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Evaluation of USDA's Broadband Loan Program: Impacts on broadband provision☆

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ABSTRACT

Since 2002 the USDA's Broadband Loan Program has directed more than $1.8 billion in subsidized loans to help expand broadband access in under-served rural communities. Program eligibility criteria included having a population of 20,000 or fewer, 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. We evaluate on the effectiveness of the Loan Program in increasing broadband availability in target locations. Specifically, we analyze whether loan receipt increases the number of broadband providers in a particular location, using various count panel methods. Our analysis is conducted at the ZIP code level over the period 1999–2008; it uses broadband provider data from the FCC's Form 477, and loan data from the Rural Utility Service (the implementing agency for the Broadband Loan Program). Results indicate that ZIP codes receiving broadband loans did in fact experience modest, statistically significant increases in the number of broadband providers vis-à-vis non-recipient locations; that average marginal effects on treated ZIP codes were approximately 0.092 additional broadband providers annually; and that these benefits accrued more towards rural locations than urban locations, in conformance with the intent of the program.

1. Introduction

Broadband technology delivers enhanced information and communications services at rapid transmission rates to end users. Previous research suggests that profit maximizing broadband providers tend to first serve areas with higher expected profit—via higher revenues and/or low costs (Czernich, Falck, Kretschmer, & Woessmann, 2011; Whitacre & Mills, 2007; Whitacre, 2010). Consequently, and similar to other emerging communications technologies, broadband diffusion has followed an S-shaped diffusion path over time and spatially so that the rate of availability and uptake in a particular geographic area has been found to diminish with the density of business and households within that area (Attewell, 1992; Geroski, 2000).

Expanding access to high-speed broadband internet, particularly to relatively under-served rural areas, has been a pillar of federal rural development policy for a span of time approaching two decades. Beginning in December 2000, Congress authorized various broadband loan programs to help expand broadband access in under-served rural communities. Through 2007, the programs had approved more than 70 loans in 40 states, totaling over $1.22 billion worth of loans across 1263 communities and

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582,000 households (USDA-Rural Development, 2007).

This paper utilizes data on two broadband loan programs administered by the United States Department of Agriculture (USDA) in order to gauge how effectively that public investment was implemented. Kandilov and Renkow (2010) is the only previous academic study to analyze the impacts of the two broadband loan programs. That paper examined whether or not various indicators of local economic performance (employment, payroll, number of establishments) have differed in systematic ways between communities that have participated in the Broadband Loan Program and those that have not. Here we examine a fundamental precursor to economic impacts that may stem from these Broadband Loan Program: whether or not the program produced significant increases in broadband availability—a necessary, but by no means sufficient, condition for the programs producing economic impacts.

To do so, we first use discrete choice methods to determine the factors that drove the disbursement of the broadband loans across the United States from 2002 through 2006. Results indicate that ZIP codes receiving broadband loans did in fact roughly conform to the programs' target populations: Statistically significant increases in the probability of receiving a loan were evident for locations characterized by relatively low initial population densities and levels of service. We then use count panel methods to model expansion of broadband availability—proxied by the number of providers in an area—over time. In particular, we seek to ascertain whether or not there was a detectable causal link between a locality receiving loan program funds and broadband availability within that locality. We identify changes in broadband availability using ZIP code level Federal Communications Commission (FCC) data from December 1999 to June 2008. Results indicate that ZIP codes receiving broadband loans experienced approximately 0.092 additional broadband providers annually and that these increases occurred to a greater degree in more rural areas *vis-a-vis* urban areas. Thus, we find evidence in support of the broadband loan programs having contributed to an increase in broadband availability in target areas.

The paper is laid out as follows. The following two sections briefly describe the USDA broadband loan programs and the data we use to analyze it. Next, we analyze econometrically the factors determining whether or not areas received broadband loans. We then estimate whether or not—and to what extent—receipt of a broadband loan contributed to an increase in the number of broadband providers. Concluding remarks are offered in the paper's final section.

2. The USDA Broadband Loan Program

The initial roll-out phase of broadband technologies across North America began around 1996 when Rogers Communications introduced the first cable modem service in Canada (FCC, 2005). The technology became available in the United States shortly thereafter, although the diffusion of broadband technologies was neither instantaneous nor ubiquitous. As seen in Fig. 1, around 2000 there were many areas within the U.S. which lacked access to broadband. After 2008, the only areas in the United States lacking access to broadband technology were extreme rural areas with limited economic activity. The early adopters of broadband across the United States were areas with favorable economic conditions: densely populated metro areas with high levels of median income (Greenstein & Prince, 2006).

A troubling issue at the turn of the millennium centered around the so-called digital divide within the United States in which there existed differences in internet access between rural and urban areas. Early work focused on computer adoption and dial-up connections (Antonelli, 2003; DiMaggio & Hargittai, 2001; Norris, 2001; Parker, 2000; Strover, 2001; Wade, 2002). With the growing ubiquity of personal computers and increasing diffusion of broadband, scholarly interest focused more on rural-urban differences in access to high-speed internet (Grubesic, 2003; LaRose, Gregg, Strover, Straubhaar, & Carpenter, 2007; Malecki, 2003). Rural areas were found to consistently lag urban areas in broadband availability. This "infrastructure inequity" was generally thought to put those rural areas at a competitive disadvantage with respect to economic development in the changing US economy (Grubesic, 2006). It was found to be rooted in the lower rural population densities and hence greater per-unit deployment costs, coupled with the idiosyncrasies of the regulatory and market environment determining the types of telecommunications providers operating in rural places (Wood, 2008).

Growing concern over rural-urban disparities in broadband availability spurred government policies aimed at reducing regional differences in broadband access. In December 2000, Congress authorized a broadband pilot program ("Pilot") to offer subsidized loans to help expand broadband access in under-served rural communities. Program eligibility criteria included having a population of 20,000 or fewer, 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, 2010).

Administered by the United States Department of Agriculture's (USDA) Rural Utilities Service (RUS), the Pilot program was implemented to gauge the effectiveness and feasibility of a larger scale program. In the first year, there were 12 loans disbursed, worth $100 million. The Agricultural Appropriations Act of 2002 allowed for a second round of funding for 16 loans of $80 million to complete the total funding of the program. Overall, the Pilot program totaled $180 million in loans to 98 communities located in 13 states. After the Pilot program, the 2002 Farm Bill established the USDA Rural Development Broadband Program that expanded upon the scope of the Pilot program. By 2007, the program had approved 70 loans in 40 states, totaling over $1.22 billion serving 1263 communities and 582,000 households (USDA Rural Development, 2007).

Although loans were ostensibly targeted toward rural areas, some of the loans went to more urbanized places located in metropolitan counties. Presumably, these loans reflected to some degree the geographical exigencies of existing broadband infrastructure expanding outward from densely populated urban areas out towards the more rural areas targeted by the program. Data on the timing and location of loan disbursals are available from RUS at the ZIP code level. Table 1 displays the distribution of

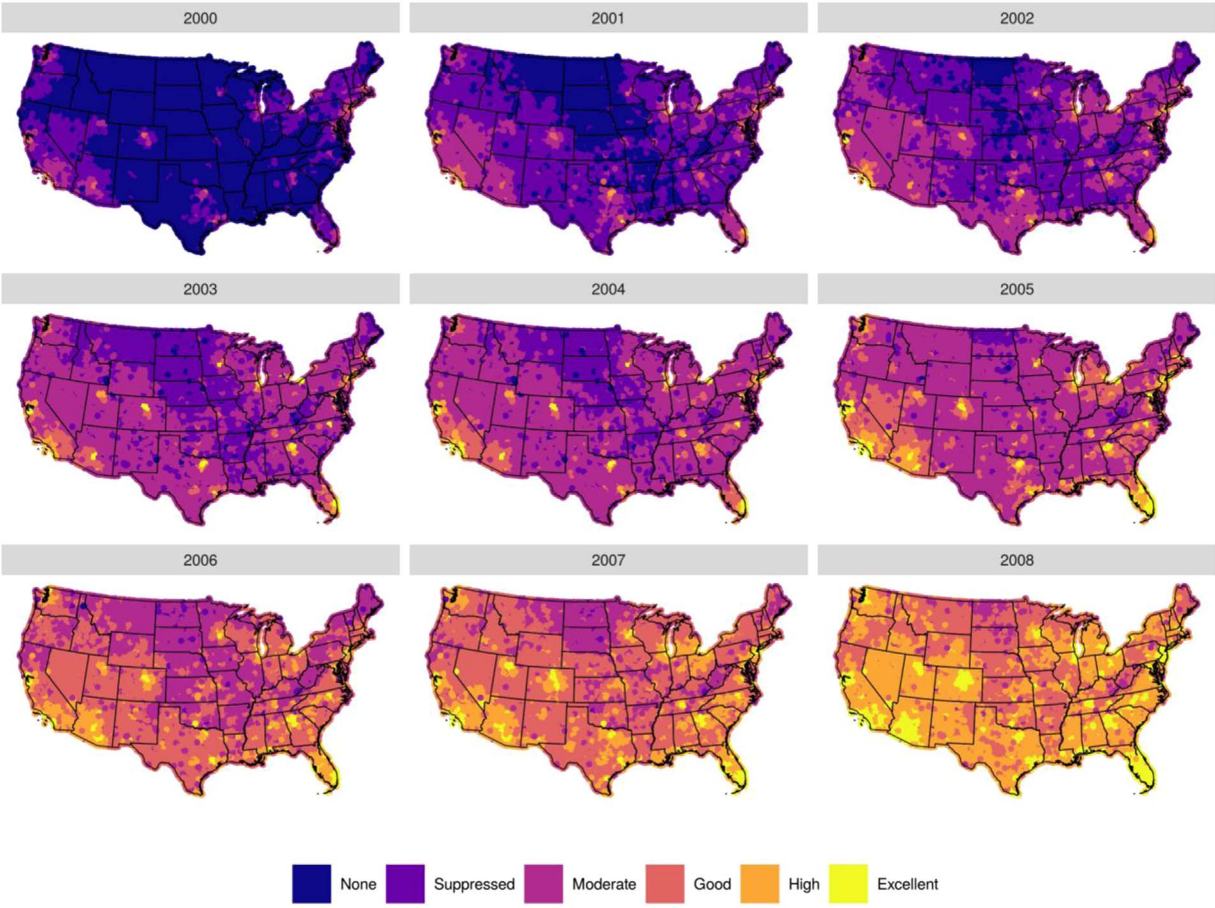

Fig. 1. U.S. Broadband Availability from 2000 to 2008. A simple kriging procedure was used using ZIP code level FCC data on number of providers with the suppressed values coded as 2 (Cressie, 1993). The predicted values were then translated to None 0–2), Suppressed 2–3), Moderate 3–5.5), Good 5.5–7.5), High 7.5–10) and Excellent (more than 10).

ZIP codes across the rural-urban continuum. Compared to the rest of the United States, both the Pilot and Farm Bill programs disbursed a higher number of loans to ZIP codes located in rural counties, although there were still more than 30% of the loan recipients located in metro counties.[2]

A concern for both the Pilot and Farm Bill 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. 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 (Kruger, 2013).[3]

The primary intent of the USDA broadband loan program is to extend loans to broadband providers in order to increase broadband availability. Increased availability could take various forms, including an increase in a given provider's coverage, an increase in the number of providers for a location, or an increase in the quality of broadband provided. Of these, only data on the number of providers that serve a ZIP code is available. The following section details these and other data used in this paper.

3. Data

3.1. FCC Form 477 Data

Broadband providers are required by the Federal Communications Commission (FCC) to submit Form 477, which reports the ZIP codes for which they provide service. The Form 477 data are available at the ZIP code level from 1999 through 2008 from

[2] Data are not available for the locations of rejected loan applicants, although it is known that there were 76 unsuccessful applicants in 2003, 39 in 2004, 37 in 2005, and 33 in 2006 for the Farm Bill (USDA-Rural Development, 2007).

[3] Our data do not contain any loans disbursed around Chicago. This could be an error in our data or from the previous report. We believe the report may have meant to say Houston as it is a large city with loans disbursed around the area that may have been confused for Chicago.

Table 1
Broadband Loans by Recipient ZIP Code's County Type.

Loan Type	Metro	Rural Adjacent	Rural Non-Adjacent
Pilot	35.4%	26.8%	37.8%
Farm Bill	48.5%	37.1%	14.4%
None	54.2%	26.1%	19.7%

telecommunication providers that are required to file Form 477 twice a year. Prior to 2005 small providers serving less than 250 lines were exempted from these reporting requirements. We include time fixed effects in our empirical analysis to account for this reporting change (see footnote 14).[4]

The FCC definition of broadband across this time period is providers offering fixed-location Internet access connections faster than 200 kilo-bits per second in either download or upload speeds. (Wireless connections are not included in the data.) Subsequently, since 2008 the FCC has progressively increased the minimum internet connection speed to define broadband and changed the geographical unit of analysis from the ZIP code level to the census tract level. These changes limit the time-frame of our analysis.

In addition, the data do not give insight into the total households served within a ZIP code or the quality of services, so the measure is imprecise. However, Kolko (2010) demonstrates that a monotonic relationship exists between number of providers and coverage of broadband within a ZIP code. He does this by combining FCC ZIP code level data and Forrester Research's December 2005 Technographic benchmark survey of 60,000 households of broadband availability at the ZIP code level. We take this as validation that the number of broadband providers is a meaningful proxy for broadband availability.

The FCC data take on a count value of 0, 1–3*, 4, 5, 6, ... 31. The value 1–3* is a suppressed value of broadband providers for confidentiality purposes. We follow Kolko (2012) by coding the suppressed (1–3*) values as 2.[5] As can be seen in Fig. 2, the count data are not normally distributed throughout the period under consideration.

The FCC data indicate that as of December of 1999, approximately 40% of the 30,000 ZIP codes lacked broadband access. In Fig. 3, this percentage is represented by the (middle) red line. The number of unserved ZIP codes rapidly declined until around 2006, by which time only very remote ZIP codes with sparse populations did not have access. By the end of the available FCC data (2008), there were effectively no ZIP codes without access—although Grubesic (2008) notes that this is not necessarily the same as universal access since not all residents in a particular "served" ZIP code will have access.[6] Fig. 3 also indicates that a larger fraction of ZIP codes that would eventually receive a Pilot loan (51%) were unserved early in the sample period (until 2006). On the other hand, and somewhat curiously, of ZIP codes that would eventually receive a Farm Bill Loan, a significantly smaller proportion (33%) had no providers up to 2006.

3.2. ZIP code level data

Our econometric analysis is conducted at the ZIP code level. ZIP codes are defined periodically by the United States Postal Service, and represent postal routes. These routes change over time: new ones are created each year, some are deleted each year, and a ZIP code does not necessarily represent an enclosed area as it is a route and not a polygon (ZIP is an acronym for Zone Improvement Plan). To deal with the enclosed area problem, we used a ZIP Code Tabulated Area (ZCTA) shapefile provided by the US Census Bureau. This shapefile approximates each ZIP code to an enclosed area using Geographic Information Systems (GIS) technology. This particular shapefile also includes interpolated values for the 2003 population of a ZCTA via Census block populations.

Because 2004 represents the midpoint of the years covered by our analysis, we chose to use the 2004 ZCTA shapefile to deal with the potential issue of changing ZIP code boundaries and those entering/leaving the USPS system. The changing ZIP codes could potentially be a problem if the changing boundaries directly—or indirectly, through a covariate—affects the number of providers in a ZIP code. This potential bias cannot signed, however, due to the unknown nature of the changing ZIP code boundaries; i.e., it is not known if the boundary changes were to positively or negatively influence the provider count. Within the framework of this study, it was not feasible to test for whether or not changing ZIP code boundaries are influencing the results because of the lack of available ZCTA shapefiles.

Another potential issue with ZCTAs is the endogenous nature of their size. As ZIP codes are based upon postal routes, this implies that the delivery times to service a postal route should be roughly equal across ZIP codes. In other words, ZIP codes are not randomly drawn;

[4] A summary of data used, including sources and time coverage, may be found in the Appendix.

[5] Note, however, that our results are not at all sensitive to alternative means of dealing with this suppression issue—e.g., shifting all of the unsuppressed count values down by two (0, 1, 2, ... 29).

[6] The FCC did not track the percentage of subscribers to broadband in a geographical area until the second half of 2008. Beginning in the second half of 2008 the FCC also changed the reporting unit from ZIP code level data to census tract level data because the latter is a consistent polygon while the former may change across time. Because of the change in reported data, we only use data from the FCC through June of 2008.

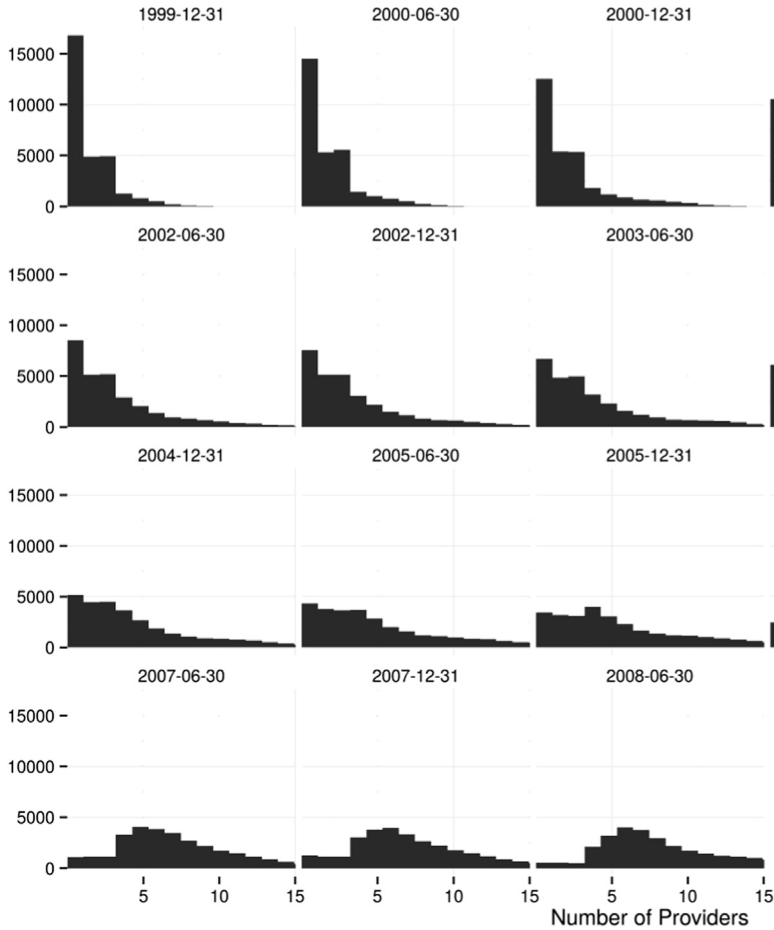

Fig. 2. Broadband Providers per ZIP Code across Time. Data are suppressed if there are between 1 and 3 providers for a ZIP code. For clarity of picture, a random uniform draw between 1 and 3 replaced the suppressed data.

rather, they are designed by the postal service and thus their goal is to efficiently serve the United States. The size of the ZIP code therefore needs to be controlled for by calculating the area of the ZCTA. The total square miles of each ZCTA was calculated from the ZCTA shapefile through GIS software in R.[7] Holding all else constant, it should be the case that larger ZIP codes have more broadband providers because they span a greater area which allows a different broadband provider to potentially serve the area.

The ZCTA shapefile also allows for the calculation of the topographical features of the area which partially determine the costs of deploying broadband in an area. In order to control for this, we used the Terrain Ruggedness Index (TRI) for each ZCTA in the 2004 shapefile. Developed by Riley et al. (1999), TRI is a measurement (scaled from 1 to 100) based on the amount of elevation difference between adjacent cells of a digital elevation grid. This is calculated through elevation shapefiles from DIVA-GIS.org and the R function 'terrain()' from the raster package. Kolko (2012) provides evidence that the costs of deploying broadband are correlated with the terrain characteristics.

The US Census Bureau's County Business Patterns dataset publishes information on number of establishments, employment during the week of March 12, first quarter payroll, and annual payroll across 6-digit North American Industry Classification System (NAICS) and across various geographies. The annual data are extracted from the Business Register (BR), a database of all known single and multi-establishment employer companies maintained and updated by the US Census Bureau. Data on number of employees and payroll values at the ZIP code level suffer from suppression issues due to the sensitivity of being able to identify particular businesses if there are a limited number of that type of business operating in a ZIP code. Suppression affects approximately 2% of ZIP codes; however the total number of establishments is not suppressed for any ZIP codes. We use annual data from 1999 to 2008 on total number of establishments[8] as a way to proxy for the economic activity in a ZIP code that should be positively related to the number of broadband providers as their potential customer base grows. In addition, we include annual

[7] Only the ZIP codes that have data from the county business pattern, FCC form 477, and 2004 ZCTA shapefile were used. We also adopt methodology from Grubesic and Matisziw (2006) to adjust for boundary, topological features, and fragmented polygons issues which arise from using ZCTAs.

[8] The values for number of employees and establishments track each other fairly well across time which, along with suppression issues, drives our choice of using number of establishments as opposed to number of employees.

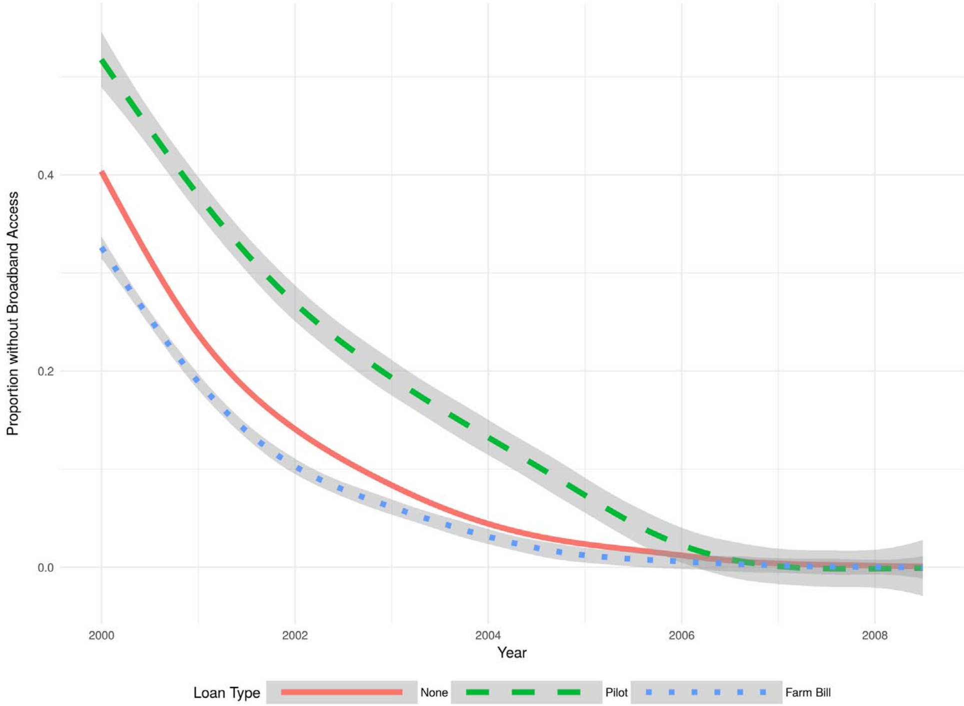

Fig. 3. ZIP Codes without Broadband Access.

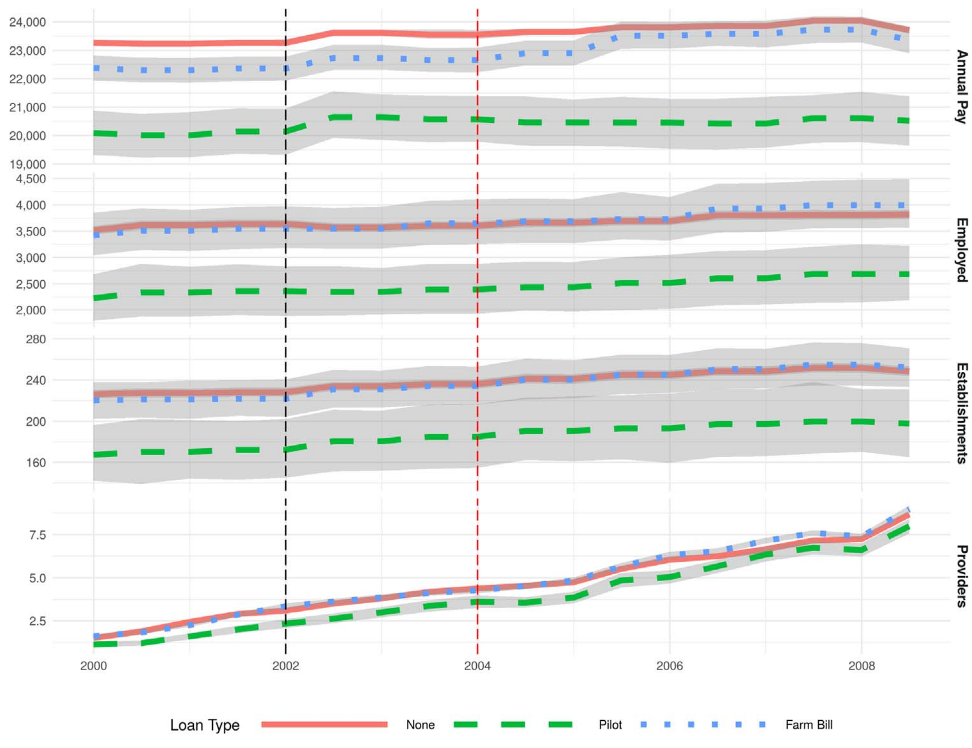

Fig. 4. Trends for ZIP Code-Level Variables. First (black) dashed line indicates initiation of the Pilot program while the second (red) dashed line is for the Farm Bill program.

payroll divided by number of employees[9] to proxy for wages in the ZIP code. Average annual pay is deflated to 1999 dollars via the Consumer Price Index.

Fig. 4 presents time trends of the relevant economic conditions for all ZIP codes and further breaks down ZIP codes by those which received either the Pilot or Farm Bill broadband loans. Each time series plots the sample mean and a 90% confidence interval as calculated through bootstrapped standard errors. The first (black) dashed line indicates the implementation of Pilot loans and the second (red) dashed line is for the Farm Bill.

Prior to the beginning of the Pilot program, very similar trends (and, for the most part, levels) are evident for recipient and non-recipient ZIP codes. This suggests there are no glaring selection issues to invalidate comparing post-program outcomes between the two types of counties. Throughout the entire period, the Pilot loan ZIP codes lag other ZIP codes for employment statistics as well as number of broadband providers. For the Farm Bill loans, it appears that the ZIP codes track the rest of the US across the years fairly well for all variables except for average annual pay. For average annual pay, the Farm Bill ZIP codes lag behind the rest of the US and this is a statistically significant difference until there is a visible uptick in annual pay for Farm Bill ZIP codes that occurs around 2005. After 2005, the Farm Bill ZIP codes still lag behind the rest of the US but the difference is not statistically significant like before 2005. Aside from the annual pay uptick, it is difficult to determine visually if the Pilot and/or Farm Bill loans made a discernible impact in increasing the number of providers, hence the need for additional statistical analysis.

A potentially confounding issue in ZIP code level data is that the area and number of establishments are negatively correlated (value of −0.0729). This stems from the endogenous nature of postal route size as more dense regions will have smaller ZIP codes on average in order to serve all of the establishments/people. Similarly, sparsely populated areas are more likely to have larger ZIP codes due to fixed costs associated with postal routes. Because of this, one needs to further control for the density of firms in a ZIP code as an arguably more important proxy for the potential business customer base within a ZIP code.

3.3. County level data

Annual ZIP code level data is not available for some variables, which necessitated the use of county level data. Using the ZCTA shapefile from 2004, we overlay each ZCTA on a county-level shapefile for the US to determine the county that each ZCTA lies within. For ZCTAs that span multiple counties, we assign the ZCTA to the county that has the majority of the overlapped area.[10] We also utilize the county shapefile to calculate the total square miles of each county to help control for density issues related to population.

The main source of county level statistics is the Internal Revenue Service (IRS) County Income dataset. The IRS bases draws its county data from administrative records of individual income tax returns (Forms 1040) filed during the 12-month period of January 1 to December 31. The IRS provides data at the county level from 1989 to 2013 on number of tax returns filed, number of exemptions filed, Adjusted Gross Income (AGI), Wages & Salaries, Dividends before exclusions, and Interest received. Because not all individuals within the United States are required to file tax returns, these data only represent the tax filing portion of the population. We utilize total number of exemptions to proxy for the population of a county in a given year. This should be a more accurate reflection of population compared to non-Census year estimates published by the Census Bureau, as the IRS data can more accurately capture migration inter-censal migration within the United States.

Population of a county is expected to be positively related to number of broadband providers as it represent the potential residential customer base. We further proxy for population density by dividing the number of exemptions by the area of a county. Population density should lower the costs of deploying broadband for an area as a broadband providers does not need to lay as much cable to connect customers to the backbone of their system.

We divided both AGI and Wages & Salaries by number of tax returns filed to proxy the mean levels of income and wages for a county, respectively, then converted them to 1999 dollars using the Consumer's Price Index.[11] The breakdown of how population and income at the county level change across time for counties receiving Pilot or Farm Bill loans—as well as non-recipient counties—can be seen in Fig. 5. All of the series are within the 90% confidence interval of each other as calculated through bootstrapped standard errors—i.e., not significantly different than one another. On average, counties receiving at least one Pilot loan have larger populations and have higher wages and incomes than the rest of the United States. In contrast, counties having received a Farm Bill loan are less populous on average than non-recipient counties.

Finally, in some of our analyses we distinguish localities on the basis of where they lie on the rural-urban continuum. We adopt a standard classification of counties as being either metro, rural but adjacent to a metro county (Rural Adjacent), and rural but non-adjacent to a metro county (Rural Non-Adjacent). These designations are derived from the USDA's rural-urban continuum code (RUCC). The classification system is germane to the loan programs insofar as rural communities, and particularly remote rural communities, were the stated target group for receiving these loans. USDA updates the RUCC in years that end in 3 (1993, 2003,

[9] To correct for suppression issues, we proceed in three steps. First, if a suppressed value has an unsuppressed value in the previous year, then we replace the suppressed value with the unsuppressed value of the previous year. If the previous year is suppressed, then we replace the suppressed value with the value of the following year. If both of these values are suppressed, then we replace the suppressed value with the average across all years. Because the variable of interest is a ratio between annual payroll and number of employees, there should be no issue with the differing size of a ZIP code as it relates to suppression.

[10] There are about 30,000 ZCTAs, of which roughly half are fully enclosed by one county, another third are spread across two counties and the rest spread across three or, in a few cases, four counties. We take the approach that broadband availability is a latent variable measured at the ZCTA level, and that use of the county level statistics applicable to the greatest fraction of the ZCTA's geography is our best approximation of relevant conditioning variables.

[11] These served as a cross-check for the ZIP code level average annual pay, as mean levels of the ZIP codes should be similar to those of counties. The ZIP code level is preferred because of the finer granularity of ZIP code level over a county level statistic. Both AGI and Wages & Salaries are expected to be positively related to number of broadband providers, as these signal the scope of local revenue base that a potential broadband provider would be interested in.

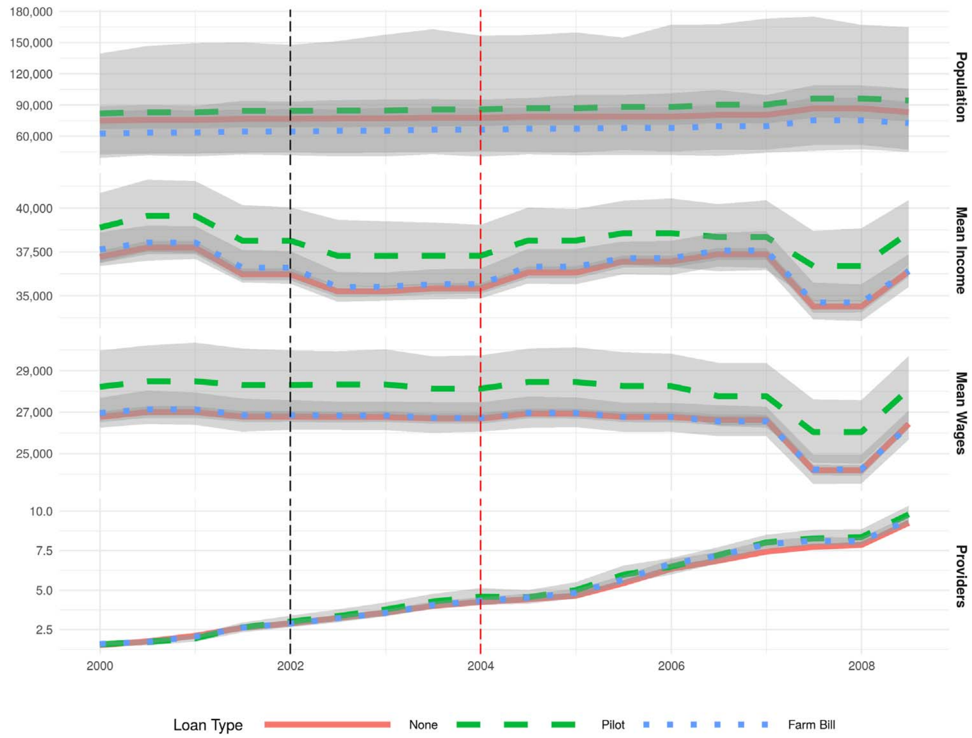

Fig. 5. Trends for County-Level Variables. First (black) dashed line indicates initiation of the Pilot program while the second (red) dashed line is for the Farm Bill program.

2013). We chose to use the values for 2003 as this would be a little bit before the halfway point in span of our analysis.[12]

4. Determinants of loan receipt

The stated objectives of the RUS for disbursement of loans were to target under-served rural communities with fewer than 20,000 inhabitants, and not located in a Standard Metropolitan Statistical Area. The figures in Table 1 suggest that some of these qualifications may not have been met, as a substantial fraction of loans were disbursed in metro counties. To be more statistically rigorous, we employed discrete choice models to examine whether or not the ZIP codes receiving these loans were likely to be in accordance with the stated goals of the programs.

Suppose that the probability of a ZIP code z receiving a loan takes the form:

$$Pr(Loan_z = 1) = f(Rural_z,\ Pop_z < 20,000,\ Prov_z < 4,\ \boldsymbol{X_z}) \tag{1}$$

where $Rural_z$ denotes county type (metro, rural adjacent, rural non-adjacent) for the ZIP code, Pop_z is the ZIP code's population, $Prov_z$ is the number of broadband providers in the ZIP code, and $\boldsymbol{X_z}$ is a vector of ZIP code and county characteristics that are believed to affect the probability of receiving a loan.

For evaluating the loan programs the key variables of interest are their stated goals, all of which are indicated by dummy variables: rural areas, fewer than 20,000 inhabitants, and low levels of broadband. While these three variables are the focus of our attention, it is also important to control for other factors that may have contributed to the probability of receiving a loan. These include the total number of existing broadband providers for a ZIP code, total population, total establishments, average income, and TRI. Number of broadband providers is expected to be negatively related to probability of receiving a loan on the assumption that more providers in an area would render less likely RUS' approval of a loan application. All other variables (except TRI) are expected to be positively associated with the probability of receiving a loan as they indicate higher potential revenues that would make it attractive for a broadband provider to attempt to service an area and thus apply for a loan. The TRI variable is ambiguous *a priori*. An area with a high TRI is more likely to not be serviced by broadband providers due to the high costs which in turn would render the area a more apt candidate for inclusion in the program. However, if the terrain is prohibitively rugged, then the subsidized rate of the loan may not be enough to offset the high costs and therefore be negatively related to the probability of receiving a loan. The Pilot program began in December of 2000. In order to stay consistent with the known information at the time the values of all variables

[12] We acknowledge the inexactness of these designations, insofar as (a) multiple definitions exist as to what constitutes whether a place is rural or urban; (b) these definitions change across time; and (c) there significant 'rural' portions of many Metro counties (Wunderlich, 2016). With that caveat, we include the USDA rural-urban classification in our analysis if for no other reason than to test for whether or not that designation accords with observed disbursal of Broadband loans.

Table 2
Logit Estimates of the Probability of Receiving a Broadband Loan.

	Dependent Variable =*1 if ZIP code received:*				
	Any Loan		**Pilot Loan**	**Farm Bill Loan**	
Variable	(1)	(2)	(3)	(4)[a]	(5)[b]
Providers < 4	0.593*** (0.089)	0.647*** (0.128)	0.013 (0.293)	0.791*** (0.140)	0.319*** (0.099)
Pop'n < 20,000	−0.331*** (0.083)	0.145 (0.092)	−0.043 (0.220)	0.204** (0.099)	0.413*** (0.101)
Rural Adjacent	0.354*** (0.061)	0.485*** (0.063)	0.245 (0.151)	0.535*** (0.069)	0.619*** (0.071)
Rural Non-adjacent	0.025 (0.072)	0.161** (0.077)	0.781*** (0.148)	−0.108 (0.092)	−0.044 (0.094)
No. of Providers		−0.020 (0.024)	−0.163*** (0.057)	0.010 (0.025)	0.004 (0.016)
ln (Population)		0.053 (0.037)	−0.037 (0.070)	0.089** (0.043)	0.074* (0.043)
ln (Establishments)		0.162*** (0.035)	0.143** (0.070)	0.161*** (0.040)	0.205*** (0.041)
ln (Annual Pay)		−0.372*** (0.077)	−0. 557*** (0.147)	−0.288*** (0.088)	−0.404*** (0.089)
TRI		−0.047*** (0.003)	−0.047*** (0.007)	−0.046*** (0.003)	−0.046*** (0.003)
Constant	−3.122 (0.072)	−0.489 (0.799)	1.377 (1.514)	−2.072** (0.918)	−0.715 (0.920)
No. Observations	29,588	29,588	29,588	29,588	29,588
Log Likelihood	−6,444.2	−6163.7	−1,783.3	−5221.6	−5242.6
AIC	12,898.4	12,347.5	3,586.6	10,463.2	10,505.3

Note: Standard errors in parentheses.
*** indicates $p < 0.01$.
** indicates $p < 0.05$.
* indicates $p < 0.10$.
[a] Uses 2000 values of control variables, except for population (which uses the interpolated 2003 value).
[b] Uses 2002 values of control variables, except for population (which uses the interpolated 2003 value).

(with exception of ZCTA population) are taken to be from December 2000.

Eq. (1) is typically estimated through maximum likelihood methods involving either a logistic or Probit regression.[13] Here we employ a logistic regression of the form:

$$Pr\ (Loan_z = \frac{1}{1 + e^{-(\beta_1 Rural_z + \beta_2 Pop_z\ <\ 20{,}000 + \beta_3 Prov_z\ <\ 4 + \boldsymbol{\beta_4 X_z})}}) \tag{2}$$

where the coefficients to be estimated have the interpretation of being a log-odds ratio. We present results of five alternate specifications in Table 2. Each specification is cross-sectional, with the dependent variable taking a value of 1 if a ZIP code received a loan and 0 otherwise.

The first model is intentionally simple. It includes only covariates that control for the three criteria stated by the broadband loan programs: dummies for rural adjacent, rural non-adjacent, fewer than 4 broadband providers, and fewer than 20,000 inhabitants. For both the logit and probit specifications, results suggest that ZIP codes with fewer than 4 broadband providers as well as rural adjacent areas were more likely to have received a broadband loan, which is consistent with stated objectives of the loan program. However, ZIP codes with fewer than 20,000 inhabitants were found to be less likely to receive a broadband loan, which is at odds with the program's stated goal of providing loans to these sorts of small communities. This result may be due to omitted variables in the model such as number of establishments which is negatively related to populations of under 20,000 and potentially positively related to the probability of receiving a loan.

[13] Note that we also ran comparable Probit regressions. Parameter estimates were qualitatively quite similar to the logit results presented in Table 2.

Because of this, we extended the benchmark model to include a number of additional variables taken from December 2000. These variables include the number of broadband providers, the log of population, the log of number of establishments, the log of average pay, and TRI. The results from these expanded regressions generally conform to expectations of how the broadband program was supposed to be implemented. Places with fewer than 4 broadband providers and rural areas (both adjacent and non-adjacent) are significant and positively related to the probability of receiving a loan. The previous perplexing result of places with fewer than 20,000 inhabitants being significantly less likely to receive loans is no longer present in the model. The model now has the predicted interpretation that a ZIP code with fewer than 20,000 inhabitants is more likely to receive a broadband loan, although this is not a statistically significant result in either specification. The additional regressors in the second model are each significant and for the most part of the expected sign. An exception is the coefficient on annual income which is negative—possibly a reflection of RUS giving special consideration to applicants from poorer locations.

The first and second models aggregate both the Pilot and Farm Bill loans. To verify if the two loans programs yielded qualitatively similar results, we considered the Pilot and Farm Bill programs separately. For the third model, the dependent variable takes on a value of 1 only if a ZIP code received a Pilot loan where before the dependent variable would have taken a value of 1 if a ZIP code received either the Pilot or Farm Bill loan. With the Pilot loan, the logit and probit regressions yield qualitatively similar results. These suggest that correspondence between disbursal of Pilot loans and the stated criteria for loan receipt was modest at best. The Pilot loans were disbursed to rural areas (adjacent and non-adjacent) with a higher probability than metro areas, although only the coefficient for rural nonadjacent communities was statistically significant. Coefficients on categorical variables denoting limited provision (Providers < 4) and small population (< 20,000) were not significant. At the same time, although results do not display a significantly positive relationship with under-served areas, there is a significantly negative relationship with the number of providers for a ZIP code. The USDA definition of an under-served area may not be consistent with the chosen metric of fewer than 4 broadband providers, so finding a significant and negative relationship with number of providers may be consistent with what the USDA finds to be under-served areas.

The fourth and fifth models focus on the Farm Bill loans but use data from different years as the basis for the control variables. The fourth model utilizes the data for the same time year selected for models 1 through 3 (December 2000). Because the Farm Bill loans were disbursed later than the Pilot loans, the fifth model utilizes data for December 2002 in order to control for potential changes in economic conditions between 2000 and 2002 that may affect results. Results for these two Farm Bill loan models indicate a stronger relationship the stated goals of the program and the probability of receiving a loan. The measure for variables denoting under-served areas and fewer than 20,000 inhabitants are of the expected sign and significant across both the probit and logit specifications. Rural areas that are adjacent to metro areas are more likely to have received loans. Rural areas which are not adjacent to metro areas have an unexpected negative sign, although it is not statistically different from 0.

All in all, then, it appears that the loan program did generally provide loans to more remote, more sparsely populated and under-served areas with greater probability than if loans were simply made randomly. Further, the evidence suggests that the Farm Bill loans improved upon the Pilot loans in terms of targeting. Given that it was relatively limited in scope, the results suggesting limited targeting “success” for the Pilot program might reflect low statistical power for detecting an increase in probability of receiving a loan. On the other hand, one might imagine that with more experience in reviewing loan applications, loan disbursement became better aligned with program goals over time. Be that as it may, and notwithstanding—or perhaps as a result of—the Inspector General findings of operational difficulties with mistargeting of loans, we find that overall the results were generally consistent with the program's stated goals. We turn next to our main concern—consideration of whether the Pilot and Farm Bill loan programs succeeded in increasing broadband availability.

5. Loan program effectiveness

The stated goal of both the Pilot and Farm Bill loan programs has been to increase broadband availability in remote, under-served areas. This goal could be met through increasing the broadband infrastructure in place, adding “last mile” telecommunications providers, or providing programs that advocate broadband at public places such as libraries.[14] As noted earlier, FCC data on number of providers for a ZIP code represent our only measure of increased broadband availability. The imprecision of broadband availability lessens the power to identify any effect that the broadband loan programs may have had on broadband availability. From a program evaluation standpoint, failure to find significant results does not necessarily mean that the program was not effective. However, if statistically significant results are found using an imprecisely measured dependent variable, then it is fairly certain that the loan programs did have an effect on broadband availability. One can then credibly assess a lower-bound estimate of this value.

We begin by assuming that the number of broadband providers in a particular location, z, follows a Poisson distribution:

$$Prov_{z,t} | \boldsymbol{X}_{z,t}, \beta \sim Pois\ (\lambda_{z,t})$$
$$\log(\lambda_{z,t}) = \beta_0 + \beta_1 Loan_{z,t} + \beta_2 \boldsymbol{X}_{z,t} + \tau_t + \varepsilon_{z,t} \tag{3}$$

where $Prov_{z,t}$ represents the number of broadband providers in ZCTA z at time t; the particular variable of interest ($Loan_{z,t}$) is a

[14] The “last mile” is a term referring to the portion of the telecommunications network that physically reaches the end-user's premises. The last portion which connects the service provider to the consumer is typically not a mile and will differ across the broadband technologies.

dummy variable indicating if a ZIP code has been awarded a subsidized loan from the USDA at time t or before[15]; τ_t is a time fixed effect that may or may not be present[16]; and $\boldsymbol{X_{z,t}}$ represents a set of other economic and demographic variables at the ZIP code level that determine the level of broadband provision. The variables chosen for $\boldsymbol{X_{z,t}}$ are log of number of establishments, log of population, and log of average annual pay to control for potential demand for broadband providers; TRI and a second order polynomial for area of ZCTA to proxy for potential costs to a broadband provider of servicing a ZCTA; population density and employment density to control for potential confounding effects related to ZCTA size; and dummy variables for rural adjacent and non-adjacent ZCTAs. As a reminder, the data are biannual from December 1999 to June 2008 across 29,588 ZCTAs.

This nonlinear model is solved via maximum likelihood estimation (MLE). Regression coefficients associated with the model can be interpreted as the effect of a one-unit change in regressors on the conditional mean. For the main variable of interest, receipt of a broadband loan, this can be seen as a biannual percentage increase in the number of broadband providers for a ZIP code (the sample average across all years is approximately 5). Another way to express the effects of a change in a predictor is to present the average response across the entire sample. This is done by taking the average across the fitted values multiplied by the coefficient of interest. For the broadband loan programs, using only a subset of the data consisting of ZIP codes which received the broadband loans is an appropriate candidate for presenting the marginal effects of the broadband loan program's impact effectiveness (Cameron & Trivedi, 2005).

One potential issue with a Poisson regression is the Poisson distribution's property that the conditional mean and the conditional variance are equal (typically termed equi-dispersion). If the distribution of the fitted values does not reflect equi-dispersion, then the standard errors associ-ated with the coefficients of the regressors may be incorrect. As a robustness check, we therefore provide results from two alternative approaches: a quasi-MLE ('Quasi-Poisson') estimator[17]; and regressions based on a negative binomial distribution for the dependent variable.

Table 3 presents results from these various specifications. The Poisson and Quasi-Poisson produce identical estimates for the coefficients but the standard errors differ due to relaxing the assumption that the conditional mean and variance are identical. The standard errors are larger for the Quasi-Poisson model and the dispersion parameter associated is less than one (0.68), indicating under-dispersion in the predictions. The Negative Binomial regression also indicates under-dispersion through its associated dispersion parameter (0.17). Be that as it may, both coefficient estimates and significance levels are quite similar across specifications.

The broadband loan coefficient for the Poisson regressions indicates a 1.0% biannual increase in the conditional mean of number of broadband providers in each ZIP code due to the loan programs, while the Negative Binomial regression indicates a 0.7% increase. These increases are statistically and economically significant. The coefficient in the Poisson regression translates to an average marginal effect of 0.046 additional broadband providers biannually per ZIP code receiving a loan—or perhaps more meaningfully, 0.092 more providers annually. Stated another way, a receipt of a broadband loan led to one more broadband provider per ZIP code on average over a ten-year period.[18]

This interpretation is for the average ZIP code, however, which is not an accurate representation of the broadband loan programs because they were specifically targeted to under-served rural communities. Further, the two separate loan programs may have had varying degrees of success in actually increasing the number of providers in a location, depending on how projects were funded and implemented. To explore these issues further, we stratified the Poisson regression across the Pilot and Farm Bill loan programs, and additionally allowed for interaction between loan receipt and position on the rural-urban continuum (metro, rural adjacent, or rural non-adjacent).

Table 4 displays four models, all of which employ Poisson estimation. The first is the first model from Table 3, repeated for ease of comparison. The second model interacts the broadband loan variable with rural adjacent and rural non-adjacent dummies to test whether or not the broadband loan programs were, on average, more effective in (targeted) rural areas than in metro areas. To interpret the results for an average rural adjacent ZIP code that received a broadband loan, this is a linear combination of three coefficients (loan, Rural Adjacent, and the interaction of loan and Rural Adjacent) which combines to be 0.044, or an effect of 4.4% increase in conditional mean of providers. A Chi-square distributed linear hypothesis test that this combined effect equals 0 is rejected with a p-value of less than 0.001. The associated average marginal effect for ZIP codes in a rural adjacent area receiving a loan is an increase in 0.40 broadband providers annually. A similar story results for the rural non-adjacent ZIP codes: the combined effect of 0.023 rejects the null of a zero effect with a p-value of 0.007. The associated average marginal effect is an increase of 0.22

[15] We assume that the loans have been deployed at the time they are awarded; however this may not have been the case. Some of the projects had a lag from disbursement to deployment and there is evidence that some projects did not deploy any infrastructure. The effect of this assumption is that the estimated (contemporaneous) impacts of deployed loans will be dampened (USDA-Rural Development, 2007).

[16] *Inter alia* the time fixed effects control for changes in how the FCC collected broadband availability data over the sample period. In June 2005, the FCC began requiring all providers to submit form 477. Prior to that time, those with less than 250 lines were not required to report. Whitacre and Mahasuweerachai (2008) document that roughly ¼ of all rural ZIP codes saw an increase in the number of reporting providers once this occurred.

[17] The Poisson MLE and quasi-MLE produce identical estimators but have different variances. The sample covariance matrix for both can be described as:
$V[\hat{\beta}_P] = \left(\sum_{i=1}^{N} \mu_i x_i x_i'\right)^{-1} \times \left(\sum_{i=1}^{N} \omega_i x_i x_i\right) \times \left(\sum_{i=1}^{N} \mu_i x_i x_i'\right)^{-1}$
where the Poisson MLE assumes that $\omega_i = \mu_i$ and the quasi-MLE defines $\omega_i = V[y_i | x_i]$, the conditional variance of y_i.

[18] The coefficient estimates for the time fixed effects (available upon request) are all positive, significant, and increasing over time. The coefficient on the time fixed effect for the period following the change (in 2005) in FCC reporting requirements takes a larger jump than is the case for the coefficient for prior periods. We take this as evidence that we are indeed capturing omitted temporal factors—including changes in FCC reporting requirements—driving the broadband diffusion process. A rough indicator of the relative importance of the loan program vis-à-vis these temporal effects is to compare the Loan coefficient (≈.01) to the average increase in the time coefficients between adjacent periods over our sample (≈.09). We take this as evidence mean that the program had a relatively small, but meaningful, impact on broadband availability relative to other forces driving diffusion.

Table 3
Count Panel Regressions of the Number of Broadband Providers.

	Dependent variable = no. of broadband providers		
Variable	**Poisson**	**Quasi-Poisson**	**Negative Binomial**
Loan (any)	0.010***	0.010***	0.007***
	(0.004)	(0.003)	(0.004)
ln (Establishments)	0.246***	0.246***	0.247***
	(0.001)	(0.0004)	(0.0005)
ln (Population)	0.077***	0.077***	0.090***
	(0.001)	(0.0005)	(0.001)
ln (Annual Pay)	0.093***	0.093***	0.065***
	(0.002)	(0.002)	(0.002)
Rural Adjacent	−0.035***	−0.035***	−0.037***
	(0.002)	(0.002)	(0.002)
Rural Non-adjacent	−0.050***	−0.050***	−0.055***
	(0.003)	(0.002)	(0.002)
No. Observations	532,584	532,584	532,584
Log Likelihood	−998,787		−1,289,931
AIC	1,997,631		2,579,920

Note: Standard errors in parentheses. ** indicates $p < 0.05$, and * indicates $p < 0.10$. All regressions also included time fixed effects, establishment density, population density, TRI, and a second order polynomial for ZCTA area (results available on request).
*** indicates $p < 0.01$.

broadband providers annually. The takeaway from the second model is that when broadband loans were disbursed to rural areas, the associated effects were larger than in metro areas.

The third model separates the broadband loan programs instead of combining the two. The results indicate that the Pilot loan program had a significant positive impact, increasing the number of broadband providers by 4% of the conditional mean (or an average annual marginal effect =0.38). In comparison, no significant impact of the Farm Bill loan program was found. Recall, however, that significant differences were found to exist between Pilot and Farm Bill loan programs in terms of effectiveness in disbursing loans to (targeted) rural areas, and that loans disbursed to rural locations had greater impact on broadband provision.

To explore these differences further, the fourth and final model separates the broadband loan programs and interacts each with the rural adjacent and rural non-adjacent dummies. This specification offers a lens for considering each loan program's effectiveness in expanding broadband availability. Again, the effects are a combination of parameters. For the Pilot loans, across both the rural adjacent (−0.018) and non-adjacent (−0.008), the linear combination of coefficients is not statistically different from zero (p-values are 0.22 and 0.55, respectively). Since these values are measured relative to the baseline of a metro ZIP code, the Pilot loan's effectiveness in increasing broadband availability appears to have stemmed largely from the limited loans that were disbursed to metro areas. These had an estimated average marginal effect of 0.231 broadband providers biannually per ZIP code.

The Farm Bill loans differ from the Pilot loans across rural areas. Both the rural adjacent (0.06) and rural non-adjacent (0.045) linear combinations for the Farm Bill loans were statistically significant at p-values less than 0.001. The associated average annual marginal effects are respectively 0.56 and 0.42 broadband providers biannually per ZIP code. This result suggests improved effectiveness in targeting when the Farm Bill program replaced the Pilot program. As the Farm Bill began disbursing loans around 2005, an average ZIP code in a rural adjacent area would expect to have seen an increase of over 1 broadband provider by June 2008, the end of the available data.

6. Concluding remarks

This paper has sought to evaluate USDA broadband loan programs designed to disburse subsidized loans to under-served rural communities from 2002 to 2007. We first examined if the programs were disbursed to their targeted population. While there is anecdotal evidence from the USDA's Inspector General that both the Pilot and Farm Bill loan programs had misdirected loans, on the whole the programs appeared to reach their intended target of under-served rural areas with fewer than 20,000 people. The results also suggest that the Farm Bill program improved upon the Pilot program in terms of targeting.

We then analyzed whether areas that received the broadband loans actually experienced an increase in broadband availability, as proxied by the number of broadband providers. Our empirical results suggested that they did: We found that the average marginal effect of loan receipt on treated ZIP codes was 0.092 additional broadband providers annually, and that these increases in provider numbers were larger in rural areas than in metro areas.

While we have found evidence in support of the broadband loan programs having contributed to an increase in broadband

Table 4
Auxiliary Poisson Regressions.

	Dependent variable= ***no. of broadband providers***			
Variable	**(1)**	**(2)**	**(3)**	**(4)**
Loan (any)	0.010 (0.004)	−0.043 (0.005)		
Pilot Loan			0.040*** (0.007)	0.049*** (0.009)
Farm Bill Loan			−0.003 (0.004)	−0.074*** (0.005)
Rural Adjacent	−0.035*** (0.002)	−0.040*** (0.002)	−0.035*** (0.002)	−0.040*** (0.002)
Rural Non-adjacent	−0.050*** (0.003)	−0.055*** (0.003)	−0.050*** (0.003)	−0.055*** (0.003)
Loan (any)$\times$Rural adjacent		0.127*** (0.008)		
Loan (any)$\times$Rural Non-adjacent		0.122*** (0.003)		
Pilot$\times$Rural adjacent				−0.040 (0.017)
Pilot$\times$Rural Non-adjacent				−0.003 (0.017)
Farm Bill$\times$Rural adjacent				−0.174*** (0.009)
Farm Bill$\times$Rural Non-adjacent				0.173*** (0.012)
No. Observations	532,584	532,584	532,584	532,584
Log Likelihood	−998,787	−998,634	−998,773	−998,787
AIC	1,997,631	1,997,631	1,997,631	1,997,631

Note: All regressions include the same control variables as in Table 3, as well as time fixed effects, log of establish-ments, log of average annual pay, log of population, establishment density, population density, TRI and ZCTA area (available on request). Standard errors in parentheses. ** indicates $p < 0.05$, and * indicates $p < 0.10$. *** indicates $p < 0.01$.

availability in target areas, it is unclear what might be the economic impact of that greater availability on economic agents within those areas. To get at that question would require combining information on adoption of those broadband services with information on the relative economic performance of adopters and non-adopters using a quasi-experimental approach (e.g., propensity score matching or inverse probability weighting techniques). Moreover, assessment of economic impacts would require a sound strategy for dealing with potential spatial dependence and spatial lags. Lack of comprehensive broadband adoption data greatly constrains such an endeavor, although more targeted data sources may allow examination of broadband's ultimate economic impact in selected industries. For example, the confidential USDA Agricultural Resource Management Survey Data provides data on farm-level adoption of broadband that allow for a more targeted analysis of the impact of broadband adoption on the economic performance of the agricultural sector. Quantifying the existence and magnitude of the impacts of broadband using more comprehensive micro-level adoption data represents a fruitful avenue for future research.

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Appendix. : Data sources and uses

Variable	Unit of Observation	Regression	Years Covered	Source
Loan Receipt	ZCTA	Loan Receipt, Effectiveness	1999–2008 (annual)	USDA-RUS
No. of Broadband Providers	ZCTA	Loan Receipt, Effectiveness	1999–2008 (biannual)	FCC Form 477
No. of Establishments	ZCTA	Loan Receipt, Effectiveness	1999–2008 (annual)	County Business Patterns Data
Annual Pay	ZCTA	Loan Receipt, Effectiveness	1999–2008 (annual)	County Business Patterns Data (annual payroll divided by number of employees)
Population (2003)	ZCTA	Loan Receipt	2003	ESRI 2004 ZCTA Shapefile, interpolated values from 2000 Census Block populations
Population (1999–2008)	County	Effectiveness	1999–2008 (annual)	IRS County Income
Rural-Urban Continuum	County	Loan Receipt, Effectiveness	2003 designation	ERS Rural-Urban Continuum Code
Area	ZCTA	Effectiveness	2004 value	ESRI 2004 ZCTA Shapefile
Terrain Ruggedness Index	ZCTA	Loan Receipt, Effectiveness	2004 value	Author's calculations from ESRI 2004 ZCTA Shapefile, Availability DIVA-GIS

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