Why broadband availability differs across states in the U.S.? Exploring the role of state administrative capacity

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Abstract. The U.S. government has made various efforts to increase broadband access, even before the pandemic. However, there is still a significant gap in broadband coverage across U.S. states, indicating the persistence of digital divides. Previous research has focused on geographic and socio-demographic factors, often overlooking the role of state governments, including state administrative efforts. In this paper, we explore how the administrative capacity of states influences the coverage of four broadband technologies across states in the U.S. Using secondary data, beta regression is employed to explore the impact of state administrative capacities, i.e., broadband plans, grantmaking, broadband offices, broadband maps, and state regulations, on the coverage of cable, fiber optics, fixed wireless, and fiber/cable at urban, rural, and state levels. The findings confirm the dominance of cable, followed by fixed wireless, while fiber shows limited coverage. Infrastructure-focused broadband plans negatively affect fiber optics' coverage, highlighting implementation challenges. Conversely, grantmaking positively affects fixed wireless but not fiber, highlighting a tendency toward cost-effective, faster-deployment technologies.
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1. Introduction

Besides highlighting the important role of broadband internet, the Covid-19 pandemic also exposed the persistent issue of digital divides in the United States. The disparity still exists, especially in terms of geographic, economic, educational, and socio-demographic aspects (Li et al., 2023). In addition to the affordability issue (Bauer, 2023), the low coverage or absence of internet access in some regions in the U.S. is caused by the lack of infrastructure (Busby et al., 2023). Efforts have been made to address the lack of broadband infrastructure, not only from the government but also scholars. At the federal level, scholars analyzed federal policies, market influences (Ali, 2020; Bauer, 2023), and subsidies (Dinterman & Renkow, 2017), while state and local studies have focused on sub-federal governance (Ali et al., 2022), state grants (Bravo & Warner, 2023), and regulation (Galperin et al., 2021).

Unfortunately, there is state-by-state variation in internet coverage across the nation, with some areas having higher coverage and other areas having limited or even no Internet access (Rachfal, 2023), as seen in the 2021 Broadband Development Report (FCC, 2021). Some states such as California, Connecticut, New Jersey, and New

York, outperformed their counterparts, with more than 98% of their population having access to fixed broadband. On the other hand, Alaska, Arkansas, Mississippi, and West Virginia fell below the average, with less than 85.5% of their residents having the service. These gaps indicate variation in broadband availability across states.

Regrettably, there is a lack of scholarly literature addressing the diffusion of broadband across states and the factors contributing to the disparities. If there were any, the earlier work focused on broadband speed and different forms of market competition instead of the variability of broadband users among states (Denni & Gruber, 2007). Nonetheless, it can be learned from previous literature that the variations can be attributed to geographic and socio-demographic factors that vary among states (Rachfal, 2023). Some states have more challenging geographic locations, such as rural or high-cost areas with low population density, discouraging telecommunication providers from investing due to the high deployment costs and the uncertain return on investment (Ali, 2021).

Furthermore, other scholars highlighted the critical but frequently overlooked role of state governments' efforts in advancing broadband deployment (Whitacre & Gallardo, 2020). They acknowledged that the diffusion of broadband among states is influenced by the state broadband policies, including the presence of state broadband office and its key functions, such as policies, stakeholder outreach, planning and capacity building, operations and funding, etcetera (Stauffer et al., 2020). These key functions demonstrate the role of administrative aspect of state capacity, or state administrative capacity (Haque et al., 2021). Stratton and Astuti (2024) also demonstrated variations in addition to uniformity among state governments' efforts in the administrative dimension.

Given the lack of discussion about the role of state administrative capacity and the broadband variation among states, this paper aims to answer the following research question: *"How do state administrative capacities correlate with the adoption of broadband technology (fiber, cable, fixed wireless, and fiber/cable) across states in the U.S.?"* As the definition of broadband could cover various technologies, this study analyzes the impact of administrative capacities on the adoption of three broadband technologies—fiber, cable, and fixed wireless as well as a fourth that combines fiber and cable or fiber/cable to capture overlapping deployment in broadband technologies. Beta regression is employed to quantify the impact of different administrative capacities on broadband coverage in the fifty states in the U.S. It is expected that the analysis can help identify which aspects of states' administrative capacities have the most significant effect on broadband availability, in urban, rural, and the state-level areas.

This paper is structured as follows. Section 2 presents the literature study, section 3 describes the methodology, subsequently, section 4 outlines the findings based on twelve beta regression models across the four technologies and geographical areas. Then, section 5 presents the discussion and section 6 concludes this paper.

2. Literature Study

2.1 From Digital Divides to Broadband-Enabled Digital Equity

Digital divide has emerged from its original focus on the "access divide", which highlighted disparities in internet connectivity based on factors such as location, age, and socioeconomic status (Campos-Castillo, 2015; Hindman, 2000), then extended to include the "usage gap" and "capability divide", which consider the skills and motivations needed to effectively use the internet (DiMaggio & Hargittai, 2001; van Deursen & van Dijk, 2014), and an "outcome divide", which focuses on the tangible benefits derived from internet access (Wei et al., 2011). Even though the concepts have evolved, digital equity has been considered as the ultimate goal (Puigjaner, 2016). Central to achieving digital equity is broadband access, which the FCC currently defines as a minimum of 25 Mbps download and 3 Mbps upload, though recent calls suggest raising this to 100 Mbps download and 20 Mbps upload (Congressional Research Service, 2021). Unfortunately, existing studies on digital divides mostly take individual perspectives, leaving the study on institutional efforts and policy initiatives to remain overlooked.

2.2 The Federal Efforts for Digital Equity

The policy initiatives in broadband development expansion across the U.S. have demonstrated a long journey. Starting from the Communications Act of 1934, an act focused on equitable access to communication services across the nation, then the Telecommunications Act of 1996 that fostered the competition in the telecommunications industries. The government also released the Broadband Data Improvement Act to improve the accuracy of federal data on broadband and create the National Broadband Map to encourage better reporting from Internet Service Providers. The American Recovery and Reinvestment Act (ARRA) of 2009 was launched to stimulate the economy during the pandemic through funding like BTOP and BIP that focused on broadband deployment in underserved areas (Kruger, 2011). The federal government then launched CARES Act of 2020 and the American Rescue Plan (ARPA) of 2021 to provide relief and support to Americans due to the Covid pandemic, including broadband support for low-income households through the Emergency Broadband Benefit. The latest, the Infrastructure Investment and Jobs Act of 2021 marked a major focus, emphasizing not only broadband expansion, but also digital equity programs.

2.3 State Government Efforts and Conceptual Framework on State Administrative Capacity

2.3.1 Variations among States Government's Efforts on Broadband Expansion

Due to a policy shift toward devolution, the federal government has allocated a considerable amount of funds and grants to states and local governments (Gainsborough, 2003; Pandey & Collier-Tenison, 2001). States have more flexibility to address problems tailored to the uniqueness of their geographic, demographic, and economic conditions (Adkisson & Peach, 2000; Dilger & Cecire, 2019). Especially due to the Covid, the federal government has allocated grants-in-aid and other categorical grants for states to implement programs to expand broadband infrastructure and increase its adoption. Despite the huge amount of grants, state broadband programs vary across the U.S. due to political, geographical, resource factors, and organizational structures (Stauffer et al., 2020). Stratton and Astuti (2024) demonstrated variations with regards to states' administrative capacity prior to the establishment of the IIJA, such as broadband offices that plan and manage broadband initiatives, state government's collaboration with other entities, the making of state broadband plans, broadband availability maps, and broadband grants.

2.3.2 Conceptual Framework on State Administrative Capacity

To systematically explain why such variations occur across the U.S. states, this study refers to the policy capacity model (Wu et al., 2015) which defines three dimensions of governance capacity necessary to shape policy outcomes: analytical, operational, and political capacities. Analytical capacities refer to the knowledge and skills required to generate, analyze, interpret, and use evidence to evaluate policies, including research skills, data analytics, and policy evaluation. Operational capacity reflects any capabilities required to implement and manage policies, including staffing, budgeting, resource allocation, collaboration, and so forth. Political capacity includes any capabilities required to successfully navigate a complex political situation, such as stakeholder engagement, public communication, political mandates and leadership.

In the context of broadband expansion, state efforts varies and their efforts (Stratton & Astuti, 2024) reflect the combination of these capacities. The variations show that some states have demonstrated the use of detailed broadband availability maps to guide their investment decision on infrastructure expansion which shows an analytical capacity. In terms of operational or managerial capacity, some states have established broadband offices to manage their broadband initiatives, developed broadband plans focusing on infrastructure, and created grantmaking programs for resource management. These activities are part of staffing, planning, and resource allocation which encompass the state's operational capacity. Regarding the political capacity, some states have also demonstrated regulatory efforts as a tool for political authority and negotiation. Furthermore, each of state's efforts is explained as follows.

Broadband office
States vary in managing broadband initiatives. While many states have dedicated broadband offices, others manage broadband tasks within existing departments. States without specific broadband offices incorporate these efforts into broader departmental agendas, like Montana's ConnectMT program (Read & Gong, 2021). Additionally, states frequently collaborate with state and local entities, including broadband task forces and committees. Their efforts in managing broadband tasks varied, suggesting that the type of state broadband office could be linked to the availability of broadband access in a state. Understanding that states that operate independently or located within a strategic departments like commerce could be more specific to focus on their broadband efforts, we propose the following hypothesis:

> *Hypothesis 1: A more independent/specialized type of broadband office has a positive and significant influence on the availability of broadband access.*

Broadband plan
In terms of broadband planning, thirty-five states had issued a broadband plan prior to the IIJA funding requirements (Stratton & Astuti, 2024). These plans varied in detail and also revealed that broadband expansion emerged as a common priority. However, only about half addressed affordability, and fewer still included digital literacy or inclusion initiatives. The variation in the details and the priority of each state in broadband expansion as state in their broadband plans could impact the variation in the broadband availability among states. Thus, we propose a second hypothesis as follows.

> *Hypothesis 2: A state with a broadband plan focusing on infrastructure expansion prior to the IIJA has a positive and significant link to the availability of broadband access.*

Broadband availability map
One of the most noticeable programs mentioned by states in their broadband plans is to develop a state broadband availability map, as a response to the inaccuracy of the FCC's national broadband map. States depend on federal grants to expand their broadband to underserved and unserved areas. However, the allocation of some federal

grants has been hindered by the national broadband map which was not detailed enough to capture unserved and underserved areas in each state in the U.S. (Peikes, 2023). To counteract this, some U.S. states have developed their broadband maps (Read & Gong, 2021) even before the IIJA, where the data sources they utilized were various, such as data obtained from the FCC sources, ISP reports, citizen input, Census Bureau, or a mix of these to obtain a clearer picture of coverage needs (Stratton & Astuti, 2024). States that developed their state broadband map could identify and address the unserved populations more accurately than states without such maps. Therefore, the third hypothesis proposes a link between the presence of the state broadband map and the availability of broadband access.

> *Hypothesis 3: There is a positive and significant association between state's broadband map and the availability of broadband access.*

Grantmaking efforts

States have shown variation in grantmaking efforts, with many of them focusing on infrastructure expansion (Stratton & Astuti, 2024). During the Covid-19 pandemic, many states funded projects to connect underserved and unserved areas (Read & Gong, 2022). Although states developed their broadband funding programs, the mechanisms were similar, often involving grants and loans sourced from the Universal Service Fund, special funds, and other revenues such as service provider fees (An, 2019). Besides, states also use other mechanisms, such as tax incentives and bonds. Mainly, federal grants, particularly ARPA, were the primary source of state's broadband funding. However, aside from that, some states also allocated funding from non-ARPA grants, such as Idaho and Arizona. States with grantmaking efforts before the IIJA could have connected more underserved areas than states without grantmaking efforts. Thus, we argue that there is a link between grantmaking efforts prior to the IIJA and broadband availability.

> *Hypothesis 4: A state with grantmaking efforts prior to the IIJA has a positive and significant impact on the availability of broadband access.*

Broadband internet regulations

Variation is also seen in the states' regulatory approaches to broadband. The State Broadband Policy Explorer (Pew, 2021) presents diverse laws in governing broadband Internet access across states. For instance, California implemented regulations on authorized services and facilities in 2018, and Maine enhanced competition among public providers through joint exercise of powers in 2015. Supportive regulation is essential for promoting broadband deployment, especially in high-cost areas. States with broadband regulations could have more coverage on Internet access. Therefore, we propose the following hypothesis.

> *Hypothesis 5: There is a positive and significant association between a state's regulations governing broadband internet access prior to the IIJA and the availability of broadband access.*

Drawing from the literature, this paper suggests that administrative capacity (in terms of task force/agency, regulation, grantmaking programs, broadband plans, state broadband availability map) influences a state's broadband-technology adoption.

3. Methodology

2.1 Data Collection

This paper is quantitative and secondary research, which aims to investigate the influence of a state's administrative capacities on broadband technology adoption. The majority of the data used in this study is the output of the work of Stratton and Astuti (2024), where the data were sourced from a variety of secondary sources, including federal and state government websites and other authoritative bodies, government reports, state broadband plans, articles, policy documents, and broadband access statistics at a state-level unit of analysis. Additional data were then added in this study, including municipal regulations and the broadband technology adoption. Together, we came up with a state-level database in an Excel file which includes all the variables needed.

To test the hypotheses, five independent variables that represent a state's administrative capacities are used, i.e., type of office, regulation, broadband plans, grantmaking, and state broadband availability map. All independent variables except the type of office are operationalized as binary (0 and 1) due to the nature of the available data and our goal to capture the "presence" as 1 and "absence" as 0 of these administrative aspects. For example, the presence of an infrastructure-focused broadband plan in a state is coded as 1, and 0 if a state did not have any broadband plan focusing on infrastructure. The state's broadband adoption is the dependent variable with three different technologies (fixed wireless, cable, fiber) and one combined technology (fiber and cable). We use the data from the FCC's broadband national map (FCC, n.d.) in 2022 for the dependent variables, considering the availability of the data, and the effect of policies on administrative capacities that were imposed before the IIJA. Finally, the required data is presented in Tab. 1, including the characteristics and the sources of the data.

Tab. 1 - The variables used in the study

Category	Dependent/ Independent	Variable	Type	Description	Data Source
Broadband Adoption	Dependent	Urban covered by fiber	Continuous (%)	Percent of urban areas covered by fiber at 25/3 Mbps in 2022	The FCC's national broadband map as of June 2022 Data
	Dependent	Rural covered by fiber	Continuous (%)	Percent of rural areas covered by fiber at 25/3 Mbps in 2022	The FCC's national broadband map as of June 2022 Data
	Dependent	State (Units) covered by fiber	Continuous (%)	Percent of units covered by fiber at 25/3 Mbps in 2022	The FCC's national broadband map as of June 2022 Data
	Dependent	Urban covered by cable	Continuous (%)	Percent of urban areas covered by cable at 25/3 Mbps in 2022	The FCC's national broadband map as of June 2022 Data
	Dependent	Rural covered by cable	Continuous (%)	Percent of rural areas covered by cable at 25/3 Mbps in 2022	The FCC's national broadband map as of June 2022 Data
	Dependent	State (Units) covered by cable	Continuous (%)	Percent of units covered by cable at 25/3 Mbps in 2022	The FCC's national broadband map as of June 2022 Data
	Dependent	Urban covered by fiber and cable	Continuous (%)	Percent of urban areas covered by fiber and cable at 25/3 Mbps in 2022	The FCC's national broadband map as of June 2022 Data
	Dependent	Rural covered by fiber and cable	Continuous (%)	Percent of rural areas covered by fiber and cable at 25/3 Mbps in 2022	The FCC's national broadband map as of June 2022 Data
	Dependent	State (Units) covered by fiber and cable	Continuous (%)	Percent of units covered by fiber and cable at 25/3 Mbps in 2022	The FCC's national broadband map as of June 2022 Data
	Dependent	Urban covered by fixed wireless	Continuous (%)	Percent of urban areas covered by fixed wireless at 25/3 Mbps in 2022	The FCC's national broadband map as of June 2022 Data
	Dependent	Rural covered by fixed wireless	Continuous (%)	Percent of rural areas covered by fixed wireless at 25/3 Mbps in 2022	The FCC's national broadband map as of June 2022 Data
	Dependent	State (Units) covered by fixed wireless	Continuous (%)	Percent of units covered by fixed wireless at 25/3 Mbps in 2022	The FCC's national broadband map as of June 2022 Data
Administrative Capacity	Independent	Type of office	Categorical (1-3)	1=Broadband office under CED/Communication department 2=Broadband office under IT department 3=Broadband office under other departments	State Government Websites State Broadband Plans/ Reports
	Independent	Regulation	Categorical (Binary)	0=State does not regulate competition/regulation before the IIJA; 1=State regulates	State Government Websites State Broadband Plans/ Reports State Broadband Policy Explorer

Category	Dependent/ Independent	Variable	Type	Description	Data Source
				competition/regulation before the IIJA	
	Independent	Broadband plans focusing on infrastructure	Categorical (Binary)	0=No broadband plans/BB plans do not focus on infrastructure; 1=State has broadband plans focusing on infrastructure	State Government Websites State Broadband Plans/ Reports State Broadband Policy Explorer
	Independent	Grantmaking programs	Categorical (Binary)	0=State does not create any grant programs for broadband before the IIJA; 1=State has grant programs before the IIJA	State Government Websites State Broadband Plans/ Reports State Broadband Policy Explorer Pew
	Independent	State broadband availability map	Categorical (Binary)	0=State with no broadband availability map before the IIJA 1=State has broadband availability map before the IIJA	State Government Websites State Broadband Plans/ Reports State Broadband Policy Explorer

2.2 Assumption Check and Data Analysis

The analysis uses beta regression because our outcomes—the percent of areas covered by broadband technologies—are continuous and have values between 0 and 1. Beta regression is ideal to be used for modeling such proportions of values (Ferrari & Cribari-Neto, 2004). Other models—such as logistics regression that requires binary dependent variables, or Ordinary Least Squares that require outside 0-1 range—are not suitable for the analysis. The general formula of beta regression is seen below, where μ_i is the mean of the dependent variable Y_i within the interval of 0 and 1 (such as the percent of broadband coverage), $g(\mu_i)$ is the logit function log, X_i is the independent variables (five aspects of state administrative capacity), and β is the regression coefficients.

$$g(\mu_i) = X_i\beta \qquad (1)$$

A beta regression model is applied to analyze broadband coverage across four technologies and geography. For each technology, we measured at urban, rural, and state. Thus, this results in 12 unique dependent variables, meaning 12 beta regression models. Each model uses five independent variables to test the hypotheses. Because each dependent variable is a proportion with the value between 0 and 1, we apply a logit transformation to handle the 0-1 range so that a linear model can be performed with 0-1 range values (Ferrari & Cribari-Neto, 2004).

Several assumptions were checked before analyzing the regression models, including the linearity check, multicollinearity, and homoscedascity as seen in Tab. 2. The linearity check was performed to assess the linearity between the dependent variable in the logit scale and trange.he independent variables. We employed residual versus fitted plots to conduct this check. Next, the second multicollinearity check is done to investigate the correlation between independent variables through their Variance Inflation Factor (VIF) value (above 5 indicates high multicollinearity). Last, the homoscedascity check is to identify heteroscedasticity through the spread of the residuals/errors. We used residual plots to perform this check.

Tab. 2 - The assumption checks and criteria

Assumption Check	Method	Expected Results
Linearity	Residual vs. Fitted Plot	No clear patterns
Multicollinearity	VIF	VIF < 5 for all predictors
Homoscedasticity	Residual Plots	Even spread of residuals

Running the assumption checks

Initially, we had seven variables, adding *taskforce* and *broadbandplans*. However, a multicollinearity issue was found between *taskforce* and *typeoffice* when we run *cablefiber* models for a state level. Since *typeoffice* is categorical type of data, centering variables to address multicollinearity could not be performed (Aiken et al., 1991), so we removed *taskforce*. Another problem was also found between *infrastructure* and *broadbandplans*. We retained the *infrastructure*, and redefined it as states with a broadband plan focusing on infrastructure expansion (Stratton & Astuti, 2024). We then run another round to ensure that all assumptions were met. Finally, five independents were used in our regression analysis: *typeoffice*, *infrastructure, regulation, broadbandmaps,* and *grantmaking*. Figure 1, Table 3, and Figure 2 represent the sample results of final assumption check we performed.

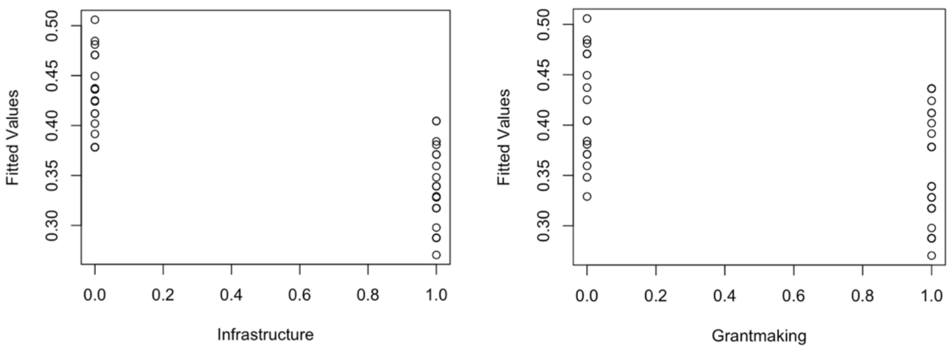

Fig. 1 - Linearity check for two variables on fiber in urban

Tab. 3 - The multicollinearity check using VIF (>5)

		Type of Office	Infrastructure-focus BB Plans	Municipal Regulation	BB Maps	Grantmaking
State	Cable/Fiber	1.34	1.06	1.16	1.17	1.43

		Type of Office	Infrastructure-focus BB Plans	Municipal Regulation	BB Maps	Grantmaking
	Fiber Only	1.31	1.06	1.15	1.21	1.46
	Cable Only	1.33	1.06	1.16	1.19	1.44
	Fixed Wireless	1.32	1.06	1.15	1.20	1.46
	Cable/Fiber	1.31	1.07	1.16	1.17	1.40
Urban	Fiber Only	1.31	1.06	1.15	1.21	1.45
	Cable Only	1.31	1.06	1.16	1.17	1.41
	Fixed Wireless	1.31	1.06	1.14	1.20	1.46
	Cable/Fiber	1.33	1.07	1.16	1.20	1.45
Rural	Fiber Only	1.31	1.07	1.13	1.21	1.46
	Cable Only	1.32	1.06	1.15	1.20	1.45
	Fixed Wireless	1.34	1.06	1.16	1.20	1.47

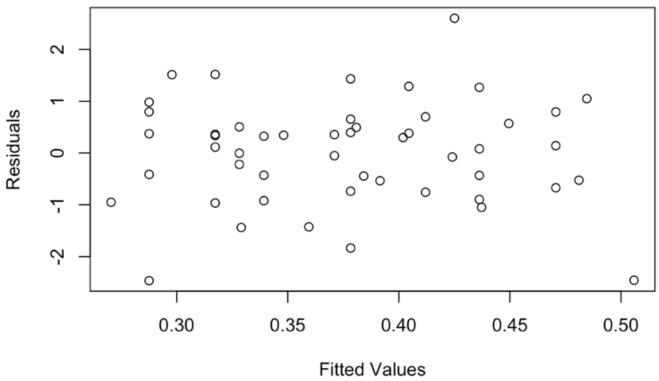

Fig. 2 - Residuals vs. Fitted for homoscedascity check on fiber in urban.

4. Findings

This section explores the link between the different broadband technologies and the states' administrative capacities in rural, urban, and overall state settings.

4.1 Broadband coverage across states based on four different technologies

At the state-wide level, the majority of the U.S. is covered by the fixed broadband, cable and fiber broadband, as seen in Table 4. However, among the four technologies, the cable technology has the highest coverage (79%) than fixed wireless (62.9%) and fiber technology (with only 35%). Regarding the spread, it is indicated that there is a widespread availability of fixed broadband, as indicated by an SD of .081 for cable and fiber technology. With moderate coverage, the wireless has an SD of .18, suggesting significant variation across states. As the technology with the lowest coverage, fiber technology also shows a significant variation (SD = .138) in fiber broadband availability across the states.

In urban areas, the coverage is dominated by cable broadband services, with 94.4% of urban areas having access to Internet access using cable technology. Fixed wireless covers 70% of the urban areas, while and fiber technology has the lowest coverage, with only 37.7%. Comparing cable and fixed wireless, interestingly, the coverage the two technologies indicates that the cable technology serves most of the Internet connection in urban regions. Surprisingly, the SD of fixed wireless (SD = .163) indicates a significant variation in urban areas across states, whereas cable coverage is widespread in urban areas (SD = .030). The fiber technology also shows a significant variation (SD = .153) that underlines the disparities in access using this technology in rural areas. Internet coverage in rural areas is considered low. Most coverage is dominated by cable (46.8%) and fixed wireless (46.7%), while fiber only covers 25.4% of the rural areas. Together, fiber and cable technology only cover 60% of the whole rural areas in the U.S. Speaking about the spread of the technology, the standard deviation of all four technologies indicates significant variation, especially the fiber technology that has the highest variability relative to its average (SD = .147), suggesting widely dispersed technology. Cable technology (SD = .217) and fixed wireless (SD = .467) also show variability, meaning the technology is spread out in rural areas, even though the spread is not as wide as the fiber.

Tab. 4 - The descriptive statistics of the four technologies

Level	Technology	Average	SD	Minimum	Median	Maximum
State	Fiber/Cable	0.854	0.081	0.643	0.862	0.993
	Fiber Only	0.351	0.138	0.061	0.352	0.792
	Cable Only	0.790	0.114	0.523	0.801	0.986
	Fixed Wireless	0.629	0.177	0.286	0.589	0.963
Urban	Fiber/Cable	0.966	0.024	0.905	0.975	0.999
	Fiber Only	0.377	0.153	0.043	0.371	0.799
	Cable Only	0.944	0.030	0.877	0.951	0.995
	Fixed Wireless	0.705	0.163	0.425	0.688	0.978
Rural	Fiber/Cable	0.609	0.173	0.294	0.591	0.954
	Fiber Only	0.254	0.147	0.084	0.231	0.738
	Cable Only	0.468	0.217	0.192	0.416	0.951
	Fixed Wireless	0.467	0.205	0.155	0.424	0.874

To sum up, statewide analysis highlights the disparities in broadband availability, depending on geographic settings and technology type. Broadband coverage is generally high and consistent across different technologies in urban areas, showing widespread access. Rural areas, however, experience more variability in coverage, with significant disparities in access to different broadband technologies. Among all technologies, fiber only is the lowest in coverage in rural and urban areas.

4.2 State-wide broadband coverage and administrative capacity

This analysis aims to see the link between broadband coverage and administrative capacity at the state level. The estimated coefficients and the p-values of the beta regression analysis are presented in Table 5. The findings show that infrastructure has a significant negative effect (-0.446, p-value <0.01) on fixed broadband (fiber/cable) coverage, meaning that broadband plans focused on infrastructure have nothing to do with increasing the Internet coverage. Other variables, show no significant impact. For fiber only technology, it shows a strong negative association to broadband plans that prioritized infrastructure development (-0.593, p-value <0.000). Surprisingly, grantmaking also shows a low significant and negative association with fiber technology (-0.360, p-value = 0.050). Other variables show no significant impact on fiber only coverage. As for cable only, no significant effects are observed from any of the variables, indicating a more stable technology. The last one, grantmaking has a positive significant impact on fixed wireless (0.518, p-value = 0.37), which could indicate that fixed wireless benefits more from state grant programs than other technologies. To sum up, our findings suggest that broadband plans focused on infrastructure deployment significantly influence broadband coverage of fixed broadband and especially fiber technology. However, they appear to have a negative impact on fiber/cable and fiber only networks. Another conclusion is that for fiber only and fixed wireless technologies, grantmaking is significant but varies in direction and magnitude. Other administrative capacity's variables do not show any significant impact.

4.3 Administrative capacity and Urban Broadband Coverage

As seen in Table 5, for fixed broadband (fiber/cable technology), it indicates that infrastructure has a significant negative effect (-0.478, p-value =0.009) on the coverage of this technology in urban areas. Other variables, such as the type of office, grantmaking, broadband maps, and municipal regulations, do not have a significant impact. For fiber technology, infrastructure shows a significant negative impact (-0.410, p-value = 0.021), while other variables do not show a significant effect. Cable technology is not affected by any variables in urban areas, as the analysis indicates that infrastructure and other factors do not significantly influence cable coverage. However, the table shows a positive link between fixed wireless coverage and state's grantmaking programs (0.501, p-value = 0.054) and no link between fixed wireless and other variables. To conclude, state broadband plans focusing on infrastructure tend to have a negative impact on the coverage of fiber and fiber/cable. However, these plans show no significant impact on the coverage of cable and fixed wireless. On the other hand, grantmaking programs demonstrate a significant and positive influence on fixed wireless coverage.

Tab. 5 - Beta regression coefficient summary with significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '°' 0.1 ' ' 1

Level	Technology	(Intercept)	Type of Office	Infrastructure	Municipal Regulation	Broadband Maps	Grantmaking
State	Fiber/Cable	2.347 (.000)***	-0.013 (.901)	-0.446 (.015)*	0.146 (.436)	-0.237 (.391)	-0.182 (.408)
	Fiber Only	0.101 (.708)	-0.033 (.720)	-0.593 (.000)***	0.090 (.5684)	0.049 (0.822)	-0.360 (.050)°
	Cable Only	1.719 (.000)***	-0.039 (.749)	-0.170 (.398)	0.159 (.448)	-0.249 (.411)	-0.126 (.608)
	Fixed Wireless	-0.007 (.985)	0.072 (.562)	0.260 (.206)	-0.064 (.762)	-0.015 (.958)	0.518 (.037)*
Urban	Fiber/Cable	4.025 (.000)***	-0.02418 (.821)	-0.478 (.009)**	-.099 (.593)	-.252 (.367)	-.137 (.526)
	Fiber Only	-0.352 (.270)	.050 (.642)	-0.410 (.021)*	0.141 (.448)	0.085 (.741)	-.280 (.194)
	Cable Only	3.436 (.000)***	.-0.081 (.382)	.-0.255 (.102)	-0.100 (.536)	-0.211 (.378)	-0.107 (.570)
	Fixed Wireless	0.349 (.361)	0.079 (.541)	0.242 (.263)	-0.061 (.783)	-0.017 (.954)	0.501 (.054)°
Rural	Fiber/Cable	0.950 (.007)**	-0.020 (.862)	-0.726 (.000)***	0.108 (.590)	0.138 (.623)	-0.326 (.167)
	Fiber Only	-0.166 (.568)	-0.147 (.139)	-0.781 (.000)***	0.004 (.982)	0.032 (.890)	-0.394 (.049)*
	Cable Only	0.130 (.763)	0.009 (.950)	-0.308 (.202)	0.146 (.560)	0.012 (.972)	-0.224 (.444)
	Fixed Wireless	-0.985 (.010)*	0.150 (.239)	0.288 (.172)	-0.163 (.457)	0.090 (.770)	0.668 (.001)**

Tab. 6 – The summary of the hypotheses

Hypothesis	Statement	Result	Hypothesis Outcome
H1	A more independent/ specialized broadband office has a positive and significant influence on broadband availability.	No significant effect in any model	Hypothesis not supported
H2	A broadband plan focused on infrastructure has a positive and significant impact.	The relationship is reversed, significantly negative in various models (fiber, fiber/cable) in rural and urban.	Not supported (significant but reversed)
H3	A broadband map has a positive and significant impact.	No significant effect in any model	Not supported
H4	Grantmaking has a positive and significant impact.	Significant only is fixed wireless models for state and rural, but not significant for fiber/cable	Supported (especially for fixed wireless)
H5	Broadband regulations have a positive and significant impact.	No significant effect in any model	Not supported

4.4 Administrative capacity and Rural Broadband Coverage

According to the Table 5, fixed broadband (fiber/cable) is negatively influenced by infrastructure-focused broadband plans (-0.726, p-value < 0.001), and not impacted by other variables. Similarly, the coverage of fiber technology is also negatively impacted by broadband plans emphasizing infrastructure deployment (-0.781, p-value < 0.001). In addition, grantmaking tends to have a negative impact on fiber coverage too (-0.394, p-value = 0.049), while other variables do not show any significant effects. Cable coverage in rural areas is not influenced by any variables. In contrast to fiber, the coverage of fixed wireless shows to be influenced positively by a state's grantmaking program (0.668, p-value < 0.001), while other variables tend to have no significant influence on this technology. The findings show a similar pattern as seen in urban areas where infrastructure-focused broadband plans tend to have a negative effect on both fiber/cable and fiber technology coverage. Grantmaking effort by states shows a negative impact on fiber technology. However, a state's effort in grantmaking is likely to increase the coverage of fixed wireless technology. Finally, we present the summary of our findings in the Table 6.

5. Discussion

Based on the findings, this section presents the discussion, especially to seek the possible explanations of the negative significance of broadband plans focusing infrastructure on fiber technology, the positive significance of grantmaking on fixed wireless adoption, and the negative significance of grantmaking on fiber.

The domination of cable technology, but disparities are still pronounced
The descriptive analysis demonstrates that cable technology dominates the Internet coverage in the U.S. at the rural, urban, and the state level, followed by the fixed wireless with moderate coverage, and fiber optic with the lowest one. The result validates the disparities in technology deployment and Internet access coverage, highlighting the challenges faced by the U.S. government in bringing digital equity. The cable technology's domination extends beyond urban areas, as it does in rural areas. According to some scholars, this domination is a result of a combination of various aspects, including regulatory (Berresford, 1999; Cooper, 2016; Garcia & Wilkins, 2001), technological (Garcia & Wilkins, 2001), and economic aspects (Garcia & Wilkins, 2001; Hazlett & Weisman, 2011).

In urban areas, cable technology shows a very high percentage, demonstrating widespread Internet availability across the U.S. urban landscape. However, despite the significant level of cable penetration in urban areas (94.4%) 5.6% of these areas are not covered by the cable broadband services, indicating that over 15 million people may not have access to the Internet. Those who live in these underserved areas are characterized by socio-economic factors, such as low-income households, Black, and Hispanic neighborhoods with the affordability issue to provide the cost of Internet services (Li et al., 2023; Mossberger et al., 2012; Zahnd et al., 2022). From the side of internet service providers, deploying network infrastructure in areas where there is not enough demand for Internet services seems to be non-profitable, because of low return on investment (Joyce, 2019; Rachfal, 2023).

Moreover, even though cable technology dominates the broadband landscape, the disparity in access coverage between urban and rural is highly distinct, with a 47.6% gap. Scholars attribute the disparity to various challenges, such as geographic (Pereira, 2015), economic viability, (Pereira, 2015; Wu, 2021), and regulatory challenges (Ali, 2020). Geographically, rural areas have less significant population densities compared to urban regions, which results in higher costs for deploying network infrastructure and less economic viable. On the other hand, the existing policies do not really address rural needs (Ali, 2020), which exacerbate the rural-urban divides.

The execution challenges of infrastructure-focused broadband plans and its influence on fiber coverage
This study demonstrates that infrastructure-focused broadband plans have a negative impact on fiber coverage at urban, rural, and state-wide level. The result implies an implementation or execution issue of the plans, which are possibly caused by several aspects, including data availability and accuracy, budget issues, intergovernmental organizations and stakeholders dynamics, and regulatory challenges.

Helderop et al. (2019) mention that the absence of precise and detailed data about broadband could impede the correctness of broadband needs and assessment, including fiber broadband. Besides, fiber broadband deployment requires a large amount of investment. However, while relying the funding on state or federal governments is insufficient, some low densely populated areas are less attractive for private service providers to invest (Valentín-Sívico et al., 2022). Nuechterlein and Shelanski (2020) also mention a real challenge, i.e., the mismatch between the capital-intensive deployment projects and the market itself that is not fully prepared which may discourage private network providers to invest. Providers usually seek immediate returns, while the deployment of fiber technology usually has a longer return due to high capital investment, mainly in rural areas and cities with low-density populations (Beardsley et al., 2010; Monath et al., 2003; Rachfal, 2023). If there is an imbalance between the push for deploying the infrastructure and the market demand for fiber technology, the growth of fiber technology could be very low compared to other less expensive technologies (such as cable or fixed wireless). Ultimately, the lack of competition will only benefit the incumbent and suppress prospective new entrants.

Moreover some challenges come from the internal organizations, such as the lack of coordination, and organization's participation among agency officials (Valentín-Sívico et al., 2022). Valentín-Sívico et al. (2022) mention the lack of the regional planning commission's involvement in the broadband initiatives, possibly due to the lack of expertise, insufficient capacity to execute the deployment projects, or limited resources. Besides, governments' priorities could change over time, and different stakeholders could even have conflicting priorities. These hurdles could obstruct fiber deployment.

Furthermore, there are other regulatory and administrative challenges such as complex permitting requirements, compliance with local regulations, and the rights-of-way access processes to place fiber optics which have made the implementation of fiber optics more challenging (Beardsley et al., 2010; Monath et al., 2003; Nuechterlein & Shelanski, 2020). The literature mentioned the physical barrier as another issue, as it needs either to lay out new cables underground or to lay out the cables along the existing utility poles. Both approaches require efforts, for example, bargaining about the rights-of-way access, complying with environmental regulations, and navigating local zoning laws. Besides, from the standpoint of policy outcomes, policymakers tend to seek technologies that show immediate visible results rather than long-term investment with almost no immediate return. As a result, their attention could shift to prioritize cheaper, faster, and less complicated technologies such as cable and fixed wireless so that network coverage can be reached quickly.

State's grantmaking and its role in the coverage of fixed wireless and fiber

The findings of this study confirms that state's funding for broadband has an impact on broadband coverage, especially on fiber coverage and fixed wireless, even though the impact varies in direction. The results show that grantmaking is positively linked to fixed wireless coverage in both rural and urban areas, meaning that grantmaking efforts could increase the fixed wireless coverage in both areas. The findings indicate that grantmaking programs are most likely to prefer wireless technologies.

Scholars mention some qualities of fixed wireless that could be used to justify why grantmaking efforts have a positive link to the availability of fixed wireless. First, fixed wireless is known for its faster deployment time, lower costs, and adequate coverage, which makes it a more economically viable option for states to connect underserved areas (Bravo & Warner, 2023; Rachfal, 2023). Second, this technology can be tailored in various geographic settings, even in a difficult terrain, making it easier to connect rural areas (Zhang et al., 2021). It can also be scaled up to accommodate various user densities (Prasad & Velez, 2010). Third, from the network provider's standpoint, deploying fixed wireless is less complicated than fiber technology due to less extensive regulatory permit, resulting in a faster deployment time.

However, different from fixed wireless, our study reveals that grantmaking has a significant and negative impact on fiber optics in rural areas. It seems that state grant programs before IIJA did not prioritize fiber optic deployments in rural areas because of high-cost investments and longer return, due to the low-density populations and geographic challenges. In addition, the complexity to deal with fiber deployment, such as permitting and securing right-of-way access, could hinder new providers—who have not as well established as incumbents or big players—in competing for state grants. Reflecting from the link between fixed wireless and grantmaking efforts, it is clear that state's grantmaking programs prefer a faster deployment technology like fixed wireless.

No significant role of other administrative capacities in broadband availability

The findings suggest that having broadband office, broadband maps, or municipal regulations is not proven enough to directly increase Internet coverage. Even though having broadband office, broadband maps, and municipal regulations sound helpful, this study shows that those factors have not had an impact as expected. For example, the existence of broadband offices has no impact on broadband coverage of states, which could be attributed to the lack of staff, expertise, shortage of funding, political supports, coordination issues, and the lack of resources to manage the broadband programs and initiatives. It designates a necessity to increase the effectiveness of this office so that this office can be more impactful.

Broadband maps also have no impact, which might be attributed to the inaccuracy issue of the data. As this map served as the guideline, inaccurate maps could lead to a wrong target for the deployment of infrastructure and grant allocation. Assuming that the maps are accurate, it indicates that they are not effectively used by state governments to support the efforts in increasing broadband coverage, such as grant allocation. For service providers, even though they identified the underserved areas on the map, if they have not enough funding to deploy broadband infrastructure, the maps will have no impact on the coverage. Additionally, whether or not a state regulates competition or has broadband-related regulation before the IIJA, it has no impact on the coverage of the state broadband at the rural, urban, and the state level. State-level regulations do not seem to serve as the key role in determining the state's broadband coverage, but there are other factors that are more influential than state's regulatory frameworks. The results imply the importance of funding availability than competition. While regulation about competition is put in place, however, many other factors such as low market demand, not enough funding availability, low return on investment—could discourage network providers, especially non big players, to invest.

6. Conclusion

This paper seeks to answer the question of *"How do the administrative capacities of states correlate with broadband technology (fiber, cable, fixed wireless) adoption across states in the U.S.?".* Our scope was to explore state administrative capacity before the IIJA and its link with broadband coverage across states in 2022. Overall, the findings regarding state administrative capacity highlight the impact of infrastructure-focused broadband plans and grantmaking programs on the availability of broadband across states, even though the direction of the impact varies. The findings show that broadband plans emphasizing infrastructure deployment have a negative impact on fiber coverage. This means that having the broadband expansion plans might tend to slow down the deployment of fiber optics, revealing the tendency that policymakers prioritize lower costs technology with faster results than fiber optics. We also discussed the challenges of executing broadband plans that impede the deployment of broadband infrastructure, including data availability and accuracy, budget issues, intergovernmental organizations and stakeholders' dynamics, and regulatory challenges. Conversely, the findings emphasize a positive influence of administrative effort in terms of states' grantmaking programs on fixed wireless coverage in rural and urban areas, meaning that the more incentives, grants, and awards given by states to network providers, the greater the availability of the wireless broadband. The findings indicate that: 1) funding availability is the main determinant of broadband deployment, and 2) broadband deployment environment in the states in the U.S. favors fixed wireless technology, as it is known for its low cost, quick deployment time, moderate coverage, flexibility, and scalability. Other administrative capacities—including broadband offices, broadband maps, and regulations—do not have any significant impacts, emphasizing issues with the effectiveness of these capacities that call for further investigation.

We suggest some future recommendations which target the demand and supply sides of broadband. First, given that funding availability is the main determinant for broadband deployment particularly for fixed wireless, state governments should prioritize finding sustainable broadband financing models to secure funding for their broadband infrastructure projects. While this study did not find evidence that broadband office has an impact of broadband availability, there is a chance that these offices have experienced a lack of fiscal authority, technical resources, and mechanism of coordination to implement such models. As such, these offices should be given authority, responsibilities, and more resources to plan, coordinate, execute, and monitor the financing models. These internal capacities of broadband offices should be explored to understand the potential of the offices. Second, a plan is just a plan if it is not well monitored and executed. As the execution of broadband plans was indicated to be problematic, the broadband offices should also be given metrics to monitor the implementation of broadband plans. Third, despite its focus on increasing broadband coverage in all areas, the state government should also focus on gradually increasing the coverage of high-speed broadband using fiber optics to prepare for next-generation digital demands. Currently, the broadband deployment environment favors fixed wireless, as it is cost-efficient with shorter deployment time. The state governments should work together with network providers to increase the coverage of fiber optics and its market, including giving more incentives for them to enter the market, encouraging them to be innovative in promoting and providing fiber services. Regulations should be more effective in supporting network providers—especially new entrants—to encourage a more competitive environment. Thus, there is a need to streamline administrative processes to reduce administrative burden in getting the right-of-way access and make the deployment faster.

There are plenty of rooms for future research, such as to investigate the roles and effectiveness of broadband offices. As our findings confirm the absence of influence of broadband offices on broadband coverage, further investigation could focus on the capability of this office in practice, which can be seen from various aspects, such as the amount of annual budget for state broadband office, the expertise of its staff, whether its leader has political support to push important policies, and so on. In addition, fiber optics is the least prioritized when it comes to broadband deployment. Exploring states' approaches to increase fiber optics through a case study could be worth investigating.

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