Connecting Communities and Boosting Incomes: An Evaluation of the Broadband Technology Program Public Computer Centers Initiative in Arizona 2009-2014

Final Applied Project

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Abstract

This study delves into the impact of the Broadband Technology Opportunities Program's Public Computer Center (BTOP PCC) grants, focusing on the Arizona Public Computer Centers initiative. These grants aimed to augment broadband access by improving computer infrastructure and broadband facilities in public libraries, particularly in underserved communities. Analyzing data from the BTOP PCC grants, public library data, and the United States Census Bureau's American Community Survey (ACS), the research specifically investigates the relationship between BTOP PCC initiatives in Arizona and household income levels at the census tract level. An empirical examination using a difference in difference regression model followed by sensitivity analysis revealed that contrary to some previous findings, the BTOP PCC program in Arizona did not demonstrate a direct effect on household income. The increased availability of broadband resources did not necessarily translate into higher household income levels. Furthermore, results revealed that the household income of households situated in census tracts belonging to the top quartile of minorities was not affected by the BTOP PCC fund either. These findings emphasize the need for further exploration to understand the intricate dynamics involved in the relationship between broadband resources, library usage, and socio-economic outcomes. Gaining insights into effective and ineffective strategies for engaging library patrons is crucial for libraries nationwide. The study contributes to the ongoing discourse on the potential impact of broadband resources on socio-economic outcomes and calls for continued investigation to inform targeted policies and enhance the effectiveness of public library initiatives.

Introduction

The Broadband[1] Technology Opportunities Program (BTOP), funded by the National Telecommunications and Information Administration (NTIA) under the American Recovery and Reinvestment Act of 2009, aimed to bridge the digital divide by boosting broadband adoption in underserved communities. Comprising infrastructure enhancements, public computer centers (PCCs), and programs for sustainable broadband adoption (SBA), BTOP strategically addressed areas with high poverty rates and significant minority populations (ASR Analytics, 2014).

Approximately 55 million Americans, or 18% of the population, benefited from BTOP awards in the PCC and SBA domains. These grant regions had greater poverty rates, and practically all of the grants were directed towards minorities. Compared to the national average of 25.5%, these localities have a non-white population of about 38.9%. The PCC and SBA initiatives were well-suited to tackle this issue given the lower broadband connectivity rates among minorities (50% for African Americans and 46% for Hispanics, compared to the national average of 68% as of late 2010) (ASR Analytics, 2012).

This study specifically examines one aspect of the BTOP's PCC initiatives, focusing on the Arizona Public Computer Centers initiative, in collaboration with the Arizona State Library, Archives, and Public Records. Between 2010 and 2012, this program significantly improved infrastructure in 86 public libraries across the state. These enhancements included broadband infrastructure upgrades, the establishment of Public Computing Centers in four Tribal libraries, and expanded broadband access to marginalized and English as a Second Language communities. The initiative also introduced a mobile training program with laptops to engage the community, particularly vulnerable groups. Its primary goal was to provide

[1] Note: "Broadband" or "broadband service" is defined in the United States as high-speed Internet access that is always on and faster than the traditional dial-up access. Specifically, the Federal Communications Commission 's broadband standard was, download speed: 25 megabits per second (Mbps) or faster and upload speed: 3 megabits per second (Mbps) or faster.

unrestricted access to valuable electronic resources while empowering libraries to offer contemporary skills training opportunities (Broadband USA - The National Telecommunications and Information Administration).

The final report on the BTOP fund assessed eight other PCC grants and uncovered one of the program's positive outcomes to be the potential improvements in the economic livelihoods of participants. Seven out of the eight assessed PCC grants reported instances of participants securing employment directly attributable to the services funded by these grants. Additionally, two grants reported instances of individuals starting or expanding their own businesses. Enhanced access to computers and broadband not only streamlined job searches but also promoted independent learning and digital literacy skills development in some cases (ASR Analytics, 2014).

Against this backdrop, our study aims to scrutinize the contribution of BTOP's PCC initiative, implemented through the Arizona Public Computer Centers, to the improvement of household income. Beginning with an overview of the BTOP program and its significance, we delve into the specifics of the Arizona Public Computer Centers initiative, emphasizing its infrastructure enhancements and socio-economic goals. The literature review contextualizes the role of public libraries in digital inclusion, setting the stage for our data-driven analysis.

Utilizing a Difference-in-Differences (DID) technique and propensity score matching, our study meticulously examines the relationship between BTOP PCC grants and household income. While detailed statistical analyses are presented in subsequent sections, key findings emphasize the nuanced dynamics at play. The report concludes by summarizing implications and proposing avenues for future research. Unraveling the complex relationship between broadband resources, library usage, and socio-economic outcomes, this study contributes insights to inform policies and enhance the effectiveness of public library initiatives.

Literature Review

Public libraries in the United States, including those that participated in the Broadband Technology Opportunities Program (BTOP) in Arizona, have been recognized for their pivotal role in promoting digital inclusion and providing access to Information and Communication Technologies (ICTs) (Barber & Wallace, 2008; Bertot et al., 2014). These institutions are instrumental in offering broadband internet access and digital literacy training to individuals, particularly in economically disadvantaged areas, with the aim of reducing the digital divide (Dailey et al., 2010; Federal Communications Commission, 2010; Institute of Museum & Library Services, 2012; Rhinesmith, 2012).

Despite the substantial efforts made by public libraries, the specific impact of their programs remains a subject of inquiry (Mandel, Bishop, McClure, Bertot, & Jaeger, 2010). In this context, it is essential to assess the outcomes and effects of public access to broadband, particularly on individuals' economic well-being.

Studies conducted in various countries provide insights into the potential impact of public library programs on income levels. For instance, Coward et al. (2020) conducted a survey in Namibia, revealing that individuals using regional libraries reported improved employment-related skills, with a subsequent increase in income. Similarly, Nordicity (2018) found that in Ontario Public Libraries in Canada, users who enhanced their job-related skills through library ICT resources experienced greater success in their job searches, indicating a potential positive correlation between library services and income. The Economic and Social Value Study of the public library system in Medellin, Colombia, and research in Latvia, have also shown that public internet access in libraries can lead to substantial social and economic returns. Among the various services considered, public internet access in libraries stood out with the highest cost-benefit ratio, which was 1:33.86 Colombian pesos (Sistema de bibliotecas públicas de Medellin, 2021). As for

Latvia, the cost-benefit ratio for public access to computers and broadband in libraries was the highest among all the evaluated library services at 1:3.04 (Strode, et al., 2012).

In the United States, Jayakar and Park (2012) demonstrated a positive association between the number of Internet-connected computers in libraries and the growth in the number of public Internet users. Metropolitan county libraries, on average, offered 74 public-use Internet-connected computers in 2012, serving various purposes, including government interactions, social networking, online education, job applications, and entrepreneurial resources (Bertot, et al., 2014). Moreover, a 2010 study by the University of Washington's Information School, funded by the Bill & Melinda Gates Foundation and the Institute of Museum and Library Services, showed that low-income individuals heavily rely on public libraries for computer and Internet access, especially those below the poverty threshold. The study found that 75 percent of approximately 30 million library users used library resources for online job searches, with half submitting job applications or resumes online. Investments in library technology significantly increased public access Internet terminals from 1998 to 2006, with 32 percent of individuals aged 14 and above using library computers or wireless networks to access the Internet. The study also highlighted that about one-third of libraries lacked sufficient Internet connections to meet patron needs (University of Washington, 2010), underscoring the importance of the implementation of the BTOP-PCC program in meeting growing demand. Other research showed that among homeless adults, public libraries were the most common location for accessing the Internet (Eyrich-Garg, 2011; Redpath, et al. 2006).

However, not all studies find consistent evidence linking local broadband availability to increased economic activity (LaRose, Strover, Gregg, & Straubhaar, 2011). Whitacre, Gallardo, & Strover (2014a,b) indicate that while increased broadband adoption rates may be associated with higher median household income, expanding broadband availability alone may not significantly impact employment or income. Whitacre & Rhinesmith (2015) found that while there was a positive correlation between the number of libraries and household broadband adoption rates, there was no significant increase in residential broadband adoption in counties that expanded Internet-accessible computers between 2008 and 2012. These findings highlight the complexity of the relationship between library programs, broadband access, and income.

The literature suggests that public libraries, including those under the BTOP program in Arizona, can potentially impact income levels by providing access to broadband technologies and enhancing individuals' digital-related skills. However, the relationship between library programs, broadband access, and income is multifaceted and not universally consistent. Further empirical research is needed to determine the specific impact of the Arizona Public Libraries under the BTOP program on income levels, taking into account local contexts and variables. This research focusses its evaluation on the tract level for higher accuracy.

Data and Methods

The study draws its data from the NTIA website along with the United States Census Bureau's American Community Survey (ACS), which delves into a wide range of topics encompassing the social, economic, demographic, and housing characteristics of the United States population. These data comprise 5-year estimates categorized as "period" estimates, capturing information over a specific timeframe. Leveraging multiyear estimates proves advantageous for ensuring robust statistical reliability, especially in sparsely populated regions and smaller demographic subgroups. This choice aligns seamlessly with our observations, where the median population of our initial sample, which consists of 1511 census tracts, is 4256.

In adopting a robust methodology, this study employs a combination of Difference-in-Differences (DID) and propensity score matching techniques. The DID model serves as a powerful tool to isolate the causal impact of the BTOP PCC grants on household income by accounting for temporal and contextual variations. It leverages the treatment and control groups to discern changes over time, providing a nuanced understanding of the program's influence. The relationship is captured through a regression model, where household income is modeled as a function of treatment status, time, and relevant covariates.

Complimenting this, a propensity score matching analysis is conducted and used to identify and create a comparable group of tracts to the treatment group (comparison group). Nearest-neighbor matching is used to create a matched dataset, ensuring balance between treatment and control groups. Propensity score matching enhances the study's internal validity by creating comparable groups, effectively mitigating selection bias. By estimating treatment effects based on pre-treatment characteristics, this technique ensures that observed outcomes are attributable to the BTOP PCC initiative rather than pre-existing differences. The matched sample size decreased to 110, 55 in the treatment group and 55 in the control group.

Many social scientists have adopted propensity score matching techniques for estimating average treatment effects (ATE) (Rosenbaum & Rubin, 1982; Winship & Morgan, 1999). These methods assess the impact of a specific treatment (e.g., libraries participating in the BTOP program) by calculating the likelihood of receiving that treatment, known as a propensity score, based on pre-treatment characteristics. The treated and non-treated groups are subsequently "matched" based on their likelihood of undergoing the treatment. Essentially, since the matched observations were similar before the treatment (due to comparable likelihoods of receiving the treatment), any divergent outcomes can reasonably be attributed to the treatment (i.e., the treatment effect). Outcomes, such as changes in household income, are then compared between the matched groups using traditional regression analysis (Whitacre and Rhinesmith, 2015).

Together, these methodological choices fortify the study's analytical rigor, offering a comprehensive evaluation of the BTOP PCC program's impact in Arizona on household income.

The relationship between the BTOP PCC grants given to Arizona Public Libraries in tract i in year t and the shift in household income is calculated as follows:

$$HouseholdIncome_{it}=\beta_0 +\beta_1 Treatment_i +\beta_2 Year_t +\beta_3 Treatment_i \times Year_t + Covariates_{it} + \varepsilon_{it}$$

Household income estimates are adjusted for inflation. Grantees, which are tracts where at least one library received a BTOP PCC grant, constitute the treatment group. The tracts in the control group did not receive any grants. In the treatment group, the binary variable "treatment" is assigned a value of one, while in the control group, it is assigned a value of zero. The variable "Year" is a binary variable recorded as one for 2014 data (post-BTOP PCC) and zero for 2009 data (pre-BTOP PCC).

β0 represents the average household income of the control group before the treatment.

β1 represents the difference between the treatment and the control group before the treatment.

β2 represents how much the average household income of the control group has changed in the post-treatment period.

β3 is the difference-in-difference estimator which is the coefficient of interest. It measures changes in household income of the treatment group in comparison to the control group between the pre- and post-BTOP PCC periods. It reflects the difference between the treatment group's average household income post-BTOP PCC and what would have happened to the same group had the intervention not taken place.

Covariates are included to control for other factors that might lead to different trends across the treated and the control tracts. Covariates include total number of households, median age, average household size, number of individuals with a college degree (Bachelor’s degree or more), and race, namely white, black or African American, American Indian and Alaska Native, Asian, Native Hawaiian and other Pacific Islander, and Hispanic or Latino, as considered in Whitacre and Rhinesmith (2015), Hauge and Prieger (2015), and Chang (2021).

Table 1: Summary statistics of the covariates and other variables in the matched dataset

	Median age	Median Household Income	Total Population	White	Black or African American	American Indian and Alaska Native	Asian	Native Hawaiian and Other Pacific Islander	Hispanic or Latino	Total Households	Average Household size	BS Degree and above
Min.	20.3	149	543	0	0	0	0	0	543	149	1.6	3
1st Qu.	28.82	1075	2669	1696	2	35.5	0	0	2669	1075	2.373	156
Median	33.95	1368	4053	2778	49	129.5	19.5	0	4053	1368	2.67	345.5
Mean	36.2	1465	4134	2711	73.07	617.1	42.28	6.691	4134	1465	2.835	469
3rd Qu.	40.38	1833	5323	3742	101	422.5	54.75	0	5323	1833	3.175	652
Max	72.3	3433	9156	7411	528	6219	413	97	9156	3433	6.09	2085

ε represents the error term.

Furthermore, sensitivity analysis was conducted by employing propensity score matching techniques to estimate the treatment effects using different matching methods. The matching methods "optimal," and "full" were applied, and for each method, propensity scores were estimated, matching was performed, and treatment effects (ATE) were estimated using a linear regression model. The goal of this analysis was to explore how different matching methods impact the estimation of treatment effects based on the specified covariates. Additionally, a bootstrap method was employed to estimate the Average Treatment Effect (ATE). Bootstrapping was performed by repeatedly sampling from the matched data and fitting linear regression models to estimate ATE. This process was iterated 1000 times to create a distribution of ATE estimates. Subsequently, a 95% bootstrap confidence interval was calculated from the quantiles of the bootstrapped estimates. A p-value was conducted to evaluate statistical significance as well.

Results

The statistical analysis uncovers crucial insights into the BTOP PCC program's impact on household income. The time effect coefficient (β2) reveals a significant increase in average household income over the post-treatment period for the control group, reflecting broader economic shifts unrelated to the BTOP PCC program. However, the non-significant coefficient for the Difference-in-Difference Estimator (β3) challenges the idea that the program directly influenced household income, highlighting the complex relationship between broadband resources, library usage, and socio-economic outcomes.

Moreover, β0 (Constant) signifies the average household income of the control group before treatment, with statistical significance at the 10% level. Conversely, β1, representing the difference in average household income between the treatment and control groups before treatment, is not statistically significant, suggesting the observed difference may be due to random variation.

Furthermore, while β2 indicates a highly statistically significant time effect, showcasing a substantial average income increase from pre-treatment (2009) to post-treatment (2014) for the control group, β3, the Difference-in-Difference Estimator, is not statistically significant. This implies that the estimated treatment effect may not significantly differ from zero.

Interestingly, variables such as average household size and education levels play a significant role. They were statistically significant at the 5% and 1% levels, respectively, emphasizing their influence on income. For instance, an additional household member corresponds to a $3,469.71 increase in average household income, while each additional household member with a Bachelor's degree or higher associates with a $12.89 increase. These nuanced findings underscore the multifaceted dynamics at play in the relationship between the BTOP PCC program and household income.

Table 2: Difference in Difference model results

	Dependent variable Average Household Income
treatment	-327.56 (-1620.71)
Year	37,026.14*** (-1674.87)
Median.age	26.56 (-79.17)
Average.HH.size	3,469.71** (-1487.96)
BS.Degree. and.above	12.89*** (-2.04)
White	0.77 (-1.43)
Black.or. African.American	-2.66 (-5.41)
American.Indian. and.Alaska.Native	-0.80 (-1.19)
Asian	0.64 (-10.51)
Native.Hawaiian.and. other.Pacific.Islander	-26.08 (-26.41)
Hispanic.or.Latin	-1.38 (-1.14)
treatment:Year	508.57 (-2312.62)
Constant	-10,736.39* (-6277.37)
Observations	220
R2	0.85
Adjusted R2	0.84
Residual Std. Error	8,479.55 (df = 207)
F Statistic	96.46*** (df = 12; 207)
Note:	*p<0.1; **p<0.05; ***p<0.01

The sensitivity analysis showed complimentary results as illustrated in table 3 below.

Table 3: ATE Estimates for Different Matching Methods

	Mean	Standard Deviation
ATE	307.94	0
P Value	0.91	0

The p-value is 0.91 which is greater than 0.05 indicating non-significance of the Average Treatment Effect (ATE) estimates. In other words, the average difference in outcomes between the treated and untreated groups is not statistically significant.

Similar results were observed in the bootstrapping method, indicating an average p-value of 0.49 for the mean Average Treatment Effect (ATE) across 1000 iterations. The 95% confidence interval's lower bound is approximately -5289.825, and the upper bound is approximately 5718.971. However, it has been statistically demonstrated to be indistinguishable from zero.

Table 4: Bootstrapping Analysis Results

	N	Mean	Standard Deviation	Minimum	Maximum
ATE	1002	405.16	2874.49	-9220.53	9751.34
P Value	1000	0.49	0.29	0.0004	1

It is evident that our matched data set has the white race as the second most populated race on average in the matched census tracts, potentially biasing our dataset as the BTOP PCC program primarily targets minorities and underserved communities. Therefore, further analysis was conducted by filtering the dataset by the highest quartiles of minorities for further scrutiny. The census tracts that had the highest quartile of minorities and simultaneously received funding from the BTOP comprised the treatment group. Specifically, minorities include Black or African American, American Indian and Alaska

Native, Asian, Native Hawaiian and Other Pacific Islander, and Hispanic or Latino. The PSM was then conducted to evaluate the effect of the BTOP on minorities' household income.

A PSM was conducted, resulting in 12 treatment census tracts matched with 12 control census tracts. Table 5 below shows the summary statistics of the matched data set.

Table 5: Summary statistics of the covariates and other variables in the matched dataset of the highest quartile of minorities

	Median age	Median Household Income	Total Population	White	Black or African American	American Indian and Alaska Native	Asian	Native Hawaiian and Other Pacific Islander	Hispanic or Latino	Total Households	Average Household Size	BS Degree and above
Min.	20.3	918	3269	0	0	0	0	0	3269	918	1.71	43
1st Qu.	27.35	2063	4834	343.5	0.75	79.25	0	0	4834	1331	2.397	143.8
Median	32.45	11748	5807	3563	30	356.5	8.5	0	5807	1932	3.08	312.5
Mean	37.48	18617	6112	3595.3	84.46	1743.81	26.96	6.771	6112	2085	3.166	599.6
3rd Qu.	47.17	29840	6963	5998.5	103	3839.5	26.5	0	6963	2458	3.842	854.5
Max	69.1	65636	14235	13151	619	6219	207	186	14235	5927	6.09	2617

The results of the different in different model reveal almost identical results as the general analysis conducted previously.

The 'Year' variable shows a statistically significant increase in average household income over the post-treatment period, with a coefficient of $31,872.55. This significant time effect highlights changes in income over time for both treatment and control groups.

Education levels play a significant role in influencing household income. Having a Bachelor's degree or more is associated with a statistically significant increase of $10.78 in average household income.

The coefficients for all other covariates including race and ethnicity variables are generally small and non-significant, suggesting that the impact of these factors on average household income of minorities is not statistically significant.

The interaction term 'treatment:Year' is not statistically significant indicating that the BTOP PCC program in Arizona does not have a direct effect on household income in the census tracts where minorities are highly populated.

The constant term, representing the average household income of the control group before treatment, is -$11,106.49 but is not statistically significant.

The model explains a substantial portion of the variance in household income (R2 = 0.89), and the Adjusted R2 (0.85) accounts for the number of predictors in the model. The Residual Standard Error is 7,249.55, providing an estimate of the variability of residuals around the fitted values. The F Statistic of 23.81 (df = 12; 35) is highly significant, indicating that the model as a whole is a good fit.

The sensitivity analysis resulted in complementary results as illustrated in table 7.

Table 7: Sensitivity analysis results of model two

	Mean	**Standard Deviation**
ATE	-425.3	0
P-value	0.25	0

The p-value is 0.25 which is greater than 0.05 indicating non-significance of the Average Treatment Effect (ATE) estimates.

Table 8: Bootstrapping Analysis Results of model two

	N	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
ATE	1002	-434.97	351.63	-1566.8	920.07
P Value	1000	0.31	0.28	0.0000	1

Similar results were observed in the bootstrapping method, indicating an average p-value of 0.31 for the mean Average Treatment Effect (ATE) across 1000 iterations. The 95% confidence interval's lower bound is approximately -1147.88, and the upper bound is approximately 244.1367. However, it has been statistically demonstrated to be indistinguishable from zero.

Table 6: Difference in Difference model results of model 2

	Average Household Income Difference in Difference Model
treatment	2,160.08 (-3164.8)
Year	31,872.55*** (-3247.96)
Median.age	92.47 (-196.2)
Average.HH.size	2,207.84 (-2323.03)
BS.Degree.and.above	10.78*** (-3.69)
White	0.09 (-2.15)
Black.or.African.American	3.12 (-8.99)
American.Indian.and. Alaska.Native	-0.45 (-1.78)
Asian	-6.11 (-35.13)
Native.Hawaiian.and .Other.Pacific.Islander	-42.54 (-40.97)
Hispanic.or.Latino	-0.63 (-2.04)
treatment:Year	1,169.02 (-4336.77)
Constant	-11,106.49 (-14042.88)
Observations	48
R2	0.89
Adjusted R2	0.85
Residual Std. Error	7,249.55 (df = 35)
F Statistic	23.81*** (df = 12; 35)
Note:	*p<0.1; **p<0.05; ***p<0.01

Conclusion and Future Work

Several previous studies have investigated the impact of the BTOP PCC initiative at the county level. However, our study takes a more focused approach, examining households at the census tract level, particularly those near BTOP-funded libraries, to minimize the influence of distance. Despite this, the BTOP PCC program in Arizona did not demonstrate a direct effect on household income, even when we focus our analysis on the census tracts belonging to the top quartile of minorities, signifying those with the highest population of minorities.

Prompting several hypotheses, our study reveals that increased broadband availability does not necessarily translate into higher household income. While literature suggests patrons use library resources for job applications or business opportunities, other potential factors may be influencing this observed lack of impact. As such, the study's findings prompt a reevaluation of the assumed link between broadband access and income. Policymakers may need to recalibrate expectations and explore alternative strategies for leveraging broadband resources in public spaces. This could involve a focus on fostering entrepreneurial opportunities, creating partnerships with local businesses, or integrating digital literacy programs that specifically address economic empowerment.

It's essential to note that while the BTOP program primarily aimed to increase broadband adoption rates, our evaluation focuses on the effects of increased broadband resource availability on household income rather than increased broadband adoption. Meaning, future work could evaluate the effect of increased broadband adoption on household income to understand whether broadband and income are completely unrelated or if the BTOP was unsuccessful in increasing broadband adoption rates, subsequently resulting in no effects on income. Further exploration is crucial to comprehend the intricate dynamics involved in the relationship between broadband resources, library usage, and socio-economic outcomes.

Discovering a causal relationship could significantly influence policies related to financial support for public library computers and Internet access, especially in lower-income communities with limited broadband adoption. Gaining insights into effective and ineffective strategies for engaging library patrons is crucial for libraries nationwide. These aspects provide promising directions for additional research to expand on the initial findings in our study. The potential impact of broadband resources on socio-economic outcomes requires continued investigation to inform targeted policies and enhance the effectiveness of public library initiatives.

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