Does Broadband Affect Local Economic Outcomes Less than We Thought? Micro Evidence from Louisiana

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Abstract

High-speed internet access is a core tenet of economic development strategies post-COVID. While expanding access is linked to many positive benefits, evidence associating broadband to job growth and business formation is more mixed. This study expands the literature along several dimensions, most notably exploring how business download speeds affect employment, business formation, and survival at a microscale. Using conventional and LASSO instrumental variables strategies, with terrain features as instruments, we find consistent evidence that broadband speeds stimulate local development. However, our estimates are 60-65% smaller than those from recent studies, suggesting that broadband may be less beneficial than previously assumed.

Keywords: broadband, economic development, jobs, instrumental variables
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1 Introduction

High-speed Internet access, often referred to as simply broadband, has become a core tenet of place-based economic development strategies at local and federal levels post-COVID. The rapid transition to distance-learning and remote work heightened public awareness to the disparities in broadband availability and access that disproportionately affect rural communities and households of color. As recent examples aimed at bridging the divide, in 2021 state legislators proposed more than 600 broadband-related bills and Congress approved the Infrastructure Investment and Jobs Act (IIJA), allocating $65 billion to improve access.[1] The IIJA, which places special emphasis on rural areas, low-income families, and tribal communities, represents the single largest public investment in broadband to date, surpassing total federal broadband investments between 2009 and 2017 by 40% (General Accountability Office 2020). In Louisiana, the focus of this study, Governor Edwards recently created the Broadband for Everyone in Louisiana (BEL) Commission, charged with facilitating universal access by 2029.

Although previous work suggests that expanded broadband access likely generates positive net social and economic benefits on average, evidence linking broadband expansion with new job and business formation is more mixed (Mack 2020; Ford 2018; Kolko 2012). There are several reasons these lines of research may be less conclusive. First, economic theory suggests broadband availability could affect job growth by enabling firms to substitute away from labor to capital. This can result in some industries, such as those participating in knowledge-intensive activities, benefiting while others are harmed (Duvivier et al. 2021; Shideler and Badasyan 2012). Thus, the net employment effect may depend on a location's sectoral mix. Second, there are empirical challenges to isolating causal effects because broadband expansion (or contraction) may be endogenously linked to areas that are growing or that have a higher willingness and ability to pay. Finally, similar to other place-based policies, targeted broadband deployment could merely reallocate existing economic activity to locations that are already highly productive. In this respect, a boom in one area due to broadband could lead to a bane in another.

In this paper, we expand the literature on broadband access and local economic development along several dimensions. To start, previous work on broadband and jobs has focused on data

[1] https://www.csg.org/2021/11/15/infrastructure-investment-and-jobs-act-broadband-affordability-and-infrastructure/ and https://www.ncsl.org/research/fiscal-policy/state-broadband-spending-in-2021.aspx (accessed: 5/22/23).

aggregated to the county (Conroy and Low 2022; Isley and Low 2022; Duvivier et al. 2021; Gallardo et al. 2021) or zip code level (Kolko 2012). We leverage a geocoded database of establishments, the National Establishment Time Series (NETS) database, and study the link between broadband access and economic outcomes at a much finer level of geography - census block groups in a single state. State legal policies and public investments in broadband expansion have changed considerably over time, but are regularly overlooked in studies with nationwide coverage. Concentrating on a single state without a history of public investments in broadband reduces this concern, allowing us to generate insights into the potential effectiveness of broadband initiatives targeting very small geographic areas for revitalization, a common theme among placed-based policies like Opportunity Zones and Enterprise Zones.

Next, building on the strategies of Conroy and Low (2022) and Isley and Low (2022) (and others), our empirical models rely on an instrumental variables (IV) strategy for identification that exploits terrain features affecting the cost of deployment (Prieger 2003). Specifically, using data from the earliest stages of broadband deployment in Louisiana (2000/2001), we instrument for broadband access in a census block group using the squared meters of tree canopy coverage and the maximum terrain ruggedness index derived from very high resolution digital elevation scans (10 meters by 10 meters). Recently, Keane and Neal (2023) and Lee et al. (2022) have shown that valid inference in IV models (a true 5 percent hypothesis test) requires a first-stage F that is much higher than previously thought – around 105. Our terrain instruments exceed this threshold, so this study does not suffer from the weak instrument problem that has plagued this literature.

Third, in addition to investigating business start-ups, we also study the relationship between broadband access and start-up survival rates at a 5- and 10-year horizon. According to the Bureau of Labor Statistics, roughly half of all start-ups fail within 5 years of opening. If expanded broadband access boosts survival rates, then this would be another mechanism to facilitate local economic development independent of stimulating new establishment births. While there is evidence that broadband influence firm exit decisions (Falk and Hagsten 2018; DeStefano et al. 2023), survival analysis of start-up firms has received little attention to date (Brunelle and Duvivier 2022).

Lastly, we use a very large set of potential covariates (26) and the three-step Least Absolute Shrinkage and Selection Operator (LASSO) instrumental variables estimator proposed by Chernozhukov et al. (2015) to examine the robustness of our estimates. Because socio-economic data available at a census block group level can be limited, the covariate pool is a combination of factors measured at the census block group and county dimensions. This allows us to empirically identify the most pertinent instrument(s) and control variables to mitigate concerns from omitted factors.

Over the period from 2014 to 2019, we find solid evidence that faster business download speeds (at the census block group dimension) are causally linked to higher employment growth among all establishments, establishments with 5 or fewer workers, and among start-up firms. Moreover, we find that expanded broadband infrastructure increases both the birth rate of new establishments and their 5- and 10-year survival rates. Considering that place-based policies can target areas as small as a few square miles, our results provide affirmation that expanded broadband can be a viable mechanism to stimulate local communities.

However, unlike previous studies, we find estimates that are an order of magnitude smaller. Thus, while expanding broadband may generate positive economic benefits, prior work may overstate the extent of those benefits. For example, relative to Kolko (2012), who studies employment growth, and Conroy and Low (2022), who study rural establishment births, we find effects that are roughly 60-65% smaller. If public funding is to be used to expand broadband, either federally or at the state level, our study suggests that a careful cost-benefit analysis may be appropriate considering alternative uses and returns of other investments.

2 Broadband and Economic Outcomes

Broadband refers to a high-speed Internet connection that allows for large amounts of data transmission. The Federal Communications Commission (FCC) defines the types of technologies commonly used for broadband connections, such as Digital Subscriber Line (DSL), cable modem, fiber optic, wireless, and satellite.[2] Examples of wireline transmission technologies are DSL, cable modem, and fiber, which tend to provide faster speeds, more stable connections, and smaller delays (or latency) for data transmission. On the other hand, wireless technologies utilize an invisible connection, such as a radio link, typically resulting in lower speeds, less robust connections, and higher latency relative to a wireline connection. In recent years, however, because of the cost-effectiveness and convenience of network installation, the availability of wireless services from

[2] https://www.fcc.gov/general/types-broadband-connections (accessed: 7/9/2023). In this study, we use the term broadband as the inclusive descriptor for Internet access.

Internet Service Providers (ISPs) has been expanding. Satellite technology is another type of wireless broadband, especially beneficial to regions with locational barriers, but various atmospheric conditions and restrictions come into play.

With broadband access, users are able to utilize various online services and applications with a reliable and high-speed connection. The users can not only experience faster downloads and uploads of files, but also enhance their capabilities in various business and education experiences, such as video conferencing or streaming, access to online content and resources, cloud-based applications, and e-commerce. Thus, broadband access has been emphasized as a crucial element for accomplishing digital inclusion among different groups of individuals and regions (Mack 2020).

Various indicators and methods exist for measuring broadband availability and access. For instance, broadband availability and access data are tracked and collected by ISPs, surveys, and census data. Governments or other organizations also frequently conduct pilot programs for data collection and analysis to develop policies for improving accessibility among the target groups (Mack 2020).[3]

The FCC has collected Internet access data through Form 477, which requires all facilities-based broadband providers to file reports biannually.[4] In addition to providing nationwide coverage, the Form 477 deployment data contain data fields that include, but are not limited to, the ISP's name, census block code, technology types, and maximum download and upload speeds.[5]

Although broadband infrastructure may be available and accessible within an area, this does not mean that broadband services are widely adopted by consumers and businesses. Much of the emphasis on broadband deployment focuses on the supply-side of infrastructure and expanding coverage areas. In other words, broadband availability generally implies the physical presence and provision of broadband networks or the extent to which the services are reachable. Unfortunately, broadband infrastructure deployment data, such as Form 477, offers little information about demand-side characteristics such as users' willingness to adopt, cost of broadband plans, digital literacy, or individual preferences.

[3] https://www.fcc.gov/affordable-connectivity-pilot-programs and https://www.fcc.gov/wireline-competition/telecommunications-access-policy-division/connected-care-pilot-program (accessed: 7/19/2023).

[4] However, as of December 2022, the FCC Form 477 system is being replaced by the Broadband Data Collection (BDC) system. https://docs.fcc.gov/public/attachments/DA-22-1345A1.pdf (accessed: 7/16/2023).

[5] Form 477 data fields have changed over time. For a more detailed description of the data fields available at various points in time, see https://www.fcc.gov/economics-analytics/industry-analysis-division/form-477-resources (accessed: 7/16/2023).

In terms of coverage, the Federal Communications Commission (FCC) indicates that 92% of Americans have access to broadband, formally defined as at least 25Mbps download and 3Mbps upload speeds, and 98% of the nation has access to at least 5Mbps download and 3Mbps upload speeds (as of 2018).[6] However, the population shares with access does not necessarily mean that all of them are using broadband or Internet services. As broadband deployment aligns with a provision of broadband infrastructure, if households and firms are not ready to adopt or choose not to subscribe to such a service, they may still lack high-speed access despite its availability in the area.

While the focus of broadband policy initiatives have historically concentrated on supply-side factors related to infrastructure expansion, recent policy initiatives are increasingly expanding in scope to target demand-side factors, such as adoption rates, that can also be barriers to equitable access. For instance, the Broadband Equity, Access, and Deployment (BEAD) Program, recently announced by the Biden-Harris Administration, provides $42.45 billion in funding for adoption-incentive programs and expanded infrastructure deployment in all 50 states, with an emphasis in underserved communities.[7] In this sense, federal, state, and local governments and other organizations have recognized that broadband expansion is a multifaceted issue with complex legal and socio-economic obstacles to overcome.

Previous studies have established an association between the adoption of broadband and its economic impacts at various scales. The firm-level study by Bertschek and Niebel (2016) finds an increase in labor productivity when employees make use of mobile internet. At a regional level, Whitacre et al. (2014a) find that high rates of broadband adoption (exceeding 60%) have a causal effect of increasing household income and lowering unemployment rates. There is also evidence that the number of business and job opportunities expand in non-metropolitan counties when broadband adoption rates increase (Whitacre et al. 2014b).

From an economic-perspective, broadband infrastructure is commonly viewed through the lens of a place-based investment that may boost regional economic growth and provide benefits to both households and firms (Whitacre and Gallardo 2020; Arvin and Pradhan 2014; Prieger 2013).

[6] https://www.fcc.gov/reports-research/reports/broadband-progress-reports/2018-broadband-deployment-report (accessed: 7/16/2023).

[7] https://broadbandusa.ntia.doc.gov/funding-programs/broadband-equity-access-and-deployment-bead-program (accessed: 7/16/2023)

Although job creation/retention and business formation has been a mainstay of broadband-related research, recent evidence has also linked broadband expansion with firm location decisions (Duvivier 2019), reducing educational attainment gaps (Hampton et al. 2020), promoting greater human capital formation (Sanchis-Guarner et al. 2021), advancing gender equality (Bahia et al. 2021), increasing rural housing values (Deller and Whitacre 2019), and even improving a variety of personal health outcomes (Bauerly et al. 2019).

Evidence of the effect of broadband expansion on employment and new business formation is generally supportive, but far from conclusive. Theoretically, broadband is generally viewed as a complementary technology for skilled workers such that infrastructure expansions boost firm output, employment, and worker wages (Akerman et al. 2015; Atasoy 2013). Three of the earliest and most frequently cited empirical broadband studies, Crandall et al. (2007), Kolko (2012), and Atasoy (2013), find evidence that greater accessibility is linked to higher employment growth.

In contrast, work by Ford (2018) and Whitacre et al. (2018) find no evidence that expanded access boosts employment at the county level. Ford (2018) relies upon a modern causal inference technique, coarsened exact matching, and argues that other studies suffer from selection bias problems because broadband expansions tend to occur in counties that are experiencing faster growth. As Gallardo et al. (2021) and Colombo et al. (2013) note, productivity gains from broadband, which theory predicts would be associated with job growth, may be sensitive to how broadband is measured and the skill-level of the local workforce. These are alternative mechanisms that could potentially dampen any relationship between broadband and employment.

There is more consensus among previous work that expanded broadband is associated with business formation decisions (Audretsch et al. 2015; Kim and Orazem 2017). Using the 1990s as the baseline because broadband was unavailable, Kim and Orazem (2017) find that new business start-ups occurred at higher rates in those same areas after the introduction of broadband. Building on this work, Conroy and Low (2022) find that broadband accessibility, measured by the number of local providers, has a positive effect on business start-up activity in rural counties. They also find stronger effects for smaller establishments and establishments led by women, which is important considering that rural communities have more disparity in broadband access and women are more likely to work from home. In fact, counties with more broadband infrastructure were able to maintain significantly higher employment rates during the COVID-19 pandemic (Isley and Low

2022).

Audretsch et al. (2015) theorize that broadband infrastructure may stimulate new entrepreneurial ventures by improving internal organization processes, expanding customer bases, and enhancing access to information. Extending this perspective, if broadband facilitates greater connectivity and access to information that encourages new business ventures, those same features could also affect the likelihood that a start-up establishment survives. Social networks, access to mentors, training, and sources of capital, are all known to be important factors affecting survival (Castaldo et al. 2021).

Past work exploring the connection between broadband and employment and business start-ups has been concentrated almost exclusively at the county or zip code level. It is also common for studies to investigate these linkages using only rural areas, given the attention around the urban-rural digital divide. This study focuses on a single state at a much finer level of geographic detail, and there are both advantages and disadvantages to our approach. We believe the advantages outweigh the limitations.

The primary drawback to focusing on a single state hinges on the external validity of any estimates. Is it reasonable to believe that estimates from a small southern state accurately reflect the employment and business formation outcomes that might be experienced in a more populated state? For one thing, Louisiana has low levels of social capital, educational attainment, and rates of patented innovation relative to the typical state (Wagner and Bologna Pavlik 2020). It is therefore possible that businesses and residents may benefit less from expansions in broadband infrastructure than what might be observed in another state because of less capacity to fully capitalize on the technological advancement.

With that limitation in mind, we believe there are several advantages in our research design relative to previous studies. First, state policies, legal environments, and financial support for broadband expansion have not been static over time (Pew Charitable Trusts 2020). While some states have just recently created broadband commissions and bolstered funding commitments, many states have a long history of providing public funding and technical assistance for broadband expansion. For instance, Maine and California created formal statewide organizations in 2006 and 2007, respectively, that provided funding for broadband expansion in underserved areas (Pew Charitable Trusts 2020). Regressions with national coverage, even those with state fixed effects, may not adequately adjust for how state-level time-varying public expenditures shape infrastructure and economic outcomes. This issue is less of a concern when the focus is on a single state, particularly one without a history of making public investments in broadband infrastructure. Focusing on a single state also allows us to include a much broader set of potential confounding factors that would be labor-intensive to collect at a national scale.

Next, while overall population growth in Louisiana has been slow and steady, the state is experiencing areas that are depopulating. This is occurring throughout the state but is most pronounced in northern rural areas. This allows us to identify the effect of broadband using a mix of urban areas that are (slowly) growing and rural areas that are depopulating.

Place-based policies generally focus on small geographic regions, ranging from census tracts (Opportunity Zones) to areas as small as a few square miles (Enterprise Zones). An empirical approach at a corresponding micro geography may be more informative for policymakers seeking targeted revitalization than estimates based on more aggregated data.

Finally, there are reasons to be concerned about local spillover effects in empirical models of business start-ups and job growth (Márquez et al. 2015; Bishop and Gripaios 2010). While some studies have explicitly addressed spatial dependency and local spillovers (Deller and Whitacre 2019; Whitacre et al. 2014b), this concern has largely been overlooked in the studies most closely related to our own, Conroy and Low (2022), Isley and Low (2022), Ford (2018), Duvivier et al. (2021) and Kolko (2012).

3 Data and Identification Strategy

3.1 Data

We explore the causal relationship between broadband and local economic outcomes using data from the Federal Communication Commission's (FCC) Form 477 combined with employment and establishment data from the National Establishment Time Series (NETS) database. Form 477 data, required under the Telecommunications Act of 1996, was first made publicly available in 1999. The information that has been collected and reported has changed periodically (Mack 2021). Early vintages of the data (pre-2014) included the number of providers that offered broadband services in specified ranges and geographies, mostly at the zip-code level. Beginning in 2014, Form 477 data began reporting maximum advertised download and upload speeds by individual providers of consumer and business services at the census block level of geography. Currently, the data are collected biannually.[8]

Since our interest is on employment and new business establishment growth, our local broadband accessibility measures are derived from the maximum contractual downstream bandwidth (in Mbps) reported by individual business service providers. A recent study of rural entrepreneurship by Deller et al. (2022) found that download speeds play a greater role in stimulating business formation than upload speeds. The use of maximum contractual speeds also deviates from prior studies such as Conroy and Low (2022) and Kolko (2012), who use the number of providers as the metric for accessibility. At the census block group dimension, there is a weakly positive correlation between the number of providers and download speeds. In 2014, for instance, the simple correlation between (mean) advertised maximum download speeds and the number of unique providers was 0.28.

Provider-level data was reported separately for consumers and businesses between December 2014 and June 2019. The FCC changed their data collection methods in 2019 and separate download/upload speeds for business providers are no longer available. As a consequence, we limit our empirical analysis to the five-year period between 2014 and 2019.[9]

There are 204,447 census blocks (2010 definition) in the State of Louisiana, so the broadband data are extremely granular.[10] To merge these with other economic data that may also affect employment and establishment activity, we average the broadband data within census block groups because block groups are the smallest geographic region for which economic data are readily available. There are 3,471 census block groups in Louisiana, so each block group consists of an average of 58.9 census blocks. In comparison to other conventional levels of geography, there are 509 zip codes and 64 parishes (or counties) in Louisiana.

[Figure 1 here]

As Figure 1 shows, there is considerable variation in terms of maximum (advertised) contractual

[8] Ford (2021) recently compared the 477 data to a state-administered survey in Georgia and found a strong correlation in reported availability by consumers and businesses.

[9] Our business provider broadband data are from the December 2014 (first) and June 2019 (last) surveys to report business provider speeds separately. We use the version 1 files that include satellite providers, although this has no bearing on our results. The Form 477 broadband deployment data are available here: https://www.fcc.gov/general/broadband-deployment-data-fcc-form-477/ (accessed: 2/23/2023).

[10] As Mack (2019) notes, Internet service providers may claim a service provision even if only one household or business in a geographic region has access to this level of broadband service.

business download speeds (in Mbps) across Louisiana. In 2014, the mean and median contractual business download speeds across all census block groups were 31.56 and 11.87 Mbps, respectively. Nine hundred eighty-three census block groups, or 28.4% of the sample, had average maximum contractual download speeds of only 1 Mbps. Twenty-five percent of block groups had average speeds exceeding 47 Mbps, and 269 block groups (about 7.8% of the sample) had average maximum contractual speeds in excess of 100 Mbps.

While communities that are not part of metropolitan or micropolitan statistical areas tend to have average slower download speeds, there is widespread variation in speeds even within the state's populated areas. For instance, in the Hammond and Alexandria metropolitan statistical areas, the *highest* mean contractual download speeds within any census block (in 2014) were 11.8 and 15.4 Mbps, respectively. Contrast that with the Baton Rouge and Lafayette metropolitan statistical areas, where 78.6% and 44.2% of all census block groups had mean contractual download speeds above 50 Mbps. The city of Ville Platte, whose population is just shy of 7,000, attracted national attention in 2020 when HighSpeedInternet.com reported it as having the third-slowest Internet speeds in the country, clocking in at an average of just 8 Mbps (Cooke 2020).[11] While 21% of census blocks in 2014 (41,599) had at least one business provider whose services met the federal definition of broadband (25Mbps download and 3Mbps upload speeds), fewer than 17% of census blocks (34,723) had at least one business provider meeting this same standard in 2019. Hence, our estimates are a reflection of the average effect in a state that has been experiencing both expansions and contractions in broadband accessibility over the sample period.

We combine the broadband infrastructure data with employment and establishment outcomes formed from the National Establishment Time Series (NETS) database. NETS data are compiled from Dun and Bradstreet's collection of Duns Marketing Information (DMI) files that have tracked more than 71 million establishments annually (in January) between 1990 and 2019, making it a private-sector alternative to the restricted-access Census Bureau business longitudinal database (Barnatchez et al. 2017).

Dun and Bradstreet tracks individual establishments in order to create marketing and credit scores, so their business model depends on accurate information (Barnatchez et al. 2017). The company's objective is to cover the entire universe of business establishments, and they rely on

[11] Ville Platte is located in Evangeline Parish (population 32,000).

many sources of information including direct phone calls, Yellow Pages, newspapers, and multiple government agencies to monitor establishment activity (Barnatchez et al. 2017). Individual establishments are also assigned a unique identifier – a DUNS number. Since the 1990s, the DUNS number has served as the official verification identifier for individual establishments doing business with the U.S. federal government, which is an indicator of Dun and Bradstreet's reputation for accuracy (Halchin 2017).[12]

The DUNS number allows one to track individual establishments across space and time, as well as to link them to a parent company if they are a subsidiary. A rich set of establishment-level characteristics are also included such as latitude and longitude, employment count, the primary North American Industrial Classification System (NAICS) at a six-digit level. NETS data have been used to study a wide range of economic issues including, but not limited to, local entrepreneurship (Clayton et al. 2019), business concentration (Rossi-Hansberg et al. 2020), employment effects from art and cultural district designation (Wagner and Portillo 2023), and how low-cost retailers affect local business concentration (Neto and Biehl 2023).

There is one important distinction between the employment concept in NETS and official government data sources, such as the Bureau of Labor Statistics. NETS includes nonemployer establishments (consisting only of business owners) in its database, whereas conventional government data sources require at least one paid employee before an entity is considered an establishment. As a result of the differing concepts, NETS includes more establishments and higher employment counts (Barnatchez et al. 2017).[13]

NETS data have been used in a more limited fashion to study the effects of broadband. For instance, Kolko (2012) constructs employment and establishment growth measures at the zip code level from 1999 to 2006 and finds that an increase in the number of broadband providers is positively associated with local growth. More recently, Conroy and Low (2022) use the NETS data to study new establishment birth rates by size and gender in rural counties from 2005 to 2007. They also measure broadband access based on the number of providers and find that more providers is causally linked to more establishment births. Our focus at the census block group level leverages

[12] On April 4, 2022, the federal government began using a new Unique Entity ID, or UEI, to identify individual establishments in place of the DUNS number.

[13] Numerous studies have validated the NETS data against other official data sources (Zeballos and Marchesi 2022; Rossi-Hansberg et al. 2020; Barnatchez et al. 2017). See Rossi-Hansberg et al. (2020) for a very detailed assessment of the NETS database.

the geocoded nature of the NETS data to a greater extent than previous work.

[Figure 2 here]

As Figure 2 demonstrates (top panel), Louisiana's economy is dominated by small and medium establishments. In terms of aggregate employment, the largest share of workers in the state (38.9%) are associated with establishments of 5 or fewer workers. More than half of workers statewide work in establishments with fewer than 100 people. The largest establishments, those with 1,000 or more workers, employ about 6% of the state's workforce.

There is also underlying churn in establishment counts during our sample, as evidenced in the bottom panel of Figure 2. In 2014, the NETS database reports a total of more than 350,000 distinct establishments in Louisiana, with an average of 101.5 per census block group. While the number of establishments in most headcount categories increased between 2014 and 2019, the overall number of establishments in the state increased by an average of less than 1% per year. The most rapid growth, both in terms of employment and establishment counts, were among firms with workforces ranging between 6 and 20 people.

3.2 Identification Strategy

To isolate the causal relationship between broadband speed and our outcomes of interest, employment growth, establishment growth, and start-up survival rates, we estimate the following regression equation:

$$\Delta Y_{i,j} = \beta \Delta B_{i,j} + \psi CB_{i,j} + \omega P_j + \varepsilon_{i,j} \tag{1}$$

where $\Delta Y_{i,j}$ is the percentage change in employment, difference in establishment birth rates, or the difference in start-up survival rates in census block group i located in parish (county) j between 2014 and 2019. The variable of interest, $\Delta B_{i,j}$, is the percentage change in the (mean) maximum contractual business download speed in census block group i in parish j between 2014 and 2019. The key parameter of interest, β, measures the effect of a one percentage point change in business download speed on the percentage change in the outcome variable, all else equal.

Given that factors other than broadband infrastructure may also affect local economic outcomes, we include numerous additional variables in equation 1 at the census block group $CB_{i,j}$ and/or county (parish) level P_j that could bias the estimate of β. Since we focus on estimates from a 5-year differenced growth model, many of our control variables are from 2014 or earlier, the standard approach in growth regressions.

At the census block group level, these additional control variables include median household income in 2014 (in thousands of dollars), the number of employed persons in 2014, percentage of housing units in 2014 that are rentals, percentage of residents with a college degree in 2014, number of active permitted oil and gas wells operating in 2014, and the unemployment rate in 2014. Given the important of place-based policies more generally, we also include an indicator variable that equals unity if any portion of the block group overlaps with an Opportunity Zone or Enterprise Zone.

While the coefficient of interest is the percentage change in broadband acess, the change in local economic outcomes may also depend on the initial level of broadband access. For example, if the maximum contractual download speed increases in one block group from 1 to 2 Mbps and from 50 to 100 Mbps in another block group, both have experienced a 100% increase. If broadband does indeed have a causal link to local economic outcomes, the initial number of jobs in the block group, initial unemployment rate, and recent trend growth in local income (one of the LASSO control variables) will be correlated with broadband speeds in 2014 and help to adjust for differences in base period access.

Previous research suggests that the local industry mix may also be important in a region's responsiveness to broadband expansion. We control for the local (block group) industry mix using two covariates derived from the NETS data. First, we include the Herfindal-Hirschman Index of employment diversification (in 2014) at the two-digit NAICS level. Next, Goldschlag and Miranda (2016) identify 14 four-digit NAICS codes for high information-technology (IT) intensive sectors. We include the share of census block group employment in these IT-intensive sectors in 2014.[14]

At the county level, the baseline regression equations include home prices in 2014 (in thousands of dollars), percentage of jobs in science, technology, engineering, and mathematics fields (STEM) in 2014 (Wagner and Bologna Pavlik 2020), and the growth in the number of active permitted oil and gas wells between 2014 and 2019.

[14]The 14 (level one) IT-intensive NAICS codes include: 5415, 5112, 5413, 5417, 5181, 3341, 5161, 3345, 5182, 3364, 3342, 3344, 3254, 5179.

Table 1 reports descriptive statistics and source information for the variables in the base regression equation. In particular, the average census block group has 503 employed persons and a median household income of $45,762. Over the sample period, the typical block group saw its contractual business download speeds increase by an average of 111.9%. However, the standard deviation (240.3) reveals that there was substantial variation across census blocks groups during this period.

Similar to broadband speed, we observe considerable variation across census block groups in terms of overall employment. For instance, the mean and median block group experienced job growth of 26.5% and 16.9%, respectively. While these figures are large, the standard deviation in employment growth is 171.1. Of the 3,432 census block groups where we have complete data, 598 (or 17.3%) experienced contractions in employment between 2014 and 2019, with the largest percentage reduction being -86.3%. In contrast, 97 census block groups (or 2.8%) experienced growth job exceeding 100% during the sample.

The large variability in employment is a natural consequence of using census block groups because employment can fluctuate if an employer expands, contracts, or relocates within the state to a new block group. We take steps, discussed in more detail in Section 4, to mitigate the concern that outliers or other high-leverage observations might be unduly affecting our estimates.

[Table 1]

We also leverage the detail in the NETS database to explore differential effects on employment and establishment growth among micro establishments (5 or fewer workers) and start-up firms (first observed). Similar to overall employment, the descriptive statistics in Table 1 reaffirm this variability, but to a lesser extent. Employment growth among micro establishments increased by 13.3% and 10.0% in the mean and median block group. Among start-up firms, there is more variation in terms of positive and negative employment growth. While the mean census block experienced a reduction in start-up employment of -16.4% between 2014 and 2019, the median block group saw start-up employment decrease almost 23%.

When examining business start-up and survival rates, we use several time horizons to smooth out some of the year-to-year fluctuations in these metrics. Across all census block groups in the sample, the mean 3-year average establishment birth rate is 10.7 per 1,000 people. The *difference* in the 3-year birth rate between 2014 and 2019 is 3.4 establishments, indicating that (on average) block groups experienced higher birth rates over the sample.

The 1-year horizon regressions capture the difference in business start-ups in 2019 (sample end) compared to business start-ups in 2014 (sample beginning). The 3-year horizon regressions measure the difference in *average* business start-up rates from 2017-2019 relative to average business start-ups from 2012-2014.

In terms of survival rates, an average of 58.5% and 32.8% of start-ups survive for at least 5 and 10 years, respectively. These figures closely match survival rates at the same time horizon from the Business Employment Dynamics database.[15] In contrast to start-up rates, however, the *difference* in both the 5- and 10-year survival years declined in the average census block group. This indicates that newly formed establishments were less likely to survive over the sample period.

Similar to start-up rates, the 5- and 10-year business survival rates are averaged over a 3-year horizon due to year-to-year variability. A 5-year survival rate is simply the fraction of establishments that started in year 0 and remain open in year 5. Our end-of-sample (2019) 5-year survival rate averages the 5-year survival rates from 2012-2017, 2013-2018, and 2014-2019. Our start-of-sample (2013) 5-year survival rate averages the 5-year survival rates from 2006-2011, 2007-2012, and 2008-2013. The 10-year survival rates are constructed in an analogous manner.

In addition to other factors that can affect employment or establishment growth, there is the potential for reverse causality, or simultaneity, between local economic outcomes and broadband infrastructure. In other words, does broadband infrastructure cause greater employment or establishment growth, or is expanded infrastructure simply a response to greater growth? Perhaps service providers are merely reacting to growth patterns and deciding to invest and deploy infrastructure in census block groups that are growing and disinvest in regions that are depopulating.

To address the potential simultaneity between local growth and expanded broadband access, we estimate equation 1 using two-stage least squares. Kolko (2012) emphasizes the fact that the costs and benefits of deploying broadband infrastructure often depend on local factors. These factors could include cost differentials resulting from terrain features or strategic decisions made by an area's dominant service provider. We focus on identification through plausibly exogenous terrain

[15] https://www.bls.gov/bdm/us_age_naics_00_table7.txt (accessed: 7/17/2023).

features, long recognized by the Federal Communication Commission's hybrid proxy cost model as important factors shaping wireline telecommunications networks.[16] Specifically, the hybrid cost model, which dates back to 1998, notes that terrain features such as water table, bedrock depth, soil type, and slope are important cost factors for deploying telecommunications networks. In our setting, if these terrain features are correlated with the placement of broadband infrastructure and have no other relationship to job growth or local economic outcomes, then they could be valid instruments.

We instrument for the percentage change in mean contractual business download speeds using the squared meters of tree canopy coverage and the maximum terrain ruggedness index (TRI) score, both measured at the block group dimension. The TRI, proposed by Riley et al. (1999), is a unitless measure of the amount of elevation difference between adjacent cells in digital elevation maps (DEM). For cell d in a digital elevation map, the terrain ruggedness index is the square root of sum of the squared differences between the evelvation of cell d and the elevation in its eight surrounding cells. The ruggedness index is non-negative, with larger values indicating more rugged terrain. Both the tree canopy coverage and terrain ruggedness index scores are constructed from highly granular 10 meter by 10 meter digital scans.[17]

Terrain features were also employed as instruments by Conroy and Low (2022), Isley and Low (2022), and Kolko (2012). Kolko (2012) uses the average terrain slope (at the zip code level), while Conroy and Low (2022) and Isley and Low (2022) use a (county-level) land developability index reflecting a range of terrain characteristics that includes water, wetlands, steep slopes, and built-up land. The statistical strength of their instruments, measured at the county or zip code dimension, are well-below the threshold now recommended by Keane and Neal (2023) and Lee et al. (2022), raising concerns about the reliability of inference. Moreover, the exclusion restriction may not hold for the land developability index because terrain features such as water could plausbily be related to economic outcomes (ports, shipping activity, commerical fishing, etc.).

For our instruments to be valid, they must be strongly correlated with the endogenous variable (testable) and satisfy the exclusion restriction (untestable). If, as the FCC's hybrid cost model

[16] https://www.fcc.gov/general/hybrid-cost-proxy-model-hcpm (accessed: 7/22/2023)

[17] The tree canopy coverage data were obtained from the U.S. Department of Agriculture's (2001) urban forest data for Louisiana, while the terrain ruggedness index was constructed from the United States Geological Survey's digital elevation model (3D Elevation Program). The digital elevation scans are available here: https://apps.nationalmap.gov/downloader/ (accessed 3/2/2023).

suggests, these terrain features affect the distribution of over-the-air or below-ground wirelines, then they would satisfy the first validity condition. To satisfy the exclusion restriction, one must be willing to assume that tree canopy coverage and terrain ruggedness have no effect on local economic outcomes other than through their role in affecting the telecommunications network. To bolster our case that the exclusion restriction holds, the tree canopy coverage and ruggedness index are constructed from digital scans conducted in 2001 and 2000, the very earliest stages of broadband delopyment. In other words, the exclusion restriction will be valid if tree canopy coverage and terrain ruggedness have no bearing on local economic outcomes more than one decade later.[18]

The first stage regression results are reported Appendix Tables A.1, A.2, and A.3. As the hybrid cost model predicts, both the tree canopy coverage and ruggedness index measures are inversely correlated with broadband access. This is consistent with the notion that infrastructure delopyment favored low-cost block groups, at least from a terrain perspective.

4 Empirical Results

The baseline results for employment growth, establishment births, and survival rates are presented in Tables 2, 3, and 4, respectively. Across all specifications, standard errors are multiway clustered at the census tract and county dimensions.

Due to the spatial nature of our data, we also test for residual spatial autocorrelation using an inverse distance weighting matrix where all census block groups are potentially interconnected to one another. P-values from those tests are reported (Moran's I p-val) for every specification, and we find no consistent evidence of residual spatial correlation.

We also report the non-robust (Cragg-Donald) and robust (Kleibergen-Paap) first-stage F statistics for instrument strength. The Kleibergen-Paap statistic is never lower than 123 in any specification. This exceeds the threshold that Keane and Neal (2023) and Lee et al. (2022) now indicate is required for valid inference (104.7). Further, across all 21 specifications in Tables 2, 3, and 4, p-values from the overidentifying restrictions (or Sargan) test are never less than 0.05. While the

[18] As a robustness check, we also explored three other terrain features as potential instruments: (i) the squared meters of water coverage in the block group, (ii) the maximum slope in the block group (similar to Kolko 2012), and (iii) the maximum geological strength index (GSI) in the block group. The GSI, which is constructed from soil scans performed in 1998, is a measure of the ease of excavation. All of these additional terrain features were negatively correlated with broadband deployment, consistent with the hybrid proxy cost model, but were also weaker than tree canopy coverage and the ruggedness index. The maximum slope was the strongest alternative instrument and water coverage was the weakest. An unpublished appendix will be provided upon request that compares the baseline estimates in the paper to alternative estimates using four different sets of terrain characteristics as instruments.

exclusion restriction is untestable, the lack of significance from the overidentifying restrictions tests provide empirical support that at least one of the terrain feature instruments is uncorrelated with the unexplained variation in local economic outcomes. Considering the instrumental variables diagnostic tests jointly, we have the strongest evidence we can provide that the instruments are both strong and exogenous.

We noted in Section 3.1 that the outcome variables vary considerably across census block groups. As a sensitivity check, we estimate multiple variations of our baseline specifications out of concern for outliers and high-leverage observations. Consider the employment growth regressions shown in columns 1-3 of Table 2. Column 1 shows the estimates using all the census block groups for which we have complete data (3,432).[19] Column 2 omits census block groups where employment growth is considered an outlier using a Bonferroini test. Lastly, column 3 removes extreme values indiscriminately by excluding census block groups where employment growth falls in either the top or bottom 1.5% of the distribution, which we refer to as "Top/bottom" outlier removal.

[Table 2]

Estimates for employment growth are reported in Table 2. The coefficient of interest, the percent change in business download speed, is interpreted as an elasticity. Apart from the regressions using all establishments (column 1), the estimates are generally robust across the full sample specifications and both methods of excluding outliers. In terms of the estimated magnitude, we find that a 10% increase in the (mean) contractual business download speed in a census block group increased overall employment between 0.31 (column 3) and 0.68% (column 1). Among micro establishments (columns 4-6) and start-up establishments (columns 7-9), a 10% increase in business download speeds leads to employment growth ranging from 0.25% to 0.35%. The effect of broadband speeds on micro establishments and start-ups is also less sensitive to removing outliers.

[Table 3]

[19] As noted in Section 3.1, there are 3,471 census block groups (2010 definition) in Louisiana. Sixteen census block groups must be omitted because we lack broadband deployment data for both 2014 and 2019. Median household income data from the American Community Survey 5-year 2014 survey are unavailable for an additional 23 census block groups. This reduces our usable sample from 3,471 to 3,432.

Turning attention to the *difference* in establishment birth rates per 1,000 residents (Table 3), we find consistent evidence that faster business download speeds lead to more business start-ups, all else equal. The point estimates and level of significance are also stable across specifications. We measure business start-up rates at a 1-year horizon (columns 1-3) and 3-year average horizon (columns 4-6) as a robustness check.

[Table 4]

Finally, Table 4 reports the estimates comparing the *difference* in 5- and 10-year business survival rates. Consistent with the findings for job growth rates and start-up rates, we find evidence that faster business download speeds have a positive causal effect on start-up survival rates. The evidence is stronger at the 5-year horizon than the 10-year horizon. In terms of the magnitude, our estimates indicate that a one standard deviation increase in business download speeds increases the 5-year and 10-year survival rates by 10 and 4.5 percentage points, respectively. This is a non-trivial effect and indicates that, in addition to stimulating new business formation, expanded broadband infrastructure may generate more comprehensive economic benefits at the local level.

4.1 Robustness Check using LASSO IV

The choice of covariates included in the baseline regressions (Tables 2, 3, and 4) was driven by previous work on broadband and growth models. There are, of course, many measured characteristics that are potentially available to include in growth regressions. In this section, we explore the robustness of our baseline estimates using a LASSO (Least Absolute Shrinkage and Selection Operator) instrumental variables approach for determining both the instruments and control variables that should appear in regression model 1.

Specifically, we rely on the IV LASSO method developed by Chernozhukov et al. (2015), which allows one to estimate model parameters in the presence of many potential instruments and control variables that, in theory, could be larger than the sample size itself. This allows us to expand the pool of potential control variables far beyond other studies and identify the characteristics that are most strongly correlated with local employment, new business formation, and survival. This, in turn, reduces the concern that our point estimates are biased due to omitted factors.

Chernozhukov et al. (2015) describe their approach as a triple-selection estimator. With potentially many predictors and instruments, the first step is to perform a lasso regression of the outcome on the predictor set to determine the most appropriate covariates. Next, regress the endogenous variable on covariates and external instruments (via LASSO) to determine the most appropriate instrument(s) and covariates. Finally, a third LASSO regression is employed, regressing the endogenous variable only on the included (exogenous) covariates. Following Chernozhukov et al. (2015), the final two-stage least estimator uses the instrument(s) selected in the (second) LASSO regression and any covariate that is selected in any one of the three LASSO regressions. Inference is based on conventional heteroscedasticity robust standard errors. See Chernozhukov et al. (2015) for technical details.

[Table 5]

In addition to the three external instruments and covariates shown in Table 1, we augment the covariate pool with 14 additional potential control variables. These covariates, including the descriptive statistics and source information, are shown in Table 5. At the census block group dimension, the additional covariates include the median age in 2014, labor force participation rate in 2014, the amount of impervious land, area covered by wetlands, and the percentage of the population (in 2014) that is non-white. At the county dimension, the expanded set includes the poverty rate in 2014, railroad freight miles, the population share age 65 and older, the percent holding at least a bachelor's degree, the number of airports and marinas, the growth rate in per capita personal income from 2010-2014, and the Herfindahl-Hirschman index of employment concentration. The IV LASSO regressions consider a total of 26 covariates, with 13 of these measured at the census block group dimension.

[Table 6]

Table 6 shows the results of our robustness checks using the LASSO IV method, with the estimates for job growth in Panel A and the estimates for establishment birth rates and survival rates in Panels B and C, respectively. Following the baseline strategy in the preceding section, we also investigate the robustness of the IV LASSO method when outliers are omitted. This means the column numbers in each panel of Table 6 correspond to the column numbers in Table 2 (Panel A), Table 3 (Panel B), and Table 4 (Panel C).

Across all specifications of the LASSO IV regressions, we find point estimates that are generally in-line with the baseline estimates. In the case of employment growth, for instance, the LASSO estimates suggest that a 10% increase in business download speeds boosts overall employment by roughly 0.26% (columns 1-3), employment for micro establishments by 0.28% (columns 4-6), and start-up employment by 0.36% (columns 7-8). Unlike the baseline specifications, the LASSO models imply a stronger linkage between broadband and start-up employment growth.

Pivoting to birth rates (Panel B) and survival rates (Panel C), the LASSO regressions further support the view that faster business broadband has a positive causal effect on start-ups and their survival. A one standard deviation increase in business download speeds raises the 1- and 3-year birth rates, all else equal, by 1.9 and 1.4 new establishments per 1,000 residents. Likewise, the LASSO estimates imply that a one standard deviation increase in business download speeds bumps up 5- and 10-year survival rates by 11.5 and 5.7 percentage points.

4.2 Discussion

Based on the baseline and LASSO estimates, our findings support the view that expanding broadband infrastructure may be a viable tool to stimulate local economic development. However, relative to other studies, our estimated effects are much smaller than those found in other (even recent) studies. For instance, Kolko (2012) is one of the most widely cited studies linking broadband access with increased employment growth. He finds that a one standard deviation increase in broadband access corresponds to a 0.085 standard deviation increase in employment. Based on the point estimates from the LASSO specifications, our standardized regression coefficient suggests that the same standard deviation increase in broadband speed will lead to a 0.030 standard deviation increase in employment, a reduction of 65%.

Similarly, Conroy and Low (2022) find that a one standard deviation increase in broadband access increases the number of new establishments in rural counties (with a population of 25,000) by 85, all else equal. Given the LASSO point estimate when start-up rates are averaged over a 3-year horizon (0.006), our estimates imply that a one standard deviation increase in broadband access leads to 1.4 new establishments per 1,000 residents. Using a population count of 25,000 for comparability with Conroy and Low (2022), our point estimates suggest that the number of start-up firms will increase by 35 rather than 85. This is roughly 60% smaller, which is also on-par with our employment estimate.

There are several potential reasons why our estimates may differ so significantly from other studies. To start with, as we note in Section 2, Louisiana ranks in the lowest quintile for many economic indicators, including innovation, social capital, labor force participation, and educational attainment. If these or other local factors play a role in the ability or willingness of residents and businesses to capitalize on broadband, the state may benefit less from expansions that a state with a more highly skilled workforce. Our estimates could be validated by performing a similar analysis in one or more states with differential workforces.

Moreover, establishments of different sizes and in different industries may be affected by broadband differently (Crandall et al. 2007; Mack and Rey 2014; Colombo et al. 2013). Louisiana has a large concentration of small establishments. More than 50% of establishments have fewer than 20 workers, and almost 40% have 5 or fewer workers. Statewide, only about 10% of establishments have more than 500 workers. Compared to large-scale firms, small-size firms may have less robust systems and be more cost-sensitive to effectively use and benefit from broadband (Colombo et al. 2013).

Third, as Ford (2020) asserts, other studies may suffer from omitted variable bias. We attempt to allay these concerns by controlling for many more factors than previous work, including employment in STEM and IT-intensive sectors, and using the LASSO estimator to empirically identify the most relevant covariates.

Next, our analysis is performed at a micro scale. This could reduce measurement error, especially among covariates, relative to studies that aggregate data to larger geographic areas.

Lastly, the terrain features we use as instruments are considerably stronger than prior work, which results in estimates with less bias (Keane and Neal 2023). The micro scale of our analysis likely plays a role here because more geographic granularity in the terrain instruments is much more strongly correlated with broadband deployment patterns than data aggregated to a county level.

5 Conclusion

This study evaluates the effect of faster business download speeds on local employment and business outcomes in Louisiana census block groups. Our main results show that overall (all) establishments, firms with 5 or fewer workers, and start-up firms experience an increase in employment when faster broadband speeds become available in the census block group. We also find significant and positive impacts of faster broadband speeds on new establishment start-up rates and survival rates. In line with the previous findings on the relationship between faster broadband speeds and employment growth (Lobo et al. 2020; Hasbi 2017), this study contributes to the literature in several ways.

First, we explore local employment effects for establishments of different sizes and find differential effects. Estimates indicate that, while faster broadband speeds stimulate employment among all establishments, the employment effect appears to be larger for start-up establishments and micro establishments (those with 5 or fewer employees). With the introduction of faster broadband into an area, smaller and younger firms may have greater digital literacy and be more willing to embrace new technologies, consistent with a recent study of adoption by the U.S. Chamber of Commerce.[20] From a policy perspective, understanding the relationship between broadband speeds and employment growth, especially in the context of start-ups, may help to shape more effective policies to aid emerging businesses.

Second, in addition to investigating new establishment births, this study is among the first to explore how broadband access shapes start-up survival rates, an important element of sustainable growth. We find that business survival rates at the 5-year and 10-year horizon are significantly higher in block groups when broadband speeds increase. This underscores another mechanism, independent of business formation, through which investments in broadband infrastructure can foster a favorable environment conducive to entrepreneurship, facilitate start-up survival, and potentially more sustainable local development.

In contrast to previous work, however, we find employment and start-up effects that are substantially smaller in magnitude. While it is difficult to pinpoint the exact reason (or reasons) behind our differential results, this study relies upon an empirical strategy that may be more robust than

[20] https://www.uschamber.com/technology/new-study-shows-technology-platforms-critical-to-small-business-growth (accessed: 7/18/2023)

past work. We use a LASSO instrumental variables approach using a large set of predictor variables (26) and a micro-geography scale that greatly boosts instrument strength. Relative to past work, we believe our estimates are less vulnerable to weak instruments and omitted factors that could explain our differential findings. Expanding this strategy to a nationwide setting would be a fruitful extension.

In conclusion, this study emphasizes the vital role of faster broadband speeds in stimulating the prosperity of establishment growth and the sustainability of start-up establishments. Policymakers and stakeholders can draw from these findings to enhance broadband infrastructure in promoting sustainable economic growth among establishments in different size and (entry) stage.

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Abbreviations

Infrastructure Investment and Jobs Act (IIJA)
National Establishment Time Series (NETS)
instrumental variables (IV)
Least Absolute Shrinkage and Selection Operator (LASSO)
Federal Communications Commission (FCC)
Internet Service Providers (ISPs)
North American Industrial Classification System (NAICS)
terrain ruggedness index (TRI)

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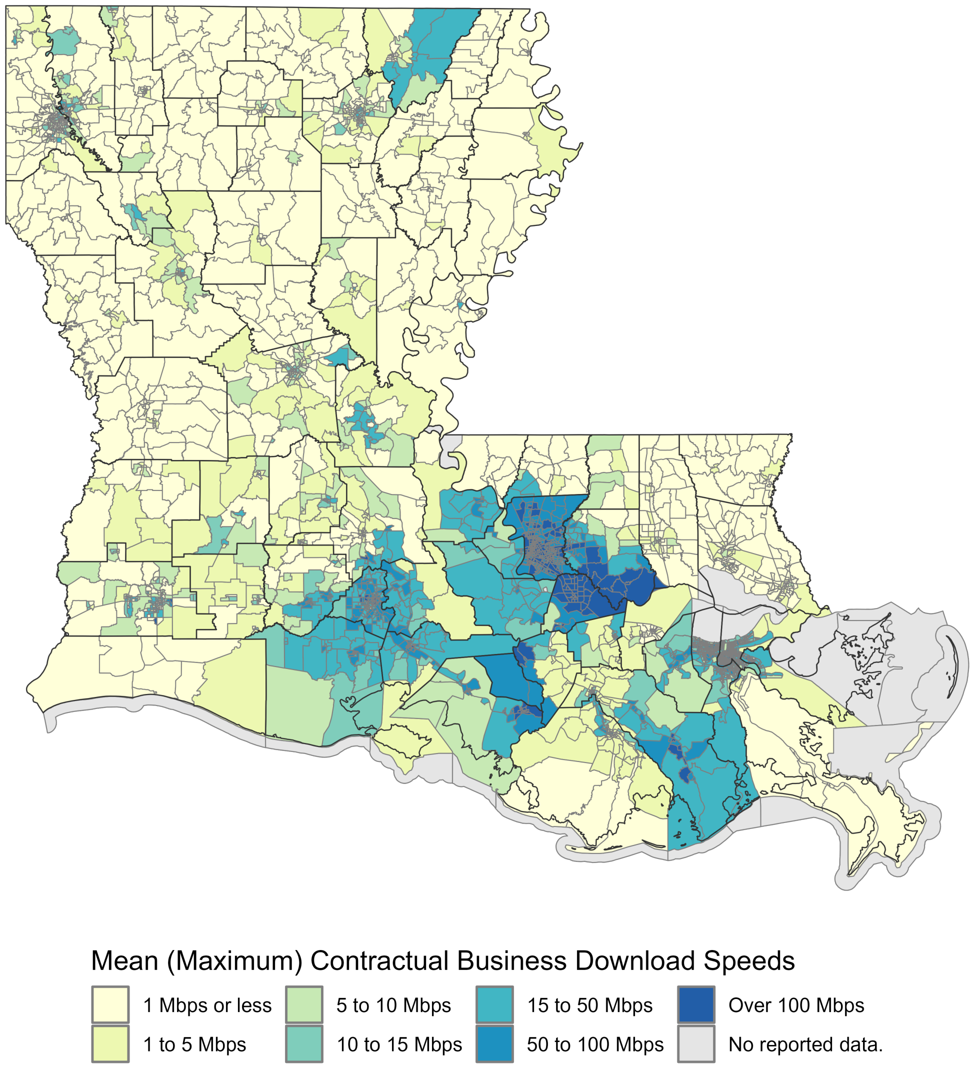
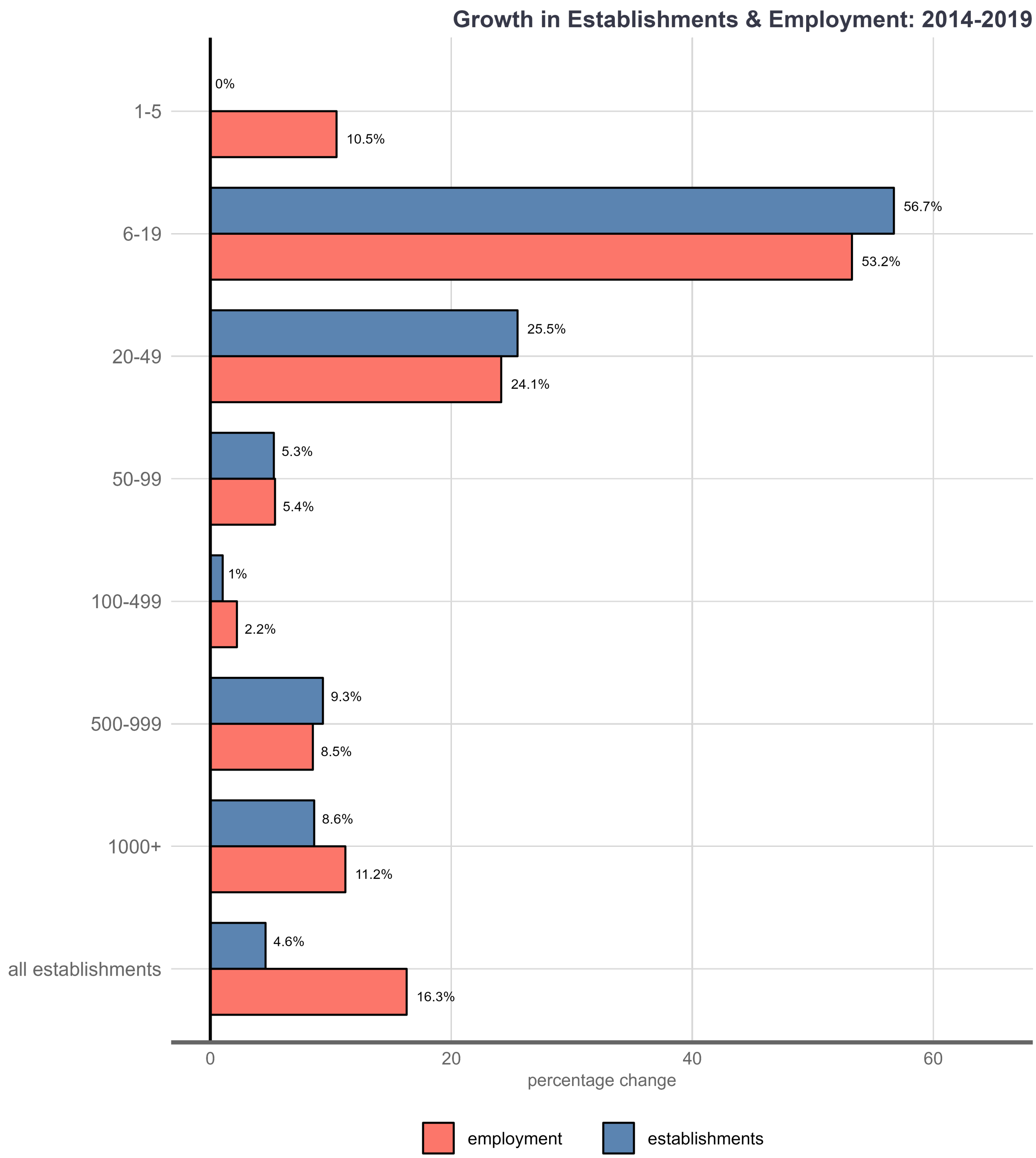
Figure 1: Maximum Advertised Business Download Speeds (Mbps), 2014



Note: This figure shows the mean maximum advertised business download speed (in Mbps) by census block group. Solid black lines denote parish boundaries. Mean values were formed from the Federal Communications Commission's broadband deployment data (form 477) that reports maximum advertised speeds at the census block dimension. There are 204,447 census blocks and 3,471 census block groups in Louisiana (2010). Broadband deployment data were available (in 2014 and 2019) for 3,453 census block groups. Block groups without data are shaded in grey.

Figure 2: Employment Composition and Establishment Growth in Louisiana



Note: These figures were constructed using data from the National Time Series Establishment (NETS) database. The composition of employment by establishment size, shown in the top panel, is the average share from 2014 to 2019. The bottom panel is the percentage change in the number of establishments, by size, from 2014 to 2019.

Table 1: Descriptive Statistics

Variable	Mean	Median	Std Deviation	Level
job growth, all establishments	26.559	16.917	171.141	block group
job growth, micro establishments	13.356	10.000	34.956	block group
job growth, startups	-16.414	-23.529	48.343	block group
birth rate, 3 yr avg, difference	3.498	2.709	5.742	block group
birth rate, 1 yr, difference	3.885	2.920	7.994	block group
birth rate, 3 yr avg	10.792	8.772	10.111	block group
survival rate, 5 year, difference	-16.643	-21.425	33.610	block group
survival rate, 10 year, difference	-44.817	-45.915	28.857	block group
survival rate, 5 year	58.577	59.505	17.675	block group
survival rate, 10 year	32.833	33.333	20.318	block group
number of jobs, 2014	503.084	295.000	914.947	block group
percent change business download speed, 2014-2019	111.926	4.242	240.393	block group
median household income, 2014	45.762	41.971	23.234	block group
rental housing unit share, 2014	35.266	30.935	23.433	block group
share of jobs in STEM, 2014	6.299	6.048	1.786	county
percent college graduates, 2014	14.464	10.403	12.904	block group
home prices, county	148.770	144.870	11.967	county
permitted wells, block group, 2014	7.289	0.000	41.171	block group
growth in permitted wells, county, 2014-2019	4.497	0.000	12.305	county
unemployment rate, 2014	9.611	7.528	8.437	block group
HHI employment, block group, 2014	2438.645	2112.248	1236.507	block group
Hi-tech employment share, 2014	1.351	0.280	3.792	block group
opportunity or enterprise zone	0.098	0.000	0.297	block group

Notes: The full sample includes 3,432 census block groups in Louisiana. The percentage change in jobs at the census block group level was constructed from the National Establishment Time Series database. The percent change in business download speed was constructed using the mean maximum contractual business download speed at the census block level via the Federal Communications Commission Form 477 data. Home prices are from the Federal Housing and Finance Agency. Median household income, the share of rental housing units, the percentage of residents with a college degree, and the unemployment rate are from the American Community Survey 5-year sample (2014). The number and location of active permitted oil and gas wells is from the Louisiana Department of Natural Resources. The share of STEM jobs in the county was constructed by applying the national Bureau of Labor Statistics industry-occupation crosswalk to employment county-level data from the Quarterly Census of Employment and Wages following Wagner and Bologna Pavlik (2020). Opportunity and enterprise zone boundaries were obtained from the Louisiana Economic Development Corporation.

Table 2: Effect of Business Broadband Speed on Job Growth

	Dependent variable:								
	all establishments			micro establishments			startups		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
percent change in business download speed, 2014-2019	0.068***	0.043***	0.031***	0.035***	0.033***	0.025***	0.030***	0.033***	0.029***
	(0.021)	(0.014)	(0.010)	(0.009)	(0.010)	(0.007)	(0.011)	(0.010)	(0.010)
median household income, 2014	0.213	0.057	0.054	0.044	0.024	-0.003	-0.118**	-0.111**	-0.056
	(0.140)	(0.052)	(0.042)	(0.029)	(0.030)	(0.029)	(0.046)	(0.044)	(0.037)
rental housing unit share, 2014	0.298**	0.093	0.088**	0.232***	0.181***	0.113***	0.150***	0.100**	0.075**
	(0.137)	(0.057)	(0.044)	(0.056)	(0.050)	(0.039)	(0.049)	(0.043)	(0.036)
share of jobs in STEM, 2014	1.587	0.634	0.476	0.253	0.214	0.074	0.425	0.479	0.812
	(0.989)	(0.618)	(0.411)	(0.459)	(0.431)	(0.372)	(0.611)	(0.590)	(0.565)
percent college graduates, 2014	-0.242	0.033	0.099	-0.041	0.008	0.048	0.081	0.062	0.151**
	(0.346)	(0.103)	(0.070)	(0.081)	(0.051)	(0.065)	(0.084)	(0.088)	(0.072)
home prices, county	0.744***	0.353**	0.143	0.301***	0.250**	0.150	0.158	0.168*	0.028
	(0.246)	(0.164)	(0.132)	(0.112)	(0.111)	(0.093)	(0.115)	(0.101)	(0.084)
permitted wells, block group, 2014	0.038***	0.028**	0.025**	0.007	0.007	0.001	0.021	0.024	0.018*
	(0.014)	(0.012)	(0.012)	(0.005)	(0.005)	(0.005)	(0.021)	(0.021)	(0.010)
growth in permitted wells, county, 2014-2019	0.093	0.037	0.002	0.000	0.000	0.009	-0.019	-0.022	0.038
	(0.079)	(0.052)	(0.038)	(0.045)	(0.043)	(0.034)	(0.061)	(0.062)	(0.055)
unemployment rate, 2014	0.922	0.142**	0.109	-0.040	-0.039	0.010	-0.081	0.003	0.106*
	(0.590)	(0.071)	(0.072)	(0.107)	(0.070)	(0.032)	(0.125)	(0.124)	(0.060)
number of jobs, 2014	-0.006***	-0.004***	-0.003***	-0.002***	-0.001***	-0.001**	0.004***	0.004***	0.003***
	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
HHI employment, block group, 2014	0.005	0.001	0.000	0.004**	0.002***	0.001**	0.000	0.000	0.000
	(0.004)	(0.001)	(0.000)	(0.002)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)
Hi-tech employment share, 2014	-0.827**	-0.553***	-0.406***	-0.103	-0.090	-0.037	-0.014	-0.018	0.147
	(0.330)	(0.188)	(0.106)	(0.106)	(0.100)	(0.073)	(0.123)	(0.120)	(0.141)
opportunity or enterprise zone	-16.752	-0.550	1.323	-0.184	1.947	3.084	-3.252	-3.684	-2.376
	(13.606)	(3.934)	(3.217)	(3.636)	(2.943)	(2.420)	(3.110)	(3.205)	(2.865)
N	3432	3429	3299	3432	3427	3300	3432	3427	3295
IV Sargan P	0.956	0.299	0.918	0.560	0.265	0.196	0.367	0.372	0.323
Cragg-Donald F	145.746	145.566	136.014	145.746	145.208	138.523	145.746	145.754	137.481
Kleibergen-Paap rk Wald F	132.123	132.068	123.612	132.123	131.708	123.172	132.123	132.312	139.501
Moran's I p-val	0.673	0.673	0.043	0.544	0.327	0.000	0.389	0.320	0.352
Outlier removal	None	Bonferroni	Top/bottom	None	Bonferroni	Top/bottom	None	Bonferroni	Top/bottom

This table shows the results of regressing the percentage change in jobs at the census block group level from 2014-2019 on the percentage change in mean business download speeds. All models were estimated by two-stage least squares assuming the percentage change in business download speeds (from 2014-2019) is endogenous. Instruments are the meters squared of tree canopy coverage in the census block group in 2001 and the maximum terrain ruggedness index in the census block group in 2000. The row 'IV Sargan p-value' shows the p-value from the Sargan test under the null hypothesis that at least one of the instruments is uncorrelated with the error term. The row 'Moran's I p-val' shows the p-value for a test of residual spatial correlation using an inverse distance weighting matrix. The row labeled 'Outlier removal' denotes how the sample size was trimmed base on extreme values in the outcome variable. N denotes the number of census block groups in each regression. Standard errors are show in parantheses and are clustered at the census tract and county dimensions. All models include an unreported constant term. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table 3: Effect of Business Broadband Speed on Establishment Birth Rates

	Dependent variable:					
	birth rate, 1 yr, difference			birth rate, 3 yr avg, difference		
	(1)	(2)	(3)	(4)	(5)	(6)
	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
percent change in business download speed, 2014-2019	0.012***	0.011***	0.009***	0.007***	0.007***	0.006***
	(0.003)	(0.003)	(0.002)	(0.001)	(0.001)	(0.001)
median household income, 2014	-0.023**	-0.019**	0.001	-0.032***	-0.023***	-0.007*
	(0.010)	(0.010)	(0.007)	(0.008)	(0.007)	(0.004)
rental housing unit share, 2014	0.004	0.002	0.004	-0.006	0.000	0.001
	(0.009)	(0.011)	(0.009)	(0.007)	(0.006)	(0.004)
share of jobs in STEM, 2014	0.212	0.216*	0.235**	0.082	0.086	0.108*
	(0.130)	(0.120)	(0.106)	(0.076)	(0.071)	(0.063)
percent college graduates, 2014	0.136***	0.142***	0.088***	0.090***	0.085***	0.042***
	(0.023)	(0.020)	(0.017)	(0.015)	(0.013)	(0.010)
home prices, county	0.037	0.022	0.023	0.013	0.005	-0.003
	(0.043)	(0.037)	(0.028)	(0.019)	(0.016)	(0.012)
permitted wells, block group, 2014	0.000	0.000	0.000	0.000	0.000	0.000
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
growth in permitted wells, county, 2014-2019	0.011	0.010	0.006	0.005	0.005	0.002
	(0.009)	(0.009)	(0.009)	(0.007)	(0.007)	(0.006)
unemployment rate, 2014	0.013	0.008	0.006	0.011	0.009	0.002
	(0.017)	(0.016)	(0.011)	(0.012)	(0.009)	(0.007)
number of jobs, 2014	0.003***	0.002***	0.001***	0.003***	0.002***	0.001***
	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
HHI employment, block group, 2014	0.000	0.000	0.000**	0.000**	0.000*	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Hi-tech employment share, 2014	-0.031	-0.018	0.031	-0.034	-0.025	0.020
	(0.076)	(0.074)	(0.025)	(0.062)	(0.061)	(0.021)
opportunity or enterprise zone	-0.692	-0.413	-0.135	-0.572	-0.497	-0.212
	(0.782)	(0.758)	(0.667)	(0.475)	(0.451)	(0.388)
N	3432	3427	3298	3432	3427	3298
IV Sargan P	0.469	0.620	0.881	0.493	0.370	0.079
Cragg-Donald F	145.746	146.167	137.847	145.746	146.337	139.075
Kleibergen-Paap rk Wald F	132.123	131.935	124.488	132.123	131.976	125.575
Moran's I p-val	0.103	0.182	0.281	0.727	0.787	0.052
Outlier removal	None	Bonferroni	Top/bottom	None	Bonferroni	Top/bottom

This table shows the results of regressing the difference in new establishment birth rates (per 1000 residents) at the census block group level from 2014-2019 on the percentage change in mean business download speeds. All models were estimated by two-stage least squares assuming the percentage change in business download speeds (from 2014-2019) is endogenous. Instruments are the meters squared of tree canopy coverage in the census block group in 2001 and the maximum terrain ruggedness index in the census block group in 2000. The row 'IV Sargan p-value' shows the p-value from the Sargan test under the null hypothesis that at least one of the instruments is uncorrelated with the error term. The row 'Moran's I p-val' shows the p-value for a test of residual spatial correlation using an inverse distance weighting matrix. The row labeled 'Outlier removal' denotes how the sample size was trimmed base on extreme values in the outcome variable. N denotes the number of census block groups in each regression. Standard errors are show in parantheses and are clustered at the census tract and county dimensions. All models include an unreported constant term. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table 4: Effect of Business Broadband Speed on Startup Survival Rates

	Dependent variable:					
	survival rate, 5 year,difference			survival rate, 10 year,difference		
	(1)	(2)	(3)	(4)	(5)	(6)
	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
percent change in business download speed, 2014-2019	0.049***	0.049***	0.040***	0.020**	0.019*	0.014*
	(0.014)	(0.014)	(0.012)	(0.010)	(0.010)	(0.008)
median household income, 2014	-0.088*	-0.082	-0.040	-0.009	-0.015	-0.005
	(0.052)	(0.052)	(0.044)	(0.025)	(0.025)	(0.020)
rental housing unit share, 2014	0.043	0.048	0.080	0.030	0.027	0.024
	(0.057)	(0.056)	(0.054)	(0.041)	(0.045)	(0.027)
share of jobs in STEM, 2014	0.466	0.476	0.423	0.992**	1.038***	0.847***
	(0.689)	(0.686)	(0.554)	(0.396)	(0.383)	(0.324)
percent college graduates, 2014	0.196*	0.198*	0.209**	0.080	0.095	0.061
	(0.103)	(0.102)	(0.081)	(0.103)	(0.095)	(0.087)
home prices, county	0.124	0.125	-0.022	0.180**	0.171*	0.118*
	(0.163)	(0.163)	(0.127)	(0.088)	(0.088)	(0.061)
permitted wells, block group, 2014	-0.008	-0.007	-0.003	0.001	0.001	0.005
	(0.013)	(0.013)	(0.013)	(0.010)	(0.009)	(0.011)
growth in permitted wells, county, 2014-2019	0.004	0.004	0.058	0.037	0.035	0.028
	(0.075)	(0.075)	(0.055)	(0.032)	(0.031)	(0.030)
unemployment rate, 2014	0.001	0.010	0.102	-0.137	-0.174**	-0.074
	(0.115)	(0.115)	(0.082)	(0.107)	(0.084)	(0.078)
number of jobs, 2014	-0.001**	-0.001**	-0.001	0.002***	0.002***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
HHI employment, block group, 2014	0.003***	0.003***	0.002***	0.000	-0.001*	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Hi-tech employment share, 2014	0.015	0.016	0.008	-0.039	-0.061	0.029
	(0.185)	(0.184)	(0.181)	(0.085)	(0.076)	(0.079)
opportunity or enterprise zone	1.132	1.257	-0.346	-0.692	0.180	-1.158
	(3.959)	(3.900)	(3.458)	(2.073)	(2.086)	(1.842)
N	3432	3431	3290	3432	3427	3198
IV Sargan P	0.299	0.324	0.118	0.361	0.273	0.325
Cragg-Donald F	145.746	145.960	135.730	145.746	145.874	136.002
Kleibergen-Paap rk Wald F	132.123	132.198	122.341	132.123	132.215	119.771
Moran's I p-val	0.228	0.229	0.085	0.514	0.612	0.465
Outlier removal	None	Bonferroni	Top/bottom	None	Bonferroni	Top/bottom

This table shows the results of regressing the difference in new establishment survival rates at the census block group level from 2014-2019 on the percentage change in mean business download speeds. All models were estimated by two-stage least squares assuming the percentage change in business download speeds (from 2014-2019) is endogenous. Instruments are the meters squared of tree canopy coverage in the census block group in 2001 and the maximum terrain roughness index in the census block group in 2000. The row 'IV Sargan p-value' shows the p-value from the Sargan test under the null hypothesis that at least one of the instruments is uncorrelated with the error term. The row 'Moran's I p-val' shows the p-value for a test of residual spatial correlation using an inverse distance weighting matrix. The row labeled 'Outlier removal' denotes how the sample size was trimmed base on extreme values in the outcome variable. N denotes the number of census block groups in each regression. Standard errors are show in parantheses and are clustered at the census tract and county dimensions. All models include an unreported constant term. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table 5: Additional Covariates for Lasso Regressions

Variable	Mean	Median	Std Deviation	Level
poverty rate, 2014	38.977	38.042	7.926	county
labor force participation rate, 2014	47.498	47.615	10.586	block group
median age, 2014	37.983	37.400	8.234	block group
impervious land (meters sq), 2001	27.521	14.520	31.407	block group
railroad freight miles, 2020	66.601	67.900	38.237	county
poor condition bridges, 2012	0.126	0.113	0.055	county
population share 65+, 2014	14.062	12.981	7.318	county
5-year growth rate in per capita income, 2010-2014	0.157	0.148	0.067	county
number of airports, 2012	0.378	0.000	0.485	county
percent college educated: county, 2014	14.458	13.950	5.400	county
wetland coverage (meters sq), 2001	91.342	5.394	232.911	block group
total marinas, 2012	0.000	0.000	0.000	county
non-white population share, 2014	39.840	29.898	33.484	block group
hhi employment, county, 2014	953.564	941.788	161.653	county

Notes: The full sample includes 3,432 census block groups in Louisiana. Poverty rate, median age, labor force participation, and the percent college educated at the county level are from the American Community Survey 5-year sample (2014). Per capita personal income data are from the Bureau of Economic Analysis. The population share 65+ is from the Census Bureau's Small Area Income and Poverty Estimates program. The condition of bridges, number of airports, and railroad freight miles are from the US Bureau of Transportation Statistics County Transportation Profiles. Finally, total wetland coverage and impervious land are from the United States Department of Agriculture's state urban forest data files (https://www.nrs.fs.fed.us/data/urban/state/?state=LA).

Table 6: Robustness Checks using Lasso IV

	Dependent variable:								
	all establishments			micro establishments			startups		
Panel A: Job Growth	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
percent change in business download speed	0.067**	0.026**	0.022***	0.03***	0.028***	0.016***	0.031**	0.037**	0.036***
	(0.033)	(0.012)	(0.008)	(0.008)	(0.007)	(0.006)	(0.015)	(0.015)	(0.012)
	birth rate, 1 yr, difference			birth rate, 3 yr avg, difference					
Panel B: Birth Rates	(1)	(2)	(3)	(4)	(5)	(6)			
percent change in business download speed	0.009***	0.008***	0.007***	0.006***	0.006***	0.006***			
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)			
	survival rate, 5 year			survival rate, 10 year					
Panel C: Survival Rates	(1)	(2)	(3)	(4)	(5)	(6)			
percent change in business download speed	0.049***	0.048***	0.044***	0.027**	0.024*	0.02*			
	(0.013)	(0.013)	(0.011)	(0.013)	(0.013)	(0.012)			

This table shows the results of regressing the percentage change in employment growth, birth rates, and survival rates at the census block group level on the percentage change in mean business download speeds from 2014-2019 treating download speeds as endogenous. All models were estimated using the Lasso instrumental variables proposed by Chernozhukov et al. (2015). The full set of Lasso covariates are listed in Tables 1 and 5. The percentage change in business download speeds is endogenous. Instruments are the meters squared of tree canopy coverage in the census block group in 2001 and the maximum terrain ruggedness index score in the census block group in 2000. Column numbers correspond to the columns presented in Table 2 (Panel A), Table 3 (Panel B), and Table 4 (Panel C). *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

A Appendix: First-Stage Regessions

Table A.1: First-Stage Regressions: Job Growth

	Dependent variable:								
	percent change business download speed, 2014-2019								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
maximum terrain ruggedness index	-30.509***	-30.464***	-29.254***	-30.509***	-30.389***	-29.258***	-30.509***	-30.521***	-29.193***
	(2.661)	(2.661)	(2.701)	(2.661)	(2.660)	(2.682)	(2.661)	(2.663)	(2.671)
block group canopy coverage, 2001	-0.127***	-0.127***	-0.131***	-0.127***	-0.127***	-0.132***	-0.127***	-0.127***	-0.131***
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.017)
median household income, 2014	0.446*	0.436*	0.432*	0.446*	0.446*	0.469*	0.446*	0.443*	0.439*
	(0.249)	(0.249)	(0.254)	(0.249)	(0.249)	(0.255)	(0.249)	(0.249)	(0.250)
rental housing unit share, 2014	1.046***	1.031***	1.070***	1.046***	1.059***	0.940***	1.046***	1.047***	0.989***
	(0.209)	(0.210)	(0.217)	(0.209)	(0.210)	(0.219)	(0.209)	(0.210)	(0.212)
share of jobs in STEM, 2014	-25.056***	-25.012***	-25.053***	-25.056***	-25.111***	-25.402***	-25.056***	-25.026***	-24.978***
	(2.189)	(2.190)	(2.225)	(2.189)	(2.188)	(2.212)	(2.189)	(2.191)	(2.216)
percent college graduates, 2014	2.492***	2.508***	2.522***	2.492***	2.486***	2.491***	2.492***	2.482***	2.544***
	(0.394)	(0.394)	(0.401)	(0.394)	(0.394)	(0.401)	(0.394)	(0.395)	(0.395)
home prices, county	-0.680**	-0.690**	-0.835**	-0.680**	-0.708**	-0.898***	-0.680**	-0.670**	-0.652*
	(0.333)	(0.333)	(0.342)	(0.333)	(0.333)	(0.342)	(0.333)	(0.334)	(0.338)
permitted wells, block group, 2014	-0.096	-0.096	-0.090	-0.096	-0.097	-0.087	-0.096	-0.097	-0.099
	(0.094)	(0.094)	(0.094)	(0.094)	(0.094)	(0.095)	(0.094)	(0.094)	(0.095)
growth in permitted wells, county, 2014-2019	-1.241***	-1.243***	-1.283***	-1.241***	-1.239***	-1.272***	-1.241***	-1.242***	-1.232***
	(0.324)	(0.324)	(0.329)	(0.324)	(0.324)	(0.328)	(0.324)	(0.324)	(0.330)
unemployment rate, 2014	0.869*	0.847*	0.475	0.869*	0.717	0.733	0.869*	0.848*	0.651
	(0.484)	(0.484)	(0.506)	(0.484)	(0.487)	(0.511)	(0.484)	(0.485)	(0.493)
number of jobs, 2014	0.004	0.004	0.003	0.004	0.004	0.005	0.004	0.004	0.005
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
HHI employment, block group, 2014	-0.008**	-0.008**	-0.011***	-0.008**	-0.008***	-0.012***	-0.008**	-0.007**	-0.009***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Hi-tech employment share, 2014	2.442**	2.439**	2.536**	2.442**	2.448**	2.492**	2.442**	2.427**	2.052**
	(0.984)	(0.984)	(1.003)	(0.984)	(0.983)	(0.984)	(0.984)	(0.985)	(0.998)
opportunity or enterprise zone	103.932***	104.445***	99.652***	103.932***	103.287***	103.815***	103.932***	103.464***	106.618***
	(12.740)	(12.745)	(13.183)	(12.740)	(12.748)	(13.126)	(12.740)	(12.765)	(12.921)
N	3432	3429	3299	3432	3427	3300	3432	3427	3295
Cragg-Donald F	145.746	145.566	136.014	145.746	145.208	138.523	145.746	145.754	137.481
Kleibergen-Paap rk Wald F	132.123	132.068	123.612	132.123	131.708	123.172	132.123	132.312	139.501
Outlier removal	None	Bonferroni	Top/bottom	None	Bonferroni	Top/bottom	None	Bonferroni	Top/bottom

This table shows the first-stage regression results from the employment growth regressions where the percent change in business download speed is endogenous. Exogenous instruments are the meters squared of tree canopy coverage in the census block group in 2001 and the maximum terrain roughness index in the census block group in 2000. The Cragg-Donald and Kliebergen-Paap rk Wald F statistics for instrument strength are reported. The row labeled 'Outlier removal' denotes how the sample size was trimmed base on extreme values in the outcome variable. Standard errors are show in parantheses and are clustered at the census tract and county dimensions. All models include an unreported constant term. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table A.2: First-Stage Regressions: Birth Rates

	Dependent variable:					
	percent change business download speed, 2014-2019					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	OLS	OLS	OLS	OLS
maximum terrain ruggedness index	-30.509***	-30.681***	-30.429***	-30.509***	-30.701***	-30.640***
	(2.661)	(2.666)	(2.718)	(2.661)	(2.666)	(2.709)
block group canopy coverage, 2001	-0.127***	-0.127***	-0.125***	-0.127***	-0.127***	-0.124***
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
median household income, 2014	0.446*	0.432*	0.248	0.446*	0.427*	0.405
	(0.249)	(0.249)	(0.262)	(0.249)	(0.250)	(0.261)
rental housing unit share, 2014	1.046***	1.022***	0.943***	1.046***	1.021***	0.994***
	(0.209)	(0.210)	(0.217)	(0.209)	(0.210)	(0.218)
share of jobs in STEM, 2014	-25.056***	-25.114***	-25.226***	-25.056***	-25.126***	-25.513***
	(2.189)	(2.191)	(2.238)	(2.189)	(2.191)	(2.236)
percent college graduates, 2014	2.492***	2.485***	2.579***	2.492***	2.492***	2.414***
	(0.394)	(0.394)	(0.416)	(0.394)	(0.395)	(0.417)
home prices, county	-0.680**	-0.673**	-0.752**	-0.680**	-0.665**	-0.788**
	(0.333)	(0.334)	(0.343)	(0.333)	(0.334)	(0.344)
permitted wells, block group, 2014	-0.096	-0.096	-0.090	-0.096	-0.096	-0.101
	(0.094)	(0.094)	(0.095)	(0.094)	(0.094)	(0.094)
growth in permitted wells, county, 2014-2019	-1.241***	-1.242***	-1.293***	-1.241***	-1.243***	-1.282***
	(0.324)	(0.324)	(0.327)	(0.324)	(0.324)	(0.328)
unemployment rate, 2014	0.869*	0.897*	0.764	0.869*	0.894*	0.837*
	(0.484)	(0.484)	(0.500)	(0.484)	(0.484)	(0.501)
number of jobs, 2014	0.004	0.006	0.009	0.004	0.006	0.009
	(0.004)	(0.005)	(0.006)	(0.004)	(0.005)	(0.006)
HHI employment, block group, 2014	-0.008**	-0.008**	-0.009***	-0.008**	-0.008**	-0.008**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Hi-tech employment share, 2014	2.442**	2.424**	2.521**	2.442**	2.424**	2.796***
	(0.984)	(0.984)	(1.064)	(0.984)	(0.984)	(1.071)
opportunity or enterprise zone	103.932***	104.272***	103.747***	103.932***	104.097***	103.346***
	(12.740)	(12.748)	(12.922)	(12.740)	(12.745)	(12.965)
N	3432	3427	3298	3432	3427	3298
Cragg-Donald F	145.746	146.167	137.847	145.746	146.337	139.075
Kleibergen-Paap rk Wald F	132.123	131.935	124.488	132.123	131.976	125.575
Outlier removal	None	Bonferroni	Top/bottom	None	Bonferroni	Top/bottom

This table shows the first-stage regression results from the new establishment birth rate regressions where the percent change in business download speed is endogenous. Exogenous instruments are the meters squared of tree canopy coverage in the census block group in 2001 and the maximum terrain roughness index in the census block group in 2000. The Cragg-Donald and Kliebergen-Paap rk Wald F statistics for instrument strength are reported. The row labeled 'Outlier removal' denotes how the sample size was trimmed base on extreme values in the outcome variable. Standard errors are show in parantheses and are clustered at the census tract and county dimensions. All models include an unreported constant term. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table A.3: First-Stage Regressions: Survival Rates

	Dependent variable:					
	percent change business download speed, 2014-2019					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	OLS	OLS	OLS	OLS
maximum terrain ruggedness index	-30.509***	-30.517***	-29.559***	-30.509***	-30.485***	-29.446***
	(2.661)	(2.661)	(2.680)	(2.661)	(2.662)	(2.707)
block group canopy coverage, 2001	-0.127***	-0.127***	-0.127***	-0.127***	-0.128***	-0.132***
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
median household income, 2014	0.446*	0.440*	0.416	0.446*	0.434*	0.342
	(0.249)	(0.249)	(0.254)	(0.249)	(0.249)	(0.256)
rental housing unit share, 2014	1.046***	1.040***	0.966***	1.046***	1.034***	0.839***
	(0.209)	(0.210)	(0.214)	(0.209)	(0.210)	(0.219)
share of jobs in STEM, 2014	-25.056***	-25.095***	-25.165***	-25.056***	-25.175***	-26.214***
	(2.189)	(2.190)	(2.226)	(2.189)	(2.192)	(2.254)
percent college graduates, 2014	2.492***	2.491***	2.564***	2.492***	2.492***	2.569***
	(0.394)	(0.394)	(0.403)	(0.394)	(0.394)	(0.404)
home prices, county	-0.680**	-0.681**	-0.906***	-0.680**	-0.688**	-0.975***
	(0.333)	(0.333)	(0.342)	(0.333)	(0.334)	(0.349)
permitted wells, block group, 2014	-0.096	-0.096	-0.093	-0.096	-0.097	-0.098
	(0.094)	(0.094)	(0.094)	(0.094)	(0.094)	(0.096)
growth in permitted wells, county, 2014-2019	-1.241***	-1.241***	-1.210***	-1.241***	-1.243***	-1.258***
	(0.324)	(0.324)	(0.341)	(0.324)	(0.324)	(0.326)
unemployment rate, 2014	0.869*	0.857*	0.674	0.869*	0.821*	0.030
	(0.484)	(0.484)	(0.503)	(0.484)	(0.488)	(0.536)
number of jobs, 2014	0.004	0.004	0.004	0.004	0.004	0.003
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
HHI employment, block group, 2014	-0.008**	-0.007**	-0.011***	-0.008**	-0.007**	-0.009***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Hi-tech employment share, 2014	2.442**	2.443**	2.519**	2.442**	2.452**	2.915***
	(0.984)	(0.984)	(0.988)	(0.984)	(0.985)	(1.011)
opportunity or enterprise zone	103.932***	103.862***	113.501***	103.932***	103.993***	104.172***
	(12.740)	(12.741)	(13.207)	(12.740)	(12.756)	(13.410)
N	3432	3431	3290	3432	3427	3198
Cragg-Donald F	145.746	145.960	135.730	145.746	145.874	136.002
Kleibergen-Paap rk Wald F	132.123	132.198	122.341	132.123	132.215	119.771
Outlier removal	None	Bonferroni	Top/bottom	None	Bonferroni	Top/bottom

This table shows the first-stage regression results from the survival rate regressions where the percent change in business download speed is endogenous. Exogenous instruments are the meters squared of tree canopy coverage in the census block group in 2001 and the maximum terrain roughness index in the census block group in 2000. The Cragg-Donald and Kliebergen-Paap rk Wald F statistics for instrument strength are reported. The row labeled 'Outlier removal' denotes how the sample size was trimmed base on extreme values in the outcome variable. Standard errors are show in parantheses and are clustered at the census tract and county dimensions. All models include an unreported constant term. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.