Order and Further Notice of Proposed Rulemaking, released Dec. 18, 2012.

packet-based dedicated services such as Ethernet."[15] By including Ethernet in its investigation, the FCC blurred the traditional lines that segmented regulated from unregulated enterprise services, and thereby raised the specter of expanding price regulations to fiber-based connections. The FCC concurrently issued a *Further Notice of Proposed Rulemaking*, which sought comment on, among other things, the terms and conditions offered by ILECs for the sale of special access services.[16] In particular, the NPRM asked whether "is it *still* appropriate to grant Phase I and Phase II pricing flexibility and, if so, what factors should guide the level of relief granted."[17] Phase I flexibility permits price-cap LECs to lower their rates, while Phase II flexibility permits price-cap LECs to raise or lower their rates throughout an area. The NPRM was agnostic as to the ILEC's technology—copper versus fiber—used to establish a connection to a business.[18]

How would price regulation of Ethernet services manifest itself? Although the FCC's December 2012 NPRM was opaque, recent comments by CLECs in the proceeding make clear precisely what they are after. For example, a coalition of CLECs including Level 3 lamented that "[d]ue to the Commission's forbearance decisions, the major incumbent LECs are not subject to dominant carrier regulation in the provision of certain Ethernet-based services."[19] They urged the FCC to "apply price cap regulation to incumbent LECs' DSn-based dedicated services subject to Phase II pricing flexibility and to their packet-based dedicated services (i.e., by adding these services to the price cap basket for special access services)."[20] With regard to wholesale rates, they proposed "that each incumbent LEC provide dedicated services to wholesale customers at prices that are no higher than the incumbent LEC's retail price minus the costs that are 'avoided' when the services are offered at wholesale."[21] Similarly, Sprint asked the FCC to take action by "returning services subject to Phase II pricing flexibility to the price cap regime and taking steps necessary to include Ethernet services under the price cap regime."[22] With regard to pricing, Sprint proposed "using existing models that measure costs of service to set appropriate caps on prices."[23]

Another indication of price regulation of Ethernet services can be gleaned from the FCC's *Technology Transition Order*, which sought to extend the FCC's purview into

15. *Id.* ¶17.
16. *Id.* ¶57.
17. *Id.* ¶85 (emphasis added).
18. *Id.* ¶15 n.38 ("We note that this definition [of a connection] does not depend on the medium used (e.g., whether it is fiber, copper, or coaxial cable), but instead on the capability of the facility.").
19. Comments of Birch, BT Americas, EarthLink and Level 3, In the Matter of Special Access Rates for Price Cap Local Exchange Carriers, WC Dkt. No 05-25 (filed Jan. 27, 2016), at 8.
20. *Id.* at 9.
21. *Id.*
22. Comments of Sprint Corporation, In the Matter of Special Access for Price Cap Local Exchange Carriers, WC Dkt. No. 05-25 (filed Jan. 27, 2016), at vi.
23. *Id.*

an ILEC's fiber-based connections for business customers.[24] In particular, the FCC adopted a rule that required ILECs "that discontinue a TDM-based service to provide competitive carriers *reasonably comparable wholesale access* on reasonably comparable rates, terms, and conditions during the pendency of the special access proceeding."[25] If an ILEC seeks to replace its copper-based connections to a business, it now faces a fresh disincentive to invest in fiber, in that the wholesale-access requirements will extend to its Ethernet services provided over a fiber-based network. The FCC clarified that "the reasonably comparable wholesale access condition that we adopt applies to two categories of service: (1) special access services at DS-1 speed and above; and (2) commercial wholesale platform services such as AT&T's Local Service Complete and Verizon's Wholesale Advantage."[26] Put differently, the FCC plans to regulate both entry paths—special access *retail* services (acquired at a discount) and the *wholesale* inputs (or platforms) used to provide those services—for competitive providers.

For the first time, these wholesale-access requirements would implicate an ILEC's fiber connections. In his dissent, Commissioner Pai explained that "the Commission now leverages its discontinuance authority to get a foothold in the Ethernet market, exporting its legacy economic regulations into an all-IP world."[27] Commissioner O'Rielly similarly recognized the threat to fiber investment: "Providers that had voluntarily agreed to offer a commercial wholesale platform service to ease the transition for competitive carriers after the obligation to provide UNE-P was struck down by the Courts are now being forced to carry it forward into an IP world for a to-be-determined duration."[28]

In addition to exporting these wholesale obligations into an all-IP world, the FCC has embraced two other policies that threaten to undermine ILEC fiber-based investment. *First*, in February 2015, the FCC reclassified broadband Internet access service (BIAS) as a telecommunications service, subjecting providers to traditional common carrier requirements.[29] To allay investor fears, the FCC simultaneously forbore from imposing the most onerous common-carrier obligations, including rate regulation and unbundling.[30] Because such forbearance could be reversed by the

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24. In the Matter of Technology Transitions Policies and Rules Governing Retirement Of Copper Loops by Incumbent Local Exchange Carriers, Report and Order, Order on Reconsideration, and Further Notice of Proposed Rulemaking, GN Dkt. No. 13-5, released Aug. 7, 2015 [hereafter *Tech Transitions Order*].

25. *Id.* ¶101 (emphasis added).

26. *Id.* ¶132.

27. Dissenting Statement of Commissioner Ajit Pai, at 175.

28. Dissenting Statement of Commissioner Michael O'Rielly, at 177.

29. In the Matter of Protecting and Promoting the Open Internet, GN Dkt. No. 14-28 (released Mar. 12, 2015).

30. *Id.* ¶37 ("Today, our forbearance approach results in over 700 codified rules being inapplicable, a "light-touch" approach for the use of Title II. This includes no unbundling of last-mile facilities, no tariffing, no rate regulation, and no cost accounting rules, which results in a carefully tailored application of only those Title II provisions found to directly further the public interest in an open Internet and more, better, and open broadband.").

current FCC (if it changed its mind) or by a future FCC, reclassification of broadband Internet access services (BIAS) potentially opens the door to full retail rate regulation of Ethernet-based services that are delivered in standardized (as opposed to customized) form.[31]

Second, in October 2015, the FCC launched an investigation of the non-price terms in ILECs' special-access contracts with competitors.[32] The *Investigation Order* seeks to determine whether, for example, the use of percentage commitments, shortfall fees, overage penalties, and long-term commitments in certain tariffed pricing plans is just and reasonable or unreasonably discriminatory under various section of the Communications Act.[33] Because the FCC has signaled a willingness to unwind contracts between ILECs and access seekers, potentially invading the purview of antitrust laws designed to address these very non-price terms, the investigation exposes special access providers to a new regulatory risk.

It is hard to know which of these regulatory developments poses the greatest threat to fiber investment by ILECs. Given how we model Ethernet price regulation—via a reduction in Ethernet retail prices and thereby a reduction in the ILEC's expected Ethernet revenue from any given lit building—our model spans the panoply of threats embodied in the FCC's special access proceedings. Put differently, whether an ILEC's Ethernet prices are suppressed by (retail) price-cap rules or by (wholesale) unbundling rules does not alter the outcome. The model considers two regulatory scenarios, described more fully in Part III:

(1) ILECs Ethernet services are subject to price-cap regulation or ILECs are compelled to make fiber-based connections available as a wholesale product on "just and reasonable" terms and conditions to competitors ("Price Regulation");

(2) ILECs are free from the special access obligations as they apply to fiber-based connections ("Baseline Case").

For each regulatory scenario outlined above, I estimate the associated ILEC investment in Charlotte, North Carolina, a city that is reasonably representative of the average commercial metropolitan statistical area in terms of total/large establishments, total/large establishments per square miles, and municipal fiber presence. The difference between any given regulatory case and the Baseline Case is

31. *Id.* ¶189 (For the purpose of defining the scope of the rules, the term "mass market" excluded "enterprise service offerings, which are typically offered to larger organizations through *customized* or individually-negotiated arrangements, or special access services.") (emphasis added). Thus, Ethernet sold on a standardized basis to small and mid-sized businesses appears to be within the scope of BIAS as defined in the *Open Internet Order*.

32. In the Matter of Investigation of Certain Price Cap Local Exchange Carrier Business Data Services Tariff Pricing Plans, Order Initiating Investigation and Designating Issues for Investigation, WC Dkt. No. 15-247 (released Oct. 16, 2015) [hereafter *Investigation Order*].

33. *Id.* ¶¶30-105.

the forgone investment attributable to that strand of regulation. The investment effects in Charlotte are then extrapolated to the national level.

We combined geospatial fiber cost modeling with unlit building Ethernet revenue modeling to construct building net cash flow curves under both regulatory scenarios. The cost modeling makes use of a minimum spanning-tree algorithm. The precise way in which these regulatory scenarios are modeled is described more fully in Parts III and IV. Before turning to the modeling of the new regulatory landscape, I briefly review the state of competition for business broadband services in Part II. Part V compares the results from the investment model to prior estimates of the impact of mandatory unbundling in the economics literature. In Part VI, I convert the estimated investment impact into a lost jobs/lost output figure based on traditional multipliers. Part VII concludes.

II. The State of Competition for Business Broadband Services

The state of competition for business broadband can be characterized in terms of structural measures (market shares), performance measures (pricing), and dynamic considerations such as entry, innovation, and investment. To the extent that the business broadband market is competitively supplied, regulatory intervention likely would generate greater harms (dynamic loss from less investment and innovation plus allocative inefficiencies from prices below costs) than benefits (static welfare gains from price reductions).

A. Structural Measures

In its *Investigation Order*, the FCC estimates that the market for "business data services" (which the Commission uses synonymously with the term "special access services") was $40 billion in 2013,[34] and that TDM-based services account for roughly 60 percent of this larger enterprise market[35] or $25 billion.[36] The FCC further estimates that ILECs accounted for about two-thirds of TDM-based revenues in the same year.[37] To the extent that business customers perceive these access technologies to be broadly interchangeable, however, it is inappropriate to assume that TDM-based business data services are a separate product market from IP-based business data services such as Ethernet. Clearly, businesses are substituting (at competitive rates) to Ethernet services at a fast clip from several providers, including cable operators, which rebuts the presumption that a hypothetical monopoly provider of TDM-based services could profitably raise prices over

34. *Investigation Order* ¶2.
35. *Id.*
36. *Id.* ¶14.
37. *Id.* ¶3.

competitive rates.[38]

To the extent that cable operators and middle-mile providers have made greater inroads in the fast-growing Ethernet segment, dividing the business broadband market into TDM versus non-TDM-based services—and claiming that ILECs account for two-thirds of the purported TDM-based services market—provides a distortionary view of the ILECs' market status. For example, by the end of 2012, cable operators captured one quarter of U.S. Ethernet service revenues.[39] Indeed, cable operators installed more new retail Ethernet ports than the large ILECs over the first half of 2013.[40]

AT&T, Verizon, and CenturyLink, the three largest ILECs, collectively accounted for only 47 percent of Ethernet service revenue in the first half of 2013,[41] and for only 39 percent of U.S.-based, browser-based business Internet traffic as of September 2011.[42] Combined with the FCC's estimate of (1) TDM's share of business broadband revenues (60 percent) and (2) ILECs' share of TDM-based services (67 percent), the FCC-implied weighted-average ILEC share of the business broadband market is

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38. As a fallback position, advocates for expanded special access rules allow that TDM- and Ethernet-based *dedicated* services are in the same product market, but that ILECs are dominant in that larger segment based on ILECs' share of in-building connections. *See, e.g.*, Letter from Thomas Jones, Attorney for tw telecom, to Marlene H. Dortch, Secretary, FCC, WC Docket No. 05-25, RM-10593, at 3-4 (filed June 5, 2012) (tw telecom June 5, 2012 Ex Parte Letter). But this argument requires exclusion from the relevant market of "best efforts" services, such as cable modem DOCSIS, and fixed wireless, which clearly compete for business broadband customers. *See, e.g.*, Windstream Business, Fixed Wireless, Frequently Asked Questions ("HOW FAST IS FIXED WIRELESS SERVICE? Windstream provides our customers with dedicated connections that offer speeds of 1.5 Mbps (megabit per second) to 1 Gigabit") (downloaded Mar. 8, 2016), *available* at http://www.windstreambusiness.com/resources/faqs/fixed-wireless; BCG Perspectives, Connecting Rural Markets: How Fixed Wireless Is Unlocking Digital—Everywhere ("When the economics are right, fixed wireless can give customers reliable access to advanced applications (such as streaming video and enterprise solutions) and offer carriers a range of benefits (such as remote management, traffic policing, and other network-grade features).") (downloaded Mar. 8, 2016), *available at* https://www.bcgperspectives.com/content/articles/telecommunications_digital_economy_connecting_rural_markets_fixed_wireless_unlocking_digital_everywhere/?chapter=2.

39. Cable MSOs Move in on Ethernet Sales, Heavy Reading Finds, Aug. 9, 2013, *available at* http://www.prnewswire.com/news-releases/cable-msos-move-in-on-ethernet-sales-heavy-reading-finds-219001661.html.

40. Cable Goes on Ethernet Role, Aug. 22, 2013, LightReading, *available at* http://www.lightreading.com/cable-video/cable-goes-on-ethernet-roll-/d/d-id/705332.

41. Business Services Grab Spotlight, LightReading, *available at* http://www.lightreading.com/ethernet-ip/ethernet-services/business-services-grab-spotlight-at-esdn-/d/d-id/705860. This figure does not distinguish an ILEC's revenue from that of its out-of-region affiliates. On the other hand, some portion of the out-of-region revenue may be retail revenue for services using wholesale last-mile inputs, and some of those wholesale inputs may be purchased from one of these other ILECs.

42. Sean Buckley, *AT&T, Verizon carry most U.S. business traffic, but competitors gain ground*, FIERCE WIRELESS, Nov. 15, 2011 (citing comScore data), *available at* http://www.fiercetelecom.com/story/att-verizon-carry-most-us-business-traffic-competitors-gain-ground/2011-11-15.

roughly 59 percent (equal to 67% x 60% + 47% x 40%).[43] Because Ethernet represents the future of the enterprise market, a better measure of ILECs' *forward-looking* market share is 47 percent (or even less given current trends), as TDM-based services achieve zero weight in a future weighted-average ILEC share. And the forward-looking perspective is what matters when regulators are evaluating the future ability of a firm to exercise market power.

Indeed, historical market share may not be indicative of an ILEC's pricing power given the nature of cost and competition in the business broadband market. As explained by Professor Glen Wororch and his co-authors:

> We understand that some parties to this proceeding have suggested that historical market shares are useful for assessing the extent of competition in the special access marketplace. That is incorrect. While market shares can be informative in certain competitive settings, they are less informative in dynamically and rapidly evolving marketplaces such as we have here. More importantly, the characteristics of dedicated services markets are such that sunk investment in network facilities provides a more accurate and complete assessment of competition.[44]

They further explain that the winning bidder of a contract to supply a business with 100 percent of its broadband access needs can be effectively constrained by alternative bids submitted by competing suppliers or by the threat of such bids.[45]

Non-ILECs continue to make inroads in the sale of Ethernet services. By mid-year 2015, Vertical Systems placed five non-ILECs—Level 3, Time Warner Cable, Comcast, XO, and Cox—on its mid-year 2015 Ethernet "Leader Board," which requires a share of at least four percent of billable port installations for Ethernet services.[46] Vertical Systems placed six other non-ILECs—Bright House, Charter, Cogent, Lightpath, Windstream and Zayo—on its "Challenge Tier," which requires a share of between one and four percent of billable port installations. Vertical Systems released a new Leader Board for the end of 2015, with Windstream moving from the Challenge Tier into the Top Tier,[47] indicating a market share of at least four percent.

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43. This FCC-implied estimate is corroborated by D.A. Davidson. *Business bandwidth demand lights up once dark fiber sector*, REUTERS, June 25, 2014 ("Market leaders in the local fiber space are AT&T, Verizon and CenturyLink, which have a combined 60 percent market share of the business enterprise market, Jaegers said."), *available at* http://www.reuters.com/article/us-fibernetworks-analysis-idUSKBN0F013A20140625;

44. Mark Israel, Daniel Rubinfeld, and Glen Woroch, Competitive Analysis of the FCC's Special Access Data Collection, Jan. 27, 2016, at 8, *available at* http://innovatewithus.org/wp-content/uploads/2016/02/Econ-White-Paper-PUBLIC.pdf.

45. *Id.* at 9.

46. Vertical Systems, Mid-Year 2015 U.S. Carrier Ethernet Leaderboard, Aug. 24, 2015, *available at* http://www.verticalsystems.com/vsglb/mid-year-2015-u-s-carrier-ethernet-leaderboard.

47. Vertical Systems, 2015 U.S. Carrier Ethernet Leaderboard, Feb. 25, 2016, *available at* http://www.verticalsystems.com/vsglb/2015-u-s-carrier-ethernet-leaderboard/

While ILECs might be dominant in the purported TDM-based services market, cable operators and middle-mile providers have made significant inroads in the fastest growing segment of the enterprise services market.

Table 1 shows estimated historical market shares of the business broadband market, which combines TDM-based and non-TDM-based services based on publically available data.

TABLE 1: HISTORICAL BUSINESS BROADBAND MARKET SHARES (2014)

Type	Providers	Shares
ILECs	AT&T, Verizon, CenturyLink	60%
Cable Operators	Comcast, Cox, Bright House, Charter, Time Warner, Cablevision	10-12%
Middle-Mile	Level 3, tw telecom	7-8%
Rest of the Pack	Zayo, Cogent, Lightpath, Windstream, XO, others	20-23%

Sources: Business bandwidth demand lights up once dark fiber sector, REUTERS, June 25, 2014 (citing D.A. Davidson & Co), *available at* http://www.reuters.com/article/us-fibernetworks-analysis-idUSKBN0F013A20140625; Business Services Grab Spotlight, LightReading, *available at* http://www.lightreading.com/ethernet-ip/ethernet-services/business-services-grab-spotlight-at-esdn-/d/d-id/705860.

Because the ILEC footprints are non-overlapping, and because the cable footprints are non-overlapping, the national metrics provide a reasonable proxy for the historical shares of a representative local broadband business market. It bears repeating that the historical ILEC shares listed in Table 1 likely overstate their forward-looking share of the enterprise market, as Ethernet overtakes TDM-based services and as cable operators and other competitors capture an ever-increasing share of Ethernet revenues.

B. Performance Measures

Over the last few years, market-based transaction prices for business broadband services are holding steady or declining, which is also inconsistent with the claim that ILECs' possess market power in the business broadband market. Zayo, a backhaul and special access provider, provides pricing trend data for special access.[48] According to its survey, monthly recurring revenue (MRR) per unit for DS-1 held steady at $200 from December 2013 through June 2015. MRR per unit for DS-3s also held steady at $1,200 over this period. By comparison, Ethernet prices have been trending downwards.[49] For example, MRR per unit for Fast E Ethernet (10 to 100 Mb) declined from $1,300 to $1,200 (a decline of 7.6 percent).[50] (That DS-3 and

48. Zayo FY2015 Supplemental Earnings Information, *available at* http://investors.zayo.com/~/media/Files/Z/Zayo-IR/earnings-releases/2015/zgh-fy2015q4-pricing-trends.pdf.

49. *Id.*

50. *Id.*

Fast E Ethernet prices have converged to the same price indicates these services are perceived as reasonably interchangeable.) MRR per unit for fractional GigE Ethernet (101 to 1000 Mb) declined from $2,300 to $1,900 (a decline of 17.4 percent).[51] MRR per unit for GigE Full Rate (over 1000 Mbs) declined from $3,300 to $2,900 (a decline of 12.1 percent).[52] Gartner Group expects the price of Ethernet access to fall by about nine percent per year from 2015 to 2018.[53]

Multiple fiber service providers, CLECs, MSOs, and ILECs have expanded their fiber footprints over the past years, increasing competition and pressure on Ethernet prices. Demand for Ethernet services has been growing due to high demand for cloud services, data center and tower backhauling circuits. Steep Ethernet price declines demonstrate the very competitive nature of this market.

C. Recent Entry and Expansion

Evidence of rapid entry suggests that the ILECs' ability to exercise marker power in business broadband will be severely constrained.[54] This section briefly reviews recent investments by cable operators, mobile operators, and middle-mile providers in the business broadband market, indicating that these entrants are committed to competing aggressively for enterprise customers in the near term.

As indicated above, cable operators are making significant advances in the supply of Ethernet services. Comcast reported "continued growth in the number of customers receiving [its] Ethernet network and cellular backhaul services."[55] In the first quarter of 2015 alone, Comcast's Business Services revenue "grew 21.4% to over $1.1 billion."[56] In just the first eight months of 2015, Comcast has added new fiber in Vermont; Connecticut; Portland; Denver; northern California; and Salt Lake City.[57] In September 2015, Comcast announced it plans to serve customers outside of its territory, including in Los Angeles in New York City, via partnerships with other cable companies.[58] In the first nine months of 2015, Time Warner "added 50,000 commercial [buildings] to [its] network, representing almost $750 million in serviceable annual opportunity."[59] Spectrum Business, the division of Charter that

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51. *Id.*

52. *Id.*

53. *Gartner Group*, *supra*.

54. Entry by CLECs and cable companies has not only been swift, but also profitable. *See* Anna Marie Kovacs, Business Broadband: Assessing the Case for Regulation, Georgetown Center for Business and Public Policy Brief, Mar. 14, 2016 (showing that CLECs and cable companies are generating higher free cash flow than the wireline segments of the largest ILECs).

55. Comcast Corp., Form 10-K, at 59, filed Feb. 27, 2015.

56. Comcast, 1st Quarter 2015 Results, at 5, May 4, 2015.

57. Various Comcast press releases.

58. Comcast Business Press Release, *Comcast Business Announces New Unit Targeting Fortune 1000 Enterprises* (Sept. 16, 2015), *available at* http://corporate.comcast.com/news-information/news-feed/comcast-business-announces-new-unit-targeting-fortune-1000-enterprises.

59. SA Transcripts, Time Warner Cable Q3 2015 Results—Earnings Call Transcripts (Oct. 29, 2015) (Oct. 29, 2015) (statement by Senior Vice President, Treasurer, and Acting Co-Chief Financial

focuses on business broadband, invested more than $800 million in capital expenditures over the last three years.[60] Charter committed to "invest at least $2.5 billion in the build-out of networks into commercial areas within [its] footprint, beyond where [it] currently operate[s]" over the coming years.[61] Charter, which serves 12,000 lit buildings,[62] claims that it is expanding Ethernet capability "to nearly 300 new companies/buildings in Charter markets every month."[63] Cox Business, which has at least "28,000 fiber lit buildings, 400,000 fiber near-net buildings and over 300,000 HFC serviceable buildings,"[64] announced that it "is on target to exceed $2 billion in revenues by 2016."[65]

Mobile operators have dramatically reduced their dependence on ILECs. For example, T-Mobile has deployed fiber backhaul connections at 50,000 of its 54,000 cell sites.[66] In addition to providing wireless services, Sprint is a major provider of Ethernet, wireless backhaul (to itself and other mobile operators), and other business broadband services.[67]

Finally, middle-mile providers including Windstream, Level 3, and XO Communications, are investing in their own facilities. For example, XO recently completed fiber-construction projects into nearly 550 enterprise buildings across 25 regional markets.[68] Throughout 2016, XO plans to add more on-net fiber connections "to certain buildings that are within proximity of the XO high density

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Officer Matthew Siegel).

60. Spectrum Business Website, *Carrier Solutions – Access Services*; Charter Communications, Form 10-K, at 56, filed Feb. 24, 2015 ($242 million in 2014, $300 million in 2013, and $269 million in 2012).

61. Public Interest Statement at 18, *Application of Charter Communications, Inc., Time Warner Cable Inc., and Advance/Newhouse Partnership for Consent to the Transfer of Control of Licenses and Authorizations*, MB Docket No. 15-149, filed June 25, 2015.

62. USTelecom, The Competitive Business Broadband Marketplace (Feb. 2016), at 5, *available at* https://www.ustelecom.org/sites/default/files/files/USTelecom-White-Paper-2.pdf.

63. Charter Business Presentation, COMPTEL PLUS Business Expo 2014 Spring, What's New and What's Next in Cable Wholesale, at slide 28 (Mar. 17, 2014), *available at* http://files.comptelplus.org/2014Spring/Slides/Cable%20Slides%20Final%203-15-14.pdf.

64. Sean Buckley, *U.S. Fiber Penetration Reaches 39.3 Percent of Buildings, Says VSG*, FIERCETELECOM, Apr. 4, 2014, *available at* http://www.fiercetelecom.com/story/us-fiber-penetration-reaches-393-percent-buildings-says- vsg/2014-04-04.

65. K.C. Neel, *Business Services Replenish Coffers*, MULTICHANNEL NEWS, Dec. 1, 2014, *available at* http://www.multichannel.com/news/technology/business-services-replenish-coffers/385901 ("Cox . . . is on track to generate $2 billion from the [commercial-services category] by 2016, Steve Rowley, senior vice president of Cox Business, said.").

66. Phil Goldstein, *T-Mobile's Carter: We'd Be A 'Very Interesting' Partner For Dish*, FIERCEWIRELESS, Mar. 5, 2015, *available at* http://www.fiercewireless.com/story/t-mobiles-carter-wed-be-very-interesting-partner-dish/2015-03-05.

67. Sprint Nextel Corp., Form 10-K, at 5, May 27, 2014, *available at* http://www.sec.gov/Archives/edgar/data/101830/000010183014000030/sprintcorp201310-kt.htm.

68. Sean Buckley, *XO Invades CenturyLink's Turf By Extending Fiber into 100 Salt Lake City Buildings*, FIERCETELECOM, Aug. 28, 2015, *available at* http://www.fiercetelecom.com/story/xo-invades-centurylinks-turf-extending-fiber-100-salt-lake-city-buildings/2015-08-28.

fiber and Ethernet network."[69] After completing its acquisition of Global Crossings and tw telecom, Level 3 has 55,000 route miles of metropolitan fiber networks with approximately 33,300 buildings on-net in 228 markets in North America.[70] In August 2015, Windstream announced new "milestones in its network expansion plans," including "12 new 100G markets" and "3,900 additional fiber route miles featuring Infinera's 500G super-channel technology."[71] Zayo operates fiber networks covering "over 300 metro markets" in "46 states, plus Washington D.C."[72] Zayo states it is "actively constructing fiber to an additional 1,200" cell towers beyond the 4,500 it already reaches with its network.[73]

Table 2 shows all non-ILEC providers that serve at least 1,000 buildings with fiber-based broadband services.

TABLE 2: COMPETITIVE BUSINESS BROADBAND ACCESS PROVIDERS SERVING OVER 1,000 ON-NET BUILDINGS (AS OF JANUARY 2015)

Company	Metro Route Miles	On-Net Buildings	Route Miles Per Building
TW Cable Business	150,000	50,000	3.00
Level 3	64,000	42,900	1.49
Cox Communications	30,000	28,000	1.07
Colt	26,875	24,158	1.11
Zayo	30,000	19,040	1.58
Charter Business	65,000	15,800	4.11
Lightower	30,000	15,000	2.00
Windstream	121,000	9,702	12.47
Lightpath	6,100	7,300	0.84
Sunesys	16,000	7,202	2.22
Hutchison Global Network	3,062	5,500	0.56
Consolidated Comm.	13,441	4,981	2.69
Indiana Fiber Network	4,000	4,100	0.98
XO Communications	13,000	4,000	3.25
Southern Light Fiber	5,000	3,773	1.33
MTS Allstream	5,625	3,300	1.7
Integra Telecom	4,000	3,300	1.21

69. *Id.* In February 2016, Verizon acquired XO's fiber business, much of which resides outside of Verizon's ILEC region. *See Verizon to acquire XO Communications' fiber business*, BUSINESS WIRE, Feb. 22, 2016.

70. Level 3 Communications, Inc., *Second Quarter 2015 Results*, at 13, July 29, 2015, http://investors.level3.com/files/doc_downloads/2Q15-Earnings/2Q15-External-Earnings-Presentation_Final- PDF.pdf (reporting approximately 42,200 total on-net buildings, 79 percent of which are in North America).

71. Windstream News Release, *Windstream and Infinera Partnership Drives Windstream Carrier Solutions' Leadership in the Wave Transport Market,* Aug. 12, 2015.

72. Zayo Group Website, *About Zayo*.

73. Zayo Group Holdings, Inc., Form 424(B)(4) Prospectus, at 95, filed Mar. 13, 2015.

Unite Private Networks	5,500	3,095	1.78
FPL Fibernet	2,500	2,722	0.92
Cogent	28,067	2,221	12.64
Lumos Networks	8,400	2,171	3.87
FiberLight	8,059	1,779	4.53
FirstLight Fiber	1,600	1,700	0.94
Oxford Networks	2,000	1,500	1.33
Wilcon	3000	1,186	2.53
euNetworks	923	1,123	0.82
DQE Communications	2,500	1,100	2.27
City Fibre Holdings	386	1,017	0.38

Source: Metro Fiber and On-Net Buildings List, Telecom Ramblings, *available at* http://www.telecomramblings.com/metro-fiber-provider-list/.
Note: For certain carriers such as Level 3 and Zayo, some of these on-net buildings are located outside of the United States. For example, roughly 80 percent of Level's buildings are located in the United States, bringing its total U.S. on-net buildings to 34,320.

Collectively, these 28 providers serve over 267,000 buildings with fiber, laying over 650,000 route miles of fiber, or 2.42 route miles per building. By comparison, AT&T's fiber network reached 500,000 route miles by January 2016.[74] From 2010 to 2015, the four major pure-play fiber service providers—Zayo, Level 3, Lightower, and TW Telecom—lit over 40,000 buildings, laid approximately 60,000 miles of metro fiber, and invested approximately $6 billion in fiber infrastructure.

D. National Metrics on Fiber Extensions

Despite the significant increase in fiber penetration among U.S. businesses over the past decade, more than half of all commercial buildings (with 20 or more employees) were still not "lit" with fiber as of 2014 according to Vertical Systems.[75] By 2014, 42.5 percent of all commercial buildings (with 20 or more employees) were lit by fiber, up from 22.9 percent in 2009. Projecting the penetration forward using a linear-trend yields an estimate of 47.1 percent of all buildings being lit by the end of 2015.

On a base of 1.3 million 20-plus-employee buildings reported by Dunn & Bradstreet in 2015,[76] the increased penetration estimated by Vertical Systems implies that approximately 252,000 additional buildings were lit with fiber over the past five years (equal to 1.3 million x [0.471-0.277]). Vertical Systems does not provide a decomposition of the business-fiber penetration rate in terms of telco versus cable.

74. AT&T Fiber Reaches 1 Million New Business Customer Locations, Jan. 20, 2016, *available at* http://about.att.com/story/fiber_reaches_1_million_business_customer_locations.html.
75. Vertical Systems, Business Fiber Penetration Hits 42.5% in U.S., Mar. 31, 2015, *available* at http://www.verticalsystems.com/vsgpr/business-fiber-penetration-hits-42-5-in-u-s/.
76. Dun & Bradstreet, Q1 2015 Analytical Dataset ("Employees here" metric).

According to FiberLocator, 308,000 buildings were lit by fiber as of August 2015,[77] implying a penetration of 23.7 percent, nearly half the rate implied by Vertical Systems at the end of 2015 (23.7 percent versus 47.1 percent).[78] In any event, the available penetration rates imply that there is significant upside in fiber investment by telcos for enterprise customers,[79] so long as regulators do not undermine investment incentives.

Our study here is limited to Ethernet over a direct fiber connection to the customer.[80] The impact of the FCC's expanded special access rules, modeled in Parts III and IV, can be understood as the percentage difference in business-fiber penetration with and without the regulation, multiplied by the investment required to increase penetration by one percentage point. For example, if by 2020, ILECs would have covered 25 percent of all commercial buildings with fiber in the absence of the rule, but will cover only 20 percent in the presence of the rule, then the impact of the rule would be modeled as five percentage points, multiplied by the requisite investment dollars to increase penetration by one percentage point.

To get a gauge of what is at stake in terms of investment dollars, consider the maximum potential investment to bring business-fiber penetration to 100 percent. Table 3 provides an estimate of the cost per lit building for three of the largest competitive providers.

TABLE 3: CAPITAL EXPENDITURE PER LIT BUILDING

Company	**Increase in Cap Ex 2010-15 (billions)**	**Increase in On-Net Buildings 2010-15**	**Cost Per Building**
Zayo	$1.523	13,723	$111,009
Level 3	$2.498	26,320	$94,909
tw telecom	$1.830	9,456	$193,533
TOTAL	$5.851	49,499	$118,213

77. *See* FiberLocator, It's Getting Hot in Here—July's Database Update, *available at* http://www.fiberlocator.com/its-getting-hot-in-here-julys-database-updates.

78. Our best understanding is that Vertical System's penetration estimate does not include PON in their lit building figures. Instead, they count enterprises and entities that make fiber-purchasing decisions similar to enterprises (CAIs, telco facilities, etc.). FiberLocator might include a very small amount of PON in its estimate.

79. Fiber penetration should continue to increase as the business case for fiber deployment strengthens. *See*, *e.g.*, Ex Parte Letter from Patrick Brogan, USTelecom, to Marlene H. Dortch, July 30, 2015, at 9 ("Fourth generation wireless has emerged with significant fiber and Ethernet backhaul requirements, and increasingly small cell deployments to efficiently utilize available spectrum. WiFi hot spots have proliferated, as have large-volume data users such as data centers, content distribution networks, carrier collocation facilities and traffic exchange points. In addition, more enterprise providers have adopted fiber and Ethernet connectivity, including large anchor tenants from industries such as hospitality, education, finance, and the public sector.").

80. Ethernet over dedicated fiber is the equivalent architecture to the special access circuit-one, private, dedicated lines that have traditionally served medium-to-large businesses. PON-based Ethernet services are business services served over a residential oriented architecture (GPON), which can be considered an evolution of the Ethernet over xDSL or better known as Ethernet to the first mile. Both of these services have traditionally targeted to small businesses.

Sources: 2015 On-Net Buildings: http://www.telecomramblings.com/metro-fiber-provider-list/
2010 On-Net Buildings:
http://web.archive.org/web/20101231170200/http://www.telecomramblings.com/metro-fiber-provider-list/. Capital expenditures over the past five years were calculated by adding up annual figures in the companies' 10-Ks.

It bears noting that these cost-per-building estimates include the shared costs associated with long-haul fiber and towers; the incremental cost of adding the last building conditional on having this infrastructure in place is significantly smaller. Put differently, much of the competitors' infrastructure investment is focused on building fiber rings, not last mile facilities; removing these shared costs reduces the average cost per building considerably. In this sense, the estimate from Table 3 (the ratio of the increase in CapEx to the increase in on-net buildings) is an upper bound of the cost per building. For example, Level 3's CFO, Sunit Patel, offered a cost-per-building estimate of between $50,000 and $100,000.[81] As explained below, based on our model of Charlotte, we estimate the average incremental cost per building of $76,000,[82] which is close to the midpoint of Mr. Patel's range ($75,000). CostQuest has estimated a competitor's cost per building to be substantially greater,[83] but this estimate is likely inflated.[84]

With an estimated 47.1 percent business-penetration rate by the end of 2015, the number of unlit buildings per Vertical Systems is roughly 687,700 (equal to [1-0.471] x 1.3 million 20-plus-employee buildings per Dun & Bradstreet). The comparable number using FiberLocator's estimate is 991,900 (equal to [1-0.237] x 1.3 million buildings. Assuming $76,000 of costs per lit building, the aggregate

81. Liana Baker, *Business bandwidth demand lights up once dark fiber sector*, REUTERS, June 25, 2014, *available at* http://www.reuters.com/article/us-fibernetworks-analysis-idUSKBN0F013A20140625 ("Sunit Patel, chief financial officer of Level 3, said it could cost between roughly $50,000 to $150,000 to connect a large client, with the investment paid off quickly—within six months to two years, depending on the length of the contract.").

82. The total average cost to add one building is the sum of the average lateral cost and the average entry cost. For the lateral, the cost calculation is: [Distance of building from network] x $146,000/mile x 1.2 routing-inefficiency factor. In Charlotte, the average distance of all unlit buildings to the fiber network was 0.13 miles; thus, the average lateral cost calculation is: 0.13 miles x $146,000/mile x 1.2 = $23,000. Entry cost is assumed to be $15,000 for small-to-medium buildings (less than 50 employees) and $100,000 for large buildings. In Charlotte, the distribution of buildings is 55 percent small-to-medium, yielding a weighted-average entry cost of $53,000. Thus, the total average cost to add one building is $76,000 (equal to $23,000 + $53,000).

83. *See, e.g.*, CostQuest, Analysis of Fiber Deployment Economics for Efficient Provision of Competitive Service To Business Locations, White Paper #1 (2015) (estimating a cost per building of $130,000).

84. CostQuest's estimate is based on a suburban "greenfield" model that assumes no existing fiber infrastructure. *Id*. at 4 (Figure 1). Yet even in this model, the existing fiber connecting the central offices (shown as a green fiber ring) could be leveraged through laterals extended to nearby buildings, which is common cost-savings practice in the industry. Moreover, per CostQuest's sensitivity analysis, selecting a denser environment brings the CapEx down to nearly half of the Baseline Case ($65,000 building). *Id.* at 15. A denser environment model is better suited for business building locations, and it also effectively models a "brownfield" situation where some fiber is already in place to serve the provider's points of presence, currently lit buildings, and towers.

capital expenditure needed to wire all remaining unlit buildings with fiber—that is, ubiquitous fiber deployment—would be between $52 and $75 billion based on Vertical Systems and FiberLocator, respectively. Although it is highly unlikely that 100 percent business-fiber penetration is achievable, this calculation is solely meant to illustrate the maximum upside for the U.S. economy over a five-year period.[85] The investment model we employ below does not assume any particular level of business-fiber penetration, but rather solves for the penetration (with and without special-access regulation) given the expected net cash flows of serving unlit buildings in Charlotte.

III. Model Overview

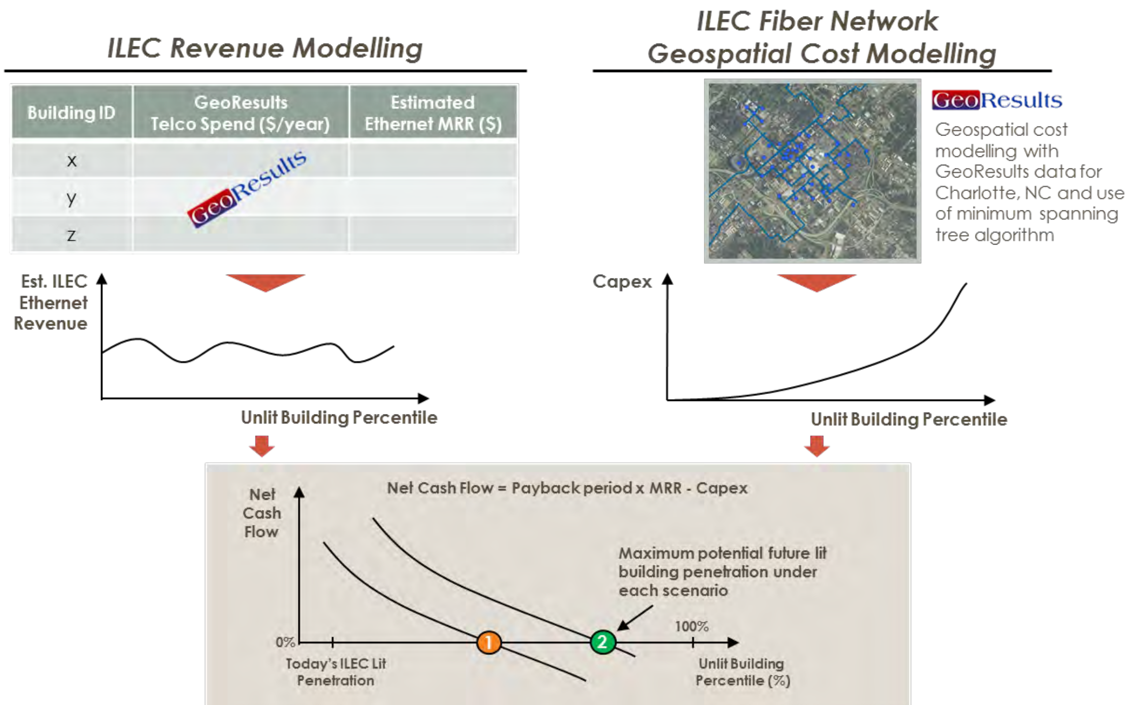
To calculate the impact of extending special-access regulation on fiber investment, we modeled the ILEC fiber business case of a single region, and extrapolated the results to the national level. Doing so allowed us to construct the model using real data on actual building locations, sizes, and ILEC financials. Charlotte, North Carolina is representative of the typical business district, as it closely matched the national averages across several key metrics.

We subsequently obtained information on the demand profile of the buildings in Charlotte[86] for use in both our cost and revenue modeling. We constructed a geospatial fiber-cost model to extend the ILEC's current fiber footprint by calculating the capital expenditure (CapEx) needed to connect new buildings based on their distance from the existing ILEC fiber network. We combined the cost model with an Ethernet revenue model, which calculated an ILEC's expected share of each building's telecommunications spending. Next, we constructed building net cash flow curves under two regulatory scenarios, with the Baseline Case of no regulation representing the greatest potential business penetration over the short run (approximately five years). Figure 1 shows the modeling approach.

85. This assumes currently lit buildings are not passed just once. If they are passed a second or third time, then the upside is even greater.

86. Data were obtained from GeoResults Geobuilding Summary & Lit Report on Charlotte, North Carolina.

FIGURE 1: MODELING APPROACH



Lit building penetration predicted by the model can be understood to occur over a five-year horizon based on current revenue, cost, risk aversion, and competition-related conditions. With respect to short-term revenues, telecom spending by businesses is expected to remain flat based on declining unit prices and increasing bandwidth needs. With respect to costs, the current fiber footprint determines the distances of unlit buildings from the network; greater distance implies greater costs to serve. The model assumes a certain level of risk aversion of fiber providers in terms of how much they are willing to spend versus anticipated revenues. Finally, buildings currently lit by competitive fiber service providers are taken into consideration. Although these factors could change over a sufficiently long time horizon,[87] the model is designed to predict investment patterns over a short-term horizon. Accordingly, the predicted penetration rates under the two regulatory scenarios are not meant to convey maximum potential penetration over the long run.

The combination of expected revenue and costs is the net cash flow associated with lighting a building. Net cash flow can be written as the 18-month building revenue

87. There are a number of factors that can change over the long term that could alter the predicted penetration level, including expansion of fiber footprint through government subsidies or access to low cost rights of way from third parties; microcell or data-center-based fiber expansion that can help build more metro fiber and decrease distances of unlit buildings from fiber footprint; advanced and more cost-efficient trenching techniques that can reduce the cost to build fiber; and increased competition levels.

less the CapEx to connect the building (less any OpEx savings from decommissioning copper). If the net cash flow of a building is positive, then the ILEC is assumed to connect the building with fiber; negative net cash flow buildings are not lit. This expected net cash flow changes under the two regulatory scenarios we outline, thereby altering the number of new buildings that are lit, and the corresponding ILEC investment in each situation. Finally, to extrapolate to a national scale, we applied the penetration levels from each regulatory scenario to our national market sizing of 1.3 million addressable, 20-plus employee buildings across the United States.

A. Selecting Charlotte, North Carolina

We used five metrics in our selection of a nationally representative MSA. These metrics were:

(1) Number of total establishments;
(2) Number of large establishments;[88]
(3) Density of establishments per square mile;
(4) Density of large establishments per square mile; and
(5) Presence of municipal fiber in the MSA

FIGURE 2: METRICS USED TO SELECT NATIONALLY REPRESENTATIVE MSA

Metric	National Average*	Charlotte, NC
Total Establishments	83,530	84,634
Large Establishments	5,291	5,527
Establishments/Sq Mile	21	16.3
Large Establishments/Sq Mile	1	1.1
Municipal Fiber Presence	No	Partial

Source: Experian, MuniNetworks, MCNC, National Broadband Map.
Note: The national average MSA is estimated using the average of the largest 100 metro statistical areas, as measured by the number of establishments.

As Figure 2 shows, Charlotte closely matches the national averages for total establishments, large establishments, and large establishment density. Although total establishment density in Charlotte is smaller than the national average, it is one of the five MSAs closest to the average that has more than 5,000 large establishments. Charlotte has partial municipal fiber presence, in the form of the Microelectronic Center of North Carolina (MCNC), which provides fiber to some public buildings, non-profits, and educational centers.[89]

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88. Large establishments are defined here as business locations with 20 or more employees, which is an assumption consistent with outside sources (e.g. Experian, etc.).
89. MCNC Fiber Services, *available at* https://www.mcnc.org/services/fiber-services.

Based on this selection, we subsequently obtained an industry-standard dataset with the demand profile of buildings in the area, including telecom spending and presence of fiber service providers within each building.

B. Modeling Assumptions

Our modeling assumptions covered Ethernet revenue, fiber connectivity costs, and the operating-expense savings earned through the decommissioning of existing copper Ethernet connections. The key assumptions are presented in Figure 3. The bases for these assumptions are explained more fully in the Revenue Model and Cost Model sections below.

FIGURE 3: ASSUMPTIONS USED IN BUSINESS CASE MODEL

Metric	Value	Description	Source
Underground Fiber Mile Cost	$173k/mi	Cost for deploying underground fiber in dense urban areas.	CTC Communications Engineering
Aerial Fiber Mile Cost	$26k-$51k/mi	Cost of deploying aerial fiber with moderate amount of make-ready work in urban areas. Selected cost $40k/mile	NATOA, CTC Communications Engineering
Underground and Aerial Division	80%/20%	Split of underground/aerial fiber in dense urban/urban areas	
Average Metro Fiber Mile Cost	$146k/mi	Calculated average fiber deployment cost in Charlotte, NC based on previous assumptions	
Building Connect Cost	$15k - $100k per building	Includes building entry cost & electronics. Larger buildings (50 employees or more) have ~$100k costs to wire telecom room & floors (fiber to the zone) while smaller have $15k (fiber to the floor). Average cost is ~$50k in Charlotte, NC.	CTC Technology & Energy TIA FOTC
Impact of Pricing Regulation	20-44% (Discount)	Range based on UNE-P regulation price discounts, average 30% selected for our model	Brattle Group & University of Florida
Payback Period	18 months	Fiber service providers expect a payback of the capex to connect a commercial building between 12 and 18 months	LightWave Online Zayo
ILEC Average Share of Building Revenue	33% 50%	Based on GeoResults, AT&T has 44% market share of lit building connections in Charlotte; we assumed 33% for fiber to the floor, 50% for fiber to the zone	GeoResults

For metro-fiber construction cost, we used a mix of 80 percent underground and 20 percent aerial fiber, with construction costs (including labor) of $173,000 per mile and $40,000 per mile, respectively. The aerial-fiber construction cost of $40,000 was based on a mid-point of a range of available public cost points.

In addition to the cost of extending the metro-fiber network to a building, we made assumptions for the cost to connect a building (entry cost and electronics). In this case, we defined two possibilities: (1) Fiber-to-the-floor, where we assumed a cost of $15,000 per building, which includes a direct fiber connection to the businesses' telecom rack (for buildings with less than 50 employees), and (2) Fiber-to-the-zone,[90] where we assumed a cost of $100,000 per building for constructing a

90. Fiber-to-the-zone is a form of structured cabling typically used in enterprise local-area networks, where fiber is used to link the main computer equipment room to an enclosure close to the desk or workstation

telecom room within the building's basement and wiring up all the floors in the building (for buildings with more than 50 employees). Related to these two types of building connectivity, we assumed the ILEC's Ethernet revenue share of the building would be 33 and 50 percent, respectively. The later assumes that the ILEC has a higher market share in cases where the building has been entirely wired up by the ILEC.

Turning to the revenue side of the equation, enterprise Ethernet revenues are modeled as being constant over time, with declining unit prices offset by increasing data rates.[91] For the effect of special-access price regulation, we assumed a 30 percent Ethernet revenue decline based prior applications of price-cap regulation (which ranged from 21 to 32 percent[92]) and unbundling (which ranged from 20 to 44 percent[93]). The model assumes the market-wide compression from Ethernet regulation to be similar to the price effects of unbundling in the past. Although the precise rate of special access pricing for Ethernet services cannot be known in advance, prior episodes of price-cap and UNE-P rates (as a percentage of prior market-determined rates) serve as reasonable predictors of Ethernet rate regulation here.

For an ILEC's decision to connect a building, we assumed a required 18-month payback period, in line with current industry practices for enterprise buildings. Although a building NPV-based decision would have allowed for more buildings to get connected with fiber, the model used the 18-month revenue rule in line with the more conservative approach that providers take in the real world.

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91. Some analysts have projected Ethernet revenues (as opposed to per unit prices) to increase. *See, e.g.*, *Ovum predicts the global enterprise Ethernet services market to exceed US$62bn by 2018*, FIERCE TELECOM, Aug. 16, 2013 (projecting a 13.6% CAGR), *available at* http://www.fiercetelecom.com/press-releases/ovum-predicts-global-enterprise-ethernet-services-market-exceed-us62bn-2018.

92. *See, e.g.*, OECD, Price Caps for Telecommunications: Policies and Experiences (1995), *available at* http://www.oecd.org/sti/ieconomy/1909801.pdf. *Id*. at 34 (showing BT's prices under various price cap systems fell by 26 percent between 1984 and 1992); *id*. at 35 (showing connection charges for BT fell by 32 percent from 1990-1994); *id*. at 36 (showing AT&T's private line price cap index decline by 21 percent from 1989 to 1991).

93. *See, e.g.*, Lisa Wood, William Zarakas, and David Sappington, Wholesale Pricing and Local Exchange Competition, Jan. 2004, at 3 n.7 ("Casual observation suggests the rate for wholesale services (i.e., resale) is roughly 20% less than retail services. (For example, the wholesale discount in New York is 19.1% with telephone company-provided operator services and 21.7% without these services.) Across all states (excluding Alaska), UNE-P prices averaged about $18 per line as of July of 2003, while revenue per access line per month averaged about $34. This $15 difference is approximately 44% of average revenue."). *See also* Kevin Hassett, Zoya Ivanova, Laurence J. Kotlikoff, Increased Investment, Lower Prices—the Fruits of Past and Future Telecom Competition, Sept. 2003, at 5 ("Unfortunately, only a few PUCs have, thus far, set their UNE-P rates close to what we measure to be their own state-specific TELRIC levels. Indeed, the average state-specific actual UNE-P rate and the average state-specific TELRIC UNE-P rate differ by 27.9 percent. Indeed, across all counties, the average broadband price under TELRIC pricing of UNE-P ends up almost 22.9 percent lower than the regulated monopoly price.").

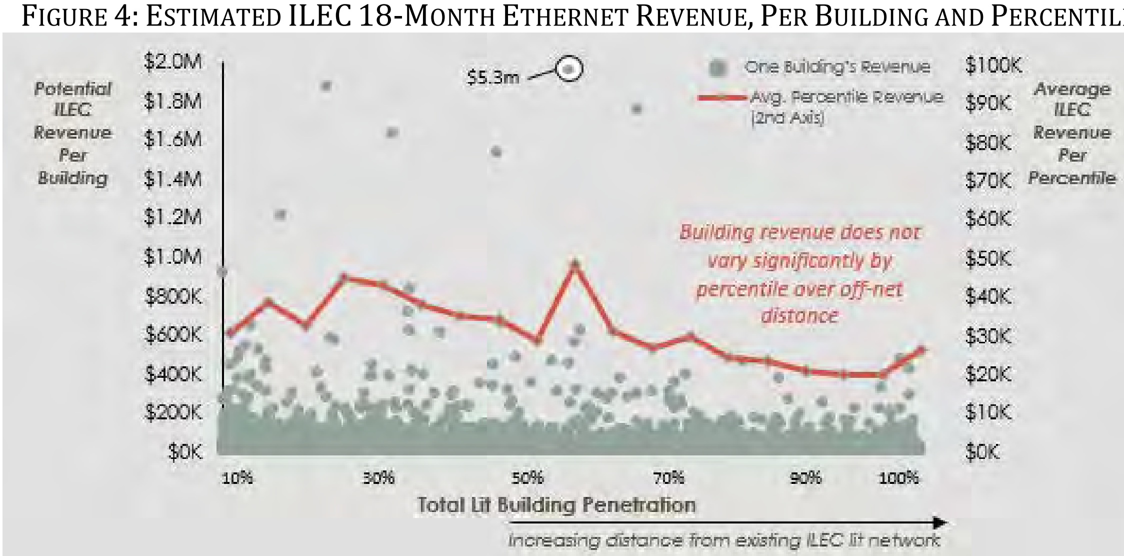
Finally, for the effect of copper decommissioning, we assumed capitalized OpEx savings of $5,500 per building by calculating an annuity of $110 per line per year for an average five copper lines per building.

C. Revenue Model

To calculate an estimate for potential ILEC fiber revenue for each building in Charlotte, we used standard industry revenues, which provides the sum of the estimated telecommunications expenditures of all businesses located in the same building. This value is converted to monthly spending and multiplied by our assumption of an 18-month payback period, which is the amount of revenue most providers consider when deciding whether a building qualifies for fiber connectivity. As noted above, we assume an ILEC will be able to capture between 33 to 50 percent of each building's telecom spending, depending on the size of the building. Given that 55 percent of the buildings in Charlotte are classified as being small, the implied ILEC market share was 44 percent.

Using the total telecom spending per building, we assume that this revenue is a good proxy for Ethernet revenue, as the next-generation networks will offer both voice and data bundled under their converged IP-based products. Also, despite the decline in individual Ethernet circuit pricing, we assume that the overall Ethernet spending per building will remain flat, consistent with the growth of the overall Ethernet segment and the growing demand for data speeds.

FIGURE 4: ESTIMATED ILEC 18-MONTH ETHERNET REVENUE, PER BUILDING AND PERCENTILE



Note: The red line measures the average ILEC revenue for each percentile, as measured in 5 percent increments, and is scaled on the second axis.

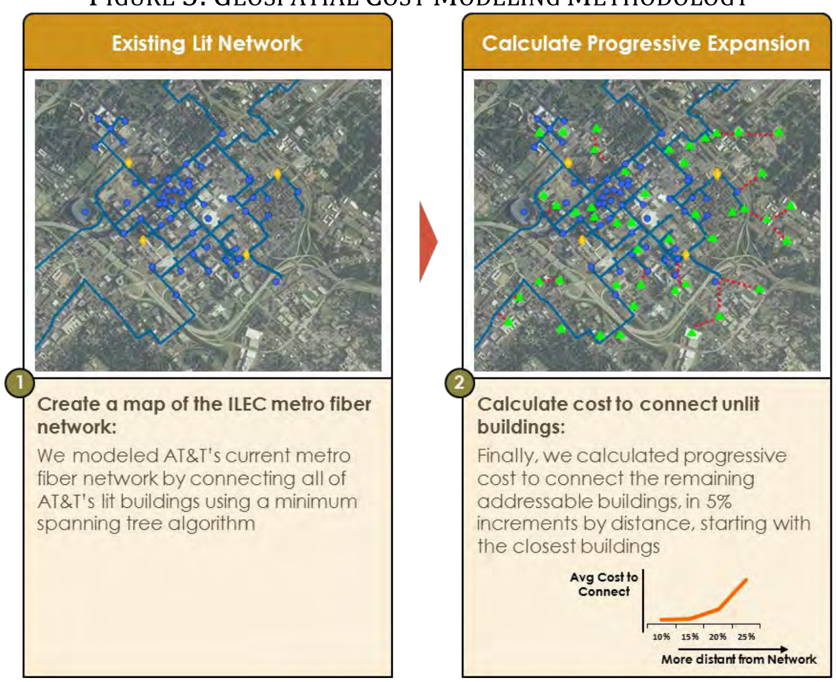
The secondary y-axis in Figure 4 shows the average 18-month revenue expected from each percentile of unlit buildings, ordered by their off-net distance. We observe low correlation between revenue and distance—that is, a very gradual revenue decline as we move away from the ILEC's footprint—due to smaller buildings farther away from the central district. Also, we notice a few outliers, exceptionally large buildings that sporadically skew the average.

Overall, the estimated average expected revenue per percentile of unlit buildings ranges between $20,000 and $50,000. The decision to light each building will depend on whether the CapEx to connect it will be greater or less than its anticipated 18-month revenue.

D. Cost Model

We used a minimum spanning tree (MST) to model the ILEC's existing metro fiber network, and to calculate the cost to connect all unlit buildings by off-net distance percentile. Lacking actual fiber-route data, we modeled the ILEC's current metro-fiber network by connecting all of the ILEC's lit buildings (endpoints) using an MST algorithm. Next, we calculated the progressive cost to connect the remaining 20-plus employee buildings, in five percent increments grouped by distance, starting with the closest buildings to the existing network, as depicted in Figure 5.

FIGURE 5: GEOSPATIAL COST MODELING METHODOLOGY



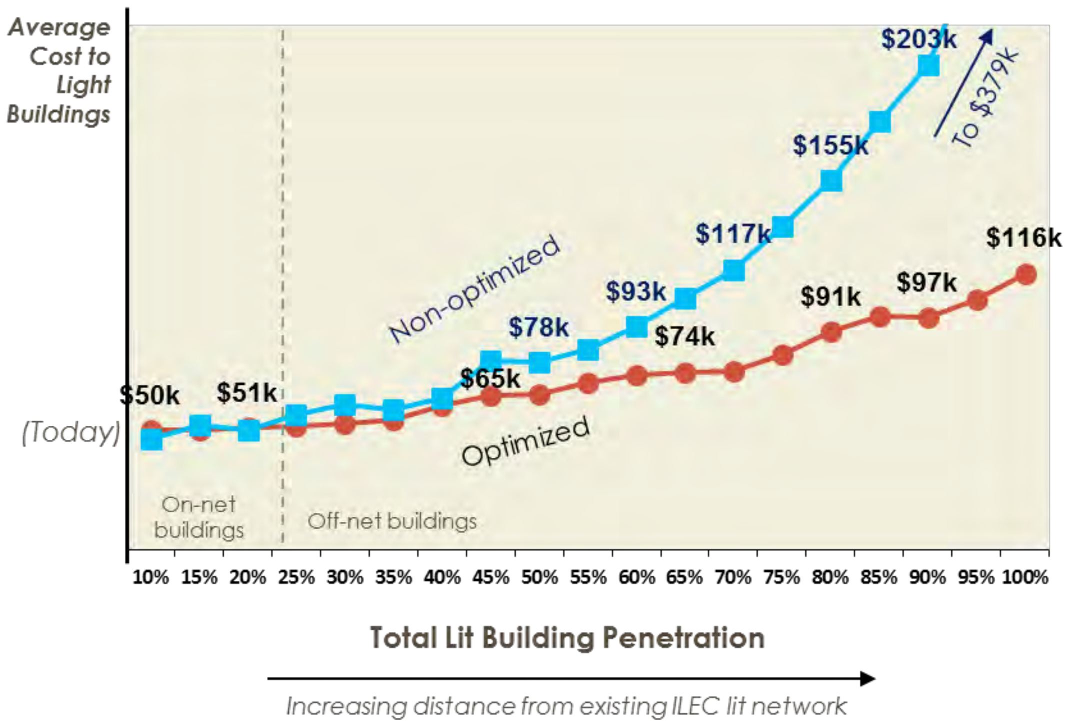
The cost to connect is calculated using the number of metro-fiber route miles required to connect a new building, multiplied by the associated cost per mile, as well as a factor for non-optimal routing with respect to the MST.[94] Because the MST creates an ideal, minimum-distance route, we estimated that inefficiencies in real-

94. The cost per mile accounts for capitalized labor costs.

world conditions would increase average build distances by approximately 20 percent.

The final cost per building also includes an entry cost, which reflects the cost to extend fiber into the building, as well as the cost of all associated electronic equipment that needs to be installed in the building. The geospatial model cost curve depicted in Figure 6 illustrates the average optimized and non-optimized costs to connect each additional five percentile of unlit buildings, starting from the ILEC's current fiber footprint. Current lit building penetration for the ILEC is at approximately 10 percent in Charlotte.

FIGURE 6: AVERAGE COST TO CONNECT UNLIT BUILDINGS BY PERCENTILE



The non-optimized curve considers the cost to connect unlit buildings directly to the ILEC's current fiber footprint, whereas the optimized curve shows the incremental cost to connect new buildings, provided that the buildings closer to the network have already been connected. For example, without optimization (blue curve), the average cost to light an additional five percent of buildings from 75 percent penetration is $155,000; with optimization (the red curve), the average cost to light that same five percent is $91,000. To assess investment effects, we use the optimized fiber-expansion scenario to capture the positive externalities that the lighting of close off-net buildings has to the remaining distant off-net ones.

As Figure 6 shows, from approximately 10 to 20 percent of total building penetration, the cost to connect is constant and equal to the entry cost. This is because these buildings are essentially on-net, with no additional fiber mileage required to connect. For the ILEC to light these buildings, all required costs are contained within the entry cost. Moreover, under the optimized scenario, the average total CapEx to light a building ranges from $50,000 to $116,000, depending on the building's off-net distance.

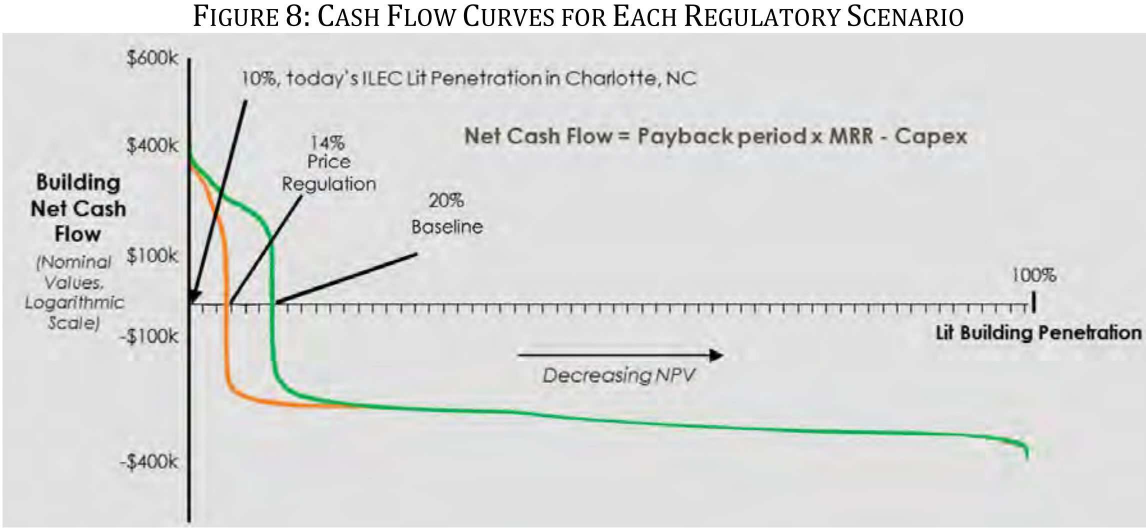
IV. Model Results

To calculate the impact of different regulatory scenarios on future ILEC fiber investment, we combined the cost and revenue aspects of each building's fiber business case. In the Baseline Case, this is as simple as calculating the potential revenue capture for each building, and subtracting the cost to connect that building with fiber. To incorporate special access price regulation, the potential revenue capture for each building is reduced by 30 percent.

A. Predicted Investment Effects in Charlotte

Our modeled scenarios show fiber connection decision points of indifference at total penetration percentages ranging from 10 to 20 percent.

FIGURE 8: CASH FLOW CURVES FOR EACH REGULATORY SCENARIO



The net cash flow curves depicted in Figure 8 use a logarithmic scale to highlight the differences in penetration between each regulatory scenario. The values displayed on the y-axis are the corresponding nominal values for each building's cash flow. The buildings in Charlotte were ordered from highest to lowest net cash flow,[95] and the point at which the curves cross the x-axis is the total amount of penetration that an ILEC can reasonably reach in that regulatory scenario. The time period over which such investment would likely occur is five years based on prior deployment patterns.

95. Note that previous model graphs have ordered buildings by distance from the existing fiber network.

This calculation means that a given ILEC starting from a similar market penetration will be able to light only an additional four percentage points of the total buildings in the market under the Price Regulation scenario, compared to an additional ten percentage points in the Baseline Case.[96] Under Price Regulation, special access obligations extend to the new fiber network. Relative to the Baseline Case, this regulation is predicted to reduce ILEC investment by 55 percent in Charlotte.

FIGURE 9: ILEC INVESTMENT OUTCOMES IN CHARLOTTE, BY REGULATORY SCENARIO

Scenario	Profitable Lit Fiber Penetration	Additional Lit Buildings	Additional Metro Fiber Route Miles	Additional Investment ($M)	Investment Difference vs. Base Case
Price Regulation	10%→14% *(+4%)*	265	10.8	$21.4M	-55%
Baseline	10%→20% *(+10%)*	589	18.6	$47.5M	0%

Notes: "Additional Investment" is calculated by multiplying the total number of new lit buildings by the average cost to connect a building (including fiber mileage construction).

B. Extrapolation of the Investment Effects to the United States

Based on the Charlotte model's penetration increases under each regulatory scenario, we extrapolated the national impact that regulation would have on ILEC fiber investment. We used 20-plus employee buildings to define the addressable market for enterprise fiber connections. Using Dun & Bradstreet's database, we calculated 1.3 million commercial buildings have 20-plus employees, out of the 3.5 million buildings with at least one business.[97] We calculated the number of new buildings that would be lit in each scenario, as well as the total investment that each scenario represents. Figure 10 shows the results of this extrapolation.

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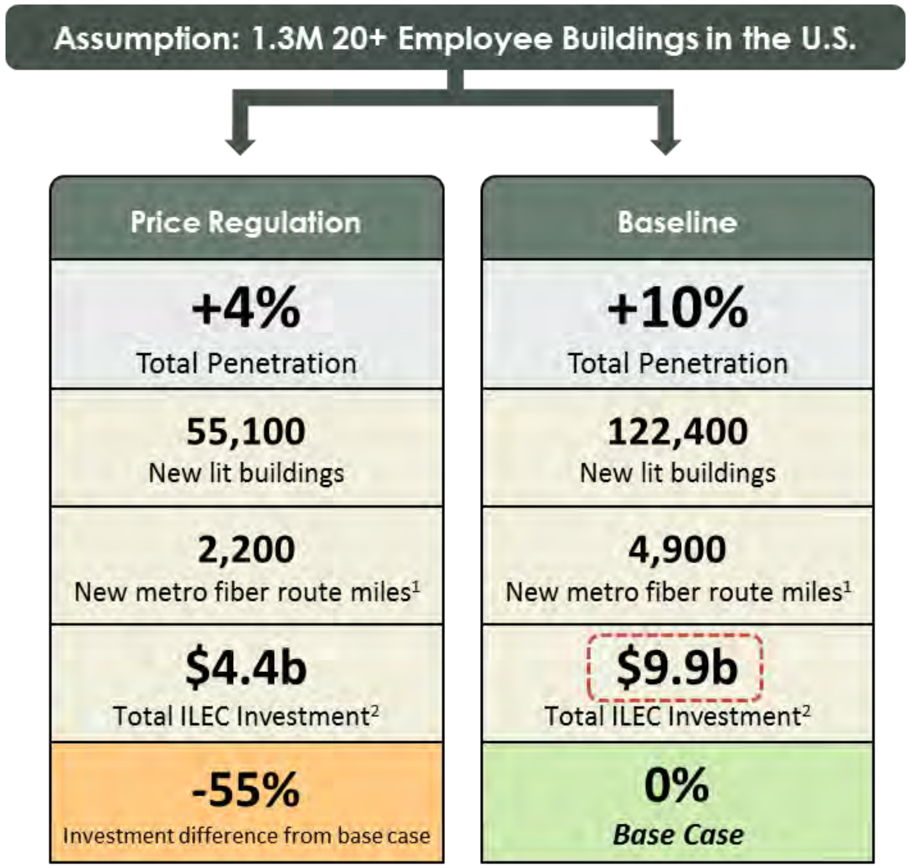
96. Considering historical growth of select pure-play providers (Level 3, Zayo, etc.), it is reasonable to assume that it will take up to five years for the modeled scenarios to fully develop.

97. *Investigation Order*, ¶ 5 ("Similarly, Windstream asserts that Level 3 and XO serve 30,000 and 4,000 commercial buildings, respectively, a small fraction of their estimate of 3.5 million business locations nationwide that house more than one business.") (citing Windstream Sept. 24, 2015 Ex Parte Letter at 2-3.).

FIGURE 10: NATIONAL ILEC INVESTMENT IN EACH ETHERNET REGULATION SCENARIO



Note: For the national extrapolation, fiber route miles are estimated by multiplying the number of new lit buildings with 0.04 miles per building, which is the average based on Charlotte modeling. The total ILEC investment value is calculated using the number of unlit buildings multiplied by the average cost to connect a building (including fiber mileage).

Moving from the Baseline Case to Price Regulation entails forgone ILEC fiber-to-the-building network investment of $5.5 billion (equal to $9.9 billion less $4.4 billion) and forgone lit buildings of 67,300 (equal to 122,400 less 55,100). Spread over a five-year deployment period, this represents a loss of roughly $1.1 billion per year in investment.

C. CLEC Investment Considerations

Although the CLEC response to expanded special access rules is not modeled here, it is reasonable to expect a scaling back of future CLEC fiber investment in the last mile as well. Not only would expected Ethernet revenue for CLECs decline, but also CLECs could avail themselves of wholesale Ethernet options that would not otherwise exist; both forces would push CLECs away from facilities-based entry and towards resale. By performing a similar analysis of lit building profitability and assuming similar cost structure for CLECs to that of the ILECs, price regulation should have a similar depressing investment effect on CLECs in last-mile facilities.

CLECs' claims of higher costs of deployment (relative to ILECs) or insurmountable entry barriers (such as building access and rights of way) are not convincing. Because ILECs account for less than half (roughly 40 percent) of lit buildings nationwide, there are at least two or more effective players in the market with scale and cost structures on par with the ILECs. For example, in Charlotte, AT&T has 636 locations compared to 541 locations by Level 3, which indicates that there have been paths for competitors to gain similar scale and fiber footprint. Moreover, due to towers, data centers, and long-haul facilities, several operators have comparable metro footprints in other geographic areas. Many CLECs have newer core fiber networks with greater fiber density and more availability for laterals; they also have flexibility to use contractors and lower cost resources for deployment in many cases.

CLECs' additional claim that expansion of special access rules for last-mile deployment would bolster their investments in metro rings is equally dubious; there has been a surge in investment in that segment of the industry over the past five years.[98] The artificial savings induced by regulatory advantages could just as likely be pocketed by the CLECs as they would be invested in other segments of their networks.

Finally, cable operators have indicated in filings with the Commission that mispriced resale opportunities for CLECs will undermine cable's incentive to invest their own facilities, further undermining deployment.[99] Accordingly, the marketwide investment effect of Ethernet price regulation would be considerably higher than what has been extrapolated in this study for ILEC providers.

D. Model Sensitivities

Figures 11 and 12 display the investment sensitivities for each parameter in the model. To measure sensitivity, we adjusted each revenue and cost parameter by ten percent (up and down), and calculated the impact on the difference in nominal investment between the Baseline Case and Price Regulation. Figure 11 focuses on changes in revenue parameters. For example, if pricing regulation suppresses Ethernet prices by 27 percent (as opposed to our best estimate of 30 percent),

98. *See, e.g.*, Telecom Ramblings, Metro Fiber Miles and Lit Buildings by Select Providers (showing that Level 3, Lightower, and tw telecom increased their metro route miles by 29,600, 24,500, and 4,000 miles, respectively), *available at* http://www.telecomramblings.com/metro-fiber-provider-list.

99. Reply Comments of NCTA, In the Matter of Special Access for Price Cap Local Exchange Carriers, WC Dkt. No. 05-25, RM-10593, Feb. 19, 2016, at 4 ("Given the substantial consumer benefits that have resulted from this facilities-based competition, the most important task for the Commission in this proceeding is to ensure that it preserves incentives for continuing and expanding facilities-based competitive entry and investment.").

investment falls by $5.0 billion (as opposed to $5.4 billion). Among the revenue parameters, the payback period has the largest impact on investment.

FIGURE 11: MODEL SENSITIVITIES ON NOMINAL INVESTMENT
DECREASE BETWEEN PRICE REGULATION AND BASELINE CASE (CHANGES IN REVENUES)

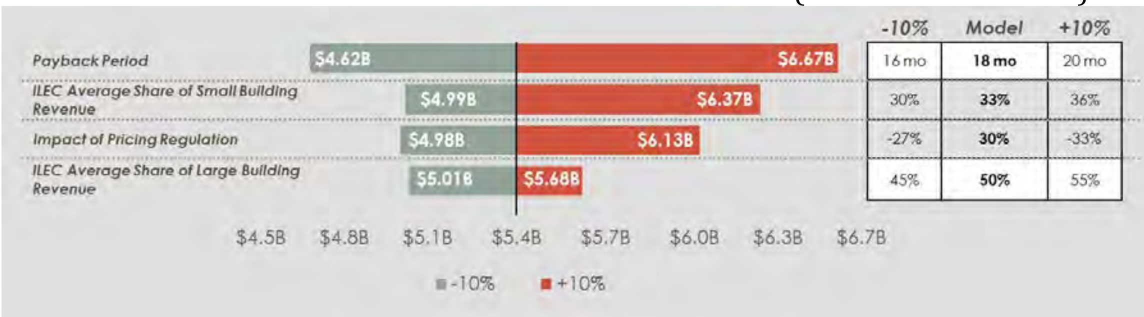
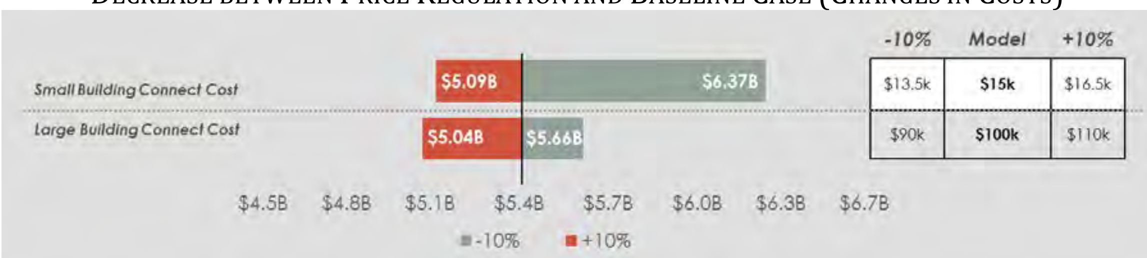


Figure 12 performs for the same exercise for changes to the cost parameters.

FIGURE 12: MODEL SENSITIVITIES ON NOMINAL INVESTMENT
DECREASE BETWEEN PRICE REGULATION AND BASELINE CASE (CHANGES IN COSTS)



For example, if small-building-connect costs are ten percent below our best estimate ($15,000), then investment falls by $5.09 billion (as opposed to $5.4 billion). If large-building-connect costs are ten percent below our best estimate ($100,000), then investment falls by $5.04 billion. The sensitivity analysis shows a robust investment decline of between $4.6 and $6.7 billion as one toggles between the Baseline Case and one plausible variant of special access price regulation.

V. Model Verification

In this section, I rely on original empirical analysis and evidence from the existing economic literature to verify the predictions from the investment model. In theory, access obligations reduce an incumbent's expected return on investment, and thus should reduce incumbent investment. The question is by how much. I begin by studying a natural experiment—the asymmetric treatment of DSL and cable modem service from 1998 through 2005. I then turn to the economic literature to refine my estimate of the likely investment effects of extending special access obligations into fiber connections.

A. A Natural Experiment in the United States: DSL Versus Cable Modem

The FCC treated telco-based ISPs differently from cable-based ISPs from 1998 through 2005. This gives rise to a natural experiment of sorts, which allows one to develop a prediction of the likely investment effect of the FCC's special access rules. Following the 1996 Telecom Act, the FCC imposed classic common-carrier obligations on telcos, including mandatory unbundling. For example, in 1999, the FCC required telcos to share a portion of their lines with resellers of DSL service at regulated rates ("line sharing"). The two access technologies did not achieve regulatory parity until August 2005, when DSL was reclassified as an information service.[100]

Unlike DSL service, cable modem service was classified as an information service from its inception, and was never subject to the FCC's unbundling regime. Thus, the natural control group to measure the impact of unbundling on telco investment is cable operators. Here, by including cable as a control in a difference-in-differences (DID) model, changes in common factors influencing the investment decisions of both telcos and cable companies are controlled for even when these variables are not directly observable. While cable modem and DSL service are not perfectly identical technologies, in the minds of broadband subscribers, they were close economic substitutes for broadband access at this time.[101] Moreover, there is no plausible basis to believe that cable modem investment would naturally grow at a faster rate than telco investment during this time period. For example, while there

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100. *FCC Classified DSL as Information Service*, TECH LAW JOURNAL, Aug. 5, 2005, *available at* http://www.techlawjournal.com/topstories/2005/20050805a.asp. The appellate courts partially dismantled the common-carrier regime before 2005. For example, the D.C. Circuit Court of Appeals vacated the FCC's Line Sharing Order in May 2002. *USAT v. FCC*, 290 F. 3d 415 (D.C. Cir. 2002). The FCC eliminated line sharing as an unbundled network element in August 2003. Review of the Section 251 Unbundling Obligations of Incumbent Local Exchange Carriers, CC Docket No. 01-338, Report and Order on Remand and Further Notice of Proposed Rulemaking, FCC 03-36 (rel. Aug. 21, 2003).

101. Robert W. Crandall & J.G. Sidak, *Is Structural Separation of Incumbent Local Exchange Carriers Necessary for Competition?*, 19(2) YALE JOURNAL ON REGULATION 335-411 (estimating that the demand for cable modem service rises by 0.59 percent for every one percent increase in the price of DSL service).

was a telco-related fiber glut around 2000, which could naturally slow telco investment during the subsequent decade, most of that investment was in long-haul fiber, and many of those long-haul fiber investors were not ILECs.

So what does the DID model tell us about the effect of unbundling on telco investment? First, we need to estimate the growth in cable CapEx over the relevant period, which will serve as a benchmark for how telco CapEx should have grown in the absence of the unbundling obligation. Next, we can compare the actual growth in telco investment against this benchmark. The difference in the differences gives a measure of the impact of unbundling on incumbent investment. According to a report by the Columbia Institute for Tele-Information (CITI),[102] cable capital CapEx had reached $15.9 billion by 2008 (the earliest date in the CITI sample), and the "major telco wireline" CapEx (excluding wireless) reached $26.3 billion. In 1996, cable CapEx was $6.7 billion, per the Telecommunications Industry Association (TIA), and telco CapEx (as measured by the CapEx of the local exchange carriers) was $18.1 billion.[103] Thus, over the intervening period where telcos were uniquely subject to unbundling (at least through 2005), cable CapEx increased by $9.2 billion for a CAGR of 7.5 percent, but telco CapEx increased by only $8.2 billion for a CAGR of 3.2 percent.

Using these data (a combination of CITI and TIA), the simple DID model suggests that unbundling was responsible for *slowing* telco investment by roughly $1 billion per year (equal to the $10.4 billion difference between the two groups in 2008 less the $11.4 billion difference in 1996). A $1 billion decline represents a 5.5 percent decline relative to the telcos' 1996 CapEx. Moreover, the growth rate of cable CapEx was double that of regulated telcos over this period (7.5 percent versus 3.2 percent).

The advantage of using CITI and TIA CapEx data is that it is public and replicable. The disadvantage is that it comes from two different sources, which potentially raises measurement issues. Using USTelecom's proprietary data for cable and telco broadband-related CapEx paints a more dramatic picture. (USTelecom makes total ISP wireline investment available on its website.[104]) The difference in the differences in CapEx between 2008 and 1996 (for comparison with the first estimate) is $10.6 billion, an implied decline of 38.7 percent attributable to the difference in regulatory treatment. The difference in the differences between 2005

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102. Robert Atkinson & Ivy Schultz, Broadband in America: Where Is It and Where Is It Going? Preliminary Report Prepared for the Staff of the FCC's Omnibus Broadband Initiative, Nov. 2009, *available at* http://www8.gsb.columbia.edu/rtfiles/citi/91a20123-2501-0000-0080-984f56e8d343.pdf.

103. TIA, Investment, Capital Spending And Service Quality In U.S. Telecommunications Networks: A Symbiotic Relationship, Nov. 2002, *available at* http://www.tiaonline.org/policy_/publications/filings/documents/Nov13-2002_CapEx_QoS_Final.pdf.

104. USTelecom, Historical Broadband Provider Capex, *available at* http://www.ustelecom.org/broadband-industry-stats/investment/historical-broadband-provider-capex. A breakdown by technology was provided to the author.

and 1996 (the relevant window) is $10.2 billion, an implied decline in telco CapEx of 37.2 percent.

B. Review of Economic Literature

The DID results—that unbundling decreased telco investment by between 5.5 percent (based on CITI and TIA data) and 37.2 percent (based on USTelecom data)—is corroborated by a 2014 paper by Kevin Hassett and Robert Shapiro, which similarly attempts to estimate the impact of unbundling obligations on telco-based ISPs. The authors exploit the FCC's asymmetric treatment of wireless and wireline investment: Like cable-based Internet service, wireless broadband service was regulated under a light-touch approach (as opposed to common-carrier regulation).[105] Hassett and Shapiro estimate the share of (regulated) wireline investment that can be explained by movements in (the relatively deregulated) wireless investment. The portion that cannot be explained this way serves as an estimate of the "constrained" wireline investment subject to unbundling, which allows one to infer the relative impacts of the different forms of regulation. They estimate that the more stringent rules were associated with a reduction in telco wireline investment between 17.8 percent and 31.7 percent per year.[106] A supplemental 2015 study by the same authors estimates that a movement from the (formerly) light-touch U.S. regulatory regime to a European-style unbundling regime is predicted to reduce investment by 36 percent.[107]

There has been limited economic research on the impact of unbundling on incumbent *investment* for countries outside the United States. Most of the research focuses on the effect of unbundling on broadband penetration, which is a proxy for investment (as there cannot be adoption without investment). For example, Wallsten and Hausladen (2009) test the effects of unbundling on fiber connections per capita.[108] Using a regression model that controlled for income, population, and other demographic variables, they examined the link between fiber connections and unbundled lines from 27 European countries between 2002 and 2007. The authors find that "countries with more broadband connections per capita provided through local loop or bitstream unbundling have *fewer fiber connections* . . . per capita

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105. Kevin A. Hassett & Robert J. Shapiro, The Impact of Title II Regulation of Internet Providers On Their Capital Investments, Sonecon, November 2014, *available at* http://www.sonecon.com/docs/studies/Impact_of_Title_II_Reg_on_Investment-Hassett-Shapiro-Nov-14-2014.pdf.

106. *Id*.

107. Kevin A. Hassett & Robert J. Shapiro, Regulation and Investment: A Note on Policy Evaluation Under Uncertainty: With an Application to FCC Title II Regulation of the Internet, July 2015, at 18-19, *available at* http://cbpp.georgetown.edu/wp-content/uploads/HassettShapiro_Policy-EvaluationunderUncertainty.pdf.

108. Scott Wallsten and Stephanie Hausladen, Net Neutrality, Unbundling, and their Effects on International Investment in Next-Generation Networks, Review of Network Economics, Vol. 8, Issue 1 (March 2009), 90-112, *available at* https://www.techpolicyinstitute.org/files/wallsten_unbundling_march_2009.pdf.

provided by the incumbent and entrants."[109] In particular, for every unbundled line per capita in a country, they estimate that the number of fiber connections per capita declines by 0.041.[110]

To compare this result to the percentage investment effects described above, consider the following scenario: If a country increased its share of unbundled lines from 5 to 10 percent of the population by extending its unbundling obligation to fiber—as did France and the UK[111]—the number of fiber connections would fall by 8.2 percent according to this model;[112] increasing the share of unbundled lines from 5 to 20 percent would lead to a 16.4 percent reduction in (per capita) fiber lines.[113] To the extent that a decrease in fiber connections is a reasonable proxy for a decrease in fiber investment, this model further corroborates the finding of the DID model discussed earlier.

My range of likely investment effects from mandatory unbundling of DSL connections is modest compared to the findings from an earlier experiment in Europe that took place in the late 1990s. Grajek and Röller (2009) estimated the effect of unbundling in 20 EU member states[114] on incumbents' and entrants' investment decisions between 1997 and 2006.[115] The authors used an index of access regulation to measure regulatory intensity, which includes full unbundling, line sharing, bitstream access, and subloop unbundling. After controlling for the presence of entrants and GDP per capita, among other things, the authors found that increasing regulatory intensity by the average change in the regulatory regime in the EU 15 between 1997 and 2002 reduced incumbents' infrastructure stock by an

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109. *Id*. at 102 (emphasis added).

110. *Id*. Table 3a.

111. *European Commission highlights regulatory approach for fiber to the home*, MUNIWIRELESS, June 21, 2009, *available at* http://www.muniwireless.com/2009/06/21/european-commission-approach-for-fiber-to-the-home/ ("Access to other passive elements (unbundling of the fiber loop) or access to active elements – service based competition ("bitstream") – should also be mandated, according to the draft Recommendation. The Commission wants its final recommendations to be applied by all European NRAs before the end of 2009. Several countries as Portugal, France, UK or Germany have already adopted obligations concerning FTTH or FTTN networks build out. In France ARCEP is supposed to announce new dispositions next week."). *See also* Wallsten & Hausladen, *supra*, Figure 4.

112. The predicted share of fiber lines per capita given a 10 percent share of unbundled lines is 4.59% (equal to 5% less 0.41 x 10%).

113. The predicted share of fiber lines per capita given a 20 percent share of unbundled lines is 4.18% (equal to 5% less 0.41 x 20%).

114. The following EU countries are included in the study (EU 15): Austria, Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Portugal, Sweden, and the United Kingdom. The study also includes the following EU 12 countries (new member states after the 2004 and 2007 accession): Bulgaria, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, and Slovenia.

115. Michal Grajek & Lars-Hendrik Röller, *Regulation and Investment in Network Industries: Evidence from European Telecoms*, 55(1) JOURNAL OF LAW AND ECONOMICS 189-216, *available at* https://www.esmt.org/regulation-and-investment-network-industries-evidence-european-telecoms-0.

estimated 48.7 percent in the short-term.[116] In the long-term, the effect is quite similar (47 percent).[117] This estimate is significantly higher than the upper bound implied by the DID model.

C. Summary of Findings

Table 4 summarizes my findings in the context of the economics literature.

TABLE 4: SUMMARY OF INCUMBENT INVESTMENT EFFECTS OF UNBUNDLING

Study	Sample	Methodology	Lower Bound %	Upper Bound %
Singer (2015)	USA	DID	5.5	37.2
Hassett & Shapiro (2014)	USA	Regression	17.8	31.7
Wallsten & Hausladen (2009)	European Union	Regression	8.2	16.4
Grajek & Röller (2009)	European Union	Regression	NA	48.7

To be fair, there are some unpublished discussion papers that are not able to detect a statistically significant impact of access regulation on incumbent investment.[118] Yet even those authors reached a different conclusion during subsequent research that was ultimately published.[119] Accordingly, based on my original analysis and the

116. *Id*. at 16. The estimate is equal to the product of 0.5 (the average change in the regulatory regime in EU 15 between 1997 and 2002) and -0.975, the estimated coefficient on the key explanatory variable (Regulation). *Id*. Table 4.

117. *Id*. ("Taking this into account, we find that increasing the regulation index by 0.5 reduces incumbents' infrastructure stock by approximately 47 percent over the long term. In other words, the negative impact of regulation on incumbent's investment incentive is only partially compensated by strategic complementarity.").

118. *See, e.g.*, Hans Friederiszick, Michal Grajek, & Lars-Hendrik Röller, Analyzing the Relationship between Regulation and Investment in the Telecom Sector, March 2008, at Table 3, *available at* http://www.researchgate.net/profile/Michal_Grajek/publication/228353806_Analyzing_the_relationship_between_regulation_and_investment_in_the_telecom_sector/links/0a85e52d517c7aa099000000.pdf (showing a negative yet statistically insignificant effect on incumbent investment). *See also* Wolfgang Briglauer, Klaus Gugler, & Adhurim Haxhimusa, Facility- and service-based competition and investment in fixed broadband networks: Lessons from a decade of access regulations in the European Union member states, ZEW Discussion Papers, No. 15-048, *available at* http://www.econstor.eu/bitstream/10419/112761/1/832562270.pdf (finding no statistically significant effect between access regulation and incumbent capex).

119. Michal Grajek & Lars-Hendrik Röller, *Regulation and Investment in Network Industries: Evidence from European Telecoms*, 55(1) JOURNAL OF LAW AND ECONOMICS 189-216 (finding that increasing regulatory intensity by the average change in the regulatory regime in the EU 15 between 1997 and 2002 reduced incumbents' infrastructure stock by an estimated 48.7 percent in the short-term). Similarly, in a subsequent published paper, Briglauer & Gugler found a negative effect of access regulation on fiber deployment, suggesting that the measure of the dependent variable (capex generally versus fiber investment in particular) is critical. *See* Wolfgang Briglauer & Klaus Gugler, *The Deployment and Penetration of High-Speed Fiber Networks and Services: Why are European Member States Lagging Behind?* 37 TELECOMMUNICATIONS POLICY 819-835, at 832 (2013) ("However, in line with the literature cited in Section 2, our qualitative analysis shows that the strict cost-based mandatory access regime underlying the EU regulatory framework is at odds with achieving the goals of the

economics literature, the estimated impact of unbundling on incumbent investment appears to range from approximately 6 to 49 percent. Thus, the likely investment effect under the Price Regulation scenario predicted by the investment model is closer to the high end of the range of observed effects in the literature.

VI. Translating the Investment Loss from the Special Access Rules into Jobs and Output Effects

So what happens to the U.S. economy when this much CapEx is removed from the system? As in other industries, broadband capital expenditures have a multiplicative effect on job creation and economic output if the economy is at less than full employment.[120] In this section, I trace the impact of the reduction of broadband CapEx on jobs and output using traditional multipliers as well as estimates of spillover effects. This section does not attempt to balance the dynamic losses from reduced ILEC fiber investment (and allocative inefficiencies) against either (1) potential increases in CLEC investment in metro fiber (excluding last-mile CLEC investment, which should also fall) or (2) welfare gains from price reductions for businesses in Ethernet services; instead, it is intended to restate the dynamic losses in terms of jobs and economic output.[121]

A. Job Impact

My analysis of employment effects from the FCC's special access rules is divided into two parts: (1) "total multiplier effects," which estimates the number of jobs directly and indirectly created by spending activities in upstream (input) industries, plus induced jobs from greater household income; and (2) "spillover effects," which accounts for additional spending by related and new downstream industries that benefit indirectly from additional broadband investment and penetration.

Digital Agenda. An international cross-sectional comparison indicates strong reluctance of European incumbent operators to undertake FTTH/B deployment. . .").

120. The multiplier is a standard principle in the macroeconomics literature. *See, e.g.,* RUDIGER DORNBUSCH & STANLEY FISCHER, MACROECONOMICS 66 (McGraw Hill 6th ed. 1994). Richard Kahn first introduced the multiplier concept as an "employment multiplier." *See* Richard F. Kahn, *The Relation of Home Investment To Employment,* 41 ECON. J. 173, 173-98 (1931). John Maynard Keynes expanded upon this concept by introducing the "investment multiplier." *See* JOHN MAYNARD KEYES, A GENERAL THEORY OF EMPLOYMENT, INTEREST, AND MONEY 115 (Harcourt Brace & Co. 1964) (1936).

121. To perform a complete cost-benefit analysis, which is beyond the scope of this report but squarely within the ambit of the FCC, one must compare these dynamic efficiency losses from less investment and innovation (the costs of intervention) against any static welfare gains from lower prices (the benefits). When measuring the benefits, it bears noting that government-induced Ethernet price declines would not begin from supra-competitive levels; instead they would begin from competitive levels (that is, closer to incremental costs), which implies that the consumer welfare generated from such price reductions could be offset in part with static losses in producer welfare (an allocative inefficiency).

1. Total Multiplier Effects

The employment effects of capital expenditures in the telecom industry extend beyond the company's direct employees. "Direct effects" are jobs generated from activities such as installing fiber, while "indirect effects" are job gains associated with communication equipment suppliers. "Induced effects" are the jobs created when the employees of an input provider use their additional income to purchase more goods and services in the local economy. These three effects (direct, indirect, and induced)—collectively referred to as the "total multiplier"—are considered to be the key elements of a traditional analysis of economic impact. Four papers in the literature inform my estimate of the total multiplier for fiber-based broadband investment.

Using the Bureau of Economic Analysis job and output multipliers, along with slated broadband investment schedules from the Columbia Institute for Tele-Information, Crandall and Singer (2010) projected an average of 509,546 jobs in the United States would be sustained from 2010 to 2015 as a result of approximately $30.4 billion of annual broadband investments relative to a world without such investments,[122] implying a weighted-average multiplier (across all broadband technologies) of 16.8 jobs for every million dollars of broadband investment.

Katz and Callorda (2014) studied the effects of repealing a sales tax exemption in Minnesota on the telecommunications industry.[123] Based on an input-output analysis, they estimate that a $154 million reduction in broadband investment would destroy 3,323 jobs in the state, implying a total job multiplier of 21.6 jobs per million dollars of broadband investment.[124] Indirect and induced effects contribute a substantial proportion of that total multiplier.[125]

Sosa and Audenrode (2012) estimated that the effects of reassigning 300 MHz of additional spectrum to mobile broadband would trigger $15.075 billion in new capital spending per year (although the study pertains to mobile broadband, the authors rely on job multipliers derived from wireline services.)[126] The authors apply BEA Type II RIMS multipliers to calculate a weighted average of Construction

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122. Robert W. Crandall & Hal J. Singer, The Economic Impact of Broadband Investment, Prepared for Broadband for America, Feb. 2010, *available at* http://internetinnovation.org/files/special-reports/Economic_Impact_of_Broadband_Investment_Broadband_for_America_.pdf.

123. Raul Katz & Fernando Callorda, Assessment of the Economic Ompact of the Repeal of the Tax Exemption on Telecommunication Investment in Minnesota (Feb. 2014), *available at* http://www.mncca.com/doc/minnesota-study-final-version.pdf.

124. *Id.* at 24.

125. *Id.*

126. David Sosa and Marc Van Audenrode, Private Sector Investment and Employment Impacts of Reassigning Spectrum to Mobile Broadband in the United States, Analysis Group (August 2011), *available at* http://www.analysisgroup.com/uploadedFiles/News_and_Events/News/Sosa_Audenrode_SpectrumImpactStudy_Aug2011.pdf.

(56%) and Broadcast and Communications Equipment (44%), implying 20.4 jobs for every $1 million invested.[127]

Finally, using the latest multipliers for telephone apparatus manufacturing (11.8), broadcast and wireless communications equipment (13.8), fiber-optic cable manufacturing (14.4), and construction (26.7),[128] Eisenach, Singer and West (2009) estimated separate multipliers for different types of broadband spending by applying weights to each of the industry multipliers based on the allocation of broadband capital spending to each industry.[129] They estimated the weighted average employment multipliers for fiber-based technologies of 19.7 jobs per million dollars of FTTH investment.[130]

Table 5 summarizes the relevant literature on the total multiplier effects from broadband investment.

TABLE 5: SUMMARY OF TOTAL MULTIPLIERS FROM BROADBAND INVESTMENT

Study	Annual Investment ($B)	Projected Total Jobs (000s)	Total Multiplier	Method
Crandall & Singer (2010)	30.4	509.5	16.8	Multiplier
Sosa & Audenrode (2012)	15.1	307.6	20.4	Multiplier
Katz & Callorda (2014)	0.2	3.3	21.6	Input-Output
Singer & West (2010)	12.7	250.4	19.7	Multiplier

Notes: Total multiplier is the sum of direct, indirect, and induced effects.

Given the consistency with which various researchers have used a multiplier of approximately 20 jobs per million dollars of investment, I adopt that figure here to estimate the initial job impact associated with the FCC's special access rules. Because the multipliers are stated in terms of annual effects, I spread the predicted investment loss equally across five years. Recall from Part IV that the special access regulation is predicted to reduce ILEC investment by between 34 and 71 percent from a baseline investment of $9.9 billion (or $1.98 billion per year over five years). Table 6 shows that before considering spillover effects, the FCC's special access rules could eliminate between 13,464 and 28,116 jobs annually over a five-year period.

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127. *Id.* at 5.

128. U.S. DEPARTMENT OF COMMERCE, BUREAU OF ECONOMIC ANALYSIS, Regional Input-Output Modeling System (RIMS II), Table 1.5 (2008). Multipliers are based on the 1997 Benchmark Input-Output Table for the Nation and 2006 regional data.

129. Jeffrey A. Eisenach, Hal J. Singer, & Jeffrey D. West, *Economic Effects of Tax Incentives for Broadband Infrastructure Deployment*, Fiber-to-the-Home Council (2008) at 8.

130. *Id.* Table 2 at 8. FTTH weights are 30 percent for telephone apparatus manufacturing, 20 percent for fiber optic cable manufacturing, and 50 percent for construction.

TABLE 6: DIRECT, INDIRECT, INDUCED JOB LOSS FROM FCC'S SPECIAL ACCESS RULES

	Annual Investment Loss ($ B)	Total Jobs Multiplier
Price Regulation	1.089	21,780

2. Spillover Effects

The total-multiplier-based jobs estimate does not account for additional spending in related downstream industries except for those industries that directly benefit from increased spending by broadband input providers. Yet broadband investment and higher broadband penetration have been shown to create additional, or "spillover" effects in myriad downstream industries, including in healthcare,[131] education,[132] and energy,[133] whose ability to enrich and enhance their service offerings is increased by greater availability of broadband internet access.[134] Broadband spillover effects tend to concentrate in service industries such as financial services and healthcare, yet some have identified an effect in manufacturing as well.[135]

In light of the recognized limitations of the multiplier approach for capturing the full economic effect of investment activities, economists have developed alternative methods and tools to estimate the full effects of broadband investment and use. Four studies inform my estimate of the spillover effect here.

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131. M. Meyer, R. Kobb, & R. Ryan, *Virtually healthy: Chronic disease management in the home*, 5 DISEASE MANAGEMENT 87-94 (2002).

132. Working Party on Communication Infrastructures and Services Policy, Network Developments in Support of Innovation and User Needs, Organization for Economic Cooperation and Development Dec. 2009 at 5 (Broadband is having a significant impact on education and e-learning by improving access to digital learning resources; encouraging communication among schools, teachers and pupils; promoting professional education for teachers; and linking local, regional, and national databases for administrative purposes or supervision.") *available at* http://www.olis.oecd.org/olis/2009doc.nsf/LinkTo/NT0000889E/$FILE/JT03275973.PDF.

133. *See, e.g.*, Justin Horner, Telework: Saving Gas and Reducing Traffic from the Comfort of your Home, Mobility Choice, *available at* http://www.mobilitychoice.org/MCtelecommuting.pdf ("By taking more than 4.7 million cars off the road every day, telecommuting already has a positive effect on congestion."); Ted Balaker, The Quiet Success: Telecommuting's Impact on Transportation and Beyond, Reason, Nov. 2005, *available at* http://reason.org/files/853263d6e320c39bfcedde642d1e16fe.pdf ("In fact, an analysis of Washington D.C. commuting by George Mason University's Laurie Schintler found that traffic delays would drop by 10 percent for every 3 percent of commuters who work at home."); Joseph Fuhr and Stephen Pociask, Broadband and Telecommuting: Helping the U.S. Environment and the Economy, Low Carbon Economy, 2011, 41-47, available at http://file.scirp.org/Html/4227.html ("Studies show that telecommuters reduce daily trips on days that they telecommute by up to 51% and automobile travel by up to 77%. ").

134. For example, using online help-wanted ads as a guide to the location of app-related jobs, Mandel and Scherer estimated the number of app-related jobs per U.S. state as of April 2012. Mike Mandel & Judith Scherer, The Geography of the App Economy, Sept. 2012 (prepared for CTIA), *available at* http://files.ctia.org/pdf/The_Geography_of_the_App_Economy.pdf.

135. Crandall, Lehr, & Litan, *supra*.

Crandall and Singer (2010) estimate spillover effects by examining how added spending in related upstream markets could impact employment.[136] Using industry-specific employment multipliers and an assumed five percent increase in capital expenditure, they estimate an additional 452,081 jobs on top of the 509,546 jobs created via the total multiplier, implying a spillover multiplier of 0.89.

Katz and Suter (2009) describe how "network-effect-driven" job gains flow from three trends: innovation leading to the creation of new services, attraction of jobs (from either other U.S. regions or overseas), and productivity enhancement.[137] They calculate the impact of innovation on the professional services sector, by applying the ratio of productivity gains to the creation of new employment, and applying this effect to the economy of the states with the lowest relative broadband penetration. The underlying assumption of this estimate is that "the economy can generate enough jobs through innovation in a rate comparable to productivity gains."[138] From these gains, they subtract: (1) the net jobs lost due to accelerated outsourcing from increased broadband penetration, and (2) the jobs lost due to more efficient processes enabled by broadband. They estimate that this (net) spillover multiplier can range from 0.07 to 7.28 of the direct effects, with a mid-point estimate of 3.65.[139] Expressed as a multiple of the total multiplier effect (direct, indirect, and induced effects combined), their midpoint estimate is slightly above one.

Atkinson, Castro and Ezell (2009) also examine the impact of spillover effects.[140] They explain how broadband investment facilitates: (1) innovative applications such as telemedicine, e-commerce, online education and social networking; (2) new forms of commerce and financial intermediation; (3) mass customization of products; and (4) marketing of excess inventories and optimization of supply chains. They explain that network externalities should not decline with the build out of networks and maturing technology over time, because penetration has not reached 100 percent and because faster connections should permit a new round of application innovation. Based on a $10 billion broadband investment program, they estimate 268,480 jobs via spillover effects, implying a spillover multiplier of 1.17.

Finally, a 2013 study by The Wireless Infrastructure Association (PCIA) explained how new technologies have been made possible as wireless broadband exceeded a critical threshold where innovators and users of new technologies "can move

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136. Robert W. Crandall & Hal J. Singer, The Economic Impact of Broadband Investment, Prepared for Broadband for America, Feb. 2010, *available at* http://internetinnovation.org/files/special-reports/Economic_Impact_of_Broadband_Investment_Broadband_for_America_.pdf.

137. Raul Katz & Stephan Suter, Estimating the Economic Impact of the Broadband Stimulus Plan, at 20.

138. *Id.* at 21.

139. *Id.* at 26.

140. Robert D. Atkinson, Daniel Castro and Stephen J. Ezell, *The Digital Road to Recovery: A Stimulus Plan to Create Jobs, Boost Productivity and Revitalize America*, INFO. TECH. & INNOV. FOUND. (Jan. 2009), *available at* http://www.itif.org/files/roadtorecovery.pdf.

forward with their business plans with the knowledge that the underlying infrastructure will be there to serve them."[141] For example, the technology for mobile payments has been growing due to the pervasiveness of wireless broadband infrastructure.[142] The study estimates that projected mobile broadband investments of roughly $35.5 billion per year will increase GDP by 1.6 percent to 2.2 percent, and will create 303,740 jobs in the first year of the study. Although their study focuses on the impact of wireless broadband investments, it nevertheless offers another application of the spillover effect.

Table 7 summarizes the relevant economic literature on spillover effects.

TABLE 7: SUMMARY OF SPILLOVER EFFECTS FROM BROADBAND INVESTMENT

Study	Annual Investment ($B)	Projected Total Jobs (000s)	Spillover Jobs (000s) (Spillover Multiplier)
Crandall & Singer (2010)	30.4	961.0	452 (0.89)
PCIA (2013)	35.5	303.7	194.9 (1.79)
Katz & Suter (2009)	6.4	263.9	136.1 (1.06)
Atkinson, Castro & Ezell (2009)	5.2	498.0	268.5 (1.17)

Given the consistency with which various researchers have used a spillover multiplier of slightly over one additional network-induced job per every job created via the total multiplier, I adopt the spillover estimate of one. Table 8 shows the results from combining the job losses from total multiplier and spillover effects.

TABLE 8: TOTAL JOB LOSS FROM FCC'S SPECIAL ACCESS RULES

	Annual Investment Loss ($B)	Total Multiplier	Spillover Jobs	Total Job Loss
Price Regulation	1.089	21,780	21,780	43,560

Under the Price Regulation scenario, the annual number of jobs lost through the total multiplier is 21,780. Including spillover effects brings the total annual number of jobs lost to 43,560.

B. Economic Output

Finally, one can measure the multiplicative effect of broadband investment on economic output. This occurs because higher expenditures on broadband equipment—equivalent to higher demand for the products of equipment manufacturers—cause equipment manufacturers to hire more employees to meet the increased demand. The equipment manufacturers' incomes increase as well due to the increased expenditures, which, according to the consumption function, will

141. Alan Perce, Richard Carlson, and Michael Pagano, Wireless Broadband Infrastructure: A Catalyst for GDP and Job Growth 2013-2017, PCIA (Sep. 2013), 9, *available at* http://www.pcia.com/images/IAE_Infrastructure_and_Economy_Fall_2013.PDF.

142. Gartner, Gartner Says Wordlwide Mobile Payment Transaction Value to Surpass $171.5 Billion, Press Release, May 29, 2012, *available at* http://www.gartner.com/newsroom/id/2028315.

increase their consumption as well. The increased consumption of equipment manufacturers will in turn increase the income and employment of their suppliers. The income and employment of those suppliers will then increase, triggering another round of spending.

Eisenach, Singer, and West estimate the weighted average output multipliers for FTTH investment (3.1293).[143] They arrive at this figure by using a weighted average of multipliers for three inputs used in the production of FTTH: telephone apparatus manufacturing, fiber-optic cable manufacturing, and construction. The weights for the three inputs were based on estimates of the capital mix used in FTTH, cable modem, and DSL deployments. Because FTTH relies more heavily on the burying of new infrastructure in the ground, the construction multiplier was given a larger weight when computing the FTTH-specific multiplier (50 percent), compared to the DSL and cable-modem multipliers (20 percent).

Because this fiber-specific broadband multiplier represents a reasonable estimate for business-fiber investment, I apply these multipliers to my annual broadband investment estimates in Table 9.

TABLE 9: TOTAL OUTPUT LOSS FROM FCC'S SPECIAL ACCESS RULES

	Annual Investment Loss ($ B)	Total Output Loss ($ B)
Price Regulation	1.089	3.407

The FCC's special access rules could reduce economic output by $3.4 billion per year over a five-year period.

VII. Conclusion

If the FCC refrains from subjecting telcos' fiber-based networks to price regulation, we project that roughly 122,000 buildings nationwide will be newly lit by ILEC fiber in the coming five years, an increase in fiber penetration of ten percentage points, representing $9.9 billion in ILEC capital expenditures. This study seeks to estimate the reduction in fiber investment relative to that baseline when special access regulation is expanded to cover Ethernet-based services. By trimming the expected revenues of unlit buildings via price regulation, expansion of the special access rules threatens to reduce ILEC fiber investment.

Using a model calibrated to the incumbent network in Charlotte and then extrapolating the results to the United States, we estimate that expansion of the FCC's special access rules could eliminate 43,560 jobs annually over a five-year period, and could reduce economic output by $3.4 billion per year over a five-year period. Moreover, the FCC's special access rules could prevent 67,300 buildings

143. Eisenach, Singer, West, *supra*, at 8.

from being lit by ILEC fiber. This material diminution in businesses served by fiber is flatly inconsistent with the FCC's Congressional mandate to expand broadband deployment.