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The Impact of Broadband on Economic Activity in Rural Areas: Evidence from German Municipalities

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The Impact of Broadband on Economic Activity in Rural Areas: Evidence from German Municipalities

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The Impact of Broadband on Economic Activity in Rural Areas: Evidence from German Municipalities*

Abstract

This paper investigates the impact of broadband availability on economic activity as measured by local employment rates. Using panel data on broadband coverage in 8,460 West German municipalities for the period from 2005 to 2009, we find, in fixed effects regressions, an overall positive, but economically rather limited, relationship between local employment and local broadband infrastructure. The effect is larger in rural municipalities and is likely to stem from the service sector.

JEL Code: L96, O1, O2, R23.

Keywords: Broadband, local economic development, local employment.

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1 Introduction

Today, most OECD countries are engaged in expanding ICT infrastructure to their so-called white spots, which are predominantly rural municipalities that have so far remained largely unprovided by the market without government intervention. For example, between 2008 and 2013, in an effort to promote broadband Internet as a source of growth in Germany, a total of 454 million from European, national, and federal state funding has been made available to German municipalities to close white spots, which chiefly occur in rural areas. In its 2009 Broadband Strategy, the German Federal Ministry of Economics and Technology (BMWi) identified broadband Internet as a crucial location factor in securing jobs and even creating workplaces by attracting businesses to rural areas.¹ In addition, local decision makers, especially in smaller communities, seem to have high hopes in regard to the effects of broadband infrastructure and actively engage in its expansion. According to a recent survey in Germany, local politicians expect to keep businesses from relocating, and to attract new businesses, if the municipality can offer broadband infrastructure (Mücke & Sturm, 2010).

Even though it appears to be widely believed that broadband infrastructure will boost local economies and labor markets, theory and empirical evidence on the effect of ICT in rural areas is far less certain. The positive effects of broadband Internet are undisputed from a macroeconomic perspective; however, it is less clear how these benefits are distributed within an economy on a regional or even local level. Two widely accepted hypotheses make contradictory predictions as to how much rural regions profit from broadband Internet. On the one hand, broadband infrastructure considerably lowers the transport costs for large batches of information and therefore allows for interplay between physically separated economic agents, even over large distances. Indeed, it is even claimed that broadband Internet, and the applications it enables, will be the "death of distance" (Cairncross, 1997) and over-proportionately foster economic growth in rural areas. On the other hand, it is argued that information and communication technologies (ICT), in general, complement certain factors prevailing in larger cities, such as a highly qualified workforce (see e.g. Autor et al., 2003). According to this argument, rural areas might receive only limited benefits

¹In addition, nation-wide broadband infrastructure is seen as a means of ensuring equivalent living conditions throughout the regions, as anchored in the German Constitution.

from broadband infrastructure.

We analyze the impact of comprehensive broadband infrastructure on local economic development as measured by local employment patterns. This paper contributes to the existing literature in that we first make use of the dataset's panel structure, thus providing a credible estimate of the relationship between broadband infrastructure and local employment. Second, we concentrate on the economic benefits that broadband infrastructure confers on rural areas.

We focus on employment as a growth indicator since it most directly reflects a benefit to the local inhabitants compared to other indicators, such as local tax revenue or the number of local businesses. We combine municipality-based employment data from *Statistik Lokal*, the Regional Database of the German Federal Office of Statistics with detailed information from the *Breitband-atlas Deutschland* on broadband access rates at the municipality level, our variable of interest. We consider infrastructure availability as the most relevant variable, policy-wise, instead of broadband usage (even if the latter generates the benefits), since it can be influenced by policymakers and local politicians. Our study covers the years 2005 to 2009 and our sample includes 8,460 West German municipalities.

There are several challenges in identifying the effect of broadband on local employment, which are mostly due to possible endogeneity of infrastructure provision. Even after controlling for the main determinants of the supply of broadband infrastructure, there could be municipality characteristics that influence the provision of broadband infrastructure as well as the local labor market. One example of this is if a local government was negotiating to attract a business at the same time it was engaged in a broadband enhancement program. To solve for time-invariant municipality characteristics that might bias our results, we make use of the panel structure of our dataset and control for municipality fixed effects.

Our estimates suggest that broadband infrastructure does have a positive but, in terms of economic size, rather limited effect on the local employment rates in the sample that includes all municipalities. A 10 percentage point increase in local DSL availability increases the local employment rate by 0.03 percentage points. This effect is stronger and about three times larger in rural municipalities. In addition, we find no effects in the manufacturing sector, suggesting the effect occurs in the service sector. Our results are robust to the inclusion of various control variables. We chose controls in order to reflect local demand for broadband services and to control for the fact that

some local governments might actively engage in attracting business, which may be correlated with the employment rate as well as municipal broadband programs.

The paper proceeds as follows: in Section 2 we provide a short overview of the literature on how broadband infrastructure influences growth and employment. Sections 3 and 4 introduce the data and the identification strategy, respectively. Section 5 presents our results and Section 6 provides some discussion and concludes.

2 Related Literature

2.1 Broadband Infrastructure and Local Labor Markets

Broadband Internet has an undisputable impact on economic growth at the macroeconomic and regional levels. For example, Crandall et al. (2007) find a positive association between broadband deployment and private-sector nonfarm employment at the U.S.-state level. These effects are strongest for certain service industries such as finance, education, and healthcare. In a cross-country study covering the years 1996 to 2007, Czernich et al. (2011) employ a technology diffusion model to confirm a causal, positive impact of broadband infrastructure on growth in GDP per capita. According to their estimates, a 10 percentage point increase in broadband penetration leads to a 0.9-1.5 percentage point increase in annual per-capita growth that is likely to create employment effects.

The positive effects observed at the macro level may be due to ICT's impact on labor demand as well as on labor supply in local markets. Various studies confirm a positive association between broadband deployment and economic activity at a less aggregate level (see, e.g., Bertschek et al., 2012; Gillett et al., 2006; Koellinger, 2006; Kolko, 2012), and in theory, there are multiple channels through which ICT can affect local labor demand. For example, ICT may affect the labor demand of already established firms. Fast Internet is the sort of technology shock that could increase these firms' productivity and thus their demand for labor. Koellinger (2006) finds that ICT use is positively associated with firm-level innovation, which in turn increases productivity growth and firms' demand for labor. A study by Bertschek et al. (2012) investigates the impact of broadband usage

on firm-level performance in the early phase of DSL expansion. The authors find that firms with DSL usage were more likely to make a process or a product innovation. Such increased performance might translate into higher labor demand. On the other hand, however, ICT might have a negative effect on employment since the new technology may facilitate the use of less labor (OECD, 2008). The overall employment effect would thus depend on which dominates—labor substitution or the income effect.

Another possible channel through which broadband may affect employment is the settlement of firms in an area. Broadband infrastructure might affect their location decisions *ex ante*, which would increase demand for labor in a region. In theory, these may be newly founded enterprises, new branches of already existing firms, or even relocating firms. A study by Mack et al. (2011) finds that broadband provision explains some decisions by knowledge-intensive industries to locate in U.S. metropolitan areas. Gillett et al. (2006) conclude from their study that U.S. communities that had broadband by 1999 experienced higher growth in employment and in the number of businesses from 1998 to 2002 than other communities.

As to how broadband Internet impacts labor *supply*, note that not only firms, but also households may make decisions based on its availability. In general, ICT advancement is assumed to increase telecommuting (see, e.g., Autor, 2001) and this may be especially relevant for rural areas. People who live in remote areas and who previously may have faced prohibitively high commuting costs might choose to enter the labor market when they have access to broadband Internet because it allows them to work from home. However, broadband availability does not necessarily induce growth in total (nation-wide) employment since employees who previously commuted to work might also choose to work from home. Thus, enhanced broadband provision might simply shift labor from metropolitan areas into more rural areas, not actually increase total employment. However, to date, these possibilities have not been empirically confirmed. Indeed, based on data from a U.S. household survey, Kolko (2012) finds no evidence of a positive relationship between broadband provision and telecommuting.

Additionally, it is suggested that broadband might improve job matching between employees and firms in that it reduces asymmetries and lowers the costs of job search (see, e.g., Autor, 2001; Stevenson, 2009). One empirical study by Mang (2012) states that individuals who found their workplaces via the Internet have higher job satisfaction than individuals who found work via other

means such as newspapers. Mang states that this finding is due to the Internet providing better job matching quality. Still, in the context of rural areas, the overall effect of better job matching on economic activity in municipalities is ambiguous. Since an individual's job search radius is likely to become larger as he or she gains access to broadband Internet, the individual may move to other municipalities, or even find work abroad. Structurally weak municipalities thus might lose workers since it is easier for them to find jobs elsewhere, whereas economically booming municipalities might benefit. This again suggests that rural areas may benefit differently from the provision of broadband than do urban areas.

2.2 The Impact of Broadband in Rural Areas

Although there is a steadily increasing amount of literature on how broadband affects the labor market, very few studies consider heterogeneity in the effects of ICT by types of municipality. In general, broadband effects are expected to be heterogeneous for urban and rural municipalities. The economic literature offers two seemingly contradictory hypotheses as to how broadband availability and usage will impact rural areas.

First, according to the "death of distance" argument (see, e.g., Cairncross, 1997), small municipalities should benefit over-proportionately from broadband usage. Broadband technology considerably reduces transport costs for the exchange of information, thus reducing the importance of agglomeration advantages for firms and citizens. In addition, broadband Internet offers a new channel of distribution. Firms that formerly operated in local markets only can serve a wider customer base via the Internet and exploit more distant markets. Indeed, there is some empirical evidence that supports the death of distance argument. Ioannides et al. (2008) find robust evidence that an increase in the number of local telephone lines per capita leads to a more concentrated distribution of U.S. city populations. The authors conclude that this necessarily leads to more dispersion in the spatial distribution of economic activity, which takes the form of a shifting economic activity away from large cities and toward less urban areas. In a recent study, Kolko (2012) discovers a positive relationship between broadband expansion and employment growth. The effect is stronger for less densely populated areas, thus confirming the theory of spatial dispersion.

The second strand of literature on how broadband will impact rural communities (see, Autor

et al., 2003; Michaels and Reenen, 2011) concludes that ICT-related technologies actually over-proportionately benefit urban areas. Broadband Internet facilitates the exchange of information and therefore enables a more efficient production of knowledge. ICT usage is therefore complementary to human capital. Given that high-skilled labor is concentrated in large cities, it may well be that broadband technology has only a small, or even no, impact in remote areas. For example, Forman et al. (2012) relate advanced Internet technology to significant employment growth, but only in areas that already had a large and highly skilled population, high income, and IT usage before the expansion of broadband.

3 Data

The sample under investigation includes all 8,460 West German municipalities that could be followed over time in the dataset, that is, those that did not amalgamate during the period from 2005 to 2009. East German municipalities had to be excluded due to a high degree of amalgamations during the observation period.

3.1 Broadband Measure

Our municipality-level broadband data are from the *Breitbandatlas Deutschland*, an annual survey by the Federal Ministry of Economics and Technology that was launched in 2005. The data are comprehensive and provide detailed information at the municipality level. They also form the basis of the German government's broadband strategy and policies. The information is based on reports by the largest Internet providers in a municipality.

Our broadband measure is defined as the share of households per municipality that could technically receive DSL services. We restrict the analysis to DSL since it is by far the most common broadband technology in Germany (see Figure 1). According to a survey conducted by TNS Infratest in 2005, 96.3 percent of responding Internet users have either DSL or the non-broadband ISDN or the equally non-broadband analogue modem installed at home. Even though the latter two are declining, the three technologies still account for 91.2 percent in 2009 (TNS Infratest, 2009). The share of broadband Internet access increases over time at the cost of the non-broadband technologies ISDN

and analogue modem and DSL emerges by far as the dominant access technology. Alternative technologies for broadband Internet access were practically nonexistent in 2005, the largest being cable modem at 1.6 percent. In 2009, cable modems were used to access the Internet by 4.7 percent of Internet users.

A household is considered to have broadband access if there was a downstream transfer rate of at least 384 kbit/s at the time the service was activated (i.e., the household had chosen to subscribe to DSL). The data in Table 1 show that in 2005, broadband was already widely available in German municipalities. Still, there is considerable variation in the *dsl* variable in the cross-section as well as over time. In each period, its values range from 0 to 100% coverage of households. Figure 2 illustrates the mean distribution of broadband availability in the municipalities during the observed time period. In 2005, the mean availability per jurisdiction was at 76 percent; in 2009 it was 92 percent.

We cannot observe actual broadband use in our data. Even though it is the take-up and use of technology, rather than the mere availability of it, that generates economic effects, we consider our broadband measure as the more policy relevant variable since it can be actively influenced by politicians. Moreover, residential broadband coverage directly affects the DSL availability for firms. Eighty-two percent of German firms depend on local DSL networks; only large firms can afford their own private access to the Internet. We therefore conclude that our broadband measure not only reflects residential, but also (at least small) firms', access to broadband Internet.

3.2 Socioeconomic Data

We combine the information on broadband availability with employment data from *Statistik Lokal*, the official statistics on German municipalities by the Federal Office of Statistics. We focus on employment as an indicator of local economic activity since it most directly reflects a benefit to the local inhabitants. The dependent variable is thus the number of employees in a municipality who are subject to social insurance contributions. This includes all workers, employees, and trainees whose monthly earnings exceed 400 Euros on average.² Employees are counted based on where

²Not included in the variable are the self-employed, family members working on a voluntary basis, civil servants and the short-term employed

they work, not where they live, and thus the variable reflects the economic activity of local firms. To remove scale dependency, the variable is reported in relation to the potential work-force, defined as the working-age population in a municipality, that is, those between 20 and 65 years. The dependent variable is therefore measured in percentages. It will be zero if no employees are registered to work in the respective municipality. In our sample, this is the case for 120 municipalities on average. The variable can take values greater than 100 percent if more people work in a municipality than are registered to live there, that is, a large share of the working population commutes to the municipality. This mostly occurs in smaller municipalities home to larger enterprises. As shown in Table 1, the unweighted average of the local employment share increases on average over time from 28.5 percent in 2005 to 30.45 percent in 2009. These seemingly small values are due to the concentration of economic activity in some (urban) areas, such that many municipalities have net out-commuters, whereas relatively few have net in-commuters.

Other variables that reflect local heterogeneity, such as population size, municipality area, business tax rates, and the industrial area are also provided by the Federal Office of Statistics. Based on tax competition theory, we include local business tax rates and the size of the industrial area since local governments may use these measures to actively attract business and promote economic activity. For ease of exposition, industrial area is expressed in terms of population size. The local business tax rate, a multiplier of the tax base, is scaled in percent (see Table 1). In addition, Table 1 reports the municipality's distance to the next regional metropolis, which serves as an indicator for how remote or rural a municipality is. The term "regional metropolis" describes a city with a high degree of centrality that is of special importance for its surrounding region in terms of facilities and infrastructure. The classification is made by the regional planning offices of the Federal States; common criteria are the existence of specialized hospitals, academic institutions, or museums. The variable is calculated as the linear distance between a municipality center, which is defined as the geographic location with the highest population density within each jurisdiction, and the center of its closest regional metropolis. The variable takes the value zero if the municipality is a regional metropolis itself. The distribution of distance to the next regional metropolis is shown in Figure 3.

4 Estimation Approach

We make use of the dataset’s panel structure and employ a model with time and municipality fixed effects. The equation we estimate is

$$e_{i,t} = \alpha + \beta dsl_{i,t} + X_{i,t}\gamma + u_i + c_t + \epsilon_{i,t} \quad (1)$$

We are interested in the causal effect of broadband infrastructure on local employment. The municipality fixed effects account for time-invariant unobserved heterogeneity. However, the estimates may still be biased by the presence of unobserved time-varying variables if such have an influence on broadband coverage as well as on the outcomes. In what follows, we discuss how endogenous local broadband coverage may affect the results.

In general, we expect to overestimate the effect of broadband infrastructure on employment due to reverse causality (see, e.g., Kolko, 2012). The spread of broadband infrastructure is largely market based, that is, its provision is based on profit-maximizing considerations of the providers. Spatial differences in broadband availability arise from expected local demand as well as the costs of supplying it. Regions with low per capita fixed costs and high expected demand have the highest broadband penetration rates. Excavation work is the most expensive part of providing broadband infrastructure and it is a fixed cost. Therefore, the more people who can be served, and the shorter the cable lengths needed (i.e., the higher the population density), the lower the per-capita costs. To account for this market force in our analysis, we include population density as a strong indicator of broadband supply.

Another reason why the effect of broadband infrastructure might be overestimated relates to time-varying unobserved heterogeneity in the local economic politics. A steadily increasing number of municipalities build their own local broadband infrastructure. Such local governments are likely to engage in other public infrastructure projects, as well as work to actively attract business, thereby directly influencing demand for labor in the region. We therefore include in our regression the local business tax rates and the industrial area as proxies for local government involvement. The local business tax rates reflect the extent to which a local government engages in tax competition to attract business to the region (see, e.g., Wilson, 1999). Allotting area to industry is another means that local governments can use to attract business and stimulate the local economy.

This paper analyzes the benefits to rural municipalities from broadband Internet. We therefore provide estimates for subsamples of increasingly rural municipalities. In accordance with the death of distance theory, we sort municipalities by their distance to the geographically next regional metropolis. The interest in sorting municipalities by their distance to the next regional center is twofold. First, it captures the physical distance between a municipality and the next large city and therefore the extent of agglomeration benefits the municipality may enjoy. Second, it acts as a proxy for local human capital, since regional centers are defined as such by the presence of universities and technical colleges. The subsamples are constructed based on quartiles of the distance distribution. Another way a municipality's rurality can be reflected is by its population density. To support our estimates based on subsamples sorted by distance to the next regional metropolis, we additionally provide estimates in which municipalities are sorted according to population density. Based on findings in previous studies, we expect broadband Internet to generate most benefits in terms of employment for the service sector. To gain further insight into how the benefits of broadband are absorbed in the economy, we would like to be able to distinguish between effects by industrial sector. Unfortunately, the employment data are not available by industrial sectors. However, since the official statistics do report employment in the manufacturing sector in addition to total employment, we can provide additional estimates for employment in the manufacturing sector.

5 Estimation Results

This section presents empirical results on the association between broadband infrastructure and local employment. We show results for the full sample of West German municipalities as a benchmark and then present results for municipalities with increasing degrees of rurality based on distance to next metropolis and population density. Robustness tests of the estimates are also provided.

Table 2 shows the baseline results for the effect of broadband on the employment rate in the full sample. Column (I) reports pooled OLS estimates as a benchmark for the fixed effects estimations in Columns (II) to (V). The effects of broadband Internet on local employment in Column (I) are considerably reduced if we control for municipality and time fixed effects. This confirms that local broadband penetration is positively correlated with time-invariant municipality characteris-

tics, which would lead to a considerable overestimation of the effect of *dsl* if not controlled for. The *dsl* coefficient in Columns (II) to (V) is positive and significant at the 10 percent significance level. A 10 percentage point increase in households' broadband availability is associated with a 0.039 (Column (V)) percentage point increase in the employment rate. This result is robust to the inclusion of population density, the local business tax rate, and the industrial area per capita; none of these change the coefficient of *dsl* significantly. All these control variables are highly significant and have the expected signs. Population density is negatively correlated with our measure of the employment rate, since in most municipalities people on average are net out-commuters. With the FE estimations we use within variation of municipalities and find that if, over time, one more person moves to the municipality but does not work there (as is on average the case for most municipalities), he or she will lower the dependent variable. The tax rate is negatively correlated with local economic activity, which is in accordance with standard tax competition theory. The size of the industrial area has a positive association with employment since more businesses can settle in the municipality if the industrial area increases.

Table 3 shows the effect of broadband on subsamples of municipalities sorted by distance to the next regional center. We find no statistically significant relationship between the employment rate and broadband availability for municipalities in the first to third quartile of the distribution. However, for municipalities above the fourth quartile, that is, those that are more than 32 kilometers away from the next regional center, there is a strong and statistically significant effect of *dsl*. For these municipalities, a 10 percentage point increase in *dsl* increases the local employment rate by 0.15 percentage points—a relatively large effect compared to the coefficient of 0.039 percentage points in the total sample. These results support the death of distance theory, since they indicate that remote municipalities over-proportionately benefit from broadband Internet whereas municipalities with high degrees of human capital—approximated by the presence of academic institutions—do not. These results are further reinforced by findings from our second measure of rurality, namely, population density, as can be seen in Columns (IV) to (VI) of Table 3. While we find no effects of broadband in the first to third quartiles of the density distribution, municipalities above the fourth quartile exhibit an increase in the employment rate of about 0.1 percentage points in response to a 10 percentage point increase in broadband availability.

The fact that we do not find a positive effect of broadband in more urban areas does not neces-

sarily imply that one does not exist. For example, it is possible that there is simply not enough variation in dsl in the concerned areas to identify the effect. In 2005, our first year of observation, broadband had already reached considerably high levels such that there was not much room for further spread in urban areas. In addition, the effect of dsl might be nonlinear, meaning that an increase in broadband might have a larger effect between 0 and 10 percentage points than between 90 and 100 percentage points. Therefore, in the following we refrain from interpreting the effect of broadband infrastructure in urban areas.

Arguably, the effect of broadband observed in rural areas might be confounded with the temporary employment impact of actually building the infrastructure, for example, the necessary excavation work. If this were the case, it would lead to an overestimation of our dsl coefficient. We rule out this possibility since firms that provide the DSL infrastructure are specialized firms that typically bring their own workers with them to do the excavation work and thus are unlikely to generate employment in the concerned municipality.

Toward the end of the observation period—in 2008—the federal government launched an initiative to provide matching grants to municipalities that were as yet without broadband access. Since this program coincided with an economy-wide economic stimulus package, it could be argued that the effect of broadband might actually be underestimated, since the eligible municipalities are predominantly in rural, less densely populated areas with presumably lower demands for broadband services. This can be seen in the second panel of Table 1, where descriptive statistics for municipalities without broadband in 2005, the so-called white spots, are provided. Nevertheless, we are confident that, for the time period considered here, the effects of broadband cannot be confounded with these infrastructure programs. Even though the program was announced in 2008, the take-up of funding and the actual public provision of broadband infrastructure did not actually occur for quite some time. In 2012, the German Federal Ministry of Economics and Technology stated that municipalities had been reluctant to take advantage of federal funding for providing broadband (BMW_i, 2012). We thus conclude that the government program does not affect our data.

To more specifically determine where the positive effects occur, it would be preferable to distinguish employment effects in specific industrial sectors; however, the official statistics only report the number of employees in the manufacturing sector. We therefore choose the local employment rate

in the manufacturing sector as an alternative dependent variable. Table 4 shows the results for all observations and subsamples. We find no effect in the full sample (Column (I)). The table also provides findings for subsamples in the manufacturing sector, analogous to Table 2. We find that *dsl* has no effect on employment in the manufacturing sector in rural areas. This matches our expectations, since the effects we find in the total employment rate are thus most likely to stem from the service sector.

6 Discussion and Conclusion

In contrast to the extant literature on broadband infrastructure, we find no overall economically meaningful effects of broadband availability on local economic activity for the full sample of municipalities. A 10 percentage point increase in broadband availability is associated with a 0.03 percentage point increase in the employment rate. Compared to an average employment rate of about 30 percentage points (see Table 1), this puts the overall economic benefits into perspective. However, when distinguishing by the degree of a municipality's rurality, we find evidence that remote and less densely populated areas benefit most from broadband infrastructure. The effect is considerably larger compared to that found in more urban areas. A 10 percentage point increase in broadband availability in rural areas is associated with a 0.09 to 0.15 percentage point increase in the local employment rate. These effects are not confounded by general economic stimulus packages that were launched during the period of observation, nor are they due to employment stemming from the actual building of the infrastructure, namely excavation work. Moreover, we find no employment effects in the manufacturing sector, indicating that the positive effects of broadband mostly manifest in the service sector.

Many of the studies that find a larger impact of broadband on economic activity use data from the early expansion phase of DSL. It may well be that the effect of broadband infrastructure was higher during that phase and that by 2005 broadband was already a widely available commodity in most municipalities. If the intensive margin becomes very small close to the saturation point, the relationship between broadband infrastructure and economic benefits would be non-linear. Another reason for our results being different from those of previous studies could involve the panel structure of the data, which allows including municipality fixed effects. As discussed above, these

estimations considerably lower the effect of broadband infrastructure.

This study may not capture activity in larger companies, since residential broadband is expected to be a good proxy for broadband Internet availability only in smaller enterprises that cannot afford their own infrastructure. Moreover, we cannot observe actual broadband use in our data, even though it is the take-up and use of technologies rather than their mere availability that generates the economic effects. The results presented here, therefore, represent a lower boundary on the effect of broadband on local employment. Nevertheless, we consider this variable most relevant for policy advice since residential broadband availability is a variable of direct political concern and can be actively influenced by the government.

This study provides helpful insight into the benefits of broadband infrastructure in rural areas, but several important questions remain: Since medium-sized and large businesses are able to buy or rent customized infrastructure, our broadband measure does not capture ICT use in large companies. In addition, broadband infrastructure may affect economic activity and the labor market in dimensions other than employment rate, for example, it could have an impact on home-based work and telecommuting. Also the presented results are short- to mid-term effects. Local infrastructure might also have longer-term effects. We cannot provide answers to these important questions with the available data and must leave them for future research.

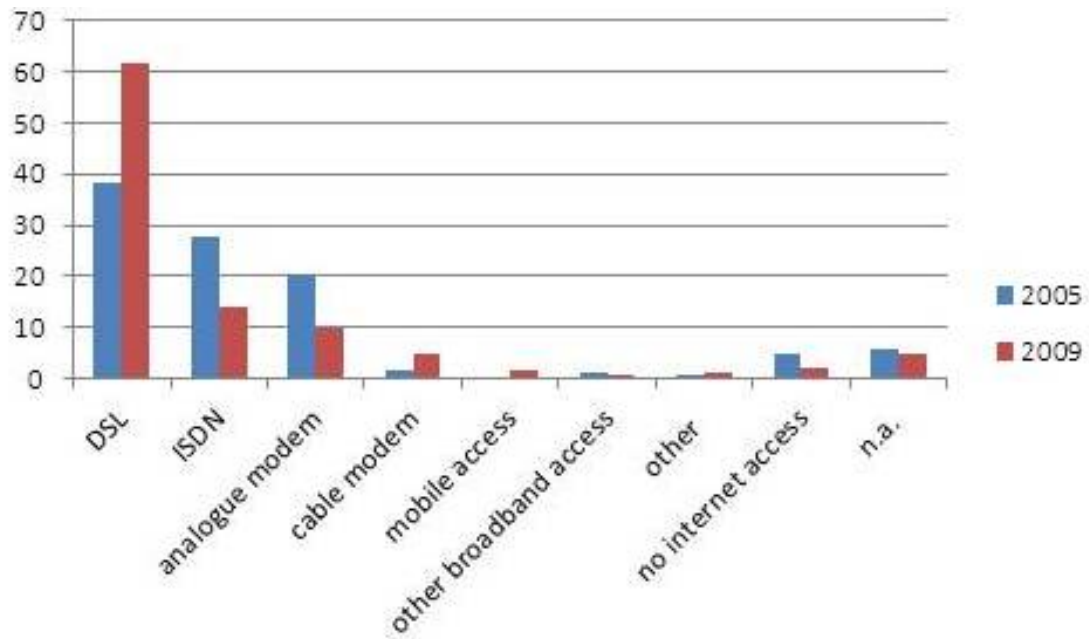
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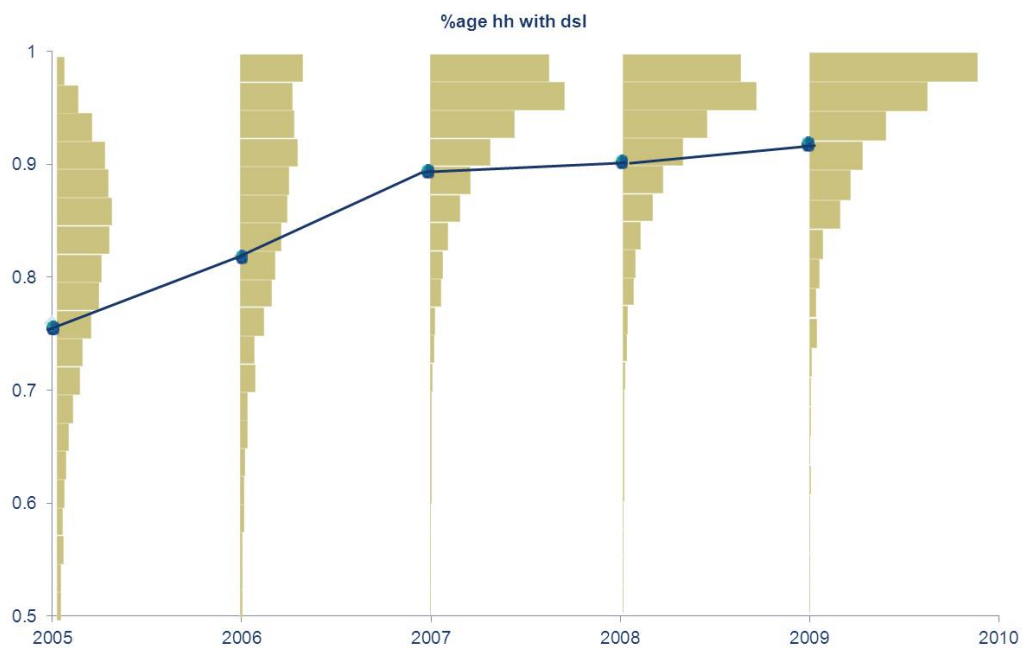
Figures and Tables

Figure 1: The development of Internet access technologies in Germany



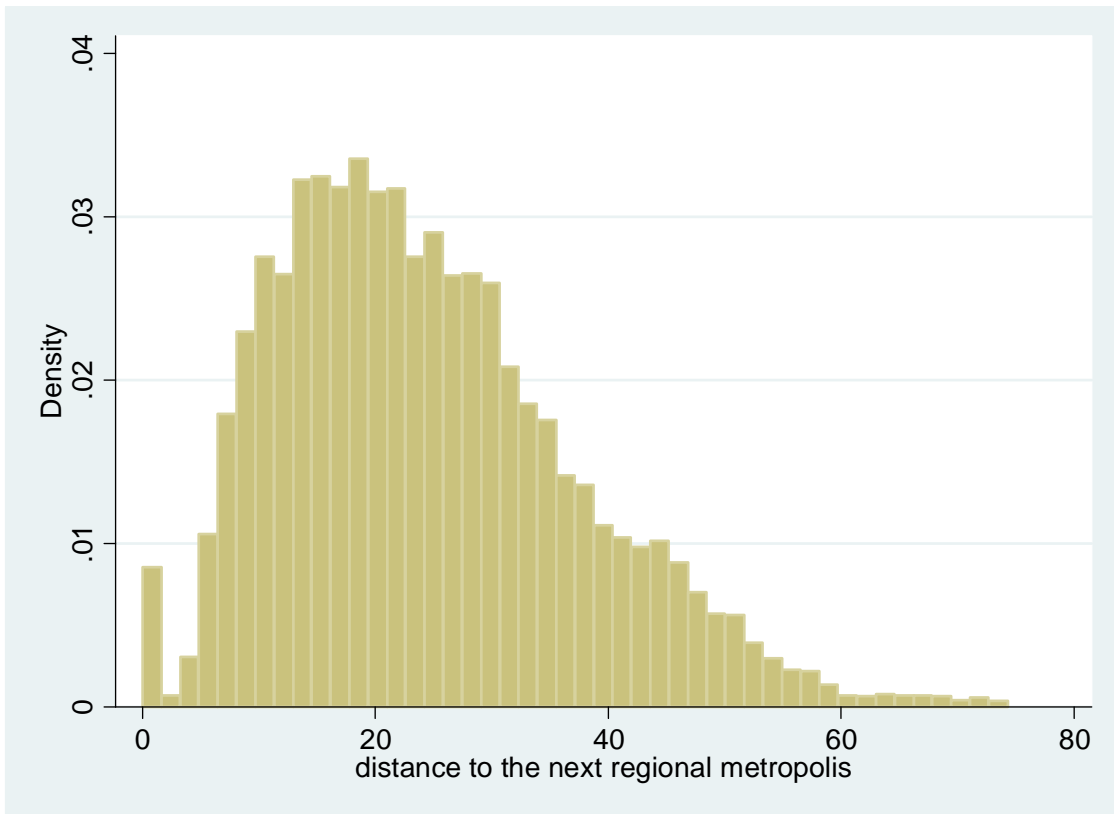
Note: Based on (N)Onliner Atlas by TNS Infratest (2005 and 2009).

Figure 2: The distribution of municipal broadband availability, by year



Note: Own calculations based on *Breitbandatlas Deutschland* (2005-2009).

Figure 3: The distribution of distance to the next regional metropolis



Note: Own calculations based on distances between municipality centers as of 2008. Municipality centers are points with the highest population density within a municipality.

Table 1: Descriptive statistics

| | | 2005 | | 2009 | |
|--|------------|-------------|------------------|-------------|------------------|
| all Municipalities | Obs | Mean | Std. Dev. | Mean | Std. Dev. |
| employment rate (in %) | 8460 | 28.50 | (26.65) | 30.45 | (31.44) |
| share of households with DSL | 8460 | 0.75 | (0.21) | 0.92 | (0.14) |
| population size | 8460 | 7,691.06 | (36,269.08) | 7,659.51 | (36,809.84) |
| area (in km^2) | 8460 | 28.71 | (34.07) | 28.71 | (34.07) |
| population density (per km^2) | 8460 | 208.67 | (291.90) | 207.08 | (292.86) |
| tax rate (in%) | 8460 | 338.34 | (31.39) | 341.39 | (31.62) |
| industrial area (m^2 per capita) | 8460 | 37.44 | (560.66) | 38.19 | (332.88) |
| distance to reg.center (in km) | 8460 | 24.40 | (12.79) | 24.40 | (12.79) |
| initially unprovided municipalities | Obs | Mean | Std. Dev. | Mean | Std. Dev. |
| employment rate (in %) | 357 | 16.57 | (26.40) | 18.02 | (30.18) |
| share of households with DSL | 357 | 0 | (0) | 0.55 | (0.44) |
| population size | 357 | 649.10 | (636.66) | 634.01 | (625.52) |
| area (in km^2) | 357 | 11.93 | (12.84) | 11.94 | (12.84) |
| population density (per km^2) | 357 | 71.34 | (77.51) | 69.67 | (78.75) |
| tax rate (in%) | 357 | 337.13 | (27.76) | 339.56 | (26.51) |
| industrial area (m^2 per capita) | 357 | 28.14 | (67.92) | 30.21 | (73.06) |
| distance to reg.center (in km) | 357 | 33.07 | (12.86) | 33.07 | (12.86) |

Note: The first panel presents descriptives for all municipalities contained in the full sample. The second panel shows descriptives for municipalities with zero broadband coverage in 2005.

Table 2: The effect of broadband availability on local employment

| | (I) | (II) | (III) | (IV) | (V) |
|-------------------------------|---------------------|---------------------|-----------------------|-----------------------|-----------------------|
| dsl | 3.974*** (0.177) | 0.370* (0.207) | 0.368* (0.207) | 0.389* (0.207) | 0.385* (0.207) |
| density | | | -0.0245*** (0.005) | -0.0246*** (0.005) | -0.0241*** (0.005) |
| tax rate | | | | -0.0165*** (0.004) | -0.0164*** (0.004) |
| industrial area (p.c.) | | | | | 175.9*** (20.763) |
| Year FE | | yes | yes | yes | yes |
| municipality FE | | yes | yes | yes | yes |
| constant | 26.19*** (0.338) | 28.22*** (0.163) | 33.40*** (0.990) | 39.00*** (1.551) | 38.29*** (1.552) |
| Observations | 41,605 | 41,605 | 41,605 | 41,605 | 41,605 |
| No. of municipalities | 8,321 | 8,321 | 8,321 | 8,321 | 8,321 |
| R-squared | 0.014 | 0.043 | 0.043 | 0.044 | 0.058 |

Note: Estimations are based on the full sample. The dependent variable is the local employment rate. * p < 0.10; ** p < 0.05; *** p < 0.01.

Table 3: The effect of broadband availability on local employment, by subsamples

| | Distance to reg. metropolis (in km) | | | Population density (per km^2) | | |
|-------------------------------|-------------------------------------|--------------------------|-----------------------|----------------------------------|-----------------------|----------------------|
| | [> 225.37] | [\leq 225.37; >64.11] | [<64.11] | [< 14.68] | [14.68; 31.80] | [> 31.80] |
| | (I) | (II) | (III) | (IV) | (V) | (VI) |
| dsl | 0.594 (0.377) | -0.392 (0.268) | 1.532*** (0.472) | -0.183 (0.438) | 0.334 (0.322) | 0.986*** (0.381) |
| density | -0.0218*** (0.005) | -0.0216*** (0.008) | -0.0394*** (0.014) | -0.0181*** (0.004) | -0.0566*** (0.014) | -0.320*** (0.057) |
| tax rate | -0.0394*** (0.005) | -0.00644 (0.005) | -0.0105 (0.009) | -0.0340*** (0.005) | -0.0210*** (0.006) | 0.000152 (0.007) |
| industrial area (p.c.) | 219.2*** (53.856) | 302.3*** (31.443) | 97.53*** (37.567) | 541.3*** (73.905) | 262.6*** (38.726) | 125.7*** (31.626) |
| Year FE | yes | yes | yes | yes | yes | yes |
| municipality FE | yes | yes | yes | yes | yes | yes |
| constant | 52.27*** (2.532) | 33.57*** (2.098) | 32.51*** (3.290) | 62.92*** (2.808) | 40.27*** (2.667) | 29.77*** (3.356) |
| Observations | 10405 | 20800 | 10400 | 10,401 | 20,803 | 10,401 |
| R-squared | 0.128 | 0.056 | 0.023 | 0.152 | 0.046 | 0.026 |
| No. of municipalities | 2,080 | 4,160 | 2,080 | 2,080 | 4,160 | 2,080 |
| Percentiles | 0 - 25 | 25 - 75 | 75 - 100 | 0 - 25 | 25 - 75 | 75 - 100 |

Note: Subsamples in columns (I) to (III) are based on population size and in columns (IV) to (VI) on the distance to the next regional metropolis. The dependent variable is the local employment rate. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table 4: The effect of broadband availability on local employment in the manufacturing sector, by subsamples

| | full sample | Population density (per km^2) | | | Distance to reg. metropolis (km) | | |
|-------------------------------|----------------------|----------------------------------|--------------------------|---------------------|----------------------------------|-----------------------|----------------------|
| | | [> 225.37] | [\leq 225.37; >64.11] | [<64.11] | [< 14.68] | [14.68; 31.80] | [> 31.80] |
| | (I) | (II) | (III) | (IV) | (V) | (VI) | (VII) |
| dsl | 0.099 (0.071) | 0.379 (0.253) | 0.280** (0.131) | 0.017 (0.049) | 0.039 (0.204) | 0.144 (0.111) | 0.067 (0.089) |
| density | -0.007*** (0.002) | -0.009*** (0.002) | 0.012** (0.006) | 0.001 (0.007) | -0.010*** (0.002) | 0.000 (0.003) | -0.009*** (0.002) |
| tax rate | -0.004*** (0.001) | -0.007** (0.003) | -0.005** (0.002) | -0.000 (0.001) | -0.003 (0.003) | -0.005** (0.002) | -0.003* (0.002) |
| industrial area (p.c.) | 36.280*** (7.033) | 155.874*** (43.307) | 115.575*** (17.265) | 8.116** (3.950) | 242.086*** (33.150) | 54.492*** (14.012) | 13.061* (6.697) |
| Year FE | yes | yes | yes | yes | yes | yes | yes |
| municipality FE | yes | yes | yes | yes | yes | yes | yes |
| constant | 8.990*** (0.543) | 19.385*** (1.654) | 6.075*** (1.088) | 1.083*** (0.414) | 12.533*** (1.392) | 8.040*** (0.903) | 6.167*** (0.602) |
| Observations | 30,010 | 7,510 | 14,234 | 8,266 | 7,276 | 14,844 | 7,890 |
| R-squared | 0.230 | 0.122 | 0.061 | 0.001 | 0.062 | 0.039 | 0.030 |
| No. of municipalities | | 2,080 | 4,160 | 2,080 | 2,080 | 4,160 | 2,080 |
| Percentiles | all | 0 - 25 | 25 - 75 | 75 - 100 | 0 - 25 | 25 - 75 | 75 - 100 |

Note: Subsamples in columns (II) to (IV) are based on population size and in columns (V) to (VI) on the distance to the next regional metropolis. The dependent variable is the local employment rate in the manufacturing sector. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

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