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Does State Aid for Broadband Deployment in Rural Areas Close the Digital and Economic Divide?

Abstract

We evaluate the impact of a major European state aid programme for broadband deployment applied to rural areas in the German state of Bavaria in the years 2010 and 2011. Using matched difference-in-differences estimation strategies, we find that aided municipalities have – depending on broadband quality – between 18.4 and 25.4 percentage points higher broadband coverage than non-aided municipalities. This increase in broadband coverage, closing the digital divide, results in an average increase of six employed individuals living in the respective aid-receiving municipalities while leaving the number of employed (measured at the place of work) or self-employed individuals and wages unaffected. We therefore conclude that an increase in broadband coverage through state aid protects rural areas from depopulation, but does not contribute to a further closing of the economic divide in the form of creating new jobs.

JEL-Codes: D620, D730, G380, H230, J230, K230, L520, L960, L980, R230.

Keywords: government policy, state aid, ex-post evaluation, broadband, employment, rural areas, European Union, Germany, Bavaria.

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1 Introduction

The interrelationship between various types of infrastructure investment and economic development has fascinated generations of researchers. While there appears to be little dispute about the positive impact of the general provision of infrastructures such as transportation or communication networks for employment, innovation and growth[1], the question of the socially optimal degree of network deployment in general and the most suitable financing options in particular are much more controversial.

While, historically, the (seemingly) public good character of many infrastructures suggested their entirely public provision, the liberalisation processes in many network industries in the 1980s and 1990s broadened the financing options to entirely private or public-private investment projects. The public provision of infrastructures is more and more seen as limited to cases of market imperfection – i.e. situations in which market forces alone are unlikely to provide the socially optimal level of network deployment.[2]

In the European Union, the belief in the strategic importance of broadband infrastructures for economic development has long been affecting policy making. Although the European Commission aims at strengthening the incentives of private companies to invest in both the deployment of broadband infrastructures and subscriptions through the design and implementation of appropriate regulatory frameworks, since 2003 this general strategy has included the granting of state aid. This applies particularly to rural areas where the private investment incentives are considered insufficient due to the interference of large deployment costs and limited revenue potentials.

In fact, between 2003 and 2014, the European Commission approved in sum 136 state aid applications[3] – mostly from regions, but also entire (smaller) countries. This aid was given for the deployment of broadband networks in rural areas, aiming at closing the digital divide and triggering welfare-enhancing externalities that are expected from a well-established

1 See Röller and Waverman (2001) and Czernich et al. (2011) for the growth effects of communication networks.

2 It should be noted here that the identification of the socially optimal level of network deployment is a complex and therefore error-prone process. For example, it cannot be ruled out that a state authority decides to provide funding for an extension of a certain infrastructure to rural areas and later learns that only a small fraction of the respective individuals is interested in using (and paying for) it (thus suggesting an inefficient investment decision).

3 See http://ec.europa.eu/competition/sectors/telecommunications/broadband_decisions.pdf (last accessed on 24 January 2018) for a full list of Commission decisions on state aid to broadband.

broadband infrastructure as ‘general purpose technology’ (see Bresnahan and Trajtenberg, 1995).

We evaluate the impact of such a state aid programme for broadband deployment in the German state of Bavaria in the years 2010 and 2011 on broadband coverage and employment. This program was meant to bring speed upgrades to rural areas. We apply a difference-in-differences (DiD) estimation strategy based on a matched sample of 1,845 aided and non-aided rural municipalities. The matching technique guarantees common pre-treatment trends in the treatment and control group for broadband availability at lower bandwidths and balanced economic characteristics of treated and non-treated municipalities. We thus argue that in our matched sample applications for state aid were as-good-as random and were rather driven by the idiosyncratic preferences of local politicians for new technologies than by economic considerations.

We find that the state aid program was indeed effective, that is the policy contributed to closing the digital divide. Aided municipalities have - depending on broadband quality - between 18.4 and 25.4 percentage points higher broadband coverage than non-aided municipalities. We further find that in the short-run this increase in broadband coverage resulted in an average increase in the number of employed individuals living in the respective aid-receiving municipalities by about six individuals; however, neither the number of employed measured at place of work nor self-employed individuals nor the average wage shows any significant effect. We therefore conclude that an increase in broadband coverage attracts workers to live in these rural municipalities – or prevents them from depopulation, respectively – but without attracting additional economic activity necessary to close the economic divide (yet).

Our finding of overall zero effects of broadband deployment on employment (measured at the place of work) and wages is line with findings from quasi-experimental studies for Germany (Falck et al. 2014), Norway (Akerman et al. 2015), Italy (Canzian et al. 2015), UK (De Stefano et al. 2014) or the USA (Kolko 2012). We add to this literature by studying the effects of broadband deployment on employment at the place of living. Our finding that broadband deployment prevents rural areas from depopulation demonstrates that such a policy targeted at rural areas can reduce the negative externalities (through depopulation) of excess provision of public goods in agglomerations.

The remainder of the paper is organised as follows. The second section continues with a description of the institutional structure of broadband state aid in the European Union in general and its implementation in the German state of Bavaria in particular. The third section provides a detailed characterisation of our empirical strategy. The fourth section describes our data, followed by the presentation and discussion of our estimation results in section five. Section six concludes the paper with a review of its main results and the identification of avenues for future research.

2 Institutional Background on Broadband State Aid

According to Article 107 of the Treaty on the Functioning of the European Union (TFEU), granting state aid is generally prohibited unless it is justified by reasons of general economic development. Yet, for the case of telecommunications and broadband infrastructures, the European Union has long recognised its strategic importance in promoting the key objectives of creating common European markets in general and fostering economic development in the Member States in particular. In its Digital Agenda for Europe[4], the Commission therefore envisages concrete goals in the form of the nationwide coverage of broadband above 30 Mbit/sec and 50% of the households in the EU subscribed to broadband above 100 Mbit/sec by the year 2020.

In the year 2007, the German state of Bavaria[5] started the initiative ‘Broadband for Bavaria’, aiming at informing local municipalities about general possibilities to foster the deployment of broadband networks in rural areas. The initiative was motivated by slower broadband deployment in Bavaria compared to other German states, for reasons such as a lower population density, a high share of rural areas with numerous far-flung municipalities, and difficult topographical conditions with medium- and high-range mountains. Moreover, the divergence in broadband coverage between rural and urban regions was substantial.

Guided by the aim of providing equivalent working and living conditions in the entire state, in November 2007, the Bavarian government decided to support the deployment of broadband in rural areas from 2008 onwards (see Bavarian Ministry of Economic Affairs and Media, Energy and Technology, 2012). However the program did not jump-start. In 2008 and 2009,

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4 See https://ec.europa.eu/digital-agenda/en (last accessed on 24 January 2018) for further information.

5 In 2015, Bavaria generated a (nominal) GDP of about €550 billion, making it the second largest German state after North Rhine-Westphalia (with a GDP of about €646 billion). Although part of the Federal Republic of Germany, Bavaria therefore had a larger GDP than entire EU member states such as Austria (about €337 billion in 2015), Belgium (about €529 billion in 2014) or Poland (about €545 billion in 2014). Data sources: Statistical Offices of the Federation and the Länder and World Bank.

only 171 municipalities received state aid for broadband deployment. After the state election in 2008, the Bavarian government therefore decided in its coalition negotiations to increase the maximum amount of aid to €500,000 per municipality project. In the following, 1,300 municipalities received approval for funding by the end of 2011, that being about 63% of all Bavarian municipalities. The total funding amount provided by the public authorities added up to €107.6 million, about €83,000 per aided municipality. Funding was granted for feasibility studies and planning activities as well as for closing the profitability gap for network infrastructure deployment.

Figure 1 shows a map of Bavaria with the boundaries of its 2,056 municipalities. White indicates municipalities that did not receive any aid, light blue flags municipalities that received aid in the period between 2008 and 2009, and dark blue shows all municipalities that received broadband aid in the 2010 to 2011 period. As revealed by Figure 1, the white areas are distributed all over Bavaria and do not show apparent concentrations in particular areas of the state. However, important exceptions are the largest white areas – labelled in Figure 1 – that are either (densely populated) larger cities or (sparsely populated) alpine regions (in the south of Bavaria).

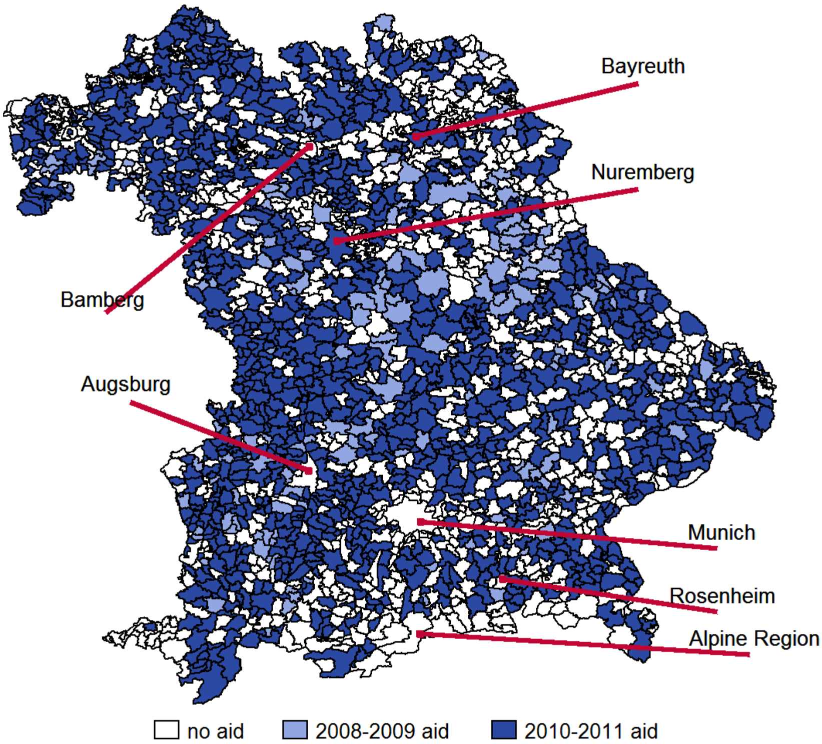


Figure 1: Aided and Non-Aided Municipalities in Bavaria

Data source: Bavarian Ministry of Economic Affairs and Media, Energy and Technology (2012)

3 Empirical Strategy

3.1 The Impact of State Aid on Broadband Deployment

In order to investigate check whether the state aid policy was effective, we first quantify the effect of state aid on broadband deployment; i.e., we estimate the following static equation (super indexed *s*) based on municipality-level panel data:

$$bb\_hh_{it}^{q} = \alpha^{sq} + \beta_1^{sq} D_2 + \beta_2^{sq} D_1 D_2 + \boldsymbol{X}_{it}^{DiD} \beta_3^{sq} + \theta_i^{sq} + \varepsilon_{it} \quad (1)$$

The outcome variable, $bb\_hh_{it}^{q}$, measures the share of household broadband coverage (i.e., availability on the supply side and not subscriptions on the demand side) in municipality *i* and in year *t* at various levels of bandwidth quality, super indexed *q*. θ_i^{s} captures municipality-specific fixed effects and ε_{it} represents the error term of the static specification. The inclusion of municipality fixed effects already captures a large share of the variation in broadband coverage, since most of the supply and demand factors show low variation over time (see also Akerman *et al*., 2015, p. 1796). Equation (1) is estimated separately for the different quality levels.

D_1 is a binary variable that indicates whether a municipality received treatment (state aid approved; D_1 = 1) in the funding period from 2010 to 2011. We exclude the 171 municipalities that received state aid in the years 2008 and 2009 since we lack information on broadband coverage at high bandwidths for these years. The variable D_2 is also binary and equals one if an observation belongs to the post-treatment period. The time window for our analysis ranges from 2010 to 2014. The treatment – i.e., the approval of state aid for broadband deployment – took place between 2010 and 2011. In view of planning rigidities, we do not believe to see program-induced roll-out in the approval year. We thus consider the year 2010 for approvals in the 2010 and the years 2010 and 2011 for approvals in 2011 as pre-treatment. Depending on whether a municipality received approval in 2010 or 2011, either 2011 or 2012 respectively is the first year after treatment. All subsequent years until 2014 define the post-treatment period for which D_2 equals one. Generally, the event window has to be long enough that changes in broadband infrastructure deployment related to state aid can be captured. However, it must also be short enough to avoid confounding effects from other changes that are not under control.

The coefficient of interest, however, is β_2^{sq}, the coefficient of the interaction term D_1D_2 which is equal to one if the observation was measured after the treatment period and the observation was treated. Hence, the DiD coefficient β_2^{sq} captures the average treatment effect over the years 2011/2012 to 2014. The matrix $\boldsymbol{X}_{it}^{DiD}$ contains time-varying covariates including the age structure of the population, share of females, population density, accessibility of motorways and regional cities, share of medium-sized firms, share of large firms, share of gross value added in secondary and tertiary sector, vote shares of CSU (Conservative) and SPD (Social Democrats) political parties in municipal elections.

Secondly, in order to explore the dynamics of the treatment effect in more detail, were are interested in estimating a 'dynamic' DiD regression. The dynamic (super indexed d) DiD regression framework for municipality i and year t with quality q is specified analogously to equation (1) and reads as follows:

$$bb\_hh_{it}^{q} = \alpha^{dq} + \sum_{t=1}^{4}(\beta_{1t}^{dq} D_t + \beta_{2t}^{dq} D_1 D_t\ ) + \boldsymbol{X}_{it}^{DiD} \beta_3^{dq} + \theta_i^{dq} + \mu_{it}^{q} \quad (2)$$

Instead of one interaction term in the static model, the dynamic model has four interaction terms, one for each year post treatment. In equation (2), t can take four distinct values corresponding to each year post treatment (the granting of state aid). Accordingly, instead of one dummy variable capturing the entire period after treatment, in the dynamic model, we include four different dummies controlling for each year after treatment individually. This dynamic specification traces out the full adjustment path and thus relaxes the assumption that the policy impact is immediate or the same in every year.

The key identifying assumption underlying the DiD estimator is that both the treated and the untreated municipalities would follow the same trend in the absence of the treatment (parallel trends assumption). In our regressions, we include a large number of covariates to control for factors that might lead to different trends across the two groups after treatment. To ensure that the treatment and control group municipalities are even more likely to show the same trend, we also relate the DiD estimator to a matched sample obtained from a propensity score matching (PSM) procedure. In the PSM, we include the above-mentioned set of controls measured in 2010 to capture pre-existing initial conditions. Additionally, we include the number of households in 2010, the type of municipality in 2010, average growth of rents in the years 2007–2009, and the average annual growth rate in coverage of 1 Mbit/s in the years 2007 to 2009, furthermore the initial deployment conditions, i.e. the availability of 2, 6 and 16 Mbit/s in 2010.

3.2 The Impact of Broadband Deployment on Employment

In a next step, we focus on the short-run indirect effects of broadband infrastructure on different employment-related outcome variables. For this purpose, we estimate a two-stage procedure in which the first stage equation is one of the above-described DiD equations. In fact, this is an IV approach with the DiD-interaction term(s) as instrument(s). In the second stage, we estimate the effect of broadband deployment on employment-related-outcomes The second stage model of our empirical analysis reads as follows:

$$Y_{it}^{I} = \delta + {\gamma_1}^{Iq} \widehat{bb\_hh}_{it}^{q} + \boldsymbol{X}_{it}^{IV} {\gamma_2}^{Iq} + \theta_i^{IV} + \lambda_t^{IV} + \varphi_{it}^{q} \quad (3)$$

where Y_{it}^{I} is the relevant employment outcome (measured by indicator *I*) in municipality i in period t. The prediction $\widehat{bb\_hh}_{it}^{q}$, from the first stage is now the explanatory variable of interest. Accordingly, the coefficient γ_1^{Iq} indicates the impact of broadband coverage on employment outcome variables. Note however, that the estimated coefficients in the employment equations represent the impact of broadband availability on employment outcomes but not the effect related to actual broadband usage: whereas the former measures the intention-to-treat effect, the latter directly impacts economic outcomes such as employment in particular and is a function of broadband availability. Accordingly, we estimate a reduced form where the estimated coefficients represent a proportional effect which is smaller than the effect via broadband usage (see Czernich, 2014). $\boldsymbol{X}_{it}^{IV}$ includes the set of covariates used in the first stage as well as education as a major employment specific covariate. $\theta_i^{IV}$and λ_t^{IV} represent the municipality fixed effects and period effects respectively, and φ_{it}^{q} is the additive error term. By interacting the coefficient β_2^{sq} from the first stage with the coefficient $\gamma_1^{Iq}$from the second stage, we can assess the causal effect (reduced form) of the state aid programme on the respective outcome variable.

4 Data

Our empirical analysis makes use of several different data sets. The GENESIS database[6] and the INKAR[7] database together provide most of our socio-structural, geo-structural, economic and political covariates. The ACXIOM[8] database provides information on the number of

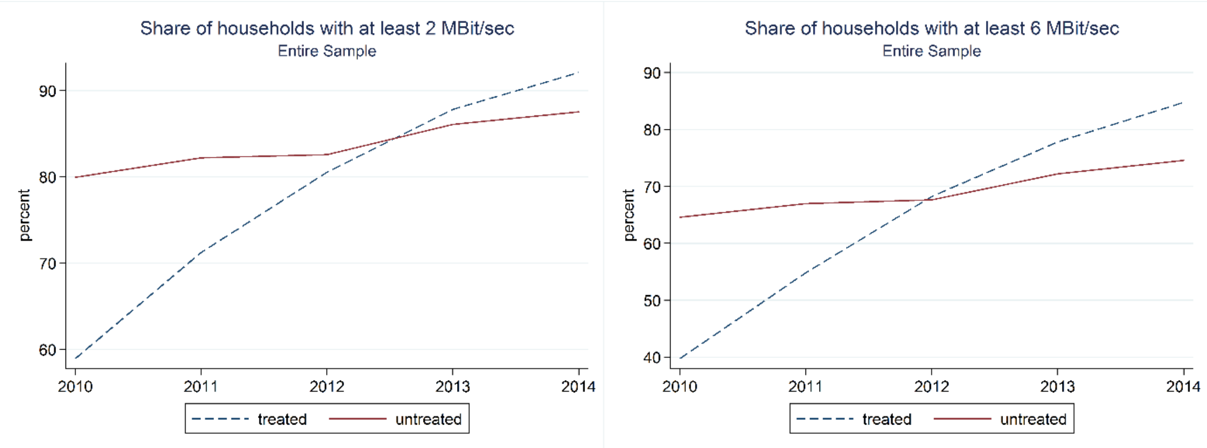
6 See https://www.statistikdaten.bayern.de/genesis/online (last accessed on 24 January 2018).
7 See http://www.inkar.de/ (last accessed on 24 January 2018).
8 See http://www.acxiom.de/ (last accessed on 24 January 2018).

freelancers. The 'Schnelles Internet für Bayern[6]' publication and the German Breitbandatlas[9] provide data on which municipalities received state aid as well as broadband coverage. All variable definitions and sources are characterized in Table A1 in the Appendix.

4.1 Broadband Availability in Bavarian Municipalities

Broadband availability in the years 2010 to 2014 is measured as the share of households in a municipality that have access to a particular bandwidth quality level. In our analysis, we measure standard broadband with three different levels of download speed, ≥ 2, ≥ 6 and ≥ 16 Mbit/sec, denoted by HH_2MB, HH_6MB and HH_16MB. Since the state aid programme was predominantly designed to provide a basic supply of broadband infrastructure, we concentrate on these low to medium speed levels.

Figure 2 illustrates the development of bandwidth in the years 2010 to 2014. Over all municipalities broadband availability increased in our time windows of analysis by 23 to 35 percentage points depending on the bandwidth. The figure clearly shows that treated municipality started at a lower availability level in 2010. However, the increase in broadband availability in treated municipalities is steeper than in untreated municipalities across all bandwidths.



9 See http://www.zukunft-breitband.de/Breitband/DE/Breitbandatlas/BreitbandVorOrt/breitband-vor-ort_node.html (last accessed on 24 January 2018).

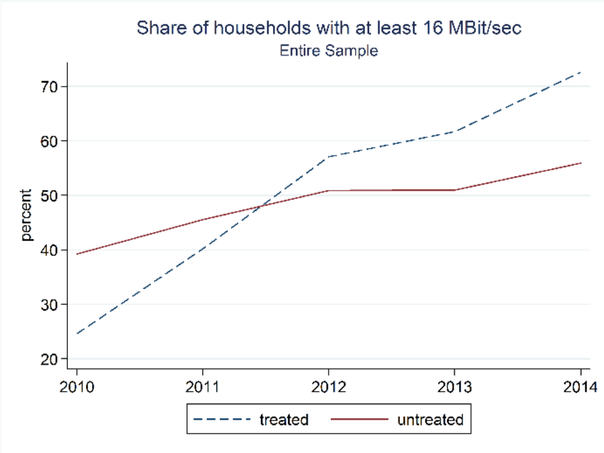


Figure 2: Development of Broadband Deployment in Bavaria

Data source: Federal Ministry of Transport and Digital Infrastructure (2016)

4.2 Employment in Bavarian Municipalities

We measure employment in a municipality by the number of employees with social insurance at place of residence as well as place of work per 100 residents. The number of employees with social insurance at place of residence measures the number of individuals with a job living in a given municipality. The number of employees with social insurance at place of work measures the number of persons working in a given municipality. The variable Self employed measures the number of self-employed workers and freelancers per 100 residents. We are also able to examine the impact of basic broadband infrastructure on the average worker's annual gross wages.

In Figure 3 we show the development of employees with social insurance per 100 inhabitants at place of work and at place of residence in the years 2010 to 2014 Treated municipalities show fewer employees measured at place of work than untreated municipalities in 2010. However, in 2012 and 2013, treated municipalities overtake the untreated ones. Compared with employees at place of work, the difference between treated and untreated municipalities is substantially larger for employees at place of residence and is more pronounced in 2014 than in 2010. In Figure 4, we depict the development of self-employed and freelancers per 100 inhabitants and the annual gross wages. It appears that treated and untreated municipalities follow rather similar trends. In treated municipalities, we observe fewer self-employed and freelancers than in untreated municipalities. This gap does not close after the treatment period. A comparable development is found in the graph plotting annual gross wages.

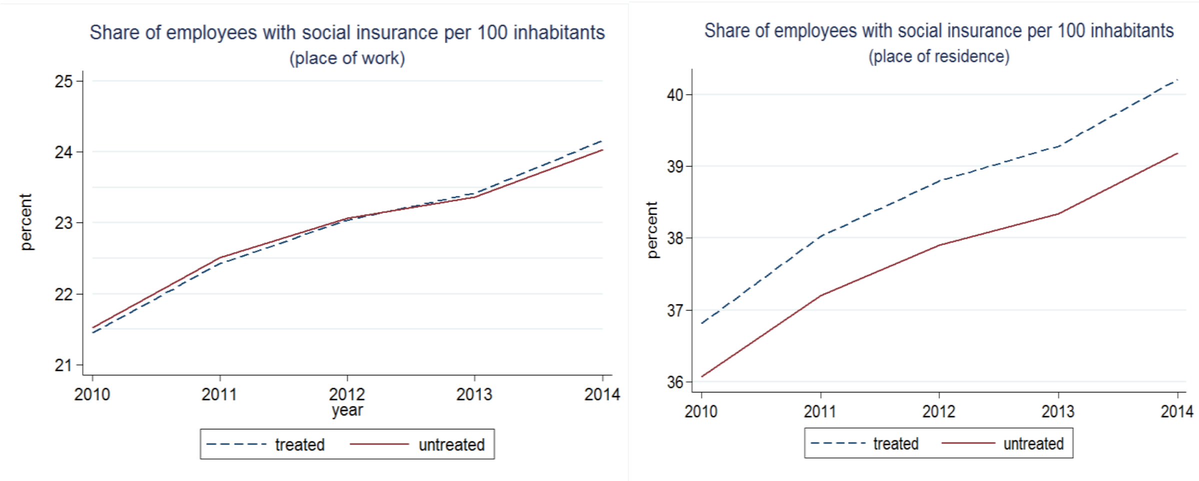


Figure 3: Development of Employees with Social Insurance at Place of Work (Left Panel) and Residence (Right Panel) in Bavaria

Data source: GENESIS database

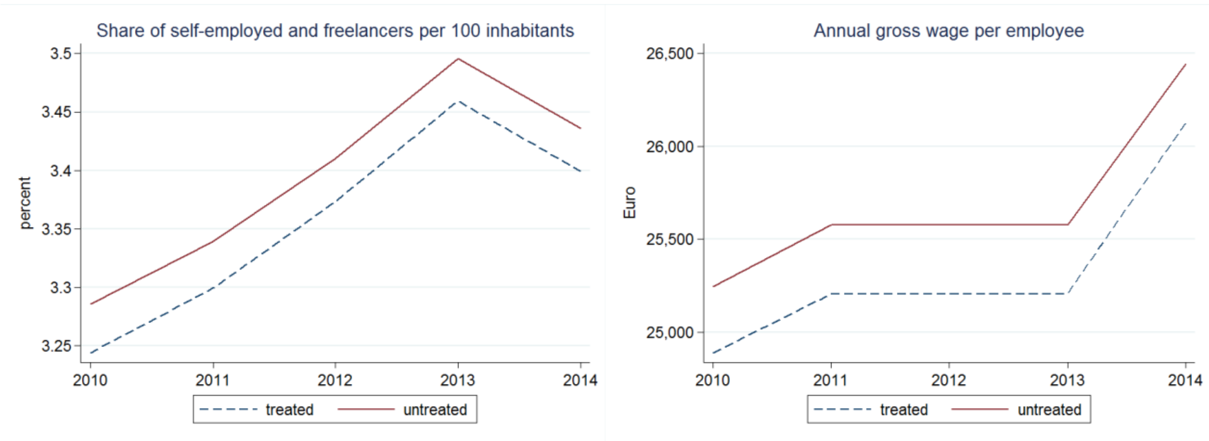


Figure 4: Development of Self-Employed (Left Panel) and Gross Annual Wages (Right Panel) in Bavaria

Data source: AXCIOM and GENESIS databases

5 Estimation Results

5.1 Matching procedure

Before turning to the results on the effectiveness of the state-aid program, we show the results of the matching procedure. Table 1 reports the mean tests applied to the entire sample – i.e. before matching is conducted – and for the sample after matching. Pre matching, almost all means of the characteristics measured in the 2010 (before treatment) are significantly different between treated municipalities (N=1129) and untreated municipalities (N=756). After matching, all municipality characteristics are balanced between treatment and control group. This result holds for two nearest neighbours as well for 3 nearest neighbours in the control group (NB=2 and NB=3). Therefore, and in line with the above tests, we are confident that our matching procedure was successful in identifying valid counterfactuals for the group of treated (i.e. state aid-receiving) municipalities. Table A3 reports the results of the probit regression of the PSM approach. This makes us confident that common-trend assumption is likely to hold at least for the matched sample.

To provide further evidence in favour of the validity of the common-trend assumption, we study trends in broadband roll-out at lower bandwidths before the treatment in 2010/2011. Since broadband infrastructure is deployed by profit-maximizing telecommunication carriers that take into account the local cost of deployment as well as the local market potential, common trends in pre-state-aid broadband deployment would be re-assuring since they would reflect a similar attractiveness of municipalities for broadband deployment. Figure 5 provides strong visual evidence of a common underlying trend for the pre-treatment period from 2005 to 2009. In these years however, data are available only for broadband coverage greater or equal to 1 Mbit/sec.[10]. During this timeframe however, a download speed of 1 Mbit/sec was then the leading technology as was a download speed of 16 Mbit/sec in our post-treatment period. Therefore the 1 Mbit/sec is a good approximation for the preceding deployment growth. If we compare the left-hand and right-hand graphs, we can infer that the remaining differences between treated and untreated municipalities are even further reduced if we focus on matched municipalities only (right-hand graph). This provides a reasonable justification for our preference of the conditional DiD approach on the basis of the matched sample.

[10] Please note that these data also include higher bandwidth levels (as separate data for ≥ 2, ≥ 6 and ≥ 16 Mbit/sec pre-treatment broadband availability is unavailable).

Table 1: Matching outcome

	Unmatched			After matching procedure				
	Control group	**Aid-receiving munici-palities**	**Results of t-test on mean difference**	**Aid-receiving munici-palities**	**Selected control group**	**Selected control group**	**Results of t-test on mean difference**	
					(2 NB)	**(3 NB)**	**(2 NB)**	**(3 NB)**
Characteristics in 2010								
HH_2MB	79.96	58.94	(15.26)***	60.94	60.06	59.64	(-0.68)	(-1.05)
HH_6MB	64.60	39.75	(16.23)***	41.65	41.10	41.35	(-0.41)	(-0.24)
HH_16MB	39.25	24.62	(9.94)***	25.81	26.47	26.68	(0.58)	(0.81)
Growth rate in rents, 2007-2009	0.05	0.05	(-1.29)	0.06	0.06	0.06	(-0.47)	(-0.88)
Growth rate in 1 Mbit/sec, 2007-2009	3.19	3.21	(0.66)	3.22	3.24	3.37	(0.16)	(1.19)
Number of Households	3.44	2.31	(1.10)	2.39	2.21	2.19	(-0.69)	(-0.86)
Individuals in Working age	62.52	62.93	(-4.22)***	62.92	62.91	62.89	(-0.12)	(-0.47)
Share of Females	50.35	49.97	(5.32)***	50.02	49.99	50.00	(-0.46)	(-0.34)
Population density	239.50	157.27	(5.32)***	160.64	161.86	161.10	(0.16)	(0.06)
Municipality type								
Type 1	0.01	0.00	(1.20)	0.00	0.00	0.00	(0.00)	(0.00)
Type 2	0.03	0.03	(0.26)	0.03	0.03	0.03	(-0.07)	(-0.32)
Type 3	0.07	0.08	(-0.56)	0.08	0.08	0.08	(-0.56)	(0.03)
Type 4	0.23	0.29	(-3.29)***	0.27	0.26	0.26	(-0.34)	(-0.18)
Type 5	0.67	0.60	(3.03)***	0.62	0.63	0.63	(0.64)	(0.25)
Medium sized firms	14.70	14.89	(-1.11)	14.85	14.90	14.85	(0.32)	(-0.03)
Large sized firms	2.38	2.43	(-1.25)	2.40	2.40	2.39	(0.07)	(-0.29)
GVA secondary sector	36.42	37.74	(-2.83)***	37.46	37.74	37.63	(0.71)	(0.46)
GVA tertiary sector	61.80	60.48	(2.79)***	60.75	60.45	60.56	(-0.77)	(-0.53)
CSU	0.26	0.24	(2.83)***	0.24	0.24	0.24	(0.17)	(-0.09)
SPD	0.13	0.10	(4.35)***	0.10	0.11	0.10	(0.56)	(-0.11)
Motorway accessibility	12.98	15.84	(-5.95)***	15.29	15.38	15.27	(0.23)	(-0.05)
City accessibility	28.77	31.97	(-4.62)***	31.53	30.83	31.01	(-1.29)	(-1.02)
# Obs.	756	1,129	1,885	1,077	2,154 (547)	3,231 (616)		

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. H_0: equal means for both groups. As the nearest neighbour matching procedure is performed with replacement, we impose Lechner's variance approximation (Lechner, 2001). Due to lack of common support, 52 municipalities had to be dropped, resulting in 1,077 treated municipalities. With two and three nearest neighbours, this corresponds to 2,154 or 3,231 observations in the control group, respectively. The numbers in parentheses in the heading of Table 1 indicate the number of real municipalities used in PSM. As we have fewer untreated than treated municipalities, we reuse municipalities in the control group for several treated municipalities. No stars in the two last columns mean that there is no statistically significant difference between treatment and control group.

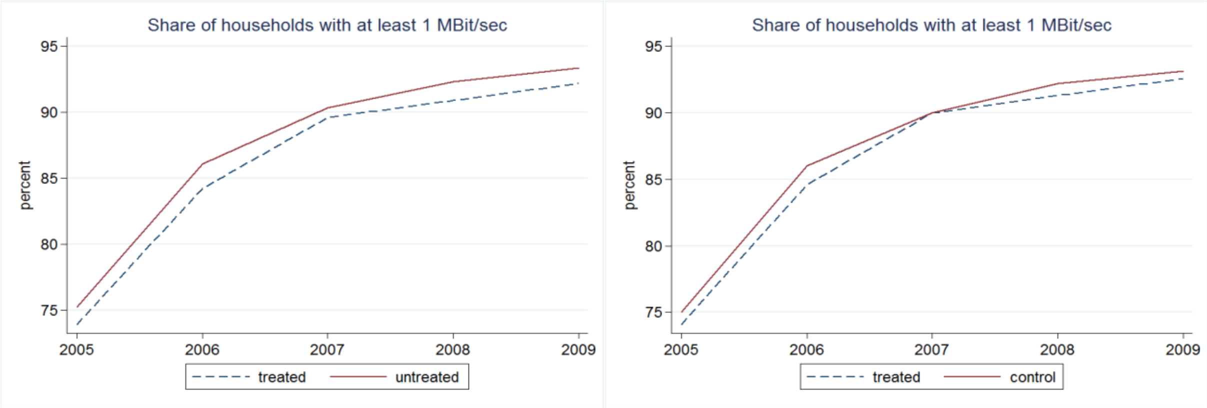


Figure 5: Trends in Years Preceding Treatment for all Municipalities (Left Panel) and Matched Municipalities only (Right Panel)

Data source: Federal Ministry of Transport and Digital Infrastructure (2016)

From Figure 5 we also infer that there is no apparent evidence of Ashenfelter's pre-treatment dip (see Ashenfelter, 1978) for aid-receiving municipalities, which might have occurred in view of expectations related to the institutional design and gradual development of the funding schemes in Bavaria. However, on the basis of the visual evidence in Figure 5, we can conclude that potential crowding-out effects and overestimation bias should be of secondary importance (if relevant at all). However, at the beginning of the pre-treatment period (2010), the observed substantial differences in higher bandwidth levels (see Figure 2) suggest some differences in pre-treatment trends. Accordingly, we also control for higher bandwidth levels in 2010 in constructing the control group in PSM.

5.2 State Aid Effectiveness: The Impact of State Aid on Broadband Deployment

Table 2 shows the estimation results of the static and dynamic DiD models on the basis of the entire (columns 1, 3 and 5) and the matched sample of treated and untreated municipalities (columns 2, 4 and 6). In order to take into account the fact that several non-treated municipalities are overrepresented in the matched sample due to replacement, we also apply weights in the DiD estimation. If a municipality from the control group was a neighbour for several treated municipalities, it accordingly received a proportionally higher weight in the DiD estimation. Table 2 reports the average treatment effect (ATE), which averages across all municipalities (whole sample), and the average treatment effect on the treated (ATT) for the matched sample.

In the static model, the treatment effect is averaged over the years following the treatment. For instance, the ATT in column 2 is 18.42, meaning that within the treatment group, the share of households which had access to at least 2 Mbit/sec increased by 18.42 percentage points after the treatment. Regarding the ATT for 6 and 16 Mbit/sec, the ATT is even larger, with up to 25 percentage points. Generally, the treatment effects are higher for 6 and 16 Mbit/sec quality levels in all specifications. These findings appear reasonable, as bandwidth of >= 2 Mbit/sec represented an elementary quality level in the post-treatment period. Hence, it appears likely that funding was used to realise higher broadband levels, since in 2010, broadband with 2 Mbit/sec bandwidth had already been widely realized, even in treated municipalities.

These highly significant and large coefficients suggest that aid-receiving municipalities indeed show a higher broadband coverage; i.e., the respective funding was actually used effectively for broadband deployment. Furthermore and more importantly, municipalities that did not receive broadband aid find themselves on a substantially lower deployment level suggesting that state aid was not simply a windfall gain to the respective providers – possibly planning to deploy broadband in the respective areas anyway – but that the respective state funds really made a difference.

The dynamic model reports the ATE/ATT for each year after treatment individually. All coefficient estimates indicate that there is a highly significant and positive treatment effect underlying all quality levels of broadband infrastructure. However, in view of the gradual infrastructure deployment process, it appears unlikely that corresponding treatment effects have already been materialised completely within the first year of the policy assessment. Due to adjustment costs, potential impacts are rather expected to unfold in the following years. In line with these expectations, the treatment effect strictly increases over the years for each broadband quality level and for both specifications (based on the entire as well as the matched & weighted sample). For instance, for the speed of 6 Mbit/sec, the treatment effect for the matched & weighted sample (column 4) increases from about 17.87 percentage points in the first year after state aid to about 29.72 three years, and to about 35.15 percentage points four years later.

Table 2: First Stage: Effectiveness of the State Aid Program – Static and Dynamic Models

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. var.:	**HH_2MB**	**HH_2MB**	**HH_6MB**	**HH_6MB**	**HH_16MB**	**HH_16MB**
Sample:	Entire	Matched & Weighted	Entire	Matched & Weighted	Entire	Matched & Weighted
Static Model						
ATE/ATT	18.8828***	18.4213***	25.9130***	25.3972***	22.8343***	22.1166***
	(23.95)	(22.73)	(28.24)	(26.29)	(24.33)	(20.69)
Dynamic Model						
ATE/ATT 1 year post	13.5677***	12.7390***	18.7384***	17.8652***	16.2537***	15.5521***
	(17.47)	(15.47)	(20.19)	(17.90)	(17.41)	(15.31)
ATE/ATT 2 years post	19.2531***	18.9234***	26.4219***	26.1659***	23.1668***	22.9164***
	(21.58)	(19.95)	(25.13)	(22.98)	(21.42)	(18.73)
ATE/ATT 3 years post	22.0217***	21.7638***	30.3188***	29.7259***	27.2619***	26.3360***
	(23.60)	(22.03)	(27.81)	(25.09)	(23.80)	(20.30)
ATE/ATT 4 years post	26.4842***	26.5232***	35.3690***	35.1531***	32.5457***	31.7353***
	(18.22)	(16.66)	(21.02)	(19.04)	(18.31)	(16.04)
# Obs.	9,425	8,120	9,425	8,120	9,425	8,120

t-Statistics in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are clustered at the municipality level and robust to heteroscedasticity. In the matched case, we use the result from the 2NN matching with the Stata 13 *pweight* option with the control variables in the year 2010: Initial broadband deployment, growth in rents, growth in 1Mbit/sec (2007-2009), number of households, share of individuals in working age, share of females, population density, municipality type, number of medium and big firms, share of GVA in secondary and tertiary sector, share of CSU and SPD in municipality election, and the accessibility of motorways and cities. The complete estimation results for the matched and weighted sample can be found in Table A4.

5.3 *Indirect Effects: The Impact of Broadband Deployment on Employment*

The second stage results of our empirical analysis on the effects of the state aid program on employment outcomes are presented in Table 3. Indeed, our instrument(s), the DiD-interaction term(s), is/are strong in all specifications. The first stage F-statistics of excluded instruments and the Cragg-Donald Wald (CDW) F-statistics clearly exceed the IV critical value by Stock and Yogo (2005) for all outcome variables and quality levels. The employment variables in columns 1a–3c are measured as a fraction of 100 residents, whereas average workers' gross wages in columns 4a–4c are measured in Euro per year. We report the estimation results in Table 3 based on the entire as well as on matched and weighted samples. OLS estimates for the full specifications of all employment outcomes are reported for comparison in Tables A7 and A8.

As revealed in Table 3, with the exception of the employees measured at the place of residence variable we do not find any (persistent) significantly positive impact of broadband coverage on employment outcome variables across all specifications.[11] This finding is at least partly in line with existing empirical evidence, which also struggles to find supportive evidence for overall significant labour market effects.

Our results suggest further that the benefit of increasing broadband coverage in rural areas is visible only with respect to employment measured at place of residence. In particular, we find that employment measured at place of residence increased (relatively) to a larger extent than a municipality's population. Taking, for example, the coefficient of HH_6MB (0.0055) in column 1b and multiplying it with the coefficient from the first stage (25.3972 in Table 2) yields an overall value of 0.1127, suggesting that the number of employees with social insurance at place of residence increased by about 0.11 percentage points. Multiplied with the average size of treated municipalities in the pre-treatment year 2010 (50.0420), this results in 6,35, meaning on average about six additional employed persons living (not working) in each municipality that received the state aid. Multiplying this result with the total number of municipalities that received aid (1,129) results in 7,174 additional individuals at place of residence (relative to changes in population). This key result suggests that households and the respective individuals remain in (or move to) rural areas to live (but not to work) there if basic broadband coverage is present – a finding well in line with recent evidence reported in Ahlfeldt *et al*. (2017). There, the authors estimate consumers' valuation of broadband speed via house prices and find an elasticity of property prices with respect to internet speed of about 3%. Their data covers similar ranges of basic broadband connection and underlines the residential importance of broadband (although this effect is more relevant in urban areas).

The fact that increased broadband coverage in treated municipalities did not induce additional jobs but kept individuals living in a municipality suggests that a basic internet infrastructure makes activities such as tele-working or commuting to other (more urban) municipalities more attractive for some of the working age people living in rural areas. In other words, these state aid initiatives made the aided municipalities more attractive for people to live in. This is certainly good news for policy makers as it is a useful tool to work against depopulation of rural areas.

[11] Table A7 in the Appendix also reports significant and positive coefficient estimates for self-employment and gross annual wages in OLS specifications; however, the magnitudes of related marginal effects are negligible.

Table 3: Second Stage: Impact of Broadband Deployment on Employment – IV Estimation Results

	1a	1b	1c	2a	2b	2c	3a	3b	3c	4a	4b	4c
Dependent variable	Number of employees place of residence			Number of employees place of work			Number of Self-employed			Annual gross wage		
Matched & Weighted												
HH_2MB	**0.0077*****			0.0123			0.0003			1.7615		
	(3.15)			(1.32)			(0.91)			(0.99)		
HH_6MB		**0.0055*****			0.0089			0.0002			1.2726	
		(3.15)			(1.32)			(0.91)			(0.99)	
HH_16MB			**0.0064*****			0.0101			0.0002			1.4554
			(2.95)			(1.32)			(0.91)			(0.99)
# Obs.	8,120	8,120	8,120	8,120	8,120	8,120	8,120	8,120	8,120	8,120	8,120	8,120
# Groups	1,624	1,624	1,624	1,624	1,624	1,624	1,624	1,624	1,624	1,624	1,624	1,624
F (excl. instr).	399.79	546.53	402.93	755.81	1041.29	633.63	755.81	1041.29	633.63	755.81	1041.29	633.63
F	627.34	627.18	620.05	56.97	57.18	57.02	274.86	274.82	274.48	158.99	158.64	158.48
CDW F	422.29	561.15	411.26	368.881	480.138	354.151	368.881	480.138	354.151	524.32	660.93	84.20
DWH	0.0182	0.0080	0.0018	0.0467	0.0381	0.0621	0.9028	0.8941	0.5302	0.8110	0.8294	0.6799
R^2	0.7026	0.7026	0.6991	0.146	0.148	0.146	0.431	0.431	0.430	0.402	0.401	0.401
Entire sample												
HH_2MB	**0.0080*****			0.0087			0.0003			0.8400		
	(3.70)			(1.48)			(1.27)			(0.49)		
HH_6MB		**0.0058*****			0.0063			0.0002			0.6085	
		(3.70)			(1.48)			(1.27)			(0.49)	
HH_16MB			**0.0066*****			0.0071			0.0003			0.6867
			(3.69)			(1.48)			(1.27)			(0.49)
# Obs.	9,425	9,425	9,425	9,425	9,425	9,425	9,425	9,425	9,425	9,425	9,425	9,425
# Groups	1,624	1,624	1,624	1,624	1,624	1,624	1,624	1,624	1,624	1,624	1,624	1,624
F excl. instr.	721.42	995.77	748.49	897.48	1235.33	882.85	897.48	1235.33	882.85	897.48	1235.33	882.85
F	754.69	754.96	747.57	71.42	71.61	71.61	331.25	331.01	330.54	172.44	172.42	172.42
CDW F	840.83	1,110.41	800.50	748.021	989.249	726.298	748.021	989.249	726.298	748.02	989.25	726.30
DWH	0.0037	0.0011	0.0002	0.0118	0.0131	0.0662	0.8378	0.7796	0.3756	0.9263	0.7366	0.8419
R^2	0.6866	0.6863	0.6834	0.153	0.155	0.155	0.412	0.411	0.410	0.350	0.350	0.350

t-statistics in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are clustered at the municipality level and robust to heteroscedasticity. All regressions include fixed effects for year, municipality and controls of equation (3), as well as a covariate measuring education (EDUC).

6 Summary and Conclusions

In this paper, we provide an ex-post evaluation of a major state aid programme for broadband deployment in rural areas of the German state of Bavaria. Using a unique micro panel dataset, we evaluate the causal effect of state aid that was granted in the period from 2010 to 2011 to 1,129 municipalities. Our post-treatment period refers to the years from 2011/2012 to 2014. Using a difference-in-differences estimation strategy based on a matched sample of 1,845 aided and non-aided rural municipalities, we first examined the question whether the granting of state aid had the desired direct effect on broadband deployment. Our treatment analysis revealed that state aid indeed had an impact on the municipalities treated; they are found to have significantly higher broadband coverage than comparable non-aided municipalities. In particular, we found that the aided municipalities have, depending on broadband quality, between 18.4 and 25.4 percentage points higher broadband coverage than non-aided municipalities. Our results further suggest that the effect of state aid is more pronounced for medium (6 Mbit/sec) bandwidth levels and that it gains strength over the years after treatment.

With respect to indirect effects of the state aid policy, we particularly examined whether the additional broadband coverage also carried over to socially desirable indirect effects in the form of creating new jobs. We found that state aid-induced higher broadband coverage generated significantly positive effects with respect to the number of employees at place of residence as well as changes in the population of the respective municipalities. Based on an average bandwidth level (6 Mbit/sec), we found that in sum 7,174 additional individuals with social insurance were induced by the broadband state aid programme in the years 2010 to 2011 to live in the treated Bavarian municipalities. Furthermore, our empirical results suggest that more people decided to move into (or did not leave) treated municipalities than left these rural areas, indicating that improved broadband coverage makes these municipalities more liveable places. In that sense, the funding programme successfully served as a means of preventing rural municipalities from depopulation; however, it does not impose a measurable effect on the closing of the economic divide in the form of creating new jobs in these municipalities.

Coming back to the main policy-related question raised in the title of the paper – namely, whether state aid can help in bridging the digital and economic divide – our empirical results for the state of Bavaria support the conclusion that state aid programmes can be an effective instrument to foster broadband deployment, particularly in rural areas. When it comes to the subsequent effects of such investments, our result of 7,174 additional individuals with social insurance being induced to live in the treated Bavarian municipalities may, on the surface, appear modest compared to the total amount of €107.6m of state aid provided by the public authorities to the respective municipalities.

However, a closer look reveals that such a simple comparison of benefits and costs would be superficial for at least three reasons. First, households are expected to be much more flexible in making relocation decisions than firms. As a consequence, it appears not unlikely that a possible impact of state aid on employment at the place of work will materialize in the years to come. Second, from a broader perspective, our analysis ignores the further positive knock-on effects of improved broadband coverage on, for example, innovation or economic growth that are expected to be generated in the longer run.

Finally yet importantly, such a simple comparison of benefits and costs ignores the additional (counterfactual) costs that would have been created by an accelerating digital and economic divide between urban and rural areas that might have occurred in the absence of the respective state aid programme. Such aspects such as increasing rents in cities or empty houses in rural villages need to be investigated as part of future research to work towards well-founded conclusions on ways to bridge the digital and economic divide.

Appendix

Table A1: Description of Variables and Sources

Variable	Description	Source
Outcome variables stage 1		
HH_XMB	Share of households with at least XMB fixed-line broadband connections. X can take the values 2, 6 and 16, municipality level (2010–2014)	Breitbandatlas/ TÜV Rheinland
Outcome variables stage 2		
Number of employees place of residence	Number of employees with social insurance at place of residence per 100 residents in 2010 (2010–2014) , municipality level	GENESIS
Number of employees place of work	Number of employees with social insurance at place of work per 100 residents in 2010 (2010–2014) , municipality level	GENESIS
Self-employed	Number of self-employed workers and freelancers per 100 residents in 2010 (2010–2014) , municipality level	ACXIOM
Wage	Annual gross wage in € per employee in a municipality (2010–2014)	GENESIS
Control variables		
Number of Households	Number of households, municipality level (2010)	Micro Census 2011
Growth in rents	Annual growth in rents, municipality level (2007–2009)	IDN Immo Daten GmbH
Growth rate 1 Mbit/sec	Average yearly growth rate in the share of households with access to 1MB, municipality level (2007–2009)	Breitbandatlas/ TÜV Rheinland
Municipality type	Municipality type, indicator of how rural a municipality is (2010)	INKAR
Female	Share of female inhabitants, municipality level (2010–2014)	GENESIS
Working age	Share of people of working age (i.e. 18 to 65 years), municipality level (2010–2014)	INKAR
Population density	Population density per square kilometre, municipality level (2010–2013)**	GENESIS
GVA secondary sector	Share of gross value added in secondary sector, county level (2010–2013)**	INKAR
GVA tertiary sector	Share of gross value added in tertiary sector, county level (2010–2013)**	INKAR
Medium sized firms	Share of firms with 50 to 250 employees, county level (2010–2013)**	INKAR
Large sized firms	Share of firms with more than 250 employees, county level (2010–2013)**	INKAR
CSU	Share of the CSU party in the municipal election (2008–2014)	GENESIS
SPD	Share of the SPD party in the municipal election (2008–2014)	GENESIS
Motorway accessibility	Average journey time (car) in minutes to the next motorway, municipality level (2010, 2012–2014)*	INKAR
City accessibility	Average journey time (car) in minutes to the next regional metropolitan area, municipality level (2010, 2012–2014)*	INKAR
Higher education	Percentage share of school leavers with a higher education entry qualification in the total number of school leavers, county level (2010–2013)**	INKAR

Notes: * Missing values for 2011 were calculated using linear interpolation. ** In case control variables were only available up to the year 2013, we have extrapolated them to the year 2014.

Table A2: Summary Statistics

	# Obs.	Mean	Std. Dev.	Min.	Max.
HH_2MB	9,425	80.351	26.727	0.000	100.000
HH_6MB	9,425	66.734	32.788	0.000	100.000
HH_16MB	9,425	50.150	34.103	0.000	100.000
Number of employees place of residence	9,425	38.234	3.517	21.463	52.522
Number of employees place of work	9,425	22.759	18.457	0.930	200.573
Self-employed	9,425	3.369	1.147	0.558	8.150
Wage	9,425	25520.433	4318.374	13662.086	83865.617
Share of municipalities with State aid	9,425	0.599	0.490	0.000	1.000
Higher education	9,425	25.965	9.796	8.900	70.300
Individuals in Working age	9,425	63.289	2.135	52.800	70.700
Growth rate in rents	9,425	2.288	2.803	0.000	5.885
Growth rate 1 Mbit/sec	9,425	1.363	5.465	-42.855	50.000
Municipality type					
Type 1	9,425	0.003	0.056	0.000	1.000
Type 2	9,425	0.029	0.168	0.000	1.000
Type 3	9,425	0.077	0.266	0.000	1.000
Type 4	9,425	0.266	0.442	0.000	1.000
Type 5	9,425	0.624	0.484	0.000	1.000
Number of Households	9,425	2.760	18.552	0.088	732.793
Share of Females	9,425	50.111	1.418	36.100	56.700
Population density	9,425	189.626	292.660	6.000	4531.200
Medium sized firms	9,425	15.325	3.754	8.200	40.200
Large sized firms	9,425	2.570	0.941	0.480	7.470
GVA secondary sector	9,425	37.908	9.601	12.800	71.700
GVA tertiary sector	9,425	60.227	9.710	26.800	86.500
CSU	9,425	0.246	0.205	0.000	1.000
SPD	9,425	0.109	0.130	0.000	0.663
Motorway accessibility	9,425	14.662	10.790	0.000	69.000
City accessibility	9,425	29.029	14.172	0.000	82.300

Table A3: Probit Regression Results

Dep. var. ($Pr(D_1 = 1)$)	Coefficient	Standard error
HH_2MB_ 2010	-0.0034	(-1.68)
HH_6MB_ 2010	-0.0163***	(-6.98)
HH_16MB_2010	0.0054**	(3.08)
Growth rate in rents	0.7224	(0.64)
Growth rate in 1 Mbit/sec	-0.0152	(-1.90)
Number of Households	0.0025	(0.96)
Individuals in Working age	0.0686***	(4.08)
Share of Females	-0.0221	(-0.91)
Population density	-0.0008***	(-4.13)
Municipality type		
Type 1	0.8892	(1.14)
Type 2	1.1595***	(5.26)
Type 3	0.9295***	(6.79)
Type 4	0.6179***	(7.81)
Type 5	0.0000	(.)
Medium sized firms	0.0015	(0.12)
Large sized firms	0.0114	(0.21)
GVA secondary sector	0.1517**	(3.16)
GVA tertiary sector	0.1481**	(3.08)
CSU	0.0558	(0.32)
SPD	-0.2006	(-0.68)
Motorway accessibility	0.0110**	(2.89)
City accessibility	0.0028	(1.02)
Constant	-17.1135***	(-3.34)
# Obs.	1,885	
Pseudo R^2	0.158	
p-value (Prob > chi^2)	0.000	

The Pseudo R^2 measures the explanatory power of the covariates and should be significantly lower after the matching procedure (see Sianesi, 2004). Indeed, comparing the Pseudo R^2 in Table A (0.158) with the respective value of the probit regression after matching based on the sample of treated units and counterfactuals (0.003 for NB=2 and 0.003 for NB=3) indicates that the systematic differences between the two groups decreased substantially after controlling for covariates. Similarly, one can compare likelihood ratio tests on the joint significance of all covariates in the probit model before and after matching. As required, the null hypothesis (all covariates are jointly insignificant) is rejected before (p=0.000) but not after matching (p=0.917 for NB=2 and p = 0.875 for NB=3).

Table A4: Static and Dynamic DiD Models with Controls Based on Matched and Weighted Sample

Dep. var.:	(1) HH_2MB	(2) HH_2MB	(3) HH_6MB	(4) HH_6MB	(5) HH_16MB	(6) HH_16MB
ATT	**18.4213*****		**25.3972*****		**22.1166*****	
	(22.73)		(26.29)		(20.69)	
ATT 1 year post		**12.7390*****		**17.8652*****		**15.5521*****
		(15.47)		(17.90)		(15.31)
ATT 2 year post		**18.9234*****		**26.1659*****		**22.9164*****
		(19.95)		(22.98)		(18.73)
ATT 3 year post		**21.7638*****		**29.7259*****		**26.3360*****
		(22.03)		(25.09)		(20.30)
ATT 4 year post		**26.5232*****		**35.1531*****		**31.7353*****
		(16.66)		(19.04)		(16.04)
Individuals in Working age	-3.0820***	2.9174***	-3.6882***	2.4152***	1.9361**	1.6673**
	(-5.49)	(4.64)	(-5.61)	(3.41)	(2.38)	(2.40)
Share of Females	4.5523***	0.3457	4.9572***	0.5494	3.8944***	0.5371
	(7.53)	(0.50)	(7.11)	(0.72)	(5.69)	(0.76)
Population density	0.1360	-0.0522	0.0540	-0.0667	-0.0624	0.0028
	(0.19)	(-1.36)	(0.07)	(-1.39)	(-0.09)	(0.07)
Medium sized firms	-0.0616*	-0.0037	-0.0652	-0.3789	-0.0161	-0.4276
	(-1.75)	(-0.01)	(-1.58)	(-0.63)	(-0.40)	(-0.73)
Large sized firms	2.1492***	1.0846	2.8417***	0.4484	2.3658***	0.6525
	(4.88)	(0.58)	(5.48)	(0.21)	(4.63)	(0.30)
Lagged GVA secondary sector	6.3342***	0.4299	8.1719***	-0.7691	7.5708***	-0.9982
	(3.72)	(0.27)	(4.08)	(-0.42)	(3.70)	(-0.54)
Lagged GVA tertiary sector	-3.7482**	0.4035	-6.9921***	-0.9412	-5.0937***	-1.3106
	(-2.55)	(0.25)	(-4.06)	(-0.51)	(-2.94)	(-0.69)
CSU	-4.2981***	0.0919	-7.8003***	-3.5811	-6.2194***	-5.3071
	(-2.90)	(0.02)	(-4.48)	(-0.57)	(-3.54)	(-0.85)
SPD	-1.6357	13.2480**	-6.3119	10.5807	-8.4743	14.4376
	(-0.29)	(1.97)	(-0.96)	(1.20)	(-1.26)	(1.38)
Motorway accessibility	7.1449	0.0247	-1.3917	0.0045	-1.3617	0.2122
	(1.09)	(0.09)	(-0.16)	(0.01)	(-0.13)	(0.46)
City accessibility	-0.1302	0.0685	-0.2725	0.0911	0.0431	0.0547
	(-0.40)	(1.63)	(-0.54)	(1.51)	(0.08)	(0.84)
Post treatment period	-0.0523		-0.1041*		-0.1008*	
	(-1.30)		(-1.81)		(-1.66)	
YEAR 2011		5.8289***		6.7873***		8.6625***
		(7.00)		(7.30)		(9.39)
YEAR 2012		4.2103***		5.2106***		12.4802***
		(4.65)		(4.92)		(11.13)
YEAR 2013		4.4612***		6.6106***		9.8004***
		(3.12)		(4.05)		(5.77)
YEAR 2014		4.9573***		8.6947***		15.6166***
		(3.44)		(5.27)		(9.08)
Constant	143.9914	-173.1964	431.2328**	-32.7150	315.8169	14.5512
	(0.85)	(-1.01)	(2.23)	(-0.17)	(1.63)	(0.07)
# Obs.	8,120	8,120	8,120	8,120	8,120	8,120
R^2 within	0.3439	0.3682	0.3970	0.4278	0.4067	0.4463
F-Test	89.45	74.89	123.04	107.44	150.71	134.28

t-Statistics in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are clustered at the municipality level. All regressions include municipality fixed effects. The share of GVA in the secondary and tertiary sectors was lagged (L.GVA) to avoid reverse causality.

Table A5: Immediate and Long-Term Treatment Effects for PSM

		(2NB)			(3NB)	
Dep. var.:	**HH_2MB**	**HH_6MB**	**HH_16MB**	**HH_2MB**	**HH_6MB**	**HH_16MB**
ATE 2012	12.19***	18.29***	18.16***	12.56***	18.30***	18.26***
	(9.58)	(14.65)	(14.37)	(11.35)	(16.37)	(16.01)
ATT 2012	15.91***	22.60***	21.77***	16.56***	22.70***	21.79***
	(8.29)	(12.73)	(12.88)	(10.14)	(14.68)	(14.73)
ATE 2013	12.96***	21.08***	20.07***	13.47***	21.45***	20.52***
	(11.43)	(17.02)	(15.38)	(13.30)	(19.42)	(17.55)
ATT 2013	16.92***	26.13***	23.37***	17.58***	26.50***	23.76***
	(9.88)	(14.76)	(13.26)	(11.74)	(17.25)	(15.52)
ATE 2014	13.24***	22.37***	23.54***	13.86***	22.82***	23.86***
	(13.76)	(19.94)	(17.81)	(13.76)	(19.76)	(17.94)
ATT 2014	17.11***	27.70***	27.37***	18.01***	28.28***	27.85***
	(12.04)	(18.07)	(16.44)	(12.02)	(17.62)	(16.31)
# Obs.	1,833	1,833	1,833	1,833	1,833	1,833

t-Statistics in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are clustered at the municipality level and robust to heteroscedasticity.

Table A6: Second Stage Full IV/2SLS Model with Matched and Weighted Sample

Dep. var.:	(1) **EMPL_RES**	(2) **EMPL_RES**	(3) **EMPL_RES**
HH_2MB	0.0077***		
	(2.69)		
HH_6MB		0.0055***	
		(2.69)	
HH_16MB			0.0064***
			(2.68)
Individuals in Working age	0.2054***	0.2130***	0.2156***
	(5.54)	(5.90)	(6.04)
Share of Females	0.0227	0.0229	0.0238
	(0.46)	(0.46)	(0.48)
Population density	-0.0231***	-0.0232***	-0.0235***
	(-3.73)	(-3.73)	(-3.75)
Medium sized firms	0.3211***	0.3213***	0.3222***
	(13.38)	(13.41)	(13.45)
Large sized firms	0.9987***	1.0004***	0.9980***
	(12.25)	(12.32)	(12.26)
Lagged GVA secondary sector	-0.3925***	-0.3821***	-0.3885***
	(-4.38)	(-4.25)	(-4.33)
Lagged GVA tertiary sector	-0.4704***	-0.4593***	-0.4632***
	(-5.17)	(-5.04)	(-5.08)
CSU	0.0812	0.1038	0.1227
	(0.16)	(0.20)	(0.24)
SPD	-2.4218***	-2.3622***	-2.3603***
	(-4.31)	(-4.19)	(-4.19)
Motorway accessibility	-0.0372**	-0.0367**	-0.0385**
	(-2.38)	(-2.36)	(-2.52)
City accessibility	-0.0173***	-0.0172***	-0.0171***
	(-7.47)	(-7.44)	(-7.39)
Higher education	0.0133***	0.0138***	0.0137***
	(5.09)	(5.33)	(5.27)
Post treatment	1.1608***	1.1615***	1.1275***
	(23.63)	(23.72)	(19.45)
# Obs.	8,120	8,120	8,120
R^2	0.600	0.600	0.600

t-Statistics in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are clustered at the municipality level. All regressions include fixed effects for year, municipality and controls of equation (1) as well as education (EDUC). The share of GVA in the secondary and tertiary sectors was lagged (L.GVA) to avoid reverse causality.

Table A7: Second Stage OLS Estimates for Self-Employment and Gross Wages

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. var.:	**SELF**	**SELF**	**SELF**	**WAGE**	**WAGE**	**WAGE**
Sample:	Matched & Weighted	Matched & Weighted	Matched & Weighted	Matched & Weighted	Matched & Weighted	Matched & Weighted
HH_2MB	**0.0003****			**1.3524****		
	(2.22)			**(2.52)**		
HH_6MB		**0.0002***			**1.0131****	
		(1.91)			**(2.33)**	
HH_16MB			**0.0001**			**0.8739****
			(0.90)			**(2.16)**
Individuals working age	-0.0088*	-0.0085*	-0.0081*	-36.1891*	-34.6957*	-33.5371
	(-1.88)	(-1.81)	(-1.73)	(-1.78)	(-1.70)	(-1.65)
Share of Females	0.0126**	0.0126**	0.0127***	35.0609	34.9465	35.1765
	(2.57)	(2.57)	(2.59)	(1.31)	(1.31)	(1.32)
Population density	-0.0033***	-0.0033***	-0.0033***	1.5518	1.5495	1.4703
	(-3.37)	(-3.37)	(-3.37)	(0.58)	(0.58)	(0.56)
Medium sized firms	0.0075*	0.0075*	0.0074*	1.8661	2.2388	2.0960
	(1.72)	(1.73)	(1.71)	(0.14)	(0.17)	(0.16)
Large sized firms	0.0229**	0.0231**	0.0230**	-24.9602	-23.9392	-24.2326
	(2.01)	(2.03)	(2.02)	(-0.50)	(-0.48)	(-0.49)
Lagged GVA secondary sector	0.0238*	0.0240*	0.0240*	-133.3653***	-132.0566***	-131.8256***
	(1.94)	(1.96)	(1.96)	(-2.70)	(-2.68)	(-2.67)
Lagged GVA tertiary sector	0.0247**	0.0250**	0.0250**	-143.9100***	-142.4625***	-142.1500***
	(1.98)	(2.00)	(2.00)	(-2.82)	(-2.79)	(-2.79)
CSU	-0.0476	-0.0469	-0.0474	204.9707	208.8540	209.3233
	(-1.15)	(-1.14)	(-1.15)	(0.62)	(0.63)	(0.63)
SPD	-0.1385**	-0.1370**	-0.1353**	491.4961	498.7508	498.5980
	(-2.07)	(-2.05)	(-2.03)	(1.00)	(1.01)	(1.01)
Motorway accessibility	-0.0045**	-0.0045**	-0.0045**	3.1267	3.1553	3.0204
	(-2.37)	(-2.36)	(-2.35)	(0.45)	(0.45)	(0.44)
City accessibility	-0.0014***	-0.0014***	-0.0014***	-2.8229**	-2.8252**	-2.7786**
	(-3.01)	(-3.02)	(-2.98)	(-2.10)	(-2.08)	(-2.04)
Higher education	-0.0011	-0.0011	-0.0011	-4.7151	-4.6833	-4.5510
	(-1.57)	(-1.55)	(-1.47)	(-1.61)	(-1.60)	(-1.55)
Constant	1.3255	1.2869	1.2662	39044.33***	38849.2784***	38773.618***
	(1.03)	(0.99)	(0.98)	(7.41)	(7.38)	(7.36)

# Obs.	8,120	8,120	8,120	8,120	8,120	8,120
R^2	0.431	0.431	0.430	0.402	0.401	0.401
F	201.83	202.41	202.79	155.27	156.03	155.25

t-Statistics in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are clustered at the municipality level and robust to heteroscedasticity. The share of GVA in the secondary and tertiary sectors was lagged (L.GVA) to avoid reverse causality.

Table A8: Second Stage OLS Estimates for Employees at Place of Residence and Place of Work

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. var.:	**EMPL_ RES**	**EMPL_ RES**	**EMPL_ RES**	**EMPL_ WORK**	**EMPL_ WORK**	**EMPL_ WORK**
Sample:	Matched & Weighted	Matched & Weighted	Matched & Weighted	Matched & Weighted	Matched & Weighted	Matched & Weighted
HH_2MB	**0.0020****			**-0.0055****		
	(2.18)			**(-2.29)**		
HH_6MB		**0.0010**			**-0.0045****	
		(1.37)			**(-2.26)**	
HH_16MB			**0.0000**			**-0.0040****
			(0.01)			**(-1.99)**
Individuals in Working age	-0.0443	-0.0405	-0.0375	-0.3002***	-0.3051***	-0.3100***
	(-1.29)	(-1.17)	(-1.08)	(-3.29)	(-3.35)	(-3.41)
Share of Females	0.1062**	0.1066**	0.1077**	0.1109	0.1117	0.1108
	(1.99)	(1.99)	(2.01)	(0.80)	(0.80)	(0.80)
Population density	-0.0231***	-0.0232***	-0.0233***	-0.0114	-0.0114	-0.0110
	(-3.03)	(-3.02)	(-3.02)	(-0.86)	(-0.86)	(-0.83)
Medium sized firms	-0.0272	-0.0270	-0.0278	0.0554	0.0535	0.0538
	(-0.96)	(-0.96)	(-0.99)	(0.59)	(0.57)	(0.57)
Large sized firms	0.1363	0.1376	0.1373	0.4546*	0.4503*	0.4516*
	(1.57)	(1.59)	(1.59)	(1.88)	(1.86)	(1.86)
Lagged GVA secondary sector	0.1745*	0.1762*	0.1759*	0.1102	0.1046	0.1034
	(1.81)	(1.83)	(1.82)	(0.41)	(0.39)	(0.39)
Lagged GVA tertiary sector	0.1729*	0.1748*	0.1742*	0.1068	0.1005	0.0989
	(1.76)	(1.78)	(1.77)	(0.40)	(0.38)	(0.37)
CSU	0.3491	0.3517	0.3463	-1.0773	-1.0950	-1.0976
	(0.68)	(0.69)	(0.68)	(-0.87)	(-0.89)	(-0.89)
SPD	-0.3333	-0.3132	-0.2956	-0.0223	-0.0450	-0.0423
	(-0.68)	(-0.63)	(-0.60)	(-0.01)	(-0.03)	(-0.03)
Motorway accessibility	-0.0020	-0.0019	-0.0017	0.0855*	0.0854*	0.0860*

	(-0.13)	(-0.12)	(-0.11)	(1.84)	(1.84)	(1.86)
City accessibility	0.0046*	0.0047*	0.0047*	-0.0017	-0.0017	-0.0019
	(1.87)	(1.90)	(1.93)	(-0.24)	(-0.23)	(-0.26)
Higher education	0.0020	0.0022	0.0026	0.0197	0.0201	0.0201
	(0.26)	(0.29)	(0.35)	(0.87)	(0.88)	(0.87)
Constant	20.6965**	20.3369**	20.2021*	23.5553	24.3033	24.6329
	(2.01)	(1.97)	(1.96)	(0.77)	(0.80)	(0.81)
# Obs.	8,120	8,120	8,120	8,120	8,120	8,120
R^2	0.706	0.706	0.706	0.157	0.157	0.157
F	404.11	402.40	400.14	38.77	38.80	38.83

t-Statistics in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are clustered at the municipality level and robust to heteroscedasticity. The share of GVA in the secondary and tertiary sectors was lagged (L.GVA) to avoid reverse causality.

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