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Economic Returns to Rural Infrastructure Investment

Impacts of USDA Broadband Loan and Grant Programs: Moving Toward Estimating a Rate of Return

This paper is one of six commissioned as part of the workshop, *Economic Returns to Rural Infrastructure Investment*, organized by Farm Foundation and USDA's Economic Research Service (ERS). The workshop took place April 10–11, 2018, in Washington, D.C. A seventh paper, which had already been published, was also presented at the workshop because of its high relevance to the topic.

Authors Mitch Renkow, Ph.D., and Ivan Kandilov, Ph.D., both of North Carolina State University, used zip code-level data to evaluate the impact of USDA's broadband loan and grant programs on the average payroll per work in the area receiving the funds.

To read the complete paper, or any of the other six papers, visit the Farm Foundation website, https://farmfoundation.org.

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The Impacts of the USDA Broadband Loan and Grant Programs: Moving Towards Estimating a Rate of Return

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Abstract:

In this paper, we take a step toward understanding the rate of return to government efforts to promote broadband. Specifically, we evaluate the impact of USDA's broadband loan and grant programs on the average payroll per worker using zip code level data from the Zip Code Business Patterns for the period from 1997 to 2007. Because we employ data on the size of the loans and grants, we are able to produce a rough estimate of the rate of return on such investments. Our results indicate that a $1 increase in zip code per capita broadband loan results in about a $1.08 increase in payroll per worker. Results were nearly identical for the pilot broadband loans ($1.07 increase in payroll per worker for each additional loan dollar). We find no statistically significant impact of broadband grants received on the payroll per worker. Rough benefit-cost calculations suggest that total benefits from the current loan program substantially outweigh costs, with benefit-cost ratios ranging from 2.8 to 5.7 depending on assumptions about discount rates.

Keywords: Broadband loans and grants; program evaluation; annual payroll per worker

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1. Introduction

The potential stimulative effect of publicly-funded infrastructure on local economic performance has been a staple in the public discourse surrounding U.S. rural development policy (Blandford, Boisvert and Davidova 2008). An important rationale offered to justify public infrastructure investments argues that they can raise private-sector output directly, as an intermediate input into private production processes, and indirectly by providing complementary inputs that raise the rate of return on private capital (Tatom 1991). At the same time, geographic remoteness and low population densities of many rural communities impose significant limits on the rate of return to private infrastructure provision—hence, the call for public infrastructure investment.

A salient example of this may be found in recent debates over the role and scope for federal investment in infrastructure enabling deployment of broadband technology in rural areas. Broadband technology delivers enhanced information and communications services at rapid transmission rates to end users. Increasing the availability of broadband in rural communities has been an explicit U.S. rural development policy goal for nearly two decades. Since 2000, federal broadband grant and loan programs authorized under consecutive Farm Bills have directed more than $1.8 billion to private telecommunications providers in 40 states with the explicit goal of making high-speed data transmission capacity available to rural residents and businesses. The American Recovery and Reinvestment Act of 2009 authorized $2.5 billion in federal funding for these same purposes (Kruger 2018). While the details are yet to be disclosed, it is possible that the Trump Administration’s recently-announced infrastructure proposal will lead to the authorization of substantial additional federal funds toward promoting broadband deployment via rural block grants.

Proponents of these programs generally point to research projecting large macroeconomic benefits from widespread broadband deployment (for example, Crandall and Jackson 2001; Crandall, et al. 2007). Other work in this literature focuses on specific types of economic impacts from broadband deployment. Stenberg et al. (2009) used county-level data to provide evidence that rural counties with greater broadband access also had greater economic growth. Gillett et al. (2006) used data on broadband availability between 1998 and 2002 and found that high-speed internet had a significant positive impact on local employment and the number of business establishments, especially in IT-intensive sectors, but not on wages.[1] Shideler et al. (2007), employing county-level broadband availability data in Kentucky, also uncovered a positive impact of broadband on employment growth in certain sectors. Kolko (2012) found that increases in broadband providers leads to increases in employment as a whole as well as within certain industries. Kim and Orazem (2017) found that broadband availability influenced firm location decisions in rural areas. Finally, a recent review by Gallardo, Whitacre, and Kim (2018) highlights broader community and social impacts of broadband deployment and adoption on migration, civic engagement, education, and healthcare.

An important takeaway message from work that has been done on the impacts of broadband is that the distribution of economic benefits is not likely to be uniform, either spatially or across industries. In our work, we have found evidence that USDA Broadband Loan Programs have created a range of impacts—some positive, some negative—that vary across industries and across the rural-to-urban continuum (Kandilov and Renkow 2010; Kandilov, et al. 2017).

We have further found that while the loan programs have been effective in meeting their

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[1] Forman, Goldfarb, and Greenstein (2012) similarly report that proliferation of information technology has had little impact on wage growth in rural areas.

goal of creating more broadband availability in rural areas (Dinterman and Renkow 2017; Kandilov, et al. 2017), it is by no means inevitable that this greater availability translates into improved economic outcomes.[2]

In addition, due to data constraints—in the form of limited access to government data on specific amounts of federal funds being invested in specific communities— the work to date on evaluating government broadband investments has not generated estimates of the rate of return or relative benefits and costs on those investments. Such information is clearly of significant value for two reasons. First, it provides a benchmark for gauging whether or not these investments pay for themselves. We note that key benefits of extending and expanding high-speed internet access into underserved areas—in areas such as telemedicine, distance education, social media and personal communication—typically would go unmeasured in most assessments of benefits mediated through local economic activity. To the extent that those potentially large (but difficult-to-measure) benefits are deemed socially desirable—or even a social imperative—a positive cost-benefit ratio reflects the fact that securing those social benefits is being done via programs that pay for themselves.

Second, estimation of a rate of return on broadband investments provides a point of reference for comparison with alternative types of public investment. For example, cost-benefit analyses or return-on-investment studies exist for public health program interventions (e.g., Masters, et al. 2017) or road investments (e.g., U.S.D.O.T 2015). Assembling comparable information for broadband investments thus has value for contributing to more efficient allocation of public resources across a more complete range of alternatives.

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[2] Similarly, analyses by Whitacre, Gallardo, and Strover (2014a; 2014b) find that broadband adoption had substantial positive economic impacts, whereas the positive impacts of increased broadband availability had little, if any, statistically significant impacts.

In this paper, we take a step toward understanding the rate of return to government efforts to promote broadband. Specifically, we evaluate the impact of USDA's Broadband Loan and Grant Programs on the average payroll per worker using zip code level data from the Zip Code Business Patterns for the period from 1997 to 2007. Because we employ data on the size of the loans and grants, we are able to produce a rough estimate of the return on such investments.

Our results indicate that a $1 increase in zip code per capita broadband loan results in about a $1.08 increase in annual payroll per worker. Results were nearly identical for pilot broadband loans—$1.07 increase in payroll per worker for each additional loan dollar. We find no statistically significant impact of broadband grants received on the payroll per worker. Rough benefit-cost calculations based on those estimates suggest that total benefits from the current loan program substantially outweigh costs, with benefit-cost ratios ranging from 2.8 to 5.7 depending on assumptions about discount rates; benefit-cost ratios for the pilot loan program range from 3.2 to 6.5.

At the outset, it should be acknowledged that the contribution of government investments in broadband to changes in payroll per worker is at best a partial indicator of rate of return on those investments. Such a measure misses any impacts on the incomes of non-payroll earners within a locale (e.g., self-employed individuals), some of whom may well reap significant benefits from the improved connectivity that accompanies broadband deployment. Neither does it account for possible contributions of broadband to community wealth creation to the extent that enhancement of communications services are capitalized into housing prices.[3] More generally, focusing only on earnings overlooks a host of non-pecuniary social benefits that high-speed

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[3] For example, Molnar, et al. (2015) estimate that access to broadband increases median house prices by $5,400 on average.

internet access facilitates; for example, improvements in delivery of public goods like health and education services (Gallardo, Whitacre, and Grant 2018).

The rest of the paper is organized as follows. The next section provides details on the USDA broadband loan and grant programs. Section 3 describes our data and presents summary statistics. Section 4 outlines the empirical model that we use to identify the impact of increased access to high-speed internet on payroll per worker. We discuss our results in section 5. Section 6 provides some concluding remarks.

2. USDA Broadband Loan and Grant Programs

In December 2000, Congress authorized a pilot broadband loan program to help expand broadband access in geographically remote and underserved rural communities. Program eligibility criteria included having a population of 20,000 or less, having no prior access to broadband, and providing a minimum matching contribution of 15% by recipients of the loan. Loans were extended mainly to small telecommunications services firms at varying (subsidized) interest rates; most participating communities qualified for a “hardship rate” of 4% (Cowan 2008).

Administered by USDA’s Rural Utilities Service (RUS), pilot loans worth $180 million were made in 2002 and 2003 to broadband providers serving 98 communities located in 13 states (Appendix Table A1). Beginning with the 2002 Farm Bill, funding for the current (post-pilot) broadband loan program was expanded (Appendix Table A2). Program operations were modified due to problems with repayment: more than one-quarter of the loans extended via the Pilot broadband loan program were defaulted (USDA 2007). As a result, RUS imposed tighter equity and loan security requirements. Another concern with both the Pilot and current programs relates to an overly broad definition of what constitutes a “rural” community. For example, a 2005 audit by the USDA’s Inspector General chided RUS for having extended nearly 12% of total loan funding to suburban communities located near large cities (USDA, Office of Inspector General 2005). A follow-up audit found that this situation was not remedied, noting that between 2005 and 2008 broadband loans were extended to 148 communities within 30 miles of cities with populations greater than 200,000, including Chicago and Las Vegas (USDA, Office of Inspector General 2009). Because the loan programs did affect access to broadband in some communities that lie within large metropolitan counties, we include all, not just rural, U.S. zip codes in our empirical analysis. Further, our two-step estimation procedure allows for a carefully designed weighting scheme, which depends on county population among other things, in order to optimally allocate weights across counties.

RUS has also operated a Community Connect Broadband Grant Program since 2002. This program appears to be targeted to the most under-served rural areas insofar as eligibility requirements specify that no high-speed internet is available in the community; by contrast, loan program eligibility only requires that at least 15% of households are unserved (Kruger 2018). Begun at the time of the Pilot Broadband Loan Program, Community Connect Grants were designed to promote telemedicine and distance learning (“community-oriented connectivity”) in rural areas with no broadband service. Grantees are required to deploy free broadband service to community facilities for at least two years, as well as offering broadband to residential and business customers. Total authorizations for the Community Connect Grant Program between 2002 and 2017 amounted to just over $210 million (Appendix Table A2).

3. Data

To analyze the impacts of the broadband loan and grant programs, our empirical analysis uses zip code level data for the 37 states that have received at least one broadband loan or grant during our sample period of 1997 to 2007.[4] Figure 1 depicts the locations in which loans or grants were made. Our sample includes only zip codes with population of 20,000 or less as of 2000, the year the Pilot Broadband Loan Program was authorized and two years before the first Pilot loans were made. We restrict the sample because the broadband loans and grants were directed to small communities of 20,000 or less. The zip code is the smallest geographic area which resembles a community eligible for these broadband loans and for which data on economic outcomes is publicly available. Data on annual payroll and employment at the five-digit zip code level were obtained from the Zip Code Business Patterns data set collected by the U.S. Census Bureau. In our empirical analysis, we investigate how payroll per employee, a measure related to the average wage rate, is affected by the broadband loan and grants.

The names of communities that received a Community Connect Grant or a loan under the Pilot Broadband Loan Program or the current Broadband Loan Program were obtained via a FOIA request, which also provided information on the size and timing of these grants and loans.[5,6] We manually matched the names of the communities that received the broadband loans or grants to the associated U.S. Postal Service zip codes, which were then matched to five-digit

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[4] The 37 states that received a broadband loan on grant during our sample period are AK, AL, AR, AZ, CA, CO, FL, GA, IA, ID, IL, IN, KS, KY, LA, MD, MI, MN, MO, MS, ND, NE, NM, NV, NY, OH, OK, OR, PA, SC, SD, TX, UT, VA, WA, WI, WV.

[5] We thank Brian Whitacre (Oklahoma State University) for sharing the data with us.

[6] No Community Connect grants from 2002 were used because of data limitations. We use data on Community Connect grants from 2003 to 2005 and data on the original Pilot loans from 2002 and the Current Broadband loan program from 2002 until 2007.

zip code tabulation areas (ZCTAs) reported in the Census Bureau's Zip Code Business Patterns data set.[7]

Table 1 reports the summary statistics for zip codes that received a broadband grant or loan. Over the period considered, Community Connect Grants were disbursed to operators in 59 zip codes spread across 24 states; Pilot Broadband Loans were distributed for projects in 302 zip codes across 13 states; and current broadband loans financed projects in 488 zip codes across 30 states. Payroll per worker, a rough proxy for average wages, and population were both somewhat higher in zip codes receiving a current broadband loan than in zip codes receiving either of the other treatments (Pilot Loans or Community Connect Grants). For zip codes that received current broadband loan, the average loan size was about $196 per capita in 2007. Average loan size for Pilot Loans was much smaller—$5 per capita—mainly due to the fact that many of these loans were spread over multiple zip codes. The average size of Community Connect grants was $157 per capita.

4. Empirical Analysis

Our empirical analysis compares changes in annual payroll per worker in locations that received a broadband loan or grant (treated zip codes) with changes in payroll per worker in that locations that did not receive a grant or a loan (control zip codes). One would like the control group of non-recipient zip codes to be otherwise identical to the group of treated zip codes that received a loan or a grant.

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[7] In this process, we necessarily omitted a small number of communities from our analysis. Their names were not disclosed; instead they were reported as "Rural Areas."

One possibility would be to compare outcomes in zip codes that received a broadband loan or grant to average outcomes for all zip codes in the 37 states in which at least one loan or grant was made. Alternatively, one can compare a zip code that received a loan or grant to non-recipient zip codes that are located in the same Census region or the same Census division.[8] Yet another comparison group could be zip codes that did not receive a loan or a grant but are geographically adjacent to one that did. While these neighboring zip codes likely share similar geographic characteristics to the treated zip codes, they may not necessarily be the best control group if the treatment (broadband loan or grant receipt) whose effects we try to evaluate, has positive spillover effects on workers or businesses in the neighboring control zip codes.

Finally, another potential control group is the group of zip codes whose broadband operators applied for a loan or a grant but were turned down. These zip codes likely share very similar characteristics, especially unobservable characteristics such as entrepreneurial spirit, with the zip codes whose operators applied for and received a loan or a grant. Unfortunately, RUS has not shared these data with researchers outside of the U.S. government.[9]

In our empirical work, we present estimates using as control group (1) all zip codes from the entire sample of 37 states we consider in analysis; (2) only zip codes in the same Census region as the community that received the loan or grant; or, our preferred specification (3) only zip codes in the same Census division.

Another issue with estimating the impacts of the broadband loans and grants is that they are not randomly assigned across zip codes in the U.S. A given zip code receives a broadband

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[8] See *https://www2.census.gov/geo/pdfs/maps-data/maps/reference/us_regdiv.pdf* for details on Census regions and division. In brief, there are 4 Census regions (West, Midwest, Northeast, and South), and 9 Census divisions (Pacific, Mountain, West North Central, East North Central, West South Central, East South Central, South Atlantic, Middle Atlantic, and New England).

[9] See, GAO report GAO-14-471 (2014), for an example using the data on denied broadband loans.

loan or grant if (1) it qualifies based on the guidelines set by the RUS (e.g. a rural community has to be smaller than 20,000 people); (2) a provider applies for the loan or grant; and (3) the RUS approves the loan or grant. First, not all communities would qualify. Second, communities with a provider who decides to apply may well be different (along both observable and unobservable dimensions, such as community entrepreneurial spirit) from communities that qualify but whose providers do not apply for these loans or grants. Third, some providers who apply for a loan or a grant may be denied.

This non-random selection process may lead to biased estimates of the impact of the broadband loans or grants on payroll per workers. To control for this, we use a technique called propensity score reweighting, recently advocated by Busso et al. (2014). This involves first estimating the factors determining the likelihood of a locality successfully getting a loan, and then using that information to improve the statistical precision with which we can link loan receipt to an economic outcome—in our case, the effect of loans and grants on payroll per worker. To control for time-invariant, zip code specific characteristics that may biased the estimates, we also include zip code fixed effects in our panel data analysis. Details of our statistical analysis and econometric specification are supplied in the Appendix.

5. Results

Determinants of Receiving a Loan or Grant

Table 2 provides summary statistics for variables used in our estimation of the determinants of receiving a broadband loan or Community Connect grant. These are means computed over the period just prior to the initial distribution of grants and loans (1997-2000). For convenience, we combine zip codes receiving any of the treatments for comparison with non-recipient (untreated) zip codes. Communities receiving a loan or a grant tended to have had lower growth rates for a variety of indicators (annual payroll, employment, establishments). Recipient zip codes also tended to be somewhat larger, more populous, and more rural than non-recipient zip codes.[10]

Table 3 presents our estimates of the determinants of receiving a broadband loan or Community Connect grant. These were estimated using a cross-sectional logit model whose dependent variable took a value of 1 if the zip code received a broadband loan or Community Connect grant at any time over our sample period (i.e., up to 2007), and 0 otherwise. To ease interpretation, we converted the estimated coefficients to elasticities at sample means. As described earlier and in the Appendix, these estimates are used to construct propensity score weights dealing with selection issues in our analysis of the impact of loan or grant receipt. But they are interesting in their own right in that they shed light on the kinds of communities that received program benefits.

The logit results suggest that the likelihood of a community (zip code) receiving a broadband loan or a grant is greater in communities that had experienced lower growth in payroll and the number of establishments in the period prior to the loan or grant receipt (1997-2000). The second column in Table 3, our preferred specification, implies that the elasticity of the likelihood of a loan or grant receipt with respect to the local employment growth is -0.02, i.e. 50 percent lower payroll growth is associated with a 1.1 percent higher probability of broadband loan or grant receipt. Additionally, the second column of Table 2 implies that a 50% lower growth in the number of zip code level establishments is also associated with a 1.1% higher

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[10] Note that provides both weighted and unweighted values of the means for treated versus untreated groups. The weights were constructed based on the estimated determinants of being selected to receive a loan or grant (see Table 3 below). The fact that the means for treated and untreated zip codes are closer to one another after weighting suggests that the inverse probability weighting technique that we employed does in fact improve the robustness of the analysis.

probability of broadband loan or grant receipt. Hence, broadband loan and grant receipt is associated with poorer prior local economic conditions.

Further, we see that among eligible zip codes, those with larger population were significantly more likely to obtain a loan or a grant. In particular, a 10% larger population results in a 7% larger likelihood of a loan or grant receipt. Rural zip codes with greater land area and a lower number of housing units are also more likely to receive a loan or a grant. Finally, and not surprisingly, zip codes located in counties that are rural (either adjacent to metropolitan areas or non-adjacent) are significantly more likely to receive a loan or a grant compared to the baseline, which is zip codes located in metropolitan counties.[11]

Finally, Figures 2a and 2b depict the differences in the distributions of the propensity scores (the predicted probabilities of treatment) between treated zip codes (those that received a broadband grant or loan) and the control group of zip codes (those that did not receive either). The figures document that there is very good overlap between the supports of the two propensity score distributions for both specifications reported in Table 3—i.e., between the groups of zip codes that received a broadband grant or loan and the groups that did not. This provides strong validation for the use of inverse probability weighting (Busso et al. 2014).

Impacts on Payroll per Worker of Receiving a Loan or Grant

The estimates from our main empirical model, which assesses the impact of the broadband loans and grants on payroll per worker at the zip code level, are presented in Table 4. The dependent variable is the average zip-code-wide payroll per worker measured in 2007 dollars. The three variables whose effects we want to estimate are (1) Community Connect

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[11] We classify the counties along the rural-urban continuum based on the ERS (USDA) classification, which can be found at *https://www.ers.usda.gov/data-products/rural-urban-continuum-codes*. We use the 2003 version of the classification.

grants per capita received by providers servicing the zip code (measured in 2007 dollars), (2) Pilot broadband loans per capita (measured in 2007 dollars), and (3) current broadband loans per capita (measured in 2007 dollars).

The three different columns in Table 4 reflect different choices of control group zip codes. In column (1) of Table 4, our control group consists of all zip codes across the 37 states included in our analysis that have not received a loan or a grant during our sample period from 1997 to 2007. In column (2) the control group includes only non-receiving zip codes located in the same Census region as the zip code that received a loan or a grant. Finally, in column (3) the control group includes only non-receiving zip codes located in the same Census division as the zip code that received a loan or a grant; these latter results represent our preferred specification.

Beginning with the Community Connect Grants, none of the estimated impacts are statistically significantly different from zero. The implication is that that these grants did not affect the average zip code level payroll per worker. Given that these grants are awarded to the least connected, hitherto unserved areas, it is possible that other community deficits render the provision of broadband alone insufficient to have promoted substantial economic impact over the period analyzed.[12]

Turning to the current broadband loan program, the results in column (1), where we use all eligible zip codes in all states in our sample, indicate that a $1 increase in the per capita current broadband loan amount is associated with a $2.41 increase in payroll per worker in the loan-receiving zip code. The estimated effect of the current broadband loan program on the

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[12] For example, the Rural Utilities Service website indicates that the "...program helps fund broadband deployment into rural communities where it is not yet economically viable for private sector providers to deliver service" (https://www.rd.usda.gov/programs-services/community-connect-grants). In addition, the program is more geared toward promoting the provision community services (e.g., telemedicine or educational resources), requiring grantees to offer provision of broadband to community facilities free of charge for at least two years (Kruger 2018).

payroll per capita is significantly smaller when (arguably better) control groups are used. We focus on our preferred specification in column (3), where the control group includes only non-receiving zip codes in the same Census division as the loan-receiving zip code. The result implies that a $1 per capita increase in the amount of a current broadband loan received in a given zip code is associated with an increase of $1.081 in payroll per worker.[13] Similarly, in the case of the Pilot Broadband Loan, the estimates in column (3) imply that $1 increase in the per capita Pilot loan amount is associated with an increase of $1.071 in payroll per worker.[14, 15]

These estimates of the marginal impact of a loan on average payroll enable us to compute a rough estimate of the benefits and costs of the two loan programs (Table 5).[16] Applying those marginal effects to the average zip code loan size provides a sense of the average per-employee impulse (or "dose") to treated zip codes attributable to an average-sized loan. Multiplying this by

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[13] These results are consistent to those found in a review of the broadband loan programs conducted by the General Accountability Office (GAO 2014). Using a somewhat different empirical methodology and a longer sample period, that study found a mild positive impacts of loan receipt on both zip code level payroll and employment. The effects of the loans on payroll they estimate are larger than the impacts on employment, which would suggest a positive impact on payroll per worker.

[14] It is possible that changes in payroll per employee are driven by changes in the composition of the workforce resulting from broadband expansion. Whitacre, Gallardo, & Strover (2014) find that increased levels of broadband availability were associated with decreased levels of employment, while Mack and Faggian (2013) find that broadband has the largest economic development effect in areas with more skilled workers, and that the benefits from broadband are diminished when controlling for differences in skill level. Both findings point to the possibility that broadband helps more skilled workers while leading to outsourcing of low-skilled jobs from rural areas. Taking these findings into consideration, increases in payroll per employee could be driven by outsourcing that causes lower skilled and lower paid workers to lose their jobs and exit the workforce, increasing the average skill and pay of the remaining workers. To take the possibility into account, we estimate the impact of the broadband grants and loans on aggregate payroll and employment separately. The results are presented in Appendix Table 3. We find some evidence that employment could have declined after the grants and loans were received. The evidence on payroll is more mixed. Hence, it is possible that the increase in payroll per employee was partly driven by a change in the distribution of wages resulting from broadband expansion. However, the data we use does not allows us to confirm this mechanism and the results from the statistical analysis are not precise enough for robust inference.

[15] We have also estimated the econometric model by using the treatment indicators for each year after a broadband grant or loan receipt (1st year after receipt, 2nd year, and 3rd + years after receipt). The baseline is all the years prior to receiving a grant or a loan. The results are presented in the Appendix Table 4. The (annual) coefficients show that the effect of the treatment does not decay over time, so it is unlikely that the estimated effect is driven by an increase in wages paid to workers who participate in deploying the broadband infrastructure.

[16] We ignore Community Connect grants as their estimated marginal effect was not significantly different than zero.

the number of employees per zip code then yields an estimate of annual benefit—essentially, our best estimate of the added increment to total payroll attributable to loan receipt. This is an annual benefit, so we compute the net present value of the stream of these annual benefits at two discount rates, 10% and 5%—rows (5) and (6) in Table 5.

On the cost side, given that broadband loans were "last mile" loans justified based on the cost of provision of broadband services, we take the cost of broadband investment to be as large as the loan itself. Dividing annual benefits by these average total costs rough benefit cost ratios, ranging from 3.46 to 6.51 for the Pilot loan program, and between 2.86 and 5.71 for the current loan program.

Impacts for Different Types of Communities

To assess heterogeneity of the estimated impacts along the rural-urban continuum, we estimate the relationship between the payroll per worker and the broadband loan and grant programs separately for zip codes in metropolitan counties, as well as those in rural counties adjacent to metropolitan counties and those in rural counties not adjacent to metropolitan ones. The results, which are presented in Table 6, imply that the impacts of the current broadband loan are highest in zip codes in rural counties adjacent to metropolitan ones. The effects are weaker in zip codes located in rural non-adjacent counties, and virtually non-existent in zip codes in metropolitan counties. On the other hand, the impacts of the Pilot loans appear to be highest in zip codes located in metropolitan counties. The effects on rural non-adjacent zip codes are still positive and statistically significant, while they disappear completely for rural nonadjacent zip codes. Finally, Community Connect grants have positive and statistically significant impacts on rural non-adjacent zip codes only. The effects are positive and large but not significant for metropolitan zip codes and, curiously, negative for rural adjacent zip codes.

6. Conclusion

In this paper, we have estimated the impact of USDA's broadband loan and grant programs on the average payroll per worker, using zip code level data spanning a period around the introduction of those programs (1997-2007). Our empirical methodology relies on a panel data fixed effects model that implements a difference-in-differences econometric strategy with multiple time periods, coupled with propensity score re-weighting to control for selection into treatment (broadband loan or grant receipt).

Our results indicate that a $1 increase in zip code per capita broadband loan results in about a $1.08 increase in annual payroll per worker. A very similar number ($1.07) was estimated for the Pilot loan program. We find no statistically significant impact of broadband grants received on the payroll per worker.

Our statistically significant estimates of the link between payroll per worker and the size of loans received enable us to compute a rough benefit-cost measure for each of the two loan programs. These indicate the net present value of the stream of benefits produced by current broadband loans outweigh the costs by 2.8 to 5.7 times, depending on how steeply one discounts future earnings. The benefit-cost ratios were a bit larger for the Pilot program

These numbers suggest that the net benefits of broadband loan programs have been substantial, very much in the same ballpark as benefit-cost estimates from a range of public health interventions (Masters et al. 2017). The incidence of those benefits—i.e., deciphering who the beneficiaries are, an in particular where they live—is not discernable from the data at our disposal. We do know that generally only a small fraction of individuals in a particular zip code would also work in that zip code, so that the benefits of increased payroll in one location would no doubt create significant spatial spillovers. Also, there would be labor market implications for nearby locations within the commutershed (Renkow and Hoover 2000). Clearly, attention to these sorts of spatial spillovers merits further attention.

We regard the foregoing analysis as encouraging, but preliminary. On a number of accounts, our measures of benefits are incomplete. Impacts on property values—notably house prices, but other commercial or agricultural land values as well—are one such unmeasured benefit. These would be the capitalized incremental net benefit of the communication services rendered. Additionally, bringing enhanced access to high-speed internet to a community increases communication opportunities for residents of that community. An assessment of the value of such opportunities—generally regarded to be positive (some might beg to differ, of course)—remains unaccounted, as well. Accounting for these benefits represents a fruitful area for future research.

Finally, there are likely substantial non-pecuniary—hence, challenging to measure—benefits related to provision of universal or near-universal access to what is now a dominant societal mode of communications. There is a long tradition of the federal government underwriting the costs of universal service provision, dating back to the implementation of Rural Free Delivery of mail in the late 1800s, and continuing on through Rural Electrification Administration (REA) subsidization of extending electrical service and telephone service into rural areas. Moreover, analysts of these public interventions suggest that despite initial skepticism about the merits of extending telecommunications services into highly remote areas, in many instances such investments have led to sufficiently large and sustained demands for those services over time to have justified the initial public investments on cost-benefit grounds (Parker 1990).[17]

In sum, there is substantial historical precedent for federal investments in communications infrastructure that provide close to universal access to dominant modes of communication in society, be they mail service or telephone service. In large measure, the impetus for federal involvement in these sorts of activities historically has been non-pecuniary: such investments were determined to be "citizenship" benefits that should be made available to all, regardless of where they dwelt. Presumably, such investments reflected an assessment by policymakers that the public goods created deployment of such integrative infrastructure were sufficiently large to outweigh the relatively steep costs of providing communication services to remote consumers of those services.

The desirability of continued or expanded federal funding of programs promoting broadband deployment into remote rural areas depends on whether a comparable assessment of these positive social externalities exists today among policy makers. That said, the empirical findings that have been presented here indicate that programs to date have generated substantial economic benefits over and above the cost of the federal investment.

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[17] In discussing the REA's rural telephone loan program, Parker writes: "In rural Alaska where distances and costs are enormous and the population density particularly low, rural telecommunications were provided because of political pressures and State government intervention, rather than because the telephone company saw greater economic opportunity. Nevertheless, the investment turned out to be economically sound because use greatly exceeded the most optimistic projections" (Parker 1990, p. 55).

References

Abadie, A. and G. W. Imbens. 2006. “Large Sample Properties of Matching Estimators for Average Treatment Effects.” *Econometrica* 74(1): 235-267.

Abadie, A. and G.W. Imbens. 2008a. “On the Failure of the Bootstrap for Matching Estimators.” *Econometrica* 76(6): 1537-1557.

Abadie, A. and G.W. Imbens. 2008b. “Estimation of the Conditional Variance in Paired Experiments.” *Annals of Economics and Statistics* 91/92: 175-187.

Blandford, D., R. Boisvert, and S. Davidova. 2008. “Infrastructure and Rural Development: US and EU Perspectives. *Eurochoices* 7(1): 52-59.

Busso, M., J. DiNardo, and J. McCrary, 2014. “New Evidence on the Finite Sample Properties of Propensity Score Reweighting and Matching Estimators” *Review of Economics and Statistics* 96(5): 885-897.

Cowan, T. 2008. “An Overview of USDA Rural Development Programs.” CRS Report for Congress No. RL 31837. Washington, DC: Congressional Research Service.

Crandall, R. and C. Jackson. 2001. “The $500 Billion Opportunity: The Potential Economic Benefit of Widespread Diffusion of Broadband Internet Access,” (mimeo), Washington, DC: Criterion Economics.

Crandall, R., W. Lehr, and R. Litan. 2007. “The Effects of Broadband Deployment on Output and Employment: A Cross-sectional Analysis of U.S. Data.” Issues in Economic Policy No. 6. Washington, DC: The Brookings Institution.

Dinterman, R. F. and M. Renkow. 2017. “Evaluation of USDA's Broadband Loan Program: Impacts on Broadband Provision.” *Telecommunications Policy* 41(2): 140-153.

Forman, C., A. Goldfarb, and S. Greenstein. 2009. “The Internet and Local Wages: A Puzzle” *American Economic Review* 102(1): 556-575.

Frolich, M. 2004. “Finite Sample Properties of Propensity-Score Matching and Weighting Estimators,” *The Review of Economics and Statistics* 86: 77–90

Gallardo, R., B. Whitacre, and A. Grant. 2018. “Broadband’s Impact: A Brief Literature Review.” Lafayette, IN: Purdue Center for Regional Development Publication No. 1. *www.pcrd.purdue.edu/files/media/Broadbands-Impact-Final.pdf*

GAO. 2014. “Telecommunications: USDA Should Evaluate the Performance of the Rural Broadband Loan Program.” Report to Congressional Requesters, GAOO-14-471.

Gillett, S., W. Lehr, C. Osorio, and M. Sirbu. 2006. “Measuring Broadband’s Economic Impact: Final Report.” National Technical Assistance, Training, Research, and Evaluation Project #00-07-13829. Washington, DC: U.S. Department of Commerce.

Hirano, K. and G.W. Imbens. 2004. "The Propensity Score with Continuous Treatments. *Applied Bayesian Modeling and Causal Inference from Incomplete-Data Perspectives* 226164: 73-84.

Kandilov, I. and M. Renkow. 2010. "Infrastructure Investment and Rural Economic Development: An Evaluation of the USDA's Broadband Loan Program." *Growth and Change* 41(2): 165-191.

Kandilov, A., I. Kandilov, X. Liu, and M. Renkow. 2017. "The Impact of Broadband on U.S. Agriculture: An Evaluation of the USDA Broadband Loan Program." *Applied Economic Perspectives and Policy* 39(4): 635–661.

Kim, Y. and P. Orazem. 2017. "Broadband Internet and New Firm Location Decisions in Rural Areas." *American Journal of Agricultural Economics* 99(1): 285–302

Kolko, J. 2012. "Broadband and Local Growth." *Journal of Urban Economics* 71 (1): 100–113.

Kruger, L. 2018. "Broadband Loan and Grant Programs in the USDA's Rural Utilities Service." CRS Report RL33816. Washington, DC: Congressional Research Service.

Mack, E. and T. Grubesic. 2009. Broadband Provision and Firm Location in Ohio: An Exploratory Spatial Analysis, *Tijdschrift voor Economische en Sociale Geografie* 100(3): 289-315.

Mack, E. and A. Faggian. 2013. "Productivity and Broadband: The Human Factor." *International Regional Science Review*, 36(3), 392-423.

Masters, R., E. Anwar, B. Collins, R. Cookson, and S. Capewell. 2017. "Return on Investment of Public Health Interventions: A Systematic Review." *Journal of Epidemiology & Community Health* 71: 827-834.

Molnar, G., S.J. Savage, and D.C. Sicker. 2015. "Reevaluating the Broadband Bonus: Evidence from Neighborhood Access to Fiber and United States Housing Prices." Fiber to the Home Council Americas. http://www.lightwaveonline.com/content/dam/lw/documents/FTTH_Report_06_26_2015.pdf

Parker, E. B. 1990. "Communications Investment to Promote Economic Development." In *Infrastructure Investment and Economic Development: Rural Strategies for the 1990s.* Staff Report No. AGES 9069, 43–67, Agriculture and Rural Economy Division, U.S. Department of Agriculture.

Renkow, M. and D. M. Hoover. 2000. "Commuting, Migration, and Rural-Urban Population Dynamics." *Journal of Regional Science* 40(2): 261-287.

Shideler, D., N. Badasyan, and L. Taylor. 2007. "The Economic Impact of Broadband Deployment in Kentucky." *Federal Reserve Bank of St. Louis Regional Economic Development* 3(2): 88-118.

Smith, J. and P. Todd. 2005. “Does Matching Overcome Lalonde's Critique of Nonexperimental Estimators?” *Journal of Econometrics* 125 (1-2): 305-353.

Stenberg, P., M. Morehart, S. Vogel, J. Cromartie, V. Breneman, and D. Brown. 2009. “Broadband Internet’s Value for Rural America” Economic Research Report No. ERR-78. Washington, DC: USDA

Tatom, J. A. 1991. “Should Government Spending on Capital Goods Be Raised?” *Federal Reserve Bank of St. Louis Review* 73(2): 3–15.

USDA. 2007. “USDA Rural Development: Bringing Broadband to Rural America.” Washington, DC: USDA. Available at *http://www.usda.gov/oig/webdocs/09601-04-TE.pdf.*

USDA, Office of Inspector General, Southwest Region. 2005. “Audit Report: Rural Utilities Service Broadband Grant and Loan Programs.” Audit Report 09601-4-TE. Available at *www.usda.gov/oig/webdocs/090641-04-TE.pdf.*

USDA, Office of Inspector General, Southwest Region. 2009. “Audit Report: Rural Utilities Service Broadband Grant and Loan Programs.” Audit Report 09601-8-TE. Available at *www.usda.gov/oig/webdocs/090641-08-TE.pdf*.

USDOT. 2015. “Use of Benefit-Cost Analysis by State Departments of Transportation.” Report to Congress, U.S. Department of Transportation. *www.fhwa.dot.gov/policy/otps/pubs/bca_report/senate_bca_report_05172016_revised.pdf*

Whitacre, B., R. Gallardo, and S. Strover. 2014a. “Does Rural Broadband Impact Jobs and Income? Evidence from Spatial and First-Differenced Regressions. *Annals of Regional Science* 53(3): 649–670.

Whitacre, B., R. Gallardo, and S. Strover. 2014b. “Broadband’s Contribution To Economic Growth in Rural Areas: Moving Towards a Causal Relationship.” *Telecommunications Policy* 38(11): 1011-1023.

APPENDIX

A.1 Econometric Strategy

Our strategy for identifying the impact of the three USDA's broadband grant and loan programs is rooted in the following reduced-form panel data model with zip code fixed effects:

$$Payroll = \mu_z + \tau_t + \beta_1 1\, CCGzt + \beta_2\, BBL_{zt} + \beta_3 Pilot_{BBL_{zt}} + \tau_t * Division_d + \varepsilon_{zt} \quad (1)$$

where *Payroll* is annual payroll per worker in zip code *z* in year *t*. To account for zip code specific time-invariant characteristics that affect payroll per worker and may be correlated with loan or grant receipt, we include zip code fixed effects μ_z. To absorb annual economy-wide fluctuations that affect payroll per worker in all zip codes, we also include year fixed effects, τ_t. So as to compare loan or grant recipient zip codes with non-recipient zip codes within the same Census division, we include division-by-year effects, $Division_d * \tau_t$ The variable CCG_{zt} reflects the amount of Community Connect Grant per capita received in zip code z. It is defined to equal to zero in all years prior to receiving the grant, and it is equal to the grant amount per capita in and after the year of grant receipt. We define the current broadband loan variable, BBL_{zt}, and the Pilot broadband loan variable, $Pilot\_BBL_{zt}$ in the same manner. he usual assumptions for the error term ε_{zt} apply. We compute heteroscedasticity robust standard errors that are clustered at the state level to allow for correlation across zip codes within a state and over time.

Note that there were no federal broadband loans distributed in year 2000, and both types of loans were distributed by 2007. The Pilot loans were distributed in 2002 and 2003; so, by 2007, four to five years had passed since the loans had been first received. On the other hand, the current broadband loan program began distributing funds after 2003, so by the end of our sample in 2007, current broadband loans had only been in effect for one to four years. Hence, the estimates of the loan impacts that equation (1) produces are short- to medium-run effects. In particular, β_1 can be interpreted as the change in the dollar value of payroll per worker if the zip code received an extra $1 increase in a loan or Community Connect grant per capita.

Causal inferences based on the econometric estimation of equation (1) may be problematic, even after we have accounted for the unobservable, time-invariant, zip code fixed effects. If the USDA's broadband loans and grants were randomly distributed across zip codes, one would easily be able to identify the impacts of the loan programs by estimating equation (1). However, in observational studies such as this one the treatment receipt mechanism determining whether or not loan or grant was received is usually not under the econometrician's control. Specifically, whether or not a county receives a broadband loan or grant (the treatment) depends on a number of factors that conceivably include both the outcome variables of interest—e.g., the growth of zip code level payroll per worker prior to loan or grant receipt—as well as other factors, such as the zip code's entrepreneurial/pro-growth spirit as well as population size and density, that would encourage internet service providers within the zip code to apply for a loan and/or the firms' success in securing a loan.

This differential selection into treatment may result in a selection bias when we use equation (1) above to estimate causal effects. To ameliorate this issue, different types of econometric methods have been used in the applied economics literature and in other disciplines such as public health, political science, and sociology. Some of the most popular techniques include instrumental variables, propensity score matching, and inverse probability weighting.[18]

While instrumental variables approaches are often favored by economists, finding appropriate instruments—ones that are associated with receiving treatment but conditional on

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[18] Some authors refer to inverse probability weighting as "probability reweighting" (see, for example, Busso et al., 2014 as well as Hogan and Lancaster, 2004).

treatment being uncorrelated with the outcome—is typically quite difficult.[19] Alternatively, propensity score matching (PSM) approaches to dealing with selection issues have gained popularity recently (Smith and Todd 2005). However, the more sophisticated matching estimators are difficult to implement; more importantly, statistical inferences can be problematic since reliable standard errors are only available for some of the existing matching estimators (see the discussion in Busso et al. 2014, as well as Abadie and Imbens 2006; 2008a; 2008b).[20]

Inverse probability weighting (IPW) has been widely used to estimate causal effects in public health and clinical medicine, and only recently has it gained popularity among applied economists (see, Hogan and Lancaster 2004; Frölich 2004; and Busso et al. 2014). In epidemiology and biostatistics, selection bias is usually analyzed in terms of confounders, and the preferred statistical methods—including IPW—are directed toward making proper adjustments by explicitly employing observed confounders. A confounder is simply a variable that is causally related to the outcome in question, is also associated with the treatment, but is not a consequence of the treatment. The IPW approach views confounding as a mechanism leading to nonrandom selection from the population of potential outcomes. This provides a natural motivation for the use of inverse weighting—a staple in the design of sample surveys—as a method to correct selection bias. Basically, confounding is viewed as an omitted variables problem that leads to a correlation between the error and the right-hand side variables. Hence, IPW estimators rely on modeling selection in terms of confounders.

We choose to employ IPW instead of PSM based on recent evidence in Busso et al. (2014) showing that in finite samples, IPW tends to perform as well as or better than even the most

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[19] Moreover, the choice of instruments in observational studies needs to be justified on substantive rather than empirical grounds – i.e., the instrument must be uncorrelated with an unobservable error term, which cannot be empirically verified.

[20] One can also use the generalized propensity score matching methodology described in Hirano & Imbens (2004).

sophisticated PSM estimators, especially when there is a good overlap in the distribution of the propensity score between the comparison and treatment groups. As noted above, given that PSM tends to be more difficult to implement empirically and standard errors are available only for some of the existing PSM estimators, IPW emerges as a natural candidate for evaluating the causal effect of broadband loan and grant receipt on farm outcomes. Note that as with PSM, the central identifying assumption of the IPW estimator is that treatment is assumed to be random conditional on the observed confounders (Hogan and Lancaster 2004).

Inverse probability weighting is an extension of inverse weighting methods employed in survey sampling and in missing data problems. Typically, in the context of sample surveys, the researcher's interest is to estimate a parameter for the entire population, but the sample used is not a random sample. Often, certain subpopulations (e.g., gender or racial groups) are over- or under-sampled. To obtain population-wide parameter estimates, the researcher can then use regression analysis and weight each unit relative to its inverse probability of being sampled. The weights represent the number of non-sampled members of the population that are being represented by the unit that was sampled.[21]

One can also estimate a population model of counterfactuals in the same fashion. To evaluate the causal impact of receiving a broadband loan (grant) on a community's economic performance, one would need data on economic outcomes after the community received a loan (grant) and counterfactual data on economic outcomes had the community not received a loan. In practice, only one of these two scenarios are observed. While the hypothetical full sample of counterfactuals (a pair of potential outcomes for each community) is assumed to be a random

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[21] For instance, if the weight for an observed unit is 1/10, then this unit's data represents information from 10 members of the overall population.

sample of the population of interest, the observed portion of these outcomes is nonrandom: for each zip code only one of the two possible outcomes is observed in reality.

This provides motivation to estimate the population model by weighting the observed data inversely by the probability of treatment. As this probability is generally unknown, it therefore must be estimated. To estimate the probability of treatment, we follow the standard approach of assuming that the treatment selection model is a logistic regression such that the log-odds of treatment are linear in the confounders, X:

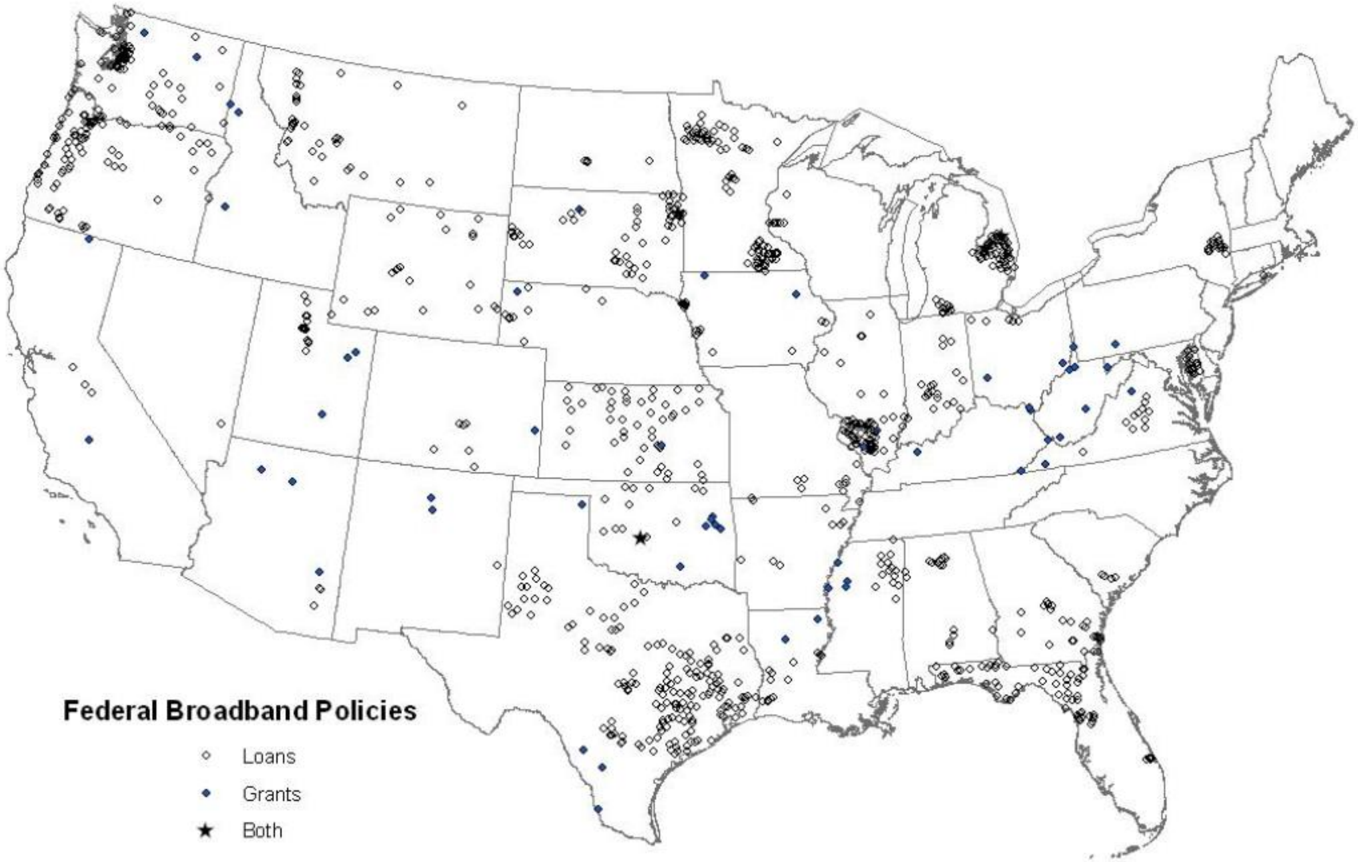
$$P(Loan_z \ or \ Grant_z = 1) = \frac{1}{1+e^{-X_z\gamma}} \qquad (2)$$

where $P(Loan_z \ or \ Grant_z = 1)$ is the probability that zip code *z* received either a Pilot or a current broadband loan or a Community Connect Grant; i.e. it is the propensity score. The vector X_z contains the set of confounding variables that are associated with the treatment.

We use a number of confounders that we believe may have been associated with treatment: the change in payroll, employment, and the number of establishments in the zip code between 1997 and 2000, which is just prior to the institution of the broadband loan and grant programs; as well as population, the number of housing units and land area in 2000. We also include indicator variables for the type of county in which the zip code is located—metropolitan (baseline), rural adjacent to metropolitan, or rural non-adjacent—and indicators for states.

Once the selection model (2) is estimated, one can compute the predicted probability of treatment for each zip code as well as its inverse to use as the sampling weight in the main equation (1). The estimated coefficients of the weighted regression equation (1) are then consistent estimates for the causal impacts of the broadband loans or grants on payroll per worker.

Figure 1. USDA Broadband Grants and Loans, 2002-2005



Source: USDA Rural Utilities Telecommunication Program

Figure 2a.

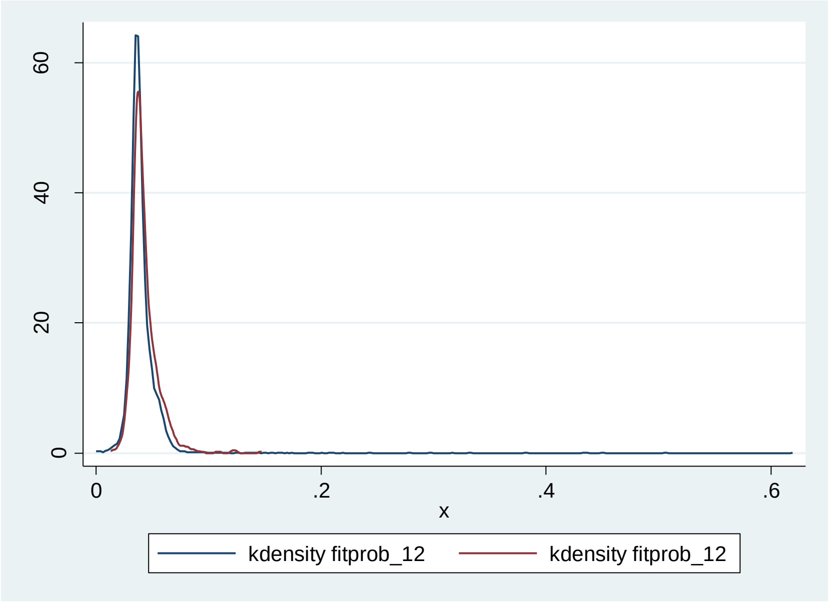


Figure 2b.

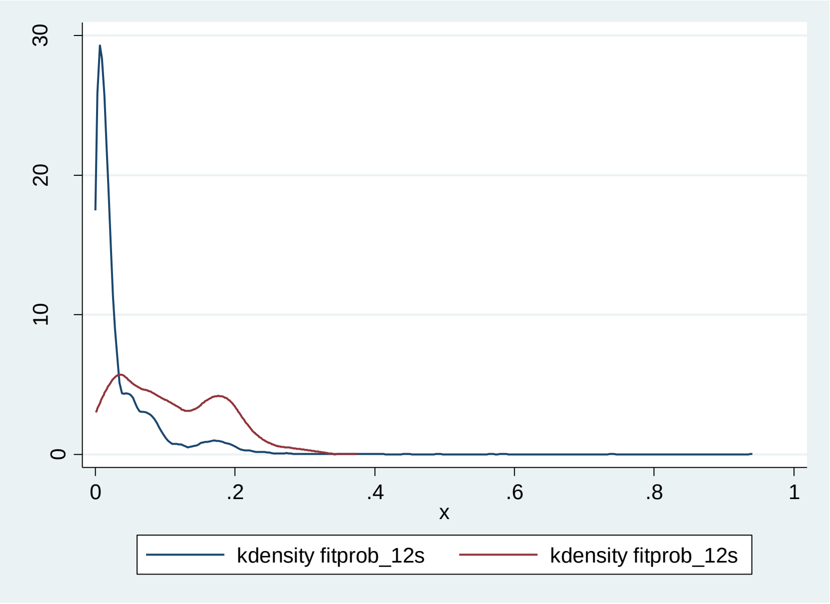


Table 1. Summary Statistics for Zip Codes Receiving Loans and Grants

Variables	Mean	St. Dev.
Current Broadband Loan Program recipient zip codes (N = 488)		
• Annual payroll per worker (2007 dollars)	\$25,032	\$9,297
• 2000 Population	5,804	3,617
• Loan amount per capita (2007 dollars)	\$195.81	\$35.050
Pilot Broadband Loan Program recipient zip codes (N = 302)		
• Annual Payroll per Worker (2007 dollars)	\$22,608	\$11,599
• 2000 Population	3,915	4,936
• Value of Grant per capita (2007 dollars)	\$5.04	\$62.03
Community Connect Grant recipient zip codes (N = 59)		
• Annual Payroll per Worker (2007 dollars)	\$22,569	\$12,918
• 2000 Population	2,842	5,158
• Value of Grant per capita (2007 dollars)	\$157.47	\$469.89
All eligible zip codes (N =19,433)		
• Annual Payroll per Worker (2007 dollars) Population	\$24,410	\$14,785
• 2000 Population	3,900	4,821

Note: There are 213,078 observations (19,433 zip codes) over the sample period from 1997 to 2007. The sample consists of zip codes with population of 20,000 or less in 37 states (see Data section) where at least one providers has received a broadband loan or grant. The Pilot program was begun in 2001 (authorized by Congress in December of 2000) while the current program started in 2003 (following the Farm Bill of 2002).

Table 2. Summary Statistics for the Selection Equation – the Likelihood of Receiving a Broadband Loan (Current or Pilot) or a Community Connect Grant.

Variable	**Zip codes receiving a loan or grant (weighted statistics in parentheses)**		**Zip codes not receiving a loan or grant (weighted statistics in parentheses)**	
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**
% chg. in Annual Payroll, 1997-2000	15.1 (11.1)	44.4 (36.1)	23.4 (15.2)	137.7 (50.4)
% chg. in Employment, 1997-2000	10.9 (8.4)	38.3 (34.0)	17.2 (11.3)	113.0 (49.0)
% chg. in No. of Establishments, 1997-2000	8.3 (1.2)	1,737 (17.1)	9.5 (2.5)	310.4 (19.1)
Population in Year 2000	4,930 (5,959)	5,087 (5,792)	3,900 (5,222)	4,821 (5,502)
Housing Units in Year 2000	2,111 (2,523)	2,144 (2,403)	1,692 (2,244)	2,116 (2,334)
Land Area (square miles)	135.8 (157.9)	202.6 (213.3)	89.8 (135.5)	190.7 (300.1)
Metropolitan	0.293 (0.186)	0.455 (0.389)	0.444 (0.314)	0.497 (0.464)
Rural Adjacent to Metropolitan	0.395 (0.469)	0.489 (0.499)	0.318 (0.397)	0.466 (0.489)
Rural Non-adjacent to Metropolitan	0.312 (0.345)	0.464 (0.476)	0.234 (0.288)	0.424 (0.453)

Note: The number of observations is 19,433, which represents zip codes with population of 20,000 or less in year 2000, located in the 37 states with at least one provider who received a broadband loan or grant.

Table 3. The Determinants of Receiving a Broadband Loan (Current or Pilot) or a Community Connect Grant[a]

	Likelihood of Receiving a Loan (0/1 Indicator Variable)	
Variables	**(1)**	**(2)**
% chg. in Annual Payroll, 1997-2000	-0.038*** (0.012)	-0.022* (0.013)
% chg. in Employment, 1997-2000	0.010 (0.008)	0.004 (0.013)
% chg. in No. of Establishments, 1997-2000	-0.025** (0.012)	-0.022** (0.010)
Population in year 2000	0.227 (0.147)	0.707*** (0.214)
Number of Housing Units in year 2000	-0.087 (0.146)	-0.469** (0.215)
Land Area (Square Miles)	0.058*** (0.021)	0.096** (0.037)
Rural Adjacent		0.298*** (0.085)
Rural Non-adjacent		0.157*** (0.054)
State Dummy Variables	No	Yes
Pseudo R^2	0.01	0.18
No. Obs.	19,433	19,433

[a] Cross-sectional logit model. The reported coefficients are elasticities. Omitted category from the Rural-Urban Continuum is Metropolitan. Heteroscedasticity adjusted standard errors that are clustered by state are presented in parenthesis below the estimated coefficients. *** indicates statistical significance at the 1 percent level, ** indicates statistical significance at the 5 percent level, and * indicates statistical significance at the 10 percent level.

Table 4. The Impact of Broadband Loans and Grant Receipt on Payroll per Worker[a]

	Annual Payroll per Worker ($)		
Variables	**(1)**	**(2)**	**(3)**
Community Connect Grant ($ per capita)	0.506 (0.830)	-0.494 (0.866)	0.437 (1.746)
Current Broadband Loans ($ per capita)	2.409*** (0.563)	0.924** (0.392)	1.081** (0.450)
Pilot Broadband Loan ($ per capita)	1.856*** (0.558)	0.953* (0.548)	1.071** (0.540)
Zip Code Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Census Region x Year Effects	No	Yes	No
Census Division x Year Effects	No	No	Yes
R^2	0.66	0.66	0.66
No. obs.	213,078	213,078	213,078
No. Zips	19,385	19,385	19,385

[a] Heteroscedasticity adjusted standard errors that are clustered by state are presented in parenthesis below the estimated coefficients. *** indicates statistical significance at the 1 percent level, ** indicates statistical significance at the 5 percent level, and * indicates statistical significance at the 10 percent level.

Table 5. Benefits versus Costs for Pilot and Current Broadband Loan Programs

Variable	Pilot Loan Program	Current Loan Program
(1) Average employment per zip code	1,256	1,660
(2) Average loan per capita (2007 dollars)	\$5.04	\$195.81
(3) Marginal effect of loan per capita on payroll/worker	1.071	1.081
(4) Local annual benefit = (1) × (2) × (3)	\$6,783	\$351,387
(5) Total benefit per zip code (10% discount rate)	\$67,831	\$3,513,874
(6) Total benefit per zip code (5% discount rate)	\$135,663	\$7,027,749
(7) Average population per zip code	3,915	5,804
(8) Total loan cost per zip code = (7) × (2)	\$20,828	\$1,230,448
Benefit-Cost ratio at 10% discount rate = (5) ÷ (8)	**3.26**	**2.86**
Benefit-Cost ratio at 5% discount rate = (6) ÷ (8)	**6.51**	**5.71**

Table 6. The Impact of Broadband Loans and Grants on Payroll per worker across the Rural-Urban Continuum[a]

	Annual Payroll per Worker ($)		
Variables	**Metropolitan (1)**	**Rural, Adjacent to Metropolitan (2)**	**Rural, Non-adjacent to Metropolitan (3)**
Community Connect Grant per capita	19.427	-0.795**	1.512**
($ per capita)	(18.892)	(0.353)	(0.670)
Current Broadband Loans per capita	0.323	1.973***	1.140***
($ per capita)	(0.837)	(0.556)	(0.401)
Pilot Broadband Loans per capita	4.987**	1.140***	-1.175
($ per capita)	(2.431)	(0.172)	(1.367)
Zip Code Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Census Division x Year Effects	Yes	Yes	Yes
R^2	0.46	0.74	0.46
No. obs.	100,978	67,202	44,898
No. of Zips	9,188	6,112	4,085

[a] Heteroscedasticity adjusted standard errors that are clustered by state are presented in parenthesis below the estimated coefficients. *** indicates statistical significance at the 1 percent level, ** indicates statistical significance at the 5 percent level, and * indicates statistical significance at the 10 percent level.

Appendix Table 1. Appropriations for the USDA Broadband Loans

Fiscal Year	Amount
2001 (Pilot)	$100 million
2002 (Pilot)	$80 million
2003	$80 million
2004	$602 million
2005	$550 million
2006	$500 million
2007	$500 million
2008	$300 million
2009	$400 million
2010	$400 million
2011	$400 million
2012	$212 million
2013	$42 million
2014	$34.5 million
2015	$24.1 million
2016	$20.6 million
2017	$27 million
2018	$29 million

Source: Kruger (2018)

Appendix Table 2. Appropriations for Community Connect Broadband Grants

Fiscal Year	Amount
2002	$20.0 million
2003	$10.0 million
2004	$9.0 million
2005	$9.0 million
2006	$9.0 million
2007	$9.0 million
2008	$13.4 million
2009	$13.4 million
2010	$17.9 million
2011	$13.4 million
2012	$10.4 million
2013	$10.4 million
2014	$10.4 million
2015	$10.4 million
2016	$10.4 million
2017	$34.5 million
2018	$30.0 million

Source: Kruger (2018)

Appendix Table 3. The Impact of Broadband Loans and Grant Receipt on Aggregate Payroll and Employment[a]

Variables	Aggregate Payroll ($) (1)	Employment (2)
Community Connect Grant ($ per capita)	-9,275.366 (6,194.582)	-0.709 (0.640)
Current Broadband Loans ($ per capita)	-5,502.791* (3,210.465)	-0.278* (0.160)
Pilot Broadband Loan ($ per capita)	781.075 -9,275.366	-0.147** -0.709
Zip Code Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Census Division x Year Effects	Yes	Yes
R^2	0.94	0.97
No. obs.	213,078	213,078
No. Zips	19,385	19,385

[a] Heteroscedasticity adjusted standard errors that are clustered by state are presented in parenthesis below the estimated coefficients. *** indicates statistical significance at the 1 percent level, ** indicates statistical significance at the 5 percent level, and * indicates statistical significance at the 10 percent level.

Appendix Table 4. The Impact of Broadband Loans and Grant Receipt on Payroll per Worker, Year by Year Changes Following Loan Receipt[a]

Variables	Annual Payroll per Worker ($) (1)
Community Connect Grant ($ per capita) 1st Year After	-2.847* (1.624)
Community Connect Grant ($ per capita) 2nd Year After	1.184 (2.115)
Community Connect Grant ($ per capita) 3rd Year + After	2.421 (3.371)
Current Broadband Loans ($ per capita) 1st Year After	0.566* (0.307)
Current Broadband Loans ($ per capita) 2nd Year After	1.174 (0.755)
Current Broadband Loans ($ per capita) 3rd Year + After	1.174* (0.664)
Pilot Broadband Loans ($ per capita) 1st Year After	1.198** (0.532)
Pilot Broadband Loans ($ per capita) 2nd Year After	0.935 (0.809)
Pilot Broadband Loans ($ per capita) 3rd Year + After	1.453 (0.870)
Zip Code Fixed Effects	Yes
Year Fixed Effects	Yes
Census Region x Year Effects	No
Census Division x Year Effects	No
R^2	0.67
No. obs.	213,078
No. Zips	19,385

[a] Heteroscedasticity adjusted standard errors that are clustered by state are presented in parenthesis below the estimated coefficients. *** indicates statistical significance at the 1 percent level, ** indicates statistical significance at the 5 percent level, and * indicates statistical significance at the 10 percent level.