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Broadband Infrastructure and Unemployment - Evidence for Germany

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Broadband Infrastructure and Unemployment
Evidence for Germany

Online job search is becoming increasingly prominent and is viewed to improve the efficiency of the search process. OLS results suggest a negative association of DSL availability with unemployment rates across German municipalities. However, the roll-out of DSL networks is not random. This paper exploits the fact that the availability of DSL connections depends on a municipality's distance to the closest interconnection point to the pre-existing voice-telephony network. Instrumental-variable results using this distance as an instrument for DSL availability do not confirm the effect of DSL availability on unemployment.

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1 Introduction

In February 2009, the German government initiated a broadband strategy, which is aimed at providing high-speed internet access to every household. Its goals were to provide nationwide broadband access by the end of 2010 and broadband access with transmission rates of at least 50 mbit/s for 75 percent of all households by 2014. The government initiated the broadband strategy because it believes that the ubiquitous roll-out of broadband networks is a prerequisite for economic growth and prosperity. It expects broadband networks to be as important for economic and social development as traditional infrastructures like road, railway and electricity networks. It is claimed that especially rural areas will gain from broadband access since it is an important factor to consider when making location decisions for companies and families as well as for jobs and for the attractiveness of rural areas. Therefore, the broadband strategy aims at providing access to the broadband network in the numerous ”white spots“, i.e. areas without broadband access (cf. Bundesministerium für Wirtschaft und Technologie 2009).

By now, broadband internet is available in all cities and towns but not yet in all rural areas. Broadband networks were first rolled-out in agglomerated areas, since roll-out is much less costly there than in rural areas due to the relatively short distances and the high number of households that can be reached. But roll-out costs also depend on other determinants than population density and therefore also between rural areas the availability of broadband internet varies.

This paper addresses the question whether differences in the availability of broadband internet between German municipalities can explain differences in the unemployment rate. Today, internet plays an important role in the job search process since it offers new possibilities to search for open positions. Numerous online job boards have been founded where firms can post open positions and applicants their CVs. Both sides can then search these boards by the criteria they are looking for. Compared to traditional job search methods, online searching promises to be more comprehensive, more efficient and more up-to-date and may therefore improve job matching and eventually productivity and growth.

A survey on behalf of Bitkom (2009), the German Federal Association for Information Technology, Telecommunications and New Media, found that in Germany job searching via the internet is becoming increasingly prominent. In the third quarter of 2009, online job boards in Germany received 23 million visits; the most frequently visited one, the job board of the Federal Employment Agency, received 7.9 million visits alone. It is also the largest job board with over 640,000 open positions and approximately 3.5 million registered profiles of applicants (Bundesagentur für Arbeit, state of November 2010). Moreover, the survey found that firms use the internet extensively to fill job vacancies: 94% of the interviewed firms advertise their job openings online (c.f. Bitkom 2009). These numbers clearly indicate that online job searching has become an important search method in the labour market.

While previous studies found that online job searches are frequently used, the results on the effects of online job searching on employment is ambiguous (Kuhn and Skuterud 2004, Stevenson 2009). This paper adds to the existing literature by analysing whether the availability of broadband internet increased the efficiency of job searching, which should show in lower unemployment rates. Data on unemployment in the year 2006 on the municipality level is combined with information on DSL availability. In 2006, broadband internet was already available in all larger towns, but not yet as widespread in rural areas. Thus, the approach estimates the effect of broadband internet on unemployment using variation of broadband internet availability between rural municipalities. OLS estimates show a negative association between DSL availability and unemployment rate. However, this association cannot be interpreted as a causal effect but may be driven by reverse causality or omitted variables. For example in areas with low unemployment rates, ability to pay and thus demand for broadband internet may be higher, resulting in a faster roll-out of broadband networks to these areas.

In order to address such concerns, an instrumental-variable approach is used, that rests on impediments to the roll-out of DSL networks that stem from the structure of the existing voice-telephony network. The DSL network is built along the existing network for voice-telephony by upgrading the pre-existing infrastructure. For this purpose, the existing copper wires of the voice-telephony network are gradually being replaced by optical fibre. This process started at the highest aggregation level, the backbones, and today the network is typically fibre-based up to the main distribution frame (mdf). This stage of the process theoretically allows the provision of DSL. At the mdf, the fibre network connects to the existing copper wires that run from the mdf to the individual households. The longer the distance, the less bandwidth is feasible via this wire. Especially in rural areas, the distance between the mdf and the individual households may be relatively long and it may be necessary to further substitute the copper wires with optical fibre. Since the wires are laid subterraneously, the substitution of the wires involves excavation works which are very costly and may delay or even prohibit the provision of broadband for the affected households. Therefore, the distance from every municipality to the location of the closest mdf is calculated and used as an instrumental-variable to predict DSL availability in a municipality. The results of the instrumental-variable estimations suggest that a causal effect of DSL availability on unemployment does not exist.

The paper is structured as follows. Section 2 gives an overview of the existing literature on internet and unemployment. Section 3 describes the instrumental-variable approach. Section 4 describes the model, data and OLS results. Section 5 shows the results of the instrumental-variable estimations and robustness tests and discusses the results. Section 6 concludes.

2 Internet and Unemployment – Related Literature

David Autor (2001) describes several ways of how the emergence of internet may affect the labour market. Through its function of enabling inexpensive and quick distribution of information, he expects the internet to have a significant impact on the labour market, which is characterised by imperfect and asymmetric information. First, the internet might change the way in which employers and employees are matched. Additionally to the traditional job advertisements in newspapers, internet job boards have grown and firms now post their job openings on their websites. Reversely, these job boards also allow employers to look for potential employees. The online advertisements have the advantage over traditional advertisements in newspapers of being more up-to-date and easier to search. Therefore, internet job boards should increase the efficiency of job matching via their function of reducing the costs of searching for job openings and acquiring information about employers or employees. Second, Autor points out that employees may deliver their work increasingly online rather than on site. Remote access to machinery, emails and documents allows employees to perform their task from different locations. Third, related to the previous point, labour demand may depend less on local market condition, but production may be divided into tasks that are done where labour supply conditions are favourable. The coordination of the different tasks could be achieved via information and communication technologies. Thus, Autor concludes that the possibilities arising from the diffusion of internet may have a strong impact on the functioning of the labour market.

A study by Kuhn and Skuterud (2004) focuses on the first aspect described by Autor (2001). They analyse the effect of different search methods, among others online search, on unemployment duration. They look at which types of unemployed searched for jobs online and whether using the internet led to finding a new job faster. They find that those unemployed who search online experience a lower unemployment duration. However, these unemployed also have observed characteristics that are typically associated with shorter unemployment duration, such as better education and having worked in occupations with low unemployment rates. When controlling for these observable characteristics, the authors find either no difference in unemployment duration or, for some specifications, even significantly longer durations for unemployed who search online. They conclude that either searching for a new job online does not reduce unemployment durations or that a negative selection on unobservables into online job search exists.

Also Stevenson (2009) analyses how the internet changes job search behaviour and worker flows. However, she looks at those who are currently unemployed as well as at those who are currently employed and finds different patterns for the two groups. For those currently unemployed, she finds that using the internet has increased the variety of job search methods and that it has increased total job search activity. Also, using the internet for job searches has led to a reallocation of effort among different job search methods, e.g. unemployed are more likely to look at ads and to contact an employer directly. However, most online job searching is done by those who are currently employed. These employed job seekers are more likely to leave their current employer and, compared to traditional on-the-job search, online on-the-job search may increase the rate at which employees change employers.

3 Identification Strategy

An association between broadband internet and unemployment cannot be interpreted as a causal effect of internet on unemployment because of endogeneity concerns that may be caused by reverse causality or omitted variables. For example, in regions with low unemployment rates demand for broadband internet connections may be high because people have more available income. This higher demand may lead to a faster roll-out of broadband networks to these regions. Further, demand for broadband internet may be driven by variables like education levels which may also have an effect on unemployment but are not observed on the municipality level. To address these concerns, an instrumental-variable approach is used that rests on technology-driven impediments to the roll-out of high-speed internet.[1]

In Germany, the most common technology to access the internet is DSL. The DSL network is built along the existing network for voice-telephony by upgrading the existing infrastructure. For this purpose, the existing copper wires of the voice-telephony network are gradually being replaced by optical fibre. This process started at the highest aggregation level, the backbones, and today the network is typically fibre-based up to the main distribution frame (mdf). This stage of the process allows the provision of DSL. At the mdf, the fibre

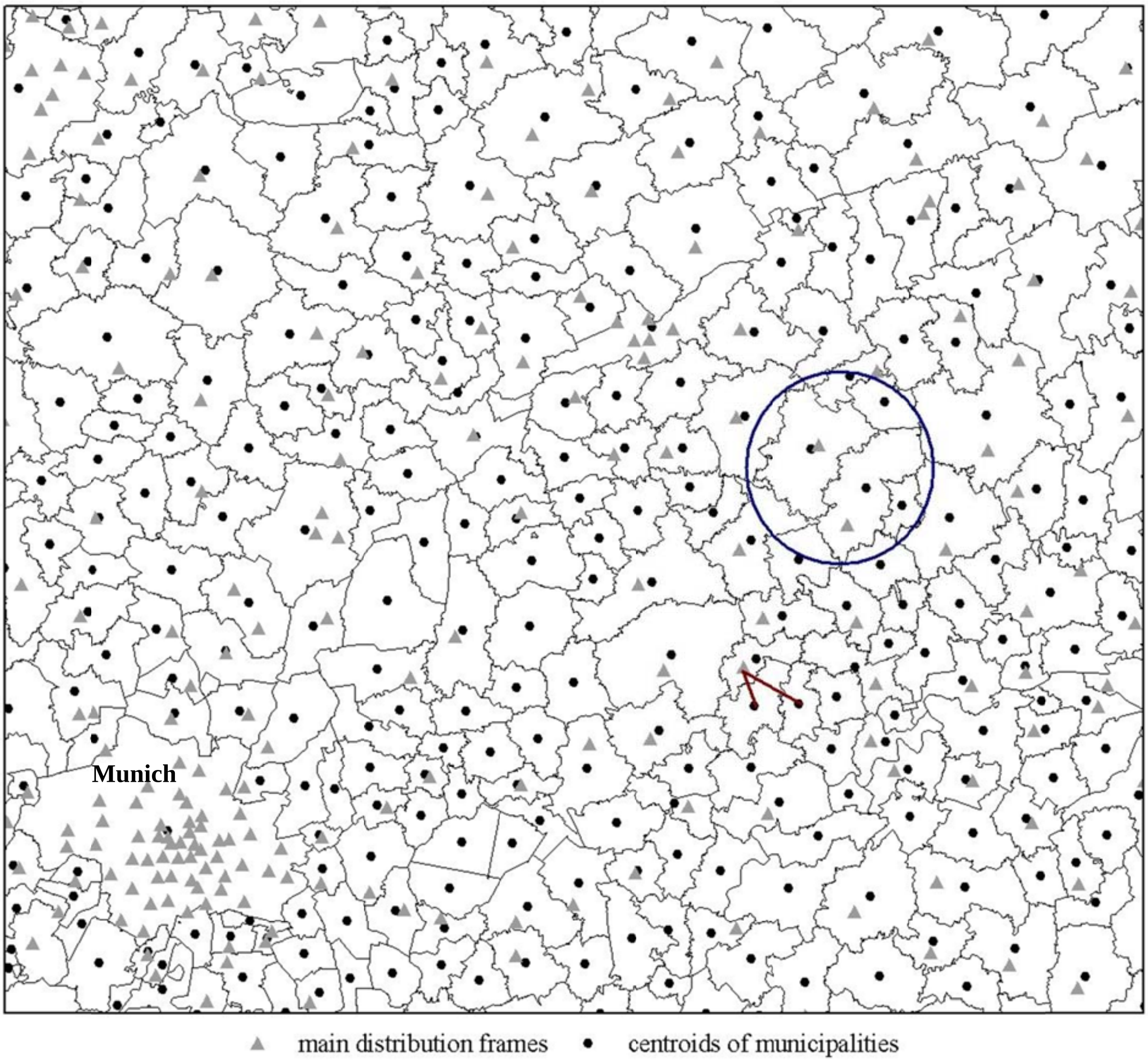
[1] The same identification strategy is used in Czernich (2011) to determine the effect of DSL availability on political participation.

network connects to the existing copper wires that run from the mdf to the individual households. Especially in rural areas, the distance between the mdf and the individual households may be relatively long. For the provision of voice-telephony services the length of this distance did not influence the quality of the connection. However, for the provision of DSL this distance matters since the longer the distance, the less bandwidth is feasible via this wire. If the distance is too long, i.e. longer than around 5 km, additional measures are necessary for the upgrade to broadband internet. It may be necessary to substitute the copper wires with optical fibre not only up to the mdf but up to the next lower network level. Since the wires are laid subterraneously, the substitution of the wires involves excavation works which are very costly and may delay or even prohibit the provision of broadband for the affected households.

In rural areas, often more than one municipality share one mdf, which is set up in one of the municipalities. This municipality can be supplied with broadband internet relatively easily, while for the other municipalities without an mdf the long distance to the mdf is an impediment for the supply of broadband internet to their homes. Hence, the location of the mdf may determine whether households in a municipality have access to the DSL network and therefore to high-speed internet. In order to construct an instrumental-variable to predict DSL availability, the distance from every municipality to the location of the closest mdf is calculated. This distance is then used as an instrumental-variable to predict the DSL rate in a municipality. The mdfs were built for the provision of voice-telephony, i.e. for other purposes than the provision of broadband internet and their set-up was finished before DSL came up. The location of the mdf, and consequently the distance between a municipality and its closest mdf, is therefore predetermined when considering DSL roll-out. However, this does not guarantee exogeneity in an econometric sense. The validity of the instrument is therefore further discussed in Section 5.

The location of each of the approximately 8,000 mdfs in Germany is taken from the broadband initiative *Zukunft Breitband* of the Federal Ministry of Economics and Technology. As a proxy for the location of the municipality, the geographic centre (centroid) of each municipality is computed and used for the calculation of the distance. Figure 1 is a section of a map of Germany showing the area north east of Munich (Munich can be found in the bottom left corner). It illustrates the distribution of the municipalities, their centres and the main distribution frames. Each area is one municipality and the black dots represent the geographic centres of the municipalities. The grey triangles represent the mdfs. While Munich has many mdfs, the more rural municipalities typically have only one or no mdf. These municipalities without their own mdf use the mdf of one of their neighbouring municipalities. The two lines in Figure 1 represent the distance to the closest mdf for two neighbouring municipalities that both do not have an mdf. Although being neighbours, the distance between the centres of the municipalities and the closest mdf varies. This variation in the distance has an important effect on the availability of broadband in a municipality and is therefore used to predict broadband availability.

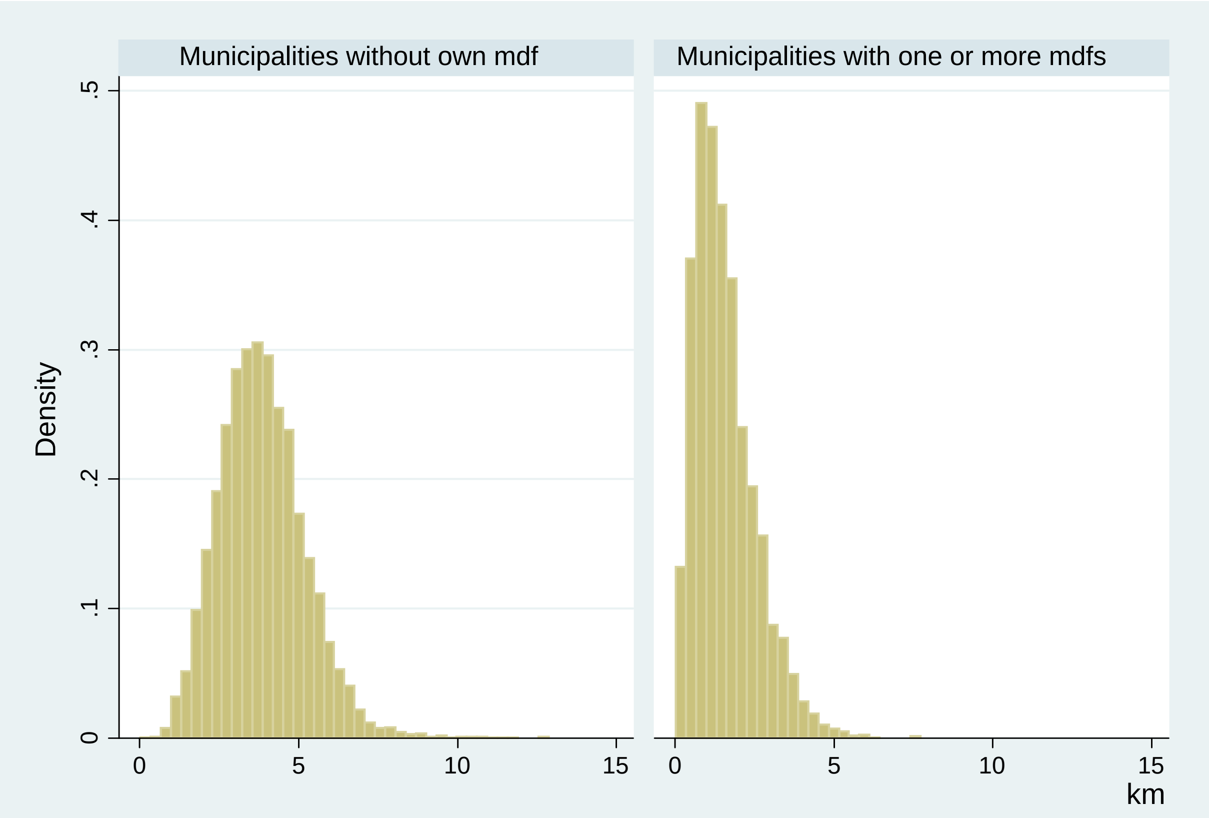
Figure 1: Distribution of Main Distribution Frames



However, this method to calculate the distance is not perfect, since the centre of a municipality is only a proxy for the location of the settlement, i.e. the area within a municipality where people actually live. This problem is most prominent in municipalities that do have their own mdf. The circle in Figure 1 points to two municipalities where this problem is particularly obvious. In the upper municipality, the geographic centre of the municipality and the mdf, which typically is set up in a village or town, lie very close to each other. Hence, here the location of the settlement within the municipality and the geographic centre of the municipality seem to coincide. In contrast, in the lower municipality, the geographic centre and the mdf are far apart. Since the mdf is typically set up within a residential area, in this example the geographic centre and the actual location of the settlement seem not to coincide and the geographic centre is not a good proxy. This problem causes the calculated distance between a municipality and its closest mdf to be higher than the actual distance in municipalities with their own mdf.

The distribution of the distance between the geographic centre of a municipality and the closest mdf differs between the samples of the approximately 7,000 municipalities without an mdf and the approximately 5,000 municipalities with at least one mdf. Figure 2 shows the distribution of the distance in kilometres for the sample of municipalities without an mdf (left panel) and the municipalities with at least one mdf (right panel). As expected, the distance is smaller for municipalities with at least one mdf, however, it is probably still too high because of the calculation error described above. Further, the municipalities with an own mdf can be supplied with DSL easily, thus, there is little variation in DSL availability in these municipalities. Therefore, the analysis will focus on the sample of municipalities without an mdf. This restriction generates a subsample of municipalities that have similar initial positions regarding DSL roll-out.

Figure 2: Distribution of the Distance to the Closest Main Distribution Frame



In East Germany, a technological particularity has to be considered. After the German Reunification, the outdated and insufficient East German telephone network was modernised. Instead of the classic copper based voice-telephony network infrastructure, optical network elements (opal technology) were used in some areas. In the 1990s, these optical network elements were considered to be the key future technology for telecommunication networks. However, only a few years later, the superior DSL technology was developed and became the prevalent technology for broadband networks since it allows higher bandwidths at lower investment costs. Unfortunately, the opal technology only allows narrowband connections and is not suitable to be upgraded to DSL. Therefore, it is much more costly to provide DSL in areas in which telephony services are provided via the opal technology than in areas where the telephone network is completely based on copper wire. The higher costs result from the need to roll-out copper wire in parallel to the fibre glass in the opal regions. In East Germany, 210 of the approximately 1,500 mdfs are equipped with the opal technology and for the areas that are served via these mdfs the roll-out of DSL is severely obstructed. To account for this, these mdfs are excluded from the list of mdfs to which the distance from the municipalities is calculated.[2]

[2] The information which main distribution frames are equipped with the opal technology was provided by the Deutsche Telekom AG.

4 Data, Model and Descriptive Evidence

4.1 Model

For the estimation of the relation between broadband internet and the unemployment rate, data for Germany on the municipality level is used. Since little information on municipality characteristics is available, a value-added model is estimated. Therefore, the lagged value of the dependent variable at a time before DSL has become a mass phenomenon is included on the right hand side of the estimation equation. This estimation equation is derived by taking first differences, i.e., the unemployment rate in the DSL era (2006) minus the unemployment rate before the DSL era (2002). Thereby, all past variables drop out and are implicitly captured by the lagged value of the dependent variable before the DSL era. Further, time-invariant omitted municipality characteristics that affect the unemployment rate in a municipality in the DSL era and before the DSL era are leveled out.

This leads to the following estimation equation:

$$u_{i2006} = \beta_1 DSLrate_{i2006} + \beta_2 u_{i2002} + \beta_3 X_{i2006} + \beta_4 Y_{j2006} + \varepsilon_{ij} \ . \quad (1)$$

The dependent variable u_{i2006}, the unemployment rate in the year 2006, is regressed on the DSL rate in 2006 and the unemployment rate in the year 2002. In the year 2002, DSL diffusion was still in its infancy. The diffusion of DSL in Germany started in the year 2000. In 2002 merely 3.3 million DSL lines existed, while in 2006 the number had more than quadrupled to 15 million (Bundesnetzagentur 2010). X_{i2006} are control variables on the municipality level, Y_{j2006} are control variables on the county level.

4.2 Data Description

Table 1 gives an overview of the descriptive statistics for the municipalities without an own mdf. The information on DSL diffusion is taken from the *Breitbandatlas Deutschland*, an annual survey on broadband availability that is conducted by the German Ministry of Economics and Technology. Network providers are asked which geographic areas they cover with their services and so a comprehensive dataset of the availability of DSL connections on the municipality level is compiled. The DSL rate is measured as the percentage of households in a municipality for which DSL is available. On average in the year 2006, DSL was available to 70.9 percent of the households, i.e. they could subscribe to a DSL connection, in a municipality without an own mdf.

The information on unemployment rates and control variables on the municipality level, population density and surface area, are taken from *Statistik lokal*, a dataset on the municipality level that is issued by the German Federal Statistical Office. The unemployment rate is defined as the number of unemployed relative to the working age population (population age 18 to 64). The unemployment rate hardly changed between 2002 and 2006 and in both years was just below eight percent. Analogue, the unemployment rate of those less than 25 years old is calculated. It also changes only slightly and is around one percent in both years.

Since many relevant control variables are not available at the municipality level, economic variables at the county level are added to the data. This regional information at the county level is taken from the regional database (*Regionaldatenbank*) of the German Federal Statistical Office. GDP per capita and number of firms relative to the population are included to represent the economic strength of the county a municipality belongs to. The percentage of pupils in a county that leave school with different degrees is included in order to represent the human capital in a region. On average, 8 percent of the pupils that left school in the year 2006 did not attain any degree. The majority, 70 percent, left school with a certificate of secondary education (*Hauptschulabschluss* or *Realschulabschluss*) and 22 percent left school with a university-entrance diploma (*Abitur*).

Finally, the division of counties into the different settlement areas, urban hinterland, rural hinterland and rural zones, follows the distinction of the Federal Institute for Research on Building, Urban Affairs and Spatial Development. The distinction is based on whether a county is part of an agglomeration area (hinterland versus zone) and on its population density (urban versus rural). Table 1 shows that 38 percent of the municipalities are in the urban hinterland, 26 percent are in the rural hinterland and 31 percent are in a rural zone.

Table 1: Descriptive Statistics

Variable	Observations	Mean	Std. Dev.	Min	Max
DSL rate	6,919	70.93	31.66	0	100
Unemployment rate 2006	6,919	7.88	5.06	0	35.48
Unemployment rate under 25 years 2006	4,794	1.09	0.67	0	6.17
Unemployment rate 2002	6,855	7.88	5.37	0.82	43.52
Unemployment rate under 25 years 2002	6,855	0.96	0.66	0	5.31
Population	6,919	1,388.69	1,789.57	43	22,803
Surface area	6,919	14.36	12.24	0.39	177.99
County level variables:					
GDP per capita	6,163	20.89	5.30	12.57	90.18
Number of firms per 1000 inhabitants	6,163	0.59	0.24	0.22	1.74
Percent of pupils without any degree	6,919	8.38	2.22	3.63	14.49
Percent of pupils with certificate of secondary education	6,919	70.13	6.74	54.93	94.01
Percent of pupils with university-entrance diploma	6,919	21.50	6.15	0	39.62
Urban hinterland	6,919	0.37	0.48	0	1
Rural hinterland	6,919	0.28	0.45	0	1
Rural area	6,919	0.34	0.47	0	1

Notes: Descriptive statistics for municipalities without an own mdf. Regional data on German municipalities for the year 2006 from the German Statistical Office, data at the county level from the regional database of the German Statistical Office. Unemployment rate is defined as the number of unemployed relative to the working age population (age 18-64) in a municipality. Data at the county level from the regional database of the German Statistical Office. Information on DSL availability is taken from the *Breitbandatlas Deutschland*. DSL rate is measured as the percentage of households for which DSL is available. The distinction into different types of settlement areas follows the distinction of the Federal Institute for Research on Building, Urban Affairs and Spatial Development. Not included are municipalities that are defined as an agglomerated city or that have more that 500,000 inhabitants.

4.3 The Association between Broadband Infrastructure and Unemployment

Table 2 presents the OLS estimation results of the association between DSL availability and the unemployment rate in 2006. All specifications include only municipalities without an own mdf and standard errors are clustered at the county level.

Model 1 shows the association between the unemployment rate and the DSL rate without any control variables. The coefficient is negative and significant at the one percent level. In Model 2, the unemployment rate in the year 2002, when the DSL diffusion was still in its infancy, is included. The coefficient drops sharply by more than a factor of ten to -0.0048, however, it is still significant at the one percent level. Model 3 additionally controls for population and the surface area of the municipality to ensure that availability of DSL is not merely capturing how rural a municipality is. Since the coefficient hardly changes when these variables are included, this does not seem to be a concern.

In Models 5 and 6, additional control variables on the county level are included. Model 5 includes GDP per capita and the number of firms per 1000 inhabitants to account for the economic strength of a region, which lowers the coefficient slightly to -0.0035. In Model 6, the percentage of pupils with a certificate of secondary education and with a university-entrance diploma are included to represent the level of human capital in a region. These variables have a significant effect on unemployment. The effect of the DSL rate on the unemployment rate gets slightly lower to -0.0031 and is significant at the 5 percent level. Model 7 controls for the different settlement types by including dummies for rural hinterland and rural zones. In Model 8, a dummy is included that indicates whether a municipality lies in East Germany. The inclusion of theses dummies decreases the size of the coefficients to -0.0028 and -0.0026, respectively. Further, given that the unemployment rate is defined relative to the working age population, changes in the population of a municipality could change the unemployment rate. Therefore, relocations across municipality boarders were included as an additional control variable in Model 8. This does not change the result.

Table 2: DSL Availability and Unemployment Rate: OLS Results

Dependent variable: Unemployment rate 2006	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
DSL rate 2006	-0.0588***	-0.0048***	-0.0045***	-0.0035**	-0.0031**	-0.0028**	-0.0026*	-0.0025*
	[8.64]	[2.69]	[2.59]	[2.40]	[2.29]	[2.18]	[1.95]	[1.87]
Unemployment rate 2002		0.8489***	0.8461***	0.8594***	0.8340***	0.8317***	0.8129***	0.8103***
		[45.59]	[44.98]	[42.82]	[36.86]	[37.06]	[28.76]	[28.60]
Population			-0.0000*	0	0.0000**	0.0000***	0.0000**	0.0000***
			[1.68]	[0.58]	[2.43]	[2.65]	[2.46]	[2.77]
Surface area			0.0095***	0.0063*	0.0042	0.0033	0.0026	0.0023
			[2.72]	[1.94]	[1.29]	[1.02]	[0.83]	[0.75]
County level variables:								
GDP per capita				-0.0133	-0.0139	-0.0145	-0.0076	-0.0061
				[1.26]	[1.35]	[1.38]	[0.74]	[0.60]
Number of firms per 1000 inhabitants				-0.7655**	-0.3433	-0.3198	-0.5087*	-0.5407*
				[2.57]	[1.24]	[1.18]	[1.70]	[1.81]
Percent of pupils with certificate of secondary education					-0.1690***	-0.1685***	-0.1598***	-0.1644***
					[5.72]	[5.88]	[5.71]	[5.88]
Percent of pupils with university-entrance diploma					-0.1736***	-0.1721***	-0.1702***	-0.1749***
					[5.55]	[5.55]	[5.54]	[5.69]
Dummy rural hinterland						-0.0198	-0.0402	-0.0435
						[0.15]	[0.29]	[0.32]
Dummy rural zone						0.1424	0.1117	0.1135
						[0.92]	[0.72]	[0.74]
Dummy East Germany							0.3799	0.347
							[1.64]	[1.51]
Net migration relative to working age population								-0.0677***
								[6.02]
Constant	12.0546***	1.4925***	1.3998***	1.9429***	17.4897***	17.3828***	16.7308***	17.1235***
	[17.42]	[8.32]	[7.62]	[6.30]	[6.25]	[6.39]	[6.31]	[6.46]
Observations	6919	6855	6855	6099	6099	6099	6099	6099
R-squared	0.14	0.84	0.84	0.85	0.85	0.85	0.85	0.86

Notes: OLS estimations for municipalities in 2006. Only municipalities without their own main distribution frame are included. The unemployment rate is defined as the number of unemployed relative to the working age population (population age 18 to 64).The DSL rate is measured as the percentage of households in a municipality for which DSL is available. Robust t statistics in brackets (clustered at the county level); * significant at 10%; ** significant at 5%; *** significant at 1%.

The size of the coefficient can be interpreted as follows: a coefficient of -0.003 means that a 10 percentage point higher DSL rate is associated with a 0.03 percentage point lower unemployment rate. Expressed in standard deviations, this means that an increase of the DSL rate by one standard deviation corresponds to a decrease of the unemployment rate by 2 percent of a standard deviation. Thus, the quantitatively the association between DSL availability and unemployment is quite small. One reason for this result might be the high persistence of the unemployment rate. This is indicated by the coefficient of the unemployment rate in the year 2002, which is in all specifications above 0.8. Hence, there is little variation of the unemployment rate in a municipality over time, but the lagged unemployment rate is a good predictor for the current unemployment rate.

The internet is used a lot more by young people. The (N)ONLINER Atlas (TNS Infratest and Initiative D 21 2006), a yearly survey on internet usage in Germany, found that in 2006 among the 14 to 29 year old 86.5% used the internet compared to 58.2% of the overall population. It is therefore likely that young people also use the internet more frequently or more intensively for their job searches. Thus, in the following the analysis focuses on the unemployed who are younger than 25 years.

The specifications of Table 3 correspond to the specifications of Table 2 with the only difference that the unemployment rate includes only unemployed younger than 25 years. Model 1, the bivariate association between DSL rate and unemployment rate shows a significantly negative coefficients of -0.0086, which is a lot smaller than the coefficient of the corresponding specification of all unemployed (-0.059). Controlling for the lagged unemployment rate reduces the coefficient by one half, thus the reduction is smaller than in the corresponding model for all unemployed. The coefficient in Model 2 (-0.0043) is now similar to the coefficient in Model 2 with all unemployed (-0.0048). Controlling for population and surface area on the municipality level (Model 3) reduces the size of the coefficient slightly to -0.0038. In Models 4 and 5, economic and educational control variables on the county level are included, which reduces the coefficient to -0.0032 and -0.0028 with significance at the one percent level. Model 6 includes dummies for the different settlement types, Model 7 a dummy indicating that a municipality is in East Germany. The coefficients are again slightly smaller (-0.0027 and -0.0022), but still significant at the 1 percent level. In Model 8, relocations across municipality boarders are included, which does not change the coefficient.

The unemployment rate under 25 for the year 2006 contains many missing values, most of them in the federal states of Schleswig-Holstein and Rhineland-Palatinate. To ensure that the results are not driven by a possibly systematic structure of the missing values, the models were also estimated excluding these two states. This did not change the results.

While the coefficient of the DSL rate is similar for all unemployed and the unemployed under 25, its explanatory power is larger for this subgroup. It means that an increase of the DSL rate by one standard deviation is associated with a decrease of the unemployment rate of those under 25 years by 15 percent of a standard deviation. This suggests that for younger unemployed having access to the internet might have a larger effect for a successful job search than for the whole group of unemployed.

The OLS estimations already take a step to overcome a potential omitted variable bias by estimating a value-added model and by restricting the sample to municipalities that have a similar initial position regarding their chances to be connected to the DSL network. However, the OLS results should be interpreted cautiously because of endogeneity concerns that may be caused by reverse causality or time varying omitted variables. In areas where unemployment declined, individuals may have a higher ability to pay and, therefore, a higher demand for internet services, resulting in a more rapid roll-out of DSL infrastructure to these areas. Further, a municipality may have an active mayor or municipal council that works towards economic development which may include the promotion of DSL roll-out to the municipality, the designation of a commercial area etc. This could cause a correlation between DSL availability and the unemployment rate, which, however, would not be a causal effect of internet availability. In order to address such concerns, the instrumental-variable approach that was described in Section 3 is used to identify potential causal effects.

Table 3: DSL Availability and Unemployment Rate under 25 Years: OLS Results

Dependent variable: Unemployment rate under 25 years 2006	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
DSL rate 2006	-0.0086***	-0.0043***	-0.0038***	-0.0032***	-0.0028***	-0.0027***	-0.0022***	-0.0022***
	[10.45]	[5.96]	[5.51]	[6.33]	[6.27]	[5.90]	[4.99]	[4.97]
Unemployment rate under 25 years 2002		0.6216***	0.5928***	0.5505***	0.4773***	0.4667***	0.3805***	0.3760***
		[24.63]	[23.24]	[16.55]	[15.10]	[14.83]	[12.32]	[12.31]
Population			-0.0000***	-0.0000***	-0.0000***	-0.0000***	-0.0000***	-0.0000***
			[6.78]	[5.53]	[4.60]	[3.62]	[3.79]	[3.67]
Surface area			-0.0008	-0.0004	-0.0006	-0.0013*	-0.0019***	-0.0020***
			[1.37]	[0.67]	[0.98]	[1.93]	[2.87]	[3.00]
County level variables:								
GDP per capita				-0.0121***	-0.0113***	-0.0116***	-0.0049*	-0.0046*
				[2.65]	[2.85]	[2.96]	[1.84]	[1.77]
Number of firms per 1000 inhabitants				-0.0488	0.0532	0.0633	-0.0842	-0.0908
				[0.68]	[0.78]	[0.96]	[1.22]	[1.32]
Percent of pupils with certificate of secondary education					-0.0480***	-0.0460***	-0.0335***	-0.0339***
					[5.93]	[5.95]	[4.69]	[4.79]
Percent of pupils with university-entrance diploma					-0.0422***	-0.0392***	-0.0340***	-0.0345***
					[4.78]	[4.58]	[4.24]	[4.33]
Dummy rural hinterland						0.0309	0.0087	0.0081
						[0.95]	[0.26]	[0.24]
Dummy rural zone						0.0945***	0.0663*	0.0666*
						[2.73]	[1.80]	[1.81]
Dummy East Germany							0.3040***	0.2978***
							[6.72]	[6.63]
Net migration relative to working age population								-0.0135***
								[2.65]
Constant	1.7143***	0.7658***	0.8471***	1.0665***	5.3160***	5.0681***	4.0012***	4.0380***
	[22.02]	[10.94]	[11.41]	[9.17]	[6.88]	[6.82]	[5.87]	[5.96]
Observations	4795	4746	4746	4166	4166	4166	4166	4166
R-squared	0.15	0.48	0.49	0.5	0.53	0.53	0.54	0.55

Notes: OLS estimations for municipalities in 2006. Only municipalities without own main distribution frame are included. The unemployment rate is defined as the number of unemployed under 25 years relative to the working age population (population age 18 to 64).The DSL rate is measured as the percentage of households in a municipality for which DSL is available. Robust t statistics in brackets (clustered at the county level). * significant at 10%; ** significant at 5%; *** significant at 1%.

5 The Causal Effect of Broadband Infrastructure on Unemployment Instrumental-Variable Results

5.1 Intrumental-Variable Results

Table 4 shows the results from the instrumental-variable estimations of the effect of DSL availability for all unemployed. The samples include only the municipalities without their own mdf. The left column of the three models shows the first stage of the two stage least square estimation with the DSL rate as the dependent variable. In all three models, the distance from a municipality to the closest mdf has a significant effect on the DSL rate. Depending on the specification, being one kilometre further away from an mdf is associated with between a 6.9 and 7.4 percentage point lower DSL rate. The F-statistics are between 146 and 169, thus confirm that the instrument is strong.

The second stage of Models 1, 2 and 3 correspond to Models 3, 5 and 7 of Table 2. In all 3 models, the coefficient of the DSL rate on the unemployment rate is positive, however not statistically different from zero. To compare the instrumental-variable coefficients to the OLS coefficients, the Durbin-Wu-Hausman test is run. The null hypothesis of an exogenous regressor is rejected at the 5 percent significance level in Model 1 and at the 10 percent level in Models 2 and 3. This indicates that the instrumental-variable estimates differ significantly from the OLS estimates of the effect of DSL availability on unemployment. These results suggest that a causal effect of DSL availability on unemployment does not exist, but that the positive association, which was found in the OLS estimations, is driven by reverse causality or omitted variables.

Table 5 shows the results of the instrumental-variable estimations with the unemployment rate of those under 25 as the dependent variable. Only the municipalities without an mdf are included and Models 1, 2 and 3 correspond to Models 3, 5 and 7 of Table 3. The left columns, the first stage with the DSL rate as the dependent variable, show that the distance to the closest mdf has a significant effect on the DSL rate. Being one kilometre further away from an mdf corresponds to between a 5.5 and 5.9 percentage point lower DSL rate. Again, the F-statistics (between 99 and 116) confirm that the instrument is strong.

Table 4: The Effect of DSL Availability on Unemployment: Instrumental-Variable Results

	Model 1		Model 2		Model 3	
Dependent variable:	DSL rate	Unemployment	DSL rate	Unemployment	DSL rate	Unemployment
2SLS:	first	second	first	second	first	second
DSL rate		0.0039		0.0021		0.0030
		[1.12]		[0.68]		[1.00]
Distance to closest mdf	-6.9178***		-7.4061***		-7.2375***	
	[12.11]		[13.04]		[12.48]	
Unemployment rate 2002	-1.7814***	0.8621***	-1.7317***	0.8442***	-1.1785***	0.8200***
	[9.86]	[40.97]	[7.32]	[35.75]	[4.16]	[28.07]
Population	0.0025***	-0.0001**	0.0019***	0	0.0016***	0
	[6.73]	[2.51]	[6.56]	[1.13]	[5.64]	[1.23]
Surface area	0.1110*	0.0113***	0.1922***	0.005	0.2423***	0.0030
	[1.72]	[3.12]	[3.04]	[1.53]	[4.10]	[0.95]
County level variables:						
GDP per capita			0.0639	-0.0139	-0.0791	-0.0066
			[0.47]	[1.33]	[0.67]	[0.65]
Firms relative to population			-5.2160	-0.3137	-1.5575	-0.5022*
			[1.42]	[1.11]	[0.47]	[1.66]
Percent of pupils with certificate of			0.6265	-0.1718***	0.3935	-0.1611***
secondary education			[1.42]	[5.60]	[0.97]	[5.62]
Percent of pupils with university-entrance			0.7010	-0.1767***	0.5817	-0.1726***
diploma			[1.56]	[5.44]	[1.43]	[5.46]
Rural hinterland					-0.2959	-0.0311
					[0.16]	[0.22]
Rural zone					-4.6479**	0.1448
					[2.41]	[0.95]
East Germany					-8.8769***	0.4410*
					[2.77]	[1.91]
Constant	106.4834***	0.6916**	51.0175	17.2878***	69.8962*	16.3790***
	[51.47]	[2.19]	[1.23]	[6.03]	[1.85]	[6.13]
Observations	6855	6855	6099	6099	6099	6099
R^2	0.24	0.84	0.26	0.85	0.27	0.85
F-test of excluded instruments	146.06		169.43		155.14	
Durbin-Wu-Hausman test of exogeneity		5.57**		3.21*		3.80*

Notes: Oonly municipalities without own main distribution frame are included. The unemployment rate is defined as the number of unemployed relative to the working age population (population age 18 to 64).The DSL rate is measured as the percentage of households in a municipality for which DSL is available. Robust z statistics in brackets brackets (clustered at the county level); * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 5: The Effect of DSL Availability on Unemployment under 25 Years: Instrumental-Variable Results

	Model 1		Model 2		Model 3	
Dependent variable:	DSL rate	Unemployment rate under 25	DSL rate	Unemployment rate under 25	DSL rate	Unemployment rate under 25
2SLS:	first	second	first	second	first	second
DSL rate		-0.0003		-0.0002		0.0012
		[0.27]		[0.16]		[1.11]
Distance to closest mdf	-5.5027***		-5.8603***		-5.5188***	
	[9.95]		[10.81]		[9.95]	
Unemployment rate under 25 in 2002	-11.3503***	0.6354***	-9.0511***	0.5044***	-4.0067***	0.3948***
	[9.06]	[23.84]	[6.40]	[15.33]	[2.91]	[12.57]
Population	0.0027***	-0.0001***	0.0017***	-0.000***	0.0015***	-0.000***
	[6.53]	[6.19]	[6.30]	[4.80]	[5.72]	[4.20]
Surface area	-0.0393	0.0002	0.0258	0.0001	0.0912*	-0.0014*
	[0.64]	[0.31]	[0.43]	[0.10]	[1.71]	[1.96]
County level variables:						
GDP per capita			0.2052	-0.0118***	-0.1033	-0.0043*
			[1.51]	[2.84]	[1.16]	[1.66]
Number of firms per 1000 inhabitants			-4.1085	0.0663	2.2733	-0.0928
			[1.06]	[0.93]	[0.62]	[1.27]
Percent of pupils with certificate of secondary education			1.5705***	-0.0523***	0.7771**	-0.0358***
			[3.54]	[6.00]	[2.02]	[4.77]
Percent of pupils with university-entrance diploma			1.5675***	-0.0464***	1.0602***	-0.0375***
			[3.47]	[4.89]	[2.72]	[4.38]
Rural hinterland					0.0546	0.0112
					[0.03]	[0.31]
Rural zone					-5.1895***	0.0866**
					[2.66]	[2.19]
East Germany					-14.3810***	0.3606***
					[5.25]	[7.91]
Constant	101.3321***	0.551***	-43.9282	5.4881***	25.2389	3.9457***
	[46.27]	[5.79]	[1.05]	[6.64]	[0.71]	[5.56]
Observations	4746	4746	4166	4166	4166	4166
R^2	0.20	0.47	0.23	0.51	0.26	0.52
F-test of excluded instruments	98.68		116.43		98.66	
Durbin-Wu-Hausman test of exogeneity		9.93***		6.23**		9.33***

Notes: Only municipalities without own main distribution frame are included. The unemployment rate is defined as the number of unemployed under 25 years relative to the working age population (population age 18 to 64).The DSL rate is measured as the percentage of households in a municipality for which DSL is available. Robust z statistics in brackets brackets (clustered at the county level); * significant at 10%; ** significant at 5%; *** significant at 1%.

In Models 1 and 2, the coefficient of the DSL rate on the unemployment rate of those under 25 years is negative, in Model 3, the coefficient is positive However, it is not statistically different from zero in any of the three models. The Durbin-Wu-Hausman test reveals that in all three models the null hypothesis that the DSL rate is exogenous must be rejected and therefore the coefficients of the OLS regressions can be excluded. Thus, the results of the instrumental-variable estimations suggest that also for those under 25 years a causal effect of DSL availability on the unemployment rate does not exist.

5.2 Robustness Tests and Discussion

For the distance between a municipality and its closest mdf to be a valid instrument, it must not influence the outcome variable in any other way than through DSL availability. This implies that the choice of the location of the mdf was not affected by municipality characteristics that may also influence voter behaviour, e.g. economic strength. An enquiry at the Deutsche Telekom, which was the monopolist at the time of the roll-out of voice-telephony network and thus set up the mdfs, led to the information that location choices were made based on technical and cost reasons, e.g. how many customers could be connected to the voice telephony network. As a result, if mdfs were set up in municipalities with a higher population density, the instrument might capture an agglomeration effect since the more populated municipalities might be "regional centres" with more firms, shops, etc. Then the distance to the closest mdf would measure how close a municipality is to a "regional centre". Being close to such a "regional centre" might influence the unemployment rate in neighbouring municipalities since their inhabitants can commute to the "regional centre" or suppliers or small businesses might settle in the neighbouring municipalities and offer jobs there. To address this concern, additional specifications of the instrumental-variable model are estimated, in which the sample is split into subsamples to ensure that the municipalities with the closest mdf are not a "regional centre".

Tables 6 and 7 show the additional estimations for all unemployed and the unemployed under 25 years, respectively. The samples include only municipalities without an mdf and are further restricted based on characteristics of a municipality relative to characteristics of the municipality in which the closest mdf stands. In Model 1, the sample is restricted to municipalities that use the mdf in a municipality that has at most the same population density as itself. The sample in Model 2 is based on the same reasoning. The sample is restricted to the municipalities where the municipality to which mdf they are connected does not have more than one mdf. These restrictions exclude the municipalities around larger municipalities and towns and should therefore rule out agglomeration effects. Imposing the restrictions decreases the number of observations in the estimations for all unemployed from 6,099 to 1,467 (Model 1) and 5,288 (Model 2) and for the unemployed under 25 from 4,166 to 1,186 (Model 1) and 3,511 (Model 2). For both dependent variables the additional restrictions do not change the results. The distance to the closest mdf still proves to be a strong instrument and the effect of the DSL rate on the unemployment rate and the unemployment rate under 25 is not statistically significant in any of the estimated models. For all models, the Durbin-Wu-Hausman-test shows that the instrumental-variable estimates differ statistically from the OLS estimates. The fact that the results do not change when imposing the additional restrictions provides confidence that the instrument indeed captures DSL availability and not agglomeration effects.

Table 6: The Effect of DSL Availability on Unemployment: Instrumental-Variable Results with Additional Sample Restrictions

	Model 1		Model 2	
Dependent variable:	DSL rate	Unemployment rate	DSL rate	Unemployment rate
2SLS:	first	second	first	second
DSL rate		0.0064		0.0033
		[1.01]		[0.98]
Distance to closest mdf	-5.9757***		-7.7140***	
	[7.86]		[12.58]	
Unemployment rate 2002	-1.2517**	0.8875***	-1.0698***	0.8136***
	[2.43]	[25.57]	[3.45]	[26.57]
Population	0.0020***	0.0001**	0.0023***	0
	[6.03]	[2.49]	[6.30]	[0.64]
Surface area	0.0941	0.0021	0.2586***	0.0026
	[1.06]	[0.46]	[4.07]	[0.75]
County level variables:				
GDP per capita	-0.1124	0.0044	-0.0803	-0.0077
	[0.67]	[0.37]	[0.67]	[0.72]
Firms relative to population	-2.0871	-0.0239	-1.7817	-0.4725
	[0.43]	[0.09]	[0.53]	[1.49]
Percent of pupils with certificate of secondary education	0.5369	-0.1477***	0.3160	-0.1731***
	[1.07]	[4.84]	[0.74]	[5.79]
Percent of pupils with university-entrance diploma	0.8911*	-0.1576***	0.5483	-0.1863***
	[1.87]	[4.94]	[1.29]	[5.76]
Rural hinterland	0.6742	-0.1547	0.0547	-0.0353
	[0.33]	[1.19]	[0.03]	[0.25]
Rural zone	-3.4255	0.1373	-3.9523**	0.1242
	[1.53]	[0.94]	[2.02]	[0.80]
East Germany	-11.7574**	0.0432	-10.3223***	0.5094**
	[2.35]	[0.13]	[3.04]	[2.09]
Constant	49.7323	13.8920***	76.1924*	17.5536***
	[1.06]	[4.88]	[1.93]	[6.33]
Observations	1467	1467	5288	5288
R^2	0.29	0.87	0.27	0.85
F-test of excluded instruments	61.50		157.60	
Durbin-Wu-Hausman test of exogeneity		2.53		3.30*

Note: Robust z statistics in brackets brackets (clustered at the county level); * significant at 10%; ** significant at 5%; *** significant at 1%. Models include only municipalities without own main distribution frame. Additional sample restrictions are based on the characteristics of the neighbouring municipality with the closest main distribution frame. Model 1 contains the municipalities where the neighbouring municipalities have at most the same population density. Model 2 contains the municipalities whose neighbouring municipalities do not have more than one main distribution frame.

Table 7: The Effect of DSL Availability on Unemployment under 25 Years: Instrumental-Variable Results with Additional Sample Restrictions

	Model 1		Model 2	
Dependent variable:	DSL rate	Unemployment rate under 25	DSL rate	Unemployment rate under 25
2SLS:	first	second	first	second
DSL rate		0.0024		0.0004
		[1.40]		[0.38]
Distance to closest mdf	-5.3839***		-6.0280***	
	[6.79]		[10.15]	
Unemployment rate under 25 in 2002	-4.2437*	0.5334***	-3.2349**	0.3628***
	[1.76]	[14.66]	[2.24]	[10.87]
Population	0.0018***	-0.0000*	0.0020***	-0.0000***
	[5.56]	[1.65]	[6.21]	[4.11]
Surface area	0.0471	-0.0002	0.1023*	-0.0022***
	[0.50]	[0.14]	[1.74]	[2.76]
County level variables:				
GDP per capita	-0.0957	-0.0047	-0.0975	-0.0040
	[0.62]	[1.62]	[1.05]	[1.42]
Number of firms per 1000 inhabitants	-0.1907	0.0246	2.0564	-0.1032
	[0.04]	[0.28]	[0.54]	[1.36]
Percent of pupils with certificate of secondary education	0.9304*	-0.0365***	0.7427*	-0.0376***
	[1.86]	[3.93]	[1.81]	[4.86]
Percent of pupils with university-entrance diploma	1.2341**	-0.0382***	1.0987***	-0.0397***
	[2.58]	[3.75]	[2.60]	[4.49]
Rural hinterland	0.2862	-0.0667	0.3371	0.0050
	[0.13]	[1.63]	[0.20]	[0.13]
Rural zone	-4.5320*	0.0451	-4.8185**	0.0811*
	[1.87]	[0.94]	[2.38]	[1.94]
East Germany	-16.5091***	0.2615***	-15.0862***	0.3777***
	[4.24]	[4.06]	[5.10]	[7.88]
Constant	9.3039	3.7312***	27.0964	4.2347***
	[0.20]	[4.33]	[0.71]	[5.75]
Observations	1186	1186	3511	3511
R^2	0.29	0.55	0.26	0.52
F-test of excluded instruments	45.99		102.73	
Durbin-Wu-Hausman test of exogeneity		6.94***		5.18**

Note: Robust z statistics in brackets brackets (clustered at the county level); * significant at 10%; ** significant at 5%; *** significant at 1%. Models include only municipalities without an own main distribution frame. Additional sample restrictions are based on the characteristics of the neighbouring municipality with the closest main distribution frame. Model 1 contains the municipalities where the neighbouring municipalities have at most the same population density. Model 2 contains the municipalities whose neighbouring municipalities do not have more than one main distribution frame.

For the interpretation of the results, one has to be aware that the DSL rate is measured as the DSL availability, i.e. the percentage of households in a municipality for which a DSL connection is available. In reality not the pure availability of DSL but its use will affect the outcome variable:

$$u_{i2006} = \delta_1 DSLuse_{i2006} + \delta_2 u_{i2002} + \delta_3 X_{i2006} + \delta_4 Y_{j2006} + v_{ij} \quad . \tag{2}$$

However, DSL use is not observed on the municipality level. Only DSL availability is observed, which influences DSL use:

$$DSLuse_{i2006} = \gamma_1 DSLavailability_{i2006} + \gamma_2 u_{i2002} + \gamma_3 X_{i2006} + \gamma_4 Y_{j2006} + u_{ij} \, . \tag{3}$$

Therefore, the two stage process towards DSL use via availability is estimated as a reduced form:

$$u_{i2006} = \delta_1 \gamma_1 DSLavailability_{i2006} + \beta_2 u_{i2002} + \beta_3 X_{i2006} + \beta_4 Y_{j2006} + v_{ij} + u_{ij} \, . \tag{4}$$

The estimated coefficient $\delta_1\gamma_1$ has to be interpreted as the effect of DSL availability on unemployment and cannot be interpreted as the effect of DSL use; the coefficient measures the intention to treat effect and not the treatment effect. Since the take-up rate for a DSL subscription γ_1, given DSL is available, is below one, the estimated coefficient is a proportional effect that is smaller than the effect of DSL use. While from the economist's view the effect of internet use on unemployment is an interesting question, from a policy perspective the effect of internet availability may actually be more interesting since availability is the parameter that can be influenced through policy interventions.

Another aspect to bear in mind is that the variation that is used to identify the effect of DSL availability comes from differences in DSL availability between municipalities that do not have their own mdf. Since these municipalities mainly lie in rather rural areas, the identified effect is only valid for those rural areas. Based on the results from this analysis, one cannot infer whether the effect is the same or different in agglomerated areas. For example, Internet might be more important for the job search in cities or towns to get information about firms and open positions while in rural areas such information might be spread via word of mouth. To make a statement about the effect of DSL availability on unemployment in agglomerated areas, further analysis is necessary. However, from a political perspective the effect of DSL availability in rural areas is a relevant question, since public policies aim at rolling-out DSL networks to "white spots" in rural areas.

As Stevenson (2009) showed, online job searches are very common among those currently employed and lead to an increased probability to change job. Using the unemployment rate as the dependent variable, however, captures only those currently unemployed finding a new job and not currently employed changing jobs, i.e. job matching improvements. But such improvements would lead to a higher productivity of the worker in the new position and may therefore contribute to economic growth. Thus, DSL availability may have a positive effect on economic growth through the labour market without decreasing the unemployment rate.

6 Conclusion

This paper addressed the question whether DSL availability affects unemployment. Two different dependent variables, unemployment rate and unemployment rate of those under 25 years, were used. The identification strategy is based on the comparison of municipalities that are similar in many respects, but differ with regard to DSL availability. This difference is determined by impediments to the roll-out of DSL networks that have their source in the structure of the pre-existing voice-telephony network. While the OLS estimations show a negative association between DSL availability and unemployment, the results from the instrumental-variable estimations cannot confirm that DSL availability has a causal effect on unemployment.

Several caveats have to be considered when interpreting the results. First, the variation that is used to identify the effect stems from differences in DSL availability between municipalities in mainly rural areas. Therefore, the identified effect is only valid for those rural areas and might be different in agglomerated areas. Second, the data on DSL diffusion in German municipalities only contains information on DSL availability and not on actual DSL use. Thus, this analysis cannot determine the effect of using the internet. Nevertheless, this approach allows the identification of the effect of DSL availability on unemployment. Hence, this analysis is suited to give advice to policy makers that are interested in the effects of the roll-out of DSL networks to rural areas. Third, DSL might improve job matching of those currently employed, which would lead to a higher productivity of the worker in the new position. This would have a positive effect on economic growth through the labour market without showing in a reduced unemployment rate.

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