Firm Responses to High-Speed Internet

Henrike Steimer (LMU Munich)

Discussion Paper No. 258

October 6, 2020

Collaborative Research Center Transregio 190 | www.rationality-and-competition.de
Ludwig-Maximilians-Universität München | Humboldt-Universität zu Berlin
Spokesperson: Prof. Dr. Klaus M. Schmidt, University of Munich, 80539 Munich, Germany
+49 (89) 2180 3405 | info@rationality-and-competition.de

Firm Responses to High-Speed Internet

Henrike Steimer*

September 2020

Abstract

Does access to the broadband internet stimulate firm growth? In this paper, I analyze within-firm growth of established firms caused by the access to faster internet using geocoded social-security data. I identify firm responses to the access to the first generation of broadband internet and later speed upgrades by exploiting technological peculiarities of the broadband internet network. I find that firms with access to the first generation of broadband internet grow more slowly in employment while keeping their output growth constant. They reduce the share of low-skilled employment in their workforce. Further, I find that firms that receive access to later speed upgrades grow more in revenues and employment than firms that got access to the first generation of broadband internet but not to the upgrades. When getting access to higher internet speed, firms over-proportionally increase medium-skilled employment.

JEL codes: D22, J23, O33

Keywords: ICT, internet, firm growth, skill-bias, technology

*LMU Munich, Seminar for Comparative Economics, Akademiestrasse 1, 80799 Munich, Germany, e-mail: henrike.steimer@econ.lmu.de. I thank Manfred Antoni (Institute for Employment Research, Nuremberg) for his permanent support and for providing access to the data. I thank Florian Zimmermann for excellent research assistance. For helpful comments and suggestions, I thank Oliver Falck, Anna Gumpert, Markus Nagler, Monika Schnitzer, Christina Stadler, Simone Schuller, and Martin Watzinger. Financial support by Deutsche Forschungsgemeinschaft through CRC TRR 190 (project number 280092119) and DFG Research Training Group 1928: Microeconomic Determinants of Labor Productivity is gratefully acknowledged.

1 Introduction

Information and communication technologies (ICT) are general purpose technologies that enable firms to reshape their business (e.g. Brynjolfsson and Saunders, 2010). Broadband internet, in particular, is said to have revolutionized many business processes. Firms may set up e-businesses and hence increase the size of the market they can serve. Further, broadband internet facilitates file-sharing and offers new communication tools like video-conferencing. Still, causal evidence on firm growth affected by broadband internet is limited as identifying the causal impact is difficult.

This paper studies how access to the broadband internet affects firm growth. My set-up allows identifying firm responses to the first generation of broadband internet access and later speed upgrades in Germany. I analyze within-firm growth and workforce adjustments caused by the access to the broadband internet and the later speed upgrades using detailed social-security data.

I find that firms with access to the first generation of broadband internet reduce their employment while keeping their output constant. They specifically reduce the share of low-skilled employment in their workforce. Further, I find that firms that get access to later speed upgrades grow more in revenues and employment than firms that do not get access to these upgrades. When getting access to higher internet speed, firms increase the share of medium-skilled while decreasing the share of high-skilled employment.

Theoretically, one would expect two distinct effects of broadband internet adoption on firm growth in revenues and employment. First, broadband internet is said to increase efficiency in production processes by reducing communication and coordination costs with customers and suppliers. As a result, required labor per unit of output decreases. Empirically, I test this hypothesis of increasing efficiency by regressing revenues per employee on broadband internet access.

Second, broadband internet potentially increases the size of the market a firm can serve by reducing search costs and offering new sales opportunities. Browsing the web provides a cheap way of searching for information on new markets. Also, firms can set up e-businesses that create new sales channels. As a result of the increase in market size, firms would grow in revenues and expand production. Thus, firms require more of each production factor, including labor. Empirically, I test this hypothesis by using revenues and value-added as the outcome variables to measure output. Further, I use different employment measures as outcome variables. In practice, both effects may occur simultaneously. In my analysis, I observe the net effect of potential expansions in output and employment as well as a decreasing ratio of required labor per unit of output.

Apart from its believed positive impact on growth, the expansion of broadband internet is said to contribute to a rising skill-biased technological change (Akerman et al., 2015). Policymakers should not only consider the overall employment effects of new technologies but also take the distribution effects into account. To contribute to this discussion, I study the changes in the skill composition of firms getting access to the broadband internet and later speed upgrades.

Identifying the impact of getting access to the broadband internet empirically poses a challenge as firms self-select into broadband internet adoption. This makes it difficult to disentangle the causal effect of broadband internet adoption from unobserved characteristics of firms that choose to adopt broadband internet. To overcome this problem, I use an identification strategy originally proposed by Falck et al. (2014) to compare firms with differential access to faster broadband internet before and after its introduction and later speed upgrades. During the early 2000s, broadband internet was diffused over the copper wires of the established telephone network in Germany. This imposed technological restrictions: the nature of the network exogenously led to differential access to higher broadband internet speed levels (here: digital subscriber line, DSL). The main distribution frames (MDFs) in the network are connected through copper wires to firms and households, also called the "last mile" of the network. With increasing distance to the MDF, the maximum speed provided decays up to a threshold distance. Whereas Falck et al. (2014) relate the distance between the geographical middle point of a municipality to the threshold to instrument the share of households with broadband internet access, I extend their strategy by calculating and using the individual distance of each firm to the main distribution frame (MDF).

I exploit the fact that distance to the MDF affected broadband internet speed availability in Germany, a technical feature that firms could not anticipate. I compare firms before and after the introduction of the first generation of broadband internet by restricting my sample to firms within small bounds around the threshold distance. Moreover, my identification strategy allows studying the impact of speed upgrading in addition to the effect of access to the first generation of broadband internet. Within the group of firms that got access to the first generation of broadband internet, only a subgroup also got access to the later speed upgrades. Again, the distance to the MDF determines how fast the internet a firm receives would be. Further, my strategy allows analyzing within-firm responses to the available speed upgrades by comparing the performance of a firm before and after the introduction of the upgrades. Hence, my findings are not driven by start-ups that particularly use the broadband internet in their business model. In my specification, I control for time- and firm-fixed effects to rule out time-constant firm characteristics and common time shocks. I analyze the impact on existing firms that get access to new technologies.

For my analysis, I assemble a novel dataset: using geographic information system software[1], I geocode single-establishment firms in a survey provided by the German Employment Agency (see Heining et al., 2016). I merge the geocoded telephone network (Bundesnetzagentur, 2017) to calculate the distance from each establishment to its MDF. I further combine the establishment-level data with employee-level social-security data

[1] I use QGIS version 2.18.3 (QGIS Development Team, 2017).

which allows me to study changes in the workforce composition.

Looking at firms getting access to the first generation of broadband internet, I find evidence that is consistent with increasing efficiency. Firms that get access to the first generation grow less in employment than firms that do not get access. They do not grow differently in revenues leading to increasing revenues per employee. Through the lense of potential theoretical impacts, this suggests increasing efficiency, but no market size effect. I also find that firms reduce the share of low-skilled employees in their workforce pointing to skill complementarity of broadband internet. The first generation of broadband internet facilitated the exchange of e-mails with large attachments (500kB and more). Hence, firms that got access probably engaged more in digitization processes that require less low-skilled labor than previous administrative work. Separating manufacturing and non-manufacturing firms reveals that non-manufacturing firms benefit most from getting access to the broadband internet.

A subgroup of firms that got access to the first generation of the broadband internet also experienced later speed upgrades. I find positive growth effects in revenues and employment indicating a market size effect. I find no significant evidence suggesting increasing efficiency, even though the results suggest a positive effect. Firms increase the share of medium-skilled employment. In contrast to the conventional understanding of skill complementarity to new technologies, firms reduce the share of high-skilled employees. The later speed upgrades of the broadband internet provided the possibility to set up online businesses. To serve a greater market, firms probably needed to expand production. If this expansion required hiring over-proportionally more medium-skilled labor, the share of high-skilled employees would fall without a reduction in the actual number of high-skilled employees.

To the best of my knowledge, I am the first to causally identify within-firm responses to broadband internet speed availability at the time of the introduction. I contribute to the literature in three ways. First, I build on and extend the literature on growth effects of broadband internet surveyed by Bertschek et al. (2015).[2] At the firm-level, the literature finds mixed results. Most papers studying the impact of the first generation of broadband internet find no significant effects on growth and differential effects on employment.[3]

One exception is Akerman et al. (2015) who find positive output elasticities as well as skill-biased employment and wage effects. They exploit the quasi-exogenous time variation in broadband infrastructure expansion in Norwegian municipalities due to the limited

[2] At the country-level, the literature mostly finds positive growth effects of broadband adoption (e.g. Czernich et al., 2011). Further, broadband availability at the county- and zip code-level is found to have a positive effect on employment in the USA (e.g. Kandilov and Renkow, 2010; Kolko, 2012), which mostly benefits skilled workers (Atasoy, 2013).

[3] De Stefano et al. (2014) exploit a fuzzy regression discontinuity design and find no effect of the broadband internet on firm growth. Stockinger (2017) employs the instrumental variable approach developed by Falck et al. (2014) directly to study employment growth of German establishments. He finds negative effects on employment growth of establishments in manufacturing and positive effects in knowledge-intensive industries. My rich dataset allows studying firm responses to broadband internet in more detail.

funding of a government initiative. In line with their results, I find increases in skill-biased demand for labor of firms with access to the broadband internet. My paper adds to their findings in a number of ways. I am able to look at within-firm responses, which allow me to control for any time-constant firm characteristics. Further, I exploit exogenously given technological restrictions which allow me to compare similar firms around the threshold distance within the same municipality. My strategy additionally allows comparing firms during the introduction of the first generation of broadband internet as well as later speed upgrades. Hence, my results provide further evidence on the economic implications of speed upgrades. Moreover, I show that broadband internet affected firms in different sectors heterogeneously. Thus, my paper contributes to the understanding of the actual sources of growth stemming from investments in broadband infrastructure.

In another relevant paper, Canzian et al. (2015) study the impact of the second generation of broadband internet (called ADSL2+) on firm growth in rural areas in the province of Trento (Italy). They exploit a government program upgrading rural areas to higher internet speed using longitudinal firm-level data. They find large positive effects on revenues and value-added and no effect on employment. My paper adds to their findings by including firms in both rural and urban areas and hence estimating an average effect which is of policy interest. Further, they analyze a later time period when the second major generation of broadband internet was already widespread in many areas. Hence, their large effects may be driven by a catch-up effect. My analysis focuses on the time of the first introduction of the broadband internet and later speed upgrades, including the second major generation of broadband internet. Analyzing a longer time period further allows me to observe effects that only show up with a time lag. Overall, my paper provides a more comprehensive picture of firm responses to broadband internet.

Second, I complement the literature on growth effects of ICT in general.[4] As a whole, the literature finds that productivity effects of ICT alone are very low. To fully exploit the potential of the new technologies, firms need to provide complementary factors like organizational adjustments (see e.g. Brynjolfsson and Hitt, 2000). I contribute to this literature by showing that firms that get access to the broadband internet and later speed upgrades increase the share of skilled labor.

Third, I extend the instrumental variable strategy by Falck et al. (2014) who study voting behavior. They exploit the distance between the geographical middle point of a municipality to its MDF as an instrument for the share of households in a municipality with broadband access. I build on this idea in my differences-in-differences approach by calculating the distance between each individual firm and the dedicated MDF. Hence, I approximate the access to the broadband internet at the firm-level instead of the municipality-level. My strategy allows measuring the technological restriction more precisely and calculating the intention-to-treat effect on similar firms within the same

[4]For a detailed survey of the literature on the impact of ICT on productivity I refer to Draca et al. (2006) and Cardona et al. (2013).

municipality.

The paper is structured as follows. The next section describes my empirical strategy. I explain the set-up, my empirical model, and the data I use. In section 3, I describe my main findings, report results from a number of robustness checks, and discuss my results. Section 4 concludes.

2 Empirical Strategy

Identifying the impact of broadband internet adoption on firm growth poses a challenge to the empirical researcher. Ideally, one would randomize technology adoption. In practice, new technologies are usually available to everyone at the same time, and firms choose whether to adopt these. Hence, measured firm responses to new technologies would be biased due to omitted variables. Firms that select into technology adoption may simultaneously be subject to different changes correlated with firm growth, e.g., innovation activity. As a result, the impact of the new technology on firm growth cannot be identified. To overcome this problem, I exploit a technological restriction to broadband internet adoption that is orthogonal to firm characteristics. This exogenous factor led to differential access of firms to the new technology that would otherwise have selected into adopting it. I restrict my sample to similar firms that are located below and above the threshold distance to the MDF and hence may or may not receive broadband internet.

2.1 Set-up

Broadband expansion. The first generation of broadband internet, asymmetric digital subscriber line (ADSL), was first presented in Germany in 1999. Providing a downstream speed of 768 kBit/s and an upstream speed of 128 kBit/s, it was considered a major improvement compared to previous dial-up technologies.[5] In 2000, about 600,000 customers subscribed to the new technology. With 768 kBit/s, one could e.g. send large attachments (500kB) in an e-mail.

In later years, the technology was further improved leading to speed upgrades (see figure A.3 in the appendix), mostly in downstream. From September 2002 on, the first generation of broadband internet allowed up to 1,536 kBit/s in download speed. In April 2004, the maximum provided speed increased to 3 MBit/s in download speed and 384 kBit/s in upstream by upgrading the technology to ADSL2, i.e. the second upgrade. With 3 MBit/s, small video conferences and online meeting presentations were possible. From 2005 on, with the third upgrade, up to 6 MBit/s in downstream and 512 kBit/s in upstream were possible. With 6 MBit/s, third-party hosted applications like e-mail and data back-up could be used.

[5]For a detailed description of the technological background see Schnabel (2015).

The fourth upgrade to ADSL2+ in 2006, called the second major generation of broadband internet, provided a major improvement to broadband internet provision as the maximum speed increased to 25 MBit/s[6] in downstream and 1,024 kBit/s in upstream. Most telecommunications providers offered up to 16 MBit/s. With 16 MBit/s, multi-point videoconferencing, remote server access, and voice over IP applications came up (CTC, 2010). Overall, these speed upgrades significantly improved the use of any application, especially file-sharing.

From 2006 on, another new internet technology called VDSL was introduced. This technology provided even higher internet speeds of up to 100 MBit/s. However, VDSL required large infrastructure investments as fiber wires needed to be installed. It therefore took several years to introduce VDSL in major cities in Germany and is still ongoing in 2018.[7]

At the time of the introduction of ADSL2+, more than 14 million customers subscribed to DSL provision.[8] Still, not every customer got access to the full potential of each technology (Bundesnetzagentur, 2011). Even in 2011, more than 22% of DSL customers received only 2 MBit/s or less. Most customers (46.3%) received between 2 and 10 MBit/s whereas only 23% received between 10 and 30 MBit/s even though ADSL2+ was already well established. Only about 8% got access to the upgrade to VDSL providing between 30 and 100 MBit/s.

Technological restrictions to broadband internet access. The early generations of broadband internet used the existing public switched telephone network (PSTN). It consisted of copper wires that could be used to transfer broadband internet. The network was constructed in West Germany in the 1960s by the state monopoly on telephone networks at that time. They aimed at providing telephone access to the universe of households. As distance is irrelevant for the quality of telephone usage, they optimized installation and maintenance costs by serving as many customers by each MDF as possible.

For broadband internet, however, the distance between a firm and the MDF matters. As shown in figure 1, there is a large decay of the technologically maximal speed provided with increasing length of the copper wires. For the first generation of broadband internet (ADSL), the maximum speed ranges from less than 4 to 8 MBit/s after the latest upgrade. Above the threshold distance of 4.2 km, no broadband internet was provided. Similarly, for ADSL2, the maximum speed for firms close to the MDF is highest and decays with the distance to the MDF. For ADSL2+, the speed decays even more steeply. Within the group of firms that got access to the first generation of broadband internet, only firms located between 0 and 2 km from the MDF got full access to the speed upgrade to usually

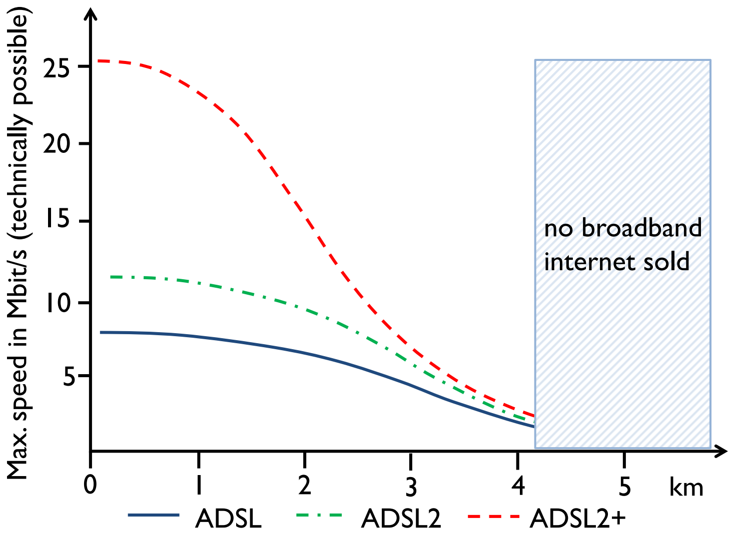
[6]Most telecommunications providers did not always provide the maximum speed (Schnabel, 2015).

[7]I provide robustness checks excluding counties where VDSL was installed until 2008 in tables B.28 and B.29 in the appendix.

[8]The number of subscriptions to DSL technologies reached 24 million in 2016. An overview of the increase in subscriptions over the considered time horizon in this paper can be found in figure A.2.

16 MBit/s. Using the network offered a cheap way to introduce the new technology. New constructions would have implied high installation costs as wires are installed subsurface in Germany.

Figure 1: Decay of broadband internet speed



The figure shows the decay of the maximum broadband internet speed that was technically possible with increasing distance to the MDF. The solid line shows the decay of the first generation (ADSL). The line above shows the decay of the less used technology called ADSL2. The dashed line shows the decay for the second major generation of broadband internet (ADSL2+). At the time of the introduction, most telecommunications companies only provided a maximum speed of 16 MBit/s. Source: Schnabel (2015) and own illustration.

2.2 Empirical specification

My basic framework consists of a fixed-effects difference-in-differences estimation equation:

$$\mathsf{y}_{i,t} = \beta_0 + \beta_{1,t}\,\textsf{broadband internet access}_i\, D_{\textsf{year,t}} + \alpha_i + \alpha_t + u_{it} \tag{1}$$

I analyze different time-varying firm outcomes $\mathsf{y}_{i,t}$ that measure performance, size or workforce composition of firm i in year t. The dummy variable $\textsf{broadband internet access}_i$ equals one if broadband internet provision to a firm is technically feasible and zero otherwise. It does not vary over time.

To study the impact of the access to the first generation of broadband internet, I interact the $\textsf{broadband internet access}_i$-dummy with a post-introduction period dummy which allows me to compare firms with and without access to broadband internet before and after the introduction of the first generation of broadband internet. The post-introduction dummy is equal to one for all years from 2001.[9] To study the impact of getting access

[9]As I observe firms as of June 30, only a very small subgroup of firms was connected to a MDF with

to later speed upgrades, I use dummies from year to year to trace out the timing of the effect. α_i are firm-fixed effects that control for all time-constant firm characteristics.

α_t are year-fixed effects that control for any economy-wide year characteristics. $\beta_{1,t}$ is thus an estimate for the difference between firms with and without access to broadband in each year t, holding all time-persistent firm characteristics constant and controlling for all year-fixed effects. u_{it} is the error term which is clustered at the firm-level. I balance treatment and control groups within three-digit sector groups following Iacus et al. (2009).

This equation would still suffer from omitted variable bias if I directly observed broadband internet adoption and simply included a dummy equal to one if the firm adopted broadband internet and zero otherwise. In this case, there could be unobserved time-varying factors that differ between firms that get access to the broadband internet and firms that do not get access. This problem can be solved by exploiting the technological peculiarities of the network as explained in sub-section 2.1. These technological restrictions affect the availability of broadband internet to each individual firm, and allow me to compare firms that lie just below a cutoff for broadband availability to firms that lie just above it. As I do not observe adoption of broadband internet, I calculate an intention-to-treat effect.

2.3 Data and descriptive statistics

For my analysis, I assemble a unique longitudinal firm-level dataset. I combine linked employer-employee data from Germany with geocoded information on the included firms and the telephone network. Germany provides an ideal setting for this study, as German social security data are rated very highly regarding availability and reliability (see Card et al., 2013).

Data. My firm-year-level data come from an establishment survey provided by the German Employment Agency (Heining et al., 2016). This dataset reports detailed establishment information on 30 June on an annual basis from 1993 to 2014. Firms report revenues, value-added, and employment, among other topics. To follow the firms before and after the introduction of the new technologies, I look at the unbalanced panel samples from 1996 to 2005 and from 2000 to 2011. The panel samples are constructed by the German Employment Agency. A subset of the establishments surveyed every year are followed over several years. I only use single-establishment firms to exclude potential interdependencies between establishments with and without broadband internet in multi-establishment firms.[10] I keep observations with non-missing sales information reducing

broadband internet access on June 30, 2000. I run a robustness check in which I drop all firms in areas where MDFs were upgraded before June 30, 2000. Further, I run a robustness check in which I define the post-dummy for all years from 2000 on. I report the results for both robustness checks in table B.1 in the appendix.

[10] Gumpert et al. (2018) analyze the differential impact of broadband internet access by establishment type in multi-establishment firms.

my dataset by about 20%.

Further, I merge linked employer-employee data from social security records. The individual-level data come from the Sample of Integrated Labor Market Biographies (SIAB). They include detailed current information on the employees of the firms in the survey. For every employee, I observe individual demographic information like education, wages, occupations, and employment status. Besides, I calculate the age and tenure of each employee. I impute missings in the education variable following Fitzenberger et al. (2005). I define individuals with a university degree as highly skilled, individuals with vocational training or a university entrance qualification as medium-skilled and those without any training or university entrance qualification as low-skilled. I consider full-time employees between age 18 and 65.

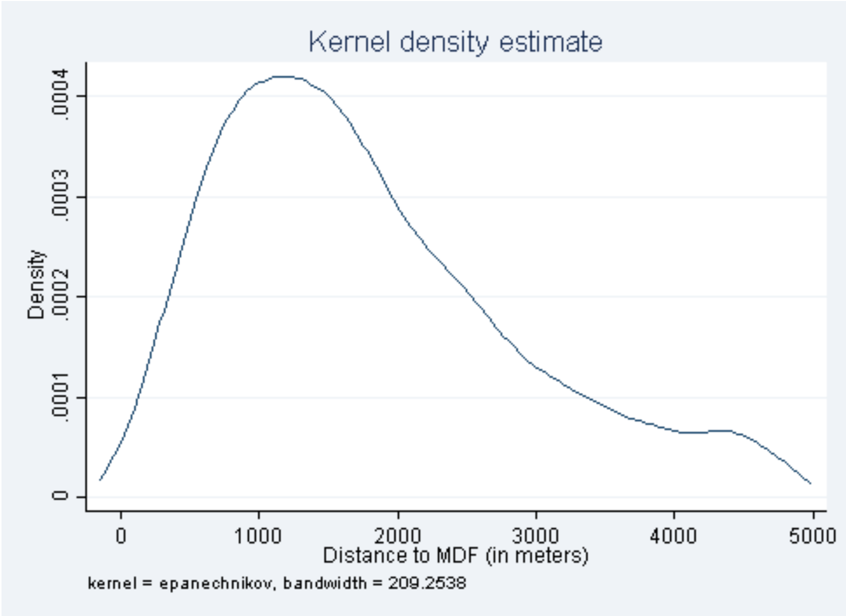
To approximate individual broadband internet access, I geocode each establishment based on the address included in the social security records. Using the geographical information on the local telephone networks provided by Bundesnetzagentur (2017), I allocate each establishment to a local network using geographic information system software. Lacking data on the actual connection of firms to MDFs, I define the closest MDF within the local network as the relevant one. To approximate the length of the copper wires, I calculate the distance via roads between the firm and the MDF using the map of road networks provided by OpenStreetMap (2017) (version as of March 2015). The distance is calculated based on the cross-sectional information provided in 2015 and does not vary over time. As the copper wires were installed subsurface, they are usually located next to roads where opening the ground is easiest.

Sample definitions. MDFs are not randomly located but rely on existing infrastructure. I argue that firms did not anticipate that distance to the MDF would matter so they did not locate strategically within small bounds. Large distances, however, might reflect very different firms. My strategy allows excluding firms that are far away from the MDF that may grow differently after the introduction of the broadband internet because of other reasons. Figure 2 shows that the distribution of the distance to the MDF in the panel sample from 2000 to 2011 within 4.7 km or less is skewed to the left. 50% of firms are located within 1.4 km from the MDF, 90% lie within 3.2 km.

My determination of broadband internet access allows me to approximate broadband internet availability for each firm but still suffers from measurement error. As I do not have exact information on the location of the copper wires, I cannot determine the exact length of the copper wires between the firms and their dedicated MDFs. To reduce potential measurement error, my control groups include a “donut”, i.e., I leave out firms that are located within a very small bound at the threshold.

Figure 3 summarizes my main samples. To study the impact of access to the first generation of broadband internet, I compare firms below and above the threshold at 4.2

Figure 2: Distribution of distance to MDF



The figure shows the kernel density of the distance between firms and their dedicated MDF. Own illustration.

km.[11] My treatment group consists of firms with a distance to the MDF between 2 and 3.5 km. These firms almost received the maximum speed provided by ADSL. My control group includes firms with a distance to the MDF between 4.2 and 5.7 km. These firms are arguably comparable as they are located very close to the treated firms and did not anticipate the implications of locating further away. These firms did not get access to the broadband internet at all. I leave out firms between 3.5 and 4.2 km from the MDF. These firms still got access to the broadband internet but did not experience the full potential speed (as shown in figure 1).[12]

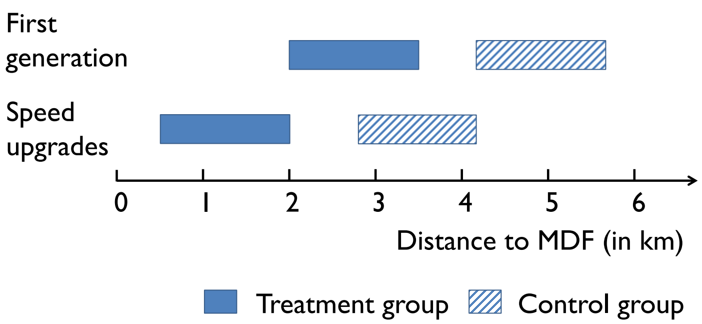
For the later speed upgrades, I exploit the fact that broadband internet speed availability differed between firms. Access to the upgrades again depended on the distance to the MDF, but the decay of the provided speed was more pronounced for shorter distances. Within the group of firms that got access to the first generation of broadband internet, only a subgroup also got full access to the speed upgrades. After the upgrade to ADSL2+, for example, firms located between 0 and 2 km from the MDF usually received 16 MBit/s from 2006 on. Above 2 km, the maximum speed decays up to the 4.2 km threshold of any broadband internet provision. I compare firms below and above the threshold of 2 km. My treatment group comprises firms with a distance between 0.5 and 2 km. My control

[11] As pointed out by Falck et al. (2014), there are other factors that also determine the maximum speed. Thus, I use this as a fuzzy threshold.

[12] In the appendix, I show the results of my second control group consisting of firms between 3.5 and 5 km. A subgroup of these firms received slow ADSL whereas firms located more than 4.2 km from the MDF did not get access to the broadband internet

group consists of firms between 2.8 and 4.2 km. For these firms, the speed upgrades hardly increased their internet speed. I leave out firms located between 2 and 2.8 km from the MDF. These firms did not get access to the full potential of the speed upgrades. An illustration of the sample definition to analyze the impact of speed upgrades is shown in figure 3.[13] Figure A.1 in the appendix illustrates the distribution of MDFs and the respective treatment and control groups.

Figure 3: Sample definitions

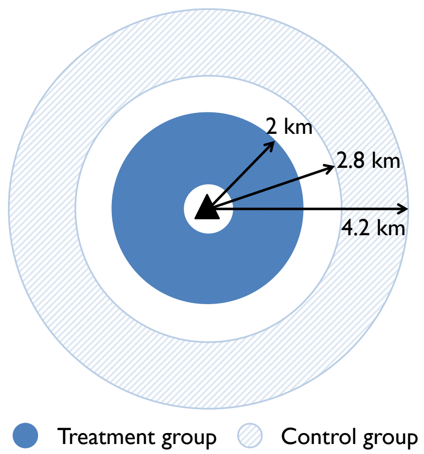


The figure shows the defined treatment and control groups for each sample by technology. The treatment group for the introduction of the broadband internet consists of firms located between 2 and 3.5 km from the MDF. The control group includes firms between 4.2 and 5.7 km. The treatment group for later speed upgrades consists of firms between 0.5 and 2 km. The control group includes firms between 2.8 and 4.2 km. Own illustration.

Descriptive statistics. For my analysis, I use different outcome variables to estimate the impact of the availability of broadband internet and later speed upgrades on firm performance, employment, and skill composition. To measure firm performance, I mainly use information from the survey data. Firms report their revenues as well as the share of purchased inputs. I further calculate annual value-added generated by the firm based on this information. To approximate efficiency, I construct two measures. Based on the survey data, I calculate revenues per employee. Based on the information on the employees from social-security data, I calculate the revenues per full-time employee. I further use full-time employment and total employment as outcome variables measuring employment size. Besides that, I use information from the survey on monthly wage sums as well as social-security data to construct daily wage sums. The main difference between the two employment measures is that the survey data includes part-time employees. Using the social-security data, I further calculate the annual skill composition using the shares of three different skill groups in the full-time employment.

[13] In sub-section B.6 in the appendix, I further show the results of a second control group including firms between 2 and 3.5 km. They consist of firms that are most closely located to the treatment group. These firms are very similar to the treatment group as they did not anticipate the threshold. These analyses, however, are more likely to suffer from measurement error as I do not have information on the exact location of the copper wires.

Figure 4: Illustration of treatment and control groups for speed upgrades



The figure illustrates the determination of treatment and control group based on the distance to the main distribution frame for speed upgrades. The black triangle resembles an exemplary main distribution frame. The circles show the areas defining the treatment and control group. White areas show the left out "donut" circles. The dark circle resembles the treatment group of firms located between 0.5 and 2 km from the MDF. The shaded circle shows the control group from 2.8 to 4.2 km around the MDF. The circles would show exemplary borders if distances were calculated via straight lines. They do not resemble the actual thresholds as the distances are calculated via roads. Own illustration.

Table 1 shows the descriptive statistics for the analysis of the impact of the introduction of the broadband internet. I pool all years before the introduction in the pre-treatment period. Firms in the treatment group perform better regarding revenues and value-added. They are also larger in total employment and wage sum. The difference is economically small. Controlling for firm-fixed effects in my specification rules out any time-persistent characteristics. Hence, different initial situations of firms and treatment and control group only cause a problem if they affect growth rates which would lead to biased estimates.

Table 2 shows the descriptive statistics in the first panel year for the analysis of the speed upgrades. Comparing the treated firms located around 0.5 to 2 km from the MDF to the control group shows that these groups of firms are very similar before the speed upgrades. Table A.1 in the appendix shows the descriptive statistics for non-manufacturing firms separately.

Table 1: Descriptive statistics of outcome variables pre-treatment, pooled sample

	Treatment group			Control group			Difference	
	Mean	SD	N	Mean	SD	N	(4) - (1)	P-value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Performance								
Log(revenues, survey)	14.53	1.89	887	14.28	1.64	343	−0.25	0.03
Log(value added, survey)	13.73	1.83	675	13.48	1.51	271	−0.25	0.04
Share of purchased inputs	0.48	0.22	684	0.44	0.21	280	−0.04	0.02
Log(revenues per FTE)	12.78	1.73	818	12.49	1.34	313	−0.29	0.01
Log(revenues per empl.)	11.32	0.84	816	11.34	0.79	312	0.02	0.71
Employment								
Log(full-time empl., SIAB)	1.68	1.49	887	1.71	1.37	343	0.03	0.74
Log(total empl., survey)	3.37	1.53	887	3.09	1.35	343	−0.28	0.00
Log(daily wage sum, SIAB)	5.88	1.61	887	5.88	1.51	343	0.00	1.00
Log(monthly wage sum, survey)	10.58	1.77	853	10.25	1.54	331	−0.33	0.01
Skill composition								
Share low-skilled	0.05	0.16	887	0.06	0.17	343	0.01	0.26
Share medium-skilled	0.83	0.26	887	0.88	0.23	343	0.05	0.01
Share high-skilled	0.10	0.22	887	0.06	0.16	343	−0.05	0.00

				Shares	
Units of observation	Treat	N	IDs	Urban	Manuf.
Firms	0	595	79	.33	.31
Firms	1	1,760	235	.47	.44
Employees	0	43,566	8,355	.34	.60
Employees	1	393,772	75,522	.55	.24

This table shows the descriptive statistics of the firms in panel sample 1996 to 2005 in the pre-treatment period (1996 to 2000). Data sources are reported in the table. The shares of skill groups are calculated based on the composition in SIAB. The p-value in column 8 indicates whether the means of the treatment and control groups are significantly different from each other.

Table 2: Descriptive statistics of outcome variables in 2000, pooled sample

	Treatment group			Control group			Difference	
	Mean	SD	N	Mean	SD	N	(4) - (1)	P-value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Performance								
Log(revenues, survey)	14.41	1.97	1,046	14.45	1.90	284	0.13	0.75
Log(value added, survey)	13.57	1.98	938	13.63	1.84	259	0.15	0.66
Share of purchased inputs	0.49	0.23	953	0.48	0.22	265	−0.01	0.63
Log(revenues per FTE)	12.69	1.78	1,012	12.55	1.73	276	0.04	0.24
Log(revenues per empl.)	11.40	0.86	974	11.38	0.76	264	−0.03	0.23
Employment size								
Log(full-time empl., SIAB)	1.69	1.53	1,046	1.91	1.58	284	0.10	0.03
Log(total empl., survey)	3.20	1.66	1,046	3.28	1.55	284	0.10	0.47
Log(daily wage sum, SIAB)	5.92	1.69	1,046	6.14	1.72	284	0.12	0.05
Log(monthly wage sum, survey)	10.46	1.98	1,013	10.58	1.84	278	0.17	0.33
Skill composition								
Share low-skilled	0.07	0.19	1,046	0.06	0.16	284	−0.01	0.44
Share medium-skilled	0.83	0.27	1,046	0.82	0.24	284	−0.00	0.93
Share high-skilled	0.09	0.21	1,046	0.11	0.21	284	0.02	0.27

				Shares	
Units of observation	Treat	N	IDs	Urban	Manuf.
Firms	0	2,516	343	.42	.55
Firms	1	10,006	1,337	.54	.47
Employees	0	264,340	50,688	.48	.47
Employees	1	629,766	120,759	.64	.37

This table shows the descriptive statistics of the firms in panel sample 2000 to 2011 in the first year. Data sources are reported in the table. The shares of skill groups are calculated based on the composition in SIAB. The p-value in column 8 indicates whether the means of the treatment and control groups are significantly different from each other.

2.4 Discussion of identification strategy

In my identification strategy, I exploit technological restrictions to broadband internet speed adoption that firms could not anticipate or directly influence. I discuss several potential concerns and argue that my estimator would, if anything, be biased towards zero.

First, the remaining threat to my identification is that unobserved time-varying shocks may impact firms in the treatment and control differently. Hence, I check if my parallel trend assumption holds for all years before treatment. As shown in tables B.2 and B.3 in sub-section B.1 in the appendix, firms in the treatment and control group have similar trends before the introduction of the broadband internet in the panel sample from 1996 to 2005. The coefficients of the interaction terms of the treatment dummy and year dummies are not significantly different from zero for the years before 2001. For the speed upgrades, I show yearly coefficients in all tables. In the panel sample from 2000 to 2011, firms in the treatment and control group have similar trends before the speed upgrades starting in 2003. Hence, the parallel trend assumption seems to hold.

Second, as I approximate the length of the copper wires between the MDF and the firm, my estimates may suffer from measurement error. This problem should, however, be reduced in my "donut" samples. I exclude firms that could be falsely allocated to the treatment or control group by calculating a shorter or longer distance to the MDF within the respective range. Firms that are still included and allocated to the wrong group bias my estimates towards zero. Lacking data on the road network in the early 2000s or even 1960s, I use the OpenStreetMap version as of March 2015. Hence, I may falsely include roads that did not exist when the copper wires were actually installed. In this case, I would underestimate the length of the copper wire. Hence, I may falsely classify an untreated firm as treated which would bias my estimates downwards.

Third, one might be concerned about non-compliance in order to scale the intention-to-treat to an average treatment effect on the treated. On the one hand, some firms might adopt broadband internet even if they belong to the control group. Indeed, firms could lease individual lines but only at high costs. In 2004, firms had to pay more than 2 million USD PPP annually for a leased line to the telephone backbone to receive 2 MBit/s (OECD, 2005). Further, anecdotal evidence suggests that even large multinational firms refused to pay for individual broadband infrastructure. The Italian multinational small appliance manufacturer De Longhi moved its German subsidiary to a different city due to slow internet connection (Koehler, 2012). As a consequence, I consider the group of always-adopting firms supposedly small. If it existed, it would bias my estimates downwards.

On the other hand, some firms may not adopt broadband internet even though it is technologically possible. This group is more likely to exist in my analyses of the first generation of the broadband internet when firms had to set up an explicit contract with the telecommunications provider. For the later speed upgrades, however, firms had little incentives not to take advantage of higher speeds of the existing technology. Further, Bertschek et al. (2013) show that 98% of the firms in their sample use the internet in 2002. Hence, general technology adoption is very high. Firms that had the possibility to take up broadband internet had little incentives to stay with inferior dial-up technologies.

3 Results

In my analysis, I find evidence that is consistent with both my hypotheses on market size and efficiency effects of the broadband internet. First, I find that firms that get access to the first generation of broadband internet demand less labor per unit of output, especially employing less low-skilled labor. This result is consistent with increasing efficiency. My results show that this effect is driven by non-manufacturing firms. Hence, I report my results for this sub-sample as my main findings. My results for manufacturing firms are reported in the appendix (tables B.7 to B.9). Second, I show that non-manufacturing firms that get access to later speed upgrades grow more strongly in revenues and employment suggesting a positive market size effect. They particularly increase the share of medium-skilled employment. I show my main results in sub-section 3.1. Further, I challenge my results in several robustness checks reported in sub-section 3.2. I discuss their economic significance in sub-section 3.3.

3.1 Main findings

Figure 5 reports the results of the first generation of broadband internet for non-manufacturing firms. The coefficients show the results of the interaction term of the $\textsf{broadband internet access}_i$- and a $D_{\textsf{post,t}}$-dummy. The $D_{\textsf{post,t}}$-dummy is one for all years after 2000 and zero otherwise. Table B.4 in the appendix shows the results for the impact of the broadband internet availability in the pooled sample as well as for non-manufacturing and manufacturing firms separately. Comparing the results reveals that the effects are mostly driven by firms in non-manufacturing sectors. The signs of the coefficients for manufacturing firms, however, are in line with my findings even though they are not always significant.

I find that firms with access to the broadband internet have 9% higher revenues per employee than firms without access (significant on the 5% level). The average firm generates revenues of about 80,800 Euro per employee before treatment. A firm that gets access to the broadband internet would generate revenues of more than 88,000 Euro per employee on average after the introduction ceteris paribus. I find no effect on revenues and value-added.

Further, I find that firms that get access to the broadband internet employ 7.5% less full-time labor after the introduction of the broadband internet (significant on 1%-level). A firm with about 13 employees before treatment would hence employ one employee less after the introduction than a similar firm without access to the broadband internet. Similarly, I find that their wage sum is smaller after getting access compared to the control group. In addition to the overall effects on employment, broadband internet access also affects the composition of the workforce with respect to their skills. Analyzing the shares of employees by skill group reveals that low-skilled employees are negatively affected by the availability of broadband internet. Firms that get access to the broadband internet employ a 2 percentage points smaller share of both low-skilled labor.

For the analysis of the effects of the speed upgrades, I report my main findings for non-manufacturing firms in figures 6 and 8 as well as tables B.5 and B.6 in the appendix. I use model (1) directly including yearly coefficients to trace out the effect over time. Figure 6 shows the results of the effects of the speed upgrading on firm performance of non-manufacturing firms. I find that firms that get access to the speed upgrades grow more in revenues and value-added compared to the control group. As an example, treated firms sell 15% more in 2006 than non-treated firms. The yearly effect remains stable within a range between 13% in 2003 and 19% in 2007. Besides, I find no effect on revenues per employee. Table B.7 shows that the effects are similar for manufacturing firms.

Figure 8 shows the results of the effects of the speed upgrades on employment of non-manufacturing firms. I find that firms that get access to the speed upgrades grow more in employment. In 2006, they were 12% larger in total employment than firms that did not get access. They also report higher wage sums. In 2004, firms that get access to the speed upgrades paid a 20% larger wage sum. The effect drops down to 12% in 2006 and then rises to 20% in 2008 and 2009 again. The coefficients for total employment are larger and significantly different from zero whereas the coefficients for full-time employment are not significant. One potential explanation would be that firms hire more part-time employees to expand production. As reported in table B.8, I find similar effects for manufacturing firms.

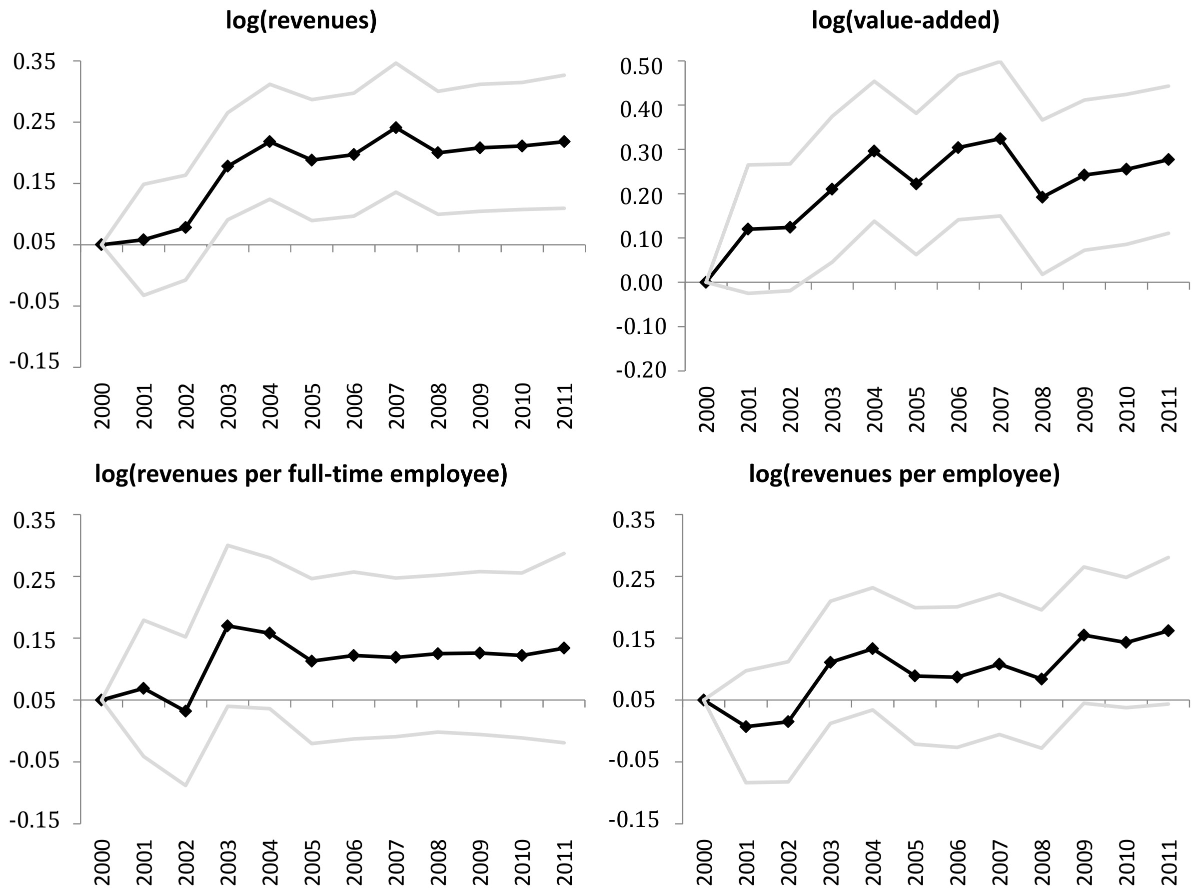
The access to later speed upgrades lead to an over-proportional increase in the use of medium-skilled labor. The share of medium-skilled employees increases, whereas the share of high-skilled employees decreases after the speed upgrades. My results support the idea that medium-skilled labor serves as a complement to ICT as found in the literature (see, e.g. Brynjolfsson and Hitt, 2000). In contrast to the classical interpretation of skill-biased technological change, I find that the share of high-skilled employees also decreases. For manufacturing firms, I find opposite results as shown in table B.9. Firms that get access to the speed upgrades decrease the share of medium-skilled and increase the share of high-skilled employees.

To summarize, I find that firms benefit from the introduction of both technologies. The first generation of broadband internet allows firms to become more efficient employing less labor per unit of output. The later speed upgrades increase output and employment. Both the access to the first generation of the broadband internet as well as to later speed upgrades lead to an over-proportional increase in the demand for medium-skilled labor in comparison to low- and high-skilled labor in non-manufacturing firms.

Figure 5: Regression results of the introduction of the broadband internet

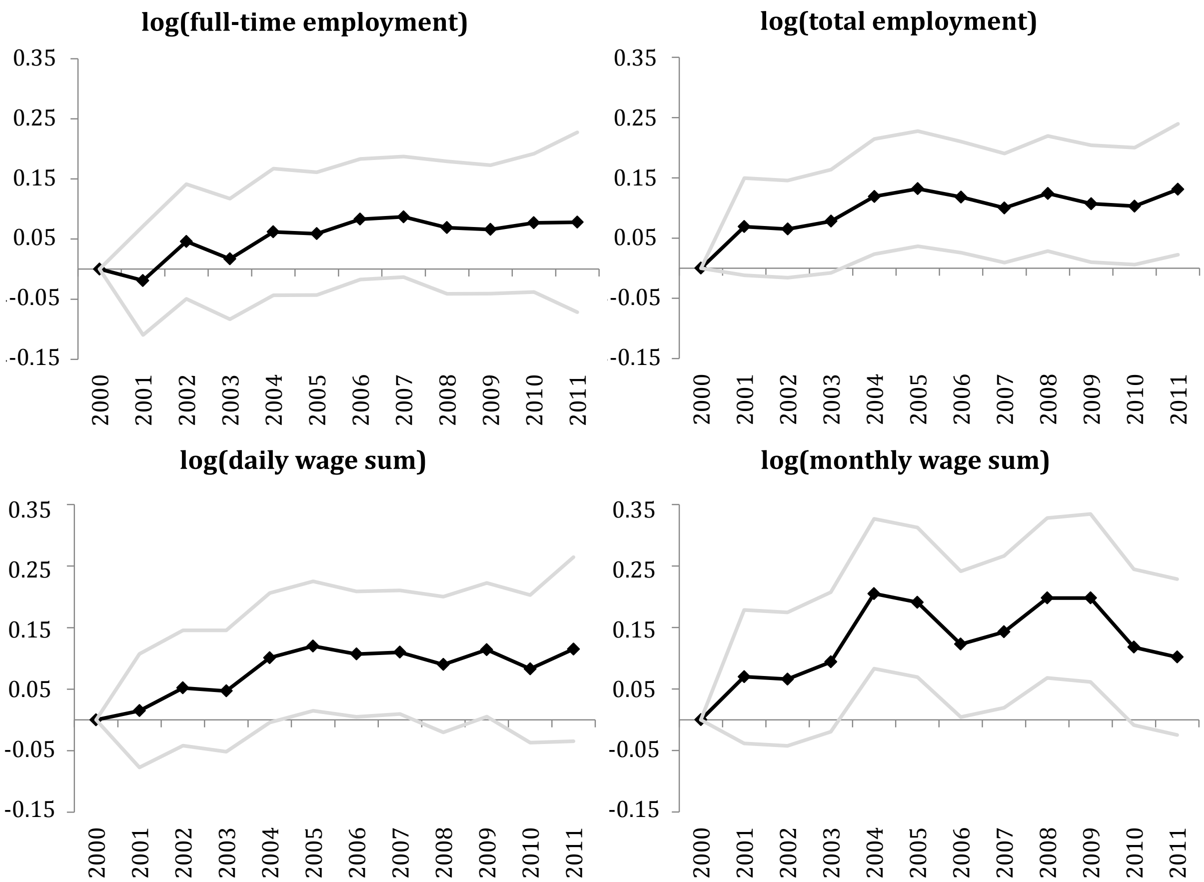
This figure shows the results from the fixed-effects difference-in-differences estimation using 1996 to 2000 as pre-treatment period and 2001 to 2005 as the treatment period. The estimation equation is: $y_{i,t} = \beta_0 + \beta_1$ broadband internet access$_i$ $D_{post,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{post,t}$ is an indicator variable for the treatment period from 2001 on. broadband internet access$_i$ is an indicator variable equal to one if the firm is located between 2 and 3.5 km from the MDF and zero for firms located between 4.2 and 5.7 km from the MDF. The table reports the results of β_1. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Significance level chosen at p < 0.10. The sample only contains non-manufacturing firms. Regression results reported in table B.4 in the appendix.

Figure 6: Regression results of speed upgrades on performance



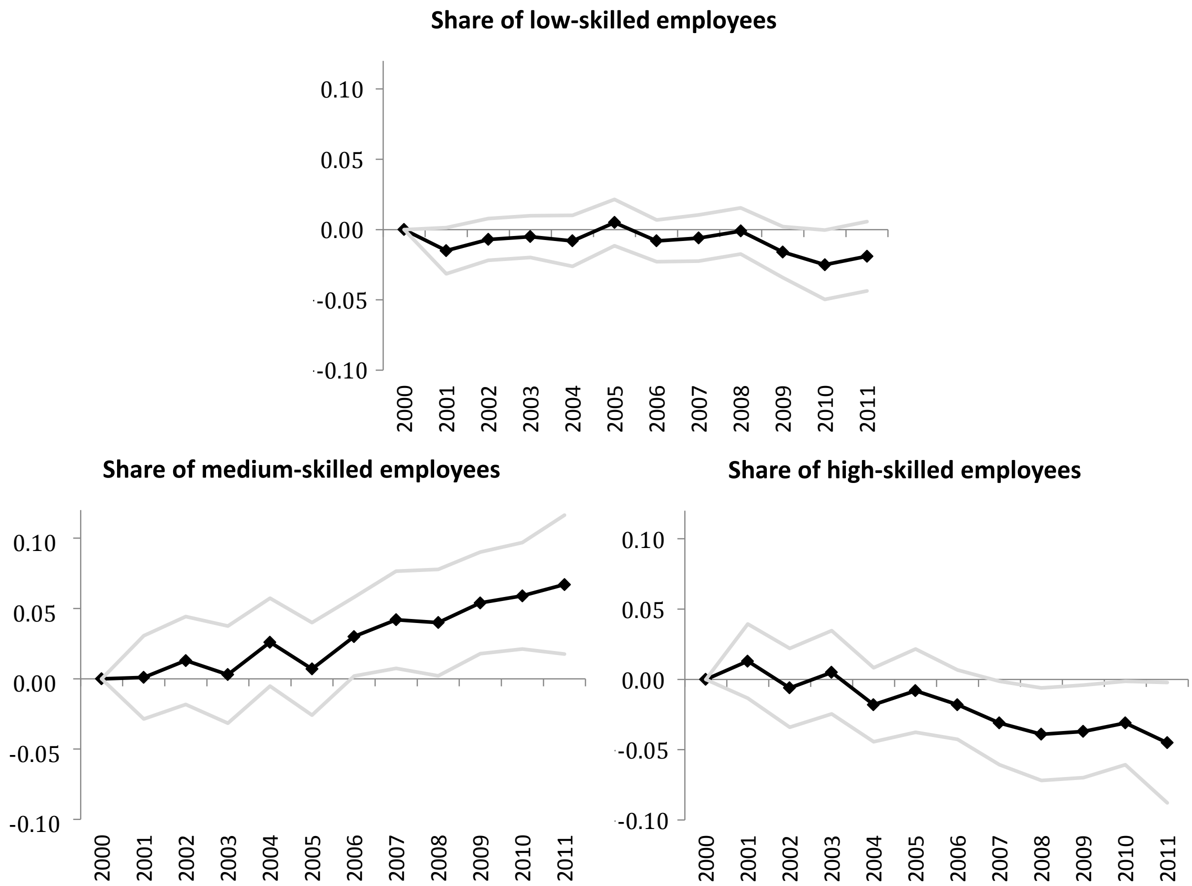
The figure shows the regression results of model (1) using the panel sample from 2000 to 2011. The upper left graph shows the results of log(revenues) as the outcome variable. The upper right graph shows the results of log(value-added) as the outcome variable. The bottom left graph shows the results of log(revenues per full-time employee) as the outcome variable. Full-time employees are counted in the administrative data. The bottom right graph shows the results of log(revenues per employee) as the outcome variable. The total number of employees is reported in the survey data. The treatment group consists of firms between 0.5 and 2 km from the MDF. The control group consists of firms between 2.8 and 4.2 km from the MDF. The samples only contain non-manufacturing firms. Grey lines mark the confidence intervals at the 10% significance level. Own illustration.

Figure 7: Regression results of speed upgrades on firm size



The figure shows the regression results of model (1) using the panel sample from 2000 to 2011. The upper left graph shows the results of log(full-time employees) as the outcome variable. The upper right graph shows the results of log(total employment) as the outcome variable using the data from the survey. The bottom left graph shows the results of log(daily wage sum) as the outcome variable. The bottom right graph shows the results of log(monthly wage sum) as the outcome variable using the data from the survey. The treatment group consists of firms between 0.5 and 2 km from the MDF. The control group consists of firms between 2.8 and 4.2 km from the MDF. The samples only contain non-manufacturing firms. Grey lines mark the confidence intervals at the 10% significance level. Own illustration.

Figure 8: Regression results of speed upgrades on the skill composition



The figure shows the regression results of model (1) using the panel sample from 2000 to 2011. The upper graph shows the results of the share of low-skilled employees (i.e. without vocational training or university entrance qualification) as the outcome variable. The bottom left graph shows the results of the share of medium-skilled employees (i.e. with vocational training or university entrance qualification) as the outcome variable. The bottom right graph shows the results of the share of high-skilled employees (i.e. with a university degree) as the outcome variable. The treatment group consists of firms between 0.5 and 2 km from the MDF. The control group consists of firms between 2.8 and 4.2 km from the MDF. The samples only contain non-manufacturing firms. Grey lines mark the confidence intervals at the 10% significance level. Own illustration.

3.2 Robustness checks

As discussed in sub-section 2.4, one might be concerned about some confounding factors biasing my results. To take these concerns into account, I run several robustness checks. Table B.10 summarizes the results of most of the following robustness checks for the introduction of the broadband internet. I report the results of the robustness checks on speed upgrading in separate tables. The results support my main findings.

First, I run the regressions using the distance to the MDF as a continuous treatment variable instead of the dummies. I report the results in tables B.17 to B.19 in the appendix. My results confirm my previous findings. Further, I repeat the regressions on the samples without considering the "donut". Hence, I compare firms that are located within even smaller bounds from the MDF, as one may be concerned about the distance to the MDF being correlated with other time-varying firm characteristics. For the analysis of broadband internet, I use the same sample of firms as the treatment group as in the main results but firms between 3.5 and 5 km as the control group. The results are presented in table B.11 in the appendix. I find similar negative employment effects as in the "donut" sample. However, I do not find comparable positive effects on revenues per employee.

Table B.12 and table B.13 report the results of the "non-donut" samples for the analysis of later speed upgrades. I use firms between 2 and 3.5 km as the second control group. I find limited evidence on employment effects as shown in table B.12 but increasing revenues per employee as reported in table B.13. To understand these results, however, one needs to take into account that these estimations are more likely to suffer from measurement error.

Second, firms may strategically locate close to the MDF, or the MDF may be installed close to specific firms. As explained above, the network in West Germany was installed in the 1960s. Hence, MDFs could be located close to firms that existed at that time. As a robustness check, I run separate regressions on firms founded before and after the 1990s when first internet technologies were introduced. Table B.20 shows the results of the speed upgrades for the firm size of firms founded in 1992 or later. Firms that get access to the speed upgrades significantly increase the wage sum. Table B.21 shows that results of increasing revenues of treated firms are robust. Table B.22 shows the results on the firm size of firms founded in 1992 or before. Indeed, firms in the treatment group already grow faster before treatment. However, results on firm performance in table B.23 show that the effect on revenues does not kick in earlier than expected. For the first generation of broadband internet, I find similar results as in the main specification. However, the results of changes in employment are not significant. This result may also be caused by the decrease in sample size.

Further, I run separate regressions excluding Eastern Germany where the MDFs were installed only in the 1990s. Table B.24 shows the results of firm size and table B.25 shows the results of the performance measures. I find my results to be weaker for firm size but similar for performance. For the introduction of the broadband internet, the sample size decreases to around 200 observations. Hence, the results need to be interpreted with caution: treated firms become smaller in revenues and value-added than non-treated firms.

Third, I check for potential measurement error because of lagged technology upgrading. If the MDF did not provide broadband internet, e.g. because it was not upgraded to provide the new technology yet, firms around the MDF would falsely be classified as receiving broadband internet. Hence, I use information on the share of households with broadband internet from 2005 to 2008 provided by the Federal Ministry for Economic Affairs and Energy (BMWi, 2009). As a robustness check, I exclude municipalities with very low shares of households with broadband internet access in 2005. Again, I find my results to be robust to this restriction as shown in table B.26 for the results on firm size and in table B.27 for the performance measures. For the introduction of the broadband internet, I find similar results. The coefficients are not always significantly different from zero which may also be due to the small sample size. Further, my estimates may be biased by the introduction of VDSL. I therefore exclude all counties in which VDSL was introduced until 2008. Tables B.28 and B.29 in the appendix show the results supporting my main findings.

Besides, I run additional regressions with different outcome variables to check for potential mechanisms how firms adjust to getting access to the broadband internet and later speed upgrades. In Appendix B.7, I report the results for the regressions using exit (table B.14) and dummy equal to one if a firm invests in ICT (table B.15 for the panel from 1996 to 2005 and table B.16 for the panel from 2000 to 2011) as outcome variables. I find no effect on these variables.

3.3 Discussion of results

My results are generally in line with the findings of the two most related papers. Similar to the analysis by Canzian et al. (2015) for a region in Italy, I analyze the impact of the availability of faster broadband internet on firm growth in revenues and value-added. Whereas Akerman et al. (2015) show skill-biased labor market implications and output elasticities caused by broadband internet, I complement their paper by studying the firm-level adjustments to the skill composition of the workforce. Also, I offer several detailed insights providing a more comprehensive picture of the impact of broadband internet on firm growth and employment.

In line with Canzian et al. (2015), I find large positive effects of the access to the speed upgrades like ADSL2+ on revenues and value-added. For my sample of non-manufacturing firms, I find that firms with faster internet generate about 15% more revenues than firms in the control group. Canzian et al. (2015) find that revenues increase by 40%. This large result may be driven by the fact that they study the impact of ADSL2+ at a time when many firms in other regions already had access to the new technology. Hence, firms in their sample may be experiencing a catch-up effect as the new technology was already established in the market. My coefficients for value-added are comparable to the results in Canzian et al. (2015). However, they do not find an effect on employment whereas I find large positive effects on employment. Firms that get access to the speed upgrades employ more than 10% more labor than the control group.

Similar to Akerman et al. (2015), I find evidence for skill complementarity of broadband internet. I find that firms reduce the share of low-skilled employment when they get access to faster internet. Akerman et al. (2015), however, do not find positive labor market effects for medium-skilled labor whereas I find that firms over-proportionally demand more medium-skilled labor. One needs to note, however, that our definitions for medium-skilled labor differ. They define individuals with a high-school but no college degree as medium-skilled. As defined in sub-section 2.3, I define individuals with vocational training but without a university degree as medium-skilled. In contrast to the classical interpretation of skill complementarity, I also find that firms reduce the share of high-skilled labor when they get access to the speed upgrades. My results are consistent with an interpretation of individuals with vocational training being the actual complement to broadband internet. Akerman et al. (2015) find positive and significant labor market effects and output elasticities for individuals with at least a college degree. In Germany, however, many occupations that require a college degree in other countries are taught in vocational training. Further, I estimate the effect of broadband internet on existing firms that get access to the broadband internet or later speed upgrades. Their result may be driven by new firms that enter markets where broadband internet is installed and employ a large share of high-skilled labor. Both analyses contribute to the understanding of the overall effect of broadband internet on firm growth.

My results on the timing of the impact of the speed upgrades reveal that the effect kicks in earlier than the large upgrade to ADSL2+. This finding suggests that treated firms already benefited from earlier smaller speed upgrades. Firms that are closer to the MDF also received faster internet speed before the upgrade to ADSL2+. One might be concerned about the validity of the comparison of treatment and control group if these groups are already different before treatment. As shown in table 2 discussed above, however, firms in the treatment and control group were very similar before the introduction of the broadband internet in 2000. Hence, these differences in the years 2003 to 2005 are probably driven by the treatment regarding speed upgrades.

This finding further raises the question on which speed upgrades matter to stimulate firm growth. Policymakers should take into account whether firms react similarly to upgrades to 6 or 16 MBit/s. Considering the results in the sample comparing firms located between 0.5 and 2 km to firms located between 2 and 3.5 km (see sub-section B.6 in the appendix) one might conclude that already smaller speed upgrades had a large impact on firm growth. In this sample, firms in the control group also receive between 6 and 16 MBit/s compared treated firms receiving 16 MBit/s. Hence, the difference in internet speed between treatment and control group is very small. If such a small difference in speed is not decisive, this may explain why the results of this sample provide very limited evidence on firm growth caused by the speed upgrades.

4 Conclusion

New technologies like ICT are believed to drive future economic growth. As policymakers expect external effects from investments in ICT, technology infrastructure is partly publicly financed in many countries. The German government, for example, decided to spend 100 billion Euro on expanding broadband infrastructure from 2017 to 2025 (as stated by the Federal Ministry of Transport and Digital Infrastructure (BMVI), 2017). Firms are expected to reshape their business adapting to an era of digitalization. So far, causal evidence of the impact of broadband internet on firm growth is limited.

This paper studies the impact of the first generations broadband internet and later speed upgrades on firm growth and employment. In particular, I analyze the effect of getting access to the first generation of broadband internet and latter speed upgrades. I exploit a natural experiment of technological restrictions which implied that not all firms had access to the broadband internet. I study within-firm growth in output, employment, and adjustments to the skill composition of the workforce. My results suggest that firms benefit from increasing internet speed. Upgrading the internet speed leads to firm growth in revenues and value-added and increases employment. My results confirm the findings that broadband internet is a skill-biased technology found by previous literature. However, I find very limited evidence of substitution of low-skilled employees but rather an increase in medium-skilled employment of growing firms.

References

Akerman, A., I. Gaarder, and M. Mogstad (2015). The Skill Complementarity of Broadband Internet. *The Quarterly Journal of Economics 130*(4), 1781–1824.

Atasoy, H. (2013). The Effects of Broadband Internet Expansion on Labor Market Outcomes. *Industrial and Labor Relations Review 66*(2), 315–345.

Bertschek, I., W. Briglauer, K. Hüschelrath, B. Kauf, and T. Niebel (2015). The Economic Impacts of Broadband Internet: A Survey. *Review of Network Economics 14*(4), 201–227.

Bertschek, I., D. Cerquera, and G. J. Klein (2013). More Bite - More Bucks? Measuring the Impact of Broadband Internet on Firm Performance. *Information Economics and Policy 25*, 190–203.

BMVI (2017). Broadband Deployment in Germany by Federal Ministry of Transport and Digital Infrastructure.

BMWi (2009). Federal Ministry of Economics and Technology, Broadband Atlas Germany.

Brynjolfsson, E. and L. M. Hitt (2000). Beyond Computation: Information Technology, Organizational Transformation and Business Performance. *The Journal of Economic Perspectives 14*(4), 23–48.

Brynjolfsson, E. and A. Saunders (2010). *Wired for Innovation: How Information Technology Is Reshaping the Economy.* The MIT Press, Cambridge, Massachusetts.

Bundesnetzagentur (2011). Annual Report. Technical report, Bundesnetzagentur.

Bundesnetzagentur (2017). Borders of Local Service Areas 2017. Web.

Canzian, G., S. Poy, and S. Schueller (2015). Broadband Diffusion and Firm Performance in Rural Areas: Quasi-Experimental Evidence. *Working Paper*.

Card, D., J. Heining, and P. Kline (2013). Workplace Heterogeneity and the Rise of West German Wage Inequality. *The Quarterly Journal of Economics 128*(3), 967–1015.

Cardona, M., T. Kretschmer, and T. Strobel (2013). ICT and Productivity: Conclusions from the Empirical Literature. *Information Economics and Policy 25*(3), 109–125.

CTC (2010). Columbia Telecommunications Corporation, the Impact of Broadband Speed and Price on Small Business.

Czernich, N., O. Falck, T. Kretschmer, and L. Woessmann (2011). Broadband Infrastructure and Economic Growth. *The Economic Journal 121*(552), 505–532.

De Stefano, T., R. Kneller, J. Timmis, et al. (2014). The (Fuzzy) Digital Divide: The Effect of Broadband Internet Use on UK Firm Performance. *University of Nottingham Discussion Papers in Economics 14*(06).

Draca, M., R. Sadun, and J. Van Reenen (2006). Productivity and ICT: A Review of the Evidence. *Centre for Economic Performance, London School of Economics and Political Science, London, UK.*.

Falck, O., R. Gold, and S. Heblich (2014). E-lections: Voting Behavior and the Internet. *The American Economic Review 104*(7), 2238–2265.

Fitzenberger, B., A. Osikominu, and R. Völter (2005). Imputation rules to improve the education variable in the IAB employment subsample. ZEW - Centre for European Economic Research Discussion Paper No. 05-10.

Gumpert, A., E. Morales, E. Oberfield, H. Steimer, and M. Antoni (2018). Information and Communication Technology and Multi-Establishment Firms. *Working Paper*.

Heining, J., W. Klosterhuber, P. Lehnert, and S. Seth (2016). Linked Employer-Employee Data from the IAB: LIAB Longitudinal Model 1993-2014 (liab lm 9314). *FDZ 10/2016.*

Iacus, S., G. King, and G. Porro (2009). CEM: Software for Coarsened Exact Matching. *Journal of Statistical Software 30*(9), 1–27.

Kandilov, I. T. and M. Renkow (2010). Infrastructure Investment and Rural Economic Development: An Evaluation of USDA's Broadband Loan Program. *Growth and Change 41*(2), 165–191.

Koehler, M. (2012). Internet-Verbindungen als Standortfaktor erster Guete. *Frankfurter Allgemeine Zeitung on August 29*.

Kolko, J. (2012). Broadband and Local Growth. *Journal of Urban Economics 71*(1), 100–113.

OECD (2005). Communications Outlook 2005. Technical report, OECD.

OpenStreetMap (2017). Planet Dump Retrieved from https://planet.osm.org. Web.

QGIS Development Team (2017). *QGIS Geographic Information System.* Open Source Geospatial Foundation.

Schnabel, P. (2015). *Kommunikationstechnik-Fibel*, Volume 4. Elektronik-Kompendium.de.

Stockinger, B. (2017). The Effect of Broadband Internet on Establishments' Employment Growth: Evidence from Germany. *Working Paper*.

Appendix

A Descriptive statistics and illustrations

A.1 Descriptive statistics

Table A.1: Descriptive statistics of non-manufacturing firms with donut, 2000

	0.5-2 km			2.8-4.2 km			difference	
	Mean	SD	N	Mean	SD	N	(4) - (1)	SD
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Performance								
Log(sales, survey)	14.11	1.88	536	13.88	1.72	120	−0.22	0.19
Log(value added, survey)	13.37	1.94	467	13.23	1.80	107	−0.14	0.20
Share of purchased inputs	0.43	0.23	474	0.43	0.20	111	0.01	0.02
Log(sales per FTE)	12.41	1.60	513	12.32	1.50	115	−0.09	0.16
Log(sales per empl.)	11.17	0.73	509	11.11	0.73	115	−0.06	0.08
Employment size								
Log(full-time empl., SIAB)	1.66	1.49	536	1.59	1.45	120	−0.07	0.15
Log(total empl., survey)	3.16	1.67	536	3.00	1.57	120	−0.16	0.17
Log(daily wage sum, SIAB)	5.87	1.66	536	5.81	1.60	120	−0.06	0.17
Log(monthly wage sum, survey)	10.34	1.99	516	10.20	1.84	117	−0.15	0.20
Skill composition								
Share low-skilled	0.07	0.18	536	0.05	0.15	120	−0.01	0.02
Share medium-skilled	0.81	0.29	536	0.87	0.22	120	0.06	0.03
Share high-skilled	0.10	0.23	536	0.08	0.16	120	−0.03	0.02

This table shows the descriptive statistics of the firms in panel sample 2000 to 2011 in the first year. Data sources are reported in the table. The shares of skill groups are calculated based on the composition in SIAB.

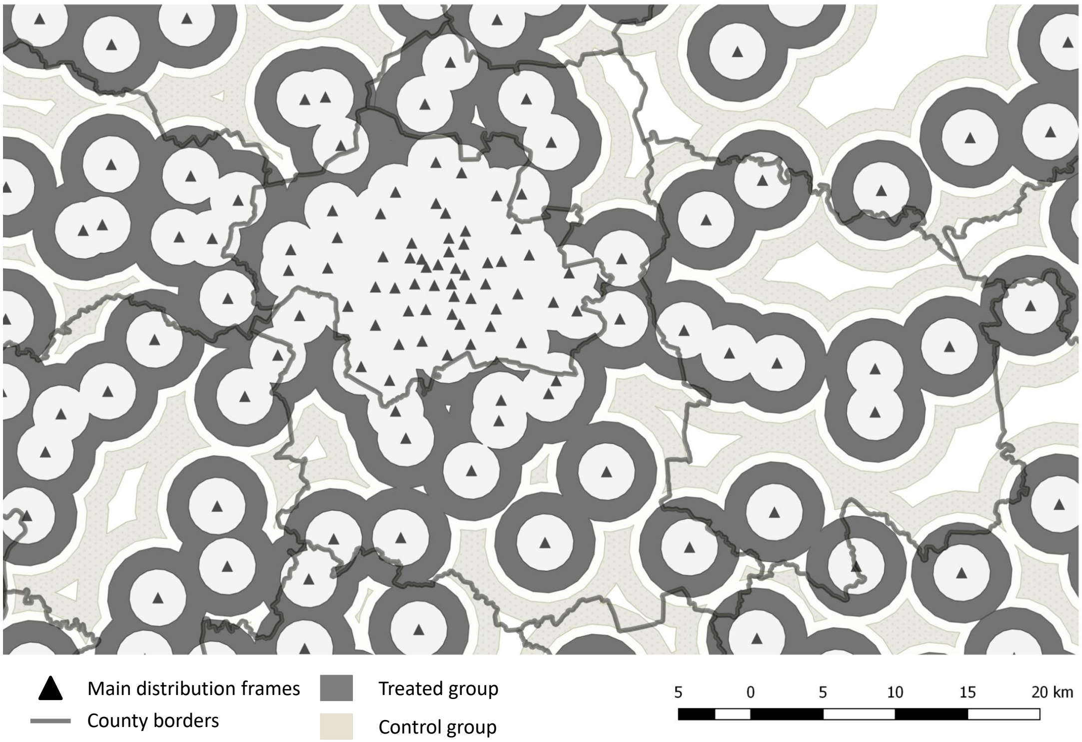
Table A.2: Descriptive statistics of non-manufacturing firms without donut, 2000

	0.5-2 km			2-3.5 km			difference	
	Mean	SD	N	Mean	SD	N	(4) - (1)	SD
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Performance								
Log(Sales, survey)	14.13	1.91	577	14.08	1.76	233	−0.05	0.15
Log(Value added, survey)	13.39	1.95	501	13.45	1.84	207	0.06	0.16
Share of purchased inputs	0.43	0.23	509	0.42	0.21	212	−0.01	0.02
Log(Sales per FTE)	12.43	1.63	552	12.32	1.48	224	−0.10	0.13
Log(Sales per empl.)	11.17	0.76	548	11.11	0.73	223	−0.05	0.06
Employment size								
Log(Full-Time Empl., SIAB)	1.66	1.50	577	1.75	1.53	233	0.08	0.05
Log(Total Empl., survey)	3.19	1.71	577	3.12	1.53	233	−0.06	0.13
Log(Daily wage sum, SIAB)	5.87	1.67	577	5.95	1.73	233	0.07	0.13
Log(Monthly wage sum, survey)	10.37	2.03	556	10.37	1.82	228	−0.00	0.15
Skill composition								
Share Low Skilled	0.07	0.18	577	0.05	0.16	233	−0.02	0.01
Share Medium Skilled	0.81	0.29	577	0.84	0.25	233	0.03	0.02
Share High Skilled	0.11	0.24	577	0.10	0.21	233	−0.01	0.02

This table shows the descriptive statistics of the firms in panel sample 2000 to 2011 in the first year. Data sources are reported in the table. The shares of skill groups are calculated based on the composition in SIAB.

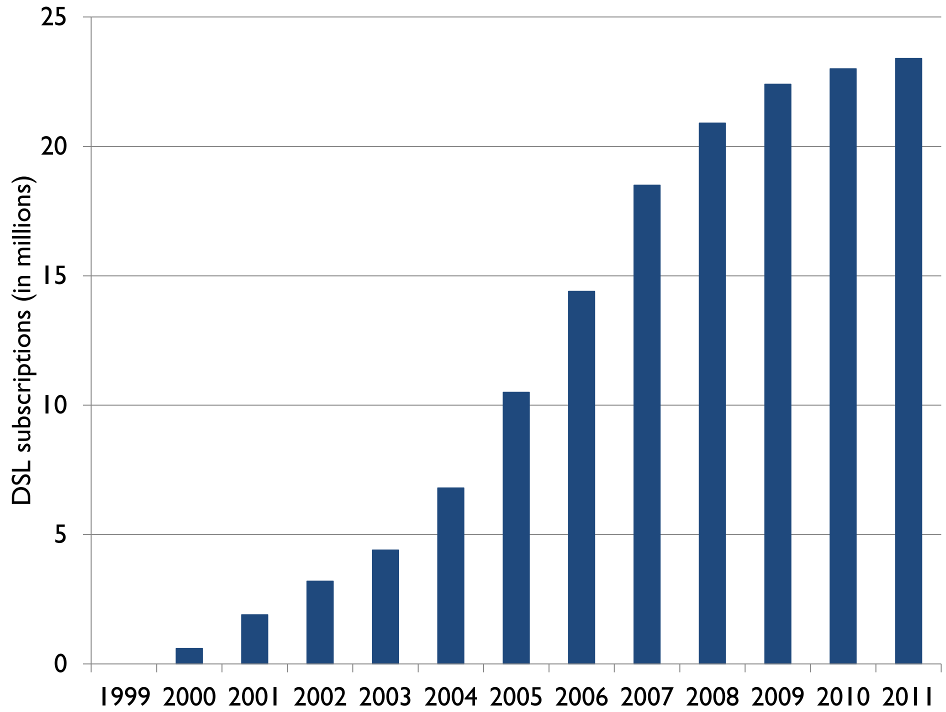
A.2 Identification strategy

Figure A.1: Map of main distribution frames



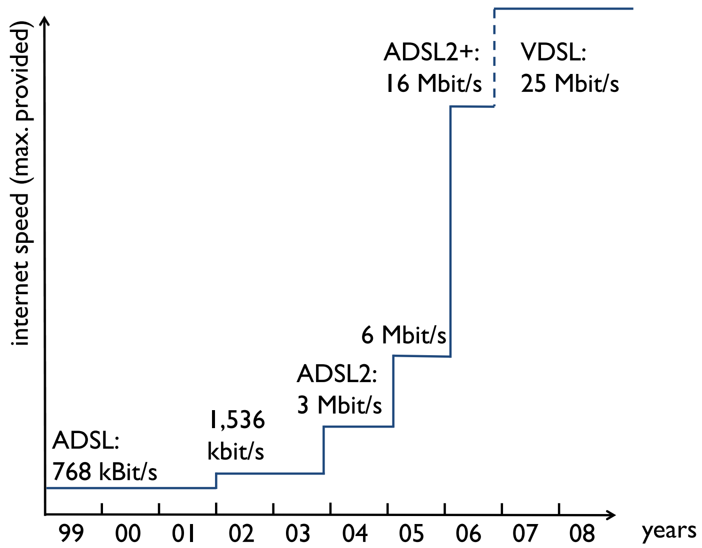
The figure illustrates the definition of treatment and control group for the analysis of speed upgrades. Grey lines show county borders. Black triangles resemble MDFs. Grey circles resemble the areas of treated firms. Light circles resemble the areas of firms in the control group.

Figure A.2: Number of DSL subscriptions in Germany



The figure shows the number of DSL subscriptions in Germany over time (Bundesnetzagentur, 2011)

Figure A.3: Timeline



The figure shows the timeline of the introduction and upgrading of broadband internet technology following Schnabel (2015). In 2000, customers received ADSL with a maximum download speed of 768 kBit/s. In later years, the speed was upgraded up to 6 MBit/s. In 2006, however, ADSL2+ provided a much larger speed upgrades with up to 16 MBit/s provided by most telecoms companies. Further, VDSL was introduced but required large infrastructure investments which took several years. Own illustration.

B Results

B.1 Results of introduction of the broadband internet

Table B.1: Regression results comparing 2-3.5 km to 4.2-5.7 km

Dependent variable		D_{post} from 2000	Excl. early municip.
Performance			
Log(revenues)		−0.018	−0.012
Source: survey		(0.077)	(0.081)
	N	1,255	1,201
Log(value added)		−0.015	0.033
Source: survey		(0.108)	(0.107)
	N	987	937
Log(revenues per full-time		0.086	0.132
employee (FTE))		(0.111)	(0.113)
Sources: survey and SIAB	N	1,123	1,073
Log(revenues per employee)		0.144**	0.147**
Source: survey		(0.063)	(0.061)
	N	1,121	1,071
Employment			
Log(total employment)		−0.084	−0.066
Source: survey		(0.068)	(0.073)
	N	1,255	1,201
Log(full-time employment)		−0.077	−0.094
Source: SIAB		(0.108)	(0.114)
	N	1,255	1,201
Log(wage sum)		−0.118	−0.128
Source: SIAB		(0.117)	(0.122)
	N	1,255	1,201
Log(wage sum)		−0.147*	−0.152*
Source: survey		(0.077)	(0.084)
	N	1,216	1,162
Skill composition			
Share of low-skilled		−0.020	−0.024
Source: SIAB		(0.015)	(0.019)
	N	1,255	1,201
Share of medium-skilled		0.033*	0.046**
Source: SIAB		(0.019)	(0.022)
	N	1,255	1,201
Share of high-skilled		−0.014	−0.024
Source: SIAB		(0.016)	(0.017)
	N	1,255	1,201

This table shows the results from the fixed-effects difference-in-differences estimation with 1996 to 2000 as pre-treatment period and 2001 to 2005 as the treatment period. The estimation equation is: $y_{i,t} = \beta_0 + \beta_1 \, \mathsf{DSL\ access}_i \, D_{post,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{post,t}$ is an indicator variable for the treatment period from 2001 on. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 2 and 3.5 km from the MDF and zero for firms located between 4.2 and 5.7 km from the MDF. The table reports the results for β_1. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The regression in the first column defines the post period from 2000 on. The sample in the second column excludes municipalities in which any MDF was upgraded to the first generation of broadband internet in 2000.

Table B.2: Yearly effects of introduction of the broadband internet: firm size

	log(employment)		log(wage sum)	
	full-time	total	daily	survey
$D_{DSL} \times D_{1997}$	−0.033	−0.050	−0.019	−0.107
	(0.142)	(0.086)	(0.149)	(0.109)
$D_{DSL} \times D_{1998}$	0.007	−0.013	0.020	−0.049
	(0.127)	(0.083)	(0.134)	(0.100)
$D_{DSL} \times D_{1999}$	0.021	−0.009	−0.007	−0.066
	(0.123)	(0.086)	(0.126)	(0.105)
$D_{DSL} \times D_{2000}$	−0.017	−0.094	−0.053	−0.134
	(0.123)	(0.083)	(0.126)	(0.100)
$D_{DSL} \times D_{2001}$	0.009	−0.103	−0.034	−0.230**
	(0.127)	(0.086)	(0.132)	(0.106)
$D_{DSL} \times D_{2002}$	0.011	−0.005	−0.015	−0.084
	(0.141)	(0.093)	(0.143)	(0.112)
$D_{DSL} \times D_{2003}$	−0.153	−0.100	−0.194	−0.305***
	(0.142)	(0.088)	(0.146)	(0.110)
$D_{DSL} \times D_{2004}$	−0.219	−0.175*	−0.272*	−0.332***
	(0.154)	(0.104)	(0.156)	(0.121)
$D_{DSL} \times D_{2005}$	−0.224	−0.197	−0.286	−0.198
	(0.176)	(0.154)	(0.183)	(0.152)
R-squared	0.937	0.965	0.948	0.967
Obs.	1,255	1,255	1,255	1,216

This table shows the results from the fixed-effects difference-in-differences estimation with 1996 to 2000 as pre-treatment and 2001 to 2005 as treatment period. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\,\mathsf{DSL\ access}_i\, D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 2 and 3.5 km from the MDF and zero for firms located between 4.2 and 5.7 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Information on total employment and monthly wage sum (last column) retrieved from survey data. The sample only contains non-manufacturing firms.

Table B.3: Yearly effects of introduction of the broadband internet: performance

	log revenues	log(VA)	Shr. of Inputs	log(rev. p. FTE)	log(rev. p. empl.)
$D_{DSL} \times D_{1997}$	0.029	0.053	0.005	0.031	0.174
	(0.084)	(0.143)	(0.046)	(0.159)	(0.122)
$D_{DSL} \times D_{1998}$	0.040	0.060	−0.009	0.058	0.140
	(0.079)	(0.147)	(0.043)	(0.143)	(0.123)
$D_{DSL} \times D_{1999}$	−0.010	−0.171	0.078*	−0.008	0.207
	(0.078)	(0.141)	(0.043)	(0.142)	(0.126)
$D_{DSL} \times D_{2000}$	0.015	−0.067	0.039	0.012	0.200
	(0.083)	(0.136)	(0.040)	(0.144)	(0.129)
$D_{DSL} \times D_{2001}$	0.001	−0.050	0.017	0.088	0.275**
	(0.088)	(0.167)	(0.044)	(0.146)	(0.130)
$D_{DSL} \times D_{2002}$	0.047	−0.058	0.031	0.083	0.354***
	(0.088)	(0.143)	(0.043)	(0.159)	(0.135)
$D_{DSL} \times D_{2003}$	−0.030	−0.003	−0.020	0.147	0.260*
	(0.093)	(0.149)	(0.046)	(0.159)	(0.134)
$D_{DSL} \times D_{2004}$	−0.098	−0.097	0.005	0.138	0.278*
	(0.107)	(0.170)	(0.049)	(0.168)	(0.148)
$D_{DSL} \times D_{2005}$	0.019	0.116	−0.005	0.288+	0.496***
	(0.128)	(0.177)	(0.049)	(0.167)	(0.157)
R-squared	0.973	0.937	0.662	0.934	0.839
Obs.	1,255	987	1,002	1,123	1,121

This table shows the results from the fixed-effects difference-in-differences estimation with 1996 to 2000 as pre-treatment and 2001 to 2005 as treatment period. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\, \textsf{DSL access}_i\, D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\textsf{DSL access}_i$ is an indicator variable equal to one if the firm is located between 2 and 3.5 km from the MDF and zero for firms located between 4.2 and 5.7 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Information on revenues, value added, share of inputs, and total employment retrieved from survey data. The number of full-time employees (FTE) is calculated based on social-security data. The sample only contains non-manufacturing firms.

Table B.4: Regression results of introduction of the broadband internet

Dependent variable		Pooled	Non-manuf.	Manuf.
Performance				
Log(revenues)		−0.006	−0.023	0.004
Source: survey		(0.031)	(0.040)	(0.047)
	N	2,184	1,255	929
Log(value added)		0.029	0.007	0.034
Source: survey		(0.054)	(0.068)	(0.087)
	N	1,734	987	747
Log(revenues per full-time		0.096**	0.116*	0.070
employee (FTE))		(0.044)	(0.060)	(0.064)
Sources: survey and SIAB	N	1,971	1,123	848
Log(revenues per employee)		0.118***	0.140***	0.088**
Source: survey		(0.036)	(0.052)	(0.049)
	N	1,967	1,121	846
Employment				
Log(total employment)		−0.074*	−0.091	−0.068
Source: survey		(0.041)	(0.056)	(0.061)
	N	2,184	1,255	929
Log(full-time employment)		−0.075***	−0.071*	−0.100***
Source: SIAB		(0.027)	(0.038)	(0.037)
	N	2,184	1,255	929
Log(wage sum)		−0.101**	−0.125**	−0.086
Source: SIAB		(0.043)	(0.057)	(0.064)
	N	2,184	1,255	929
Log(wage sum)		−0.079**	−0.150***	−0.013
Source: survey		(0.037)	(0.047)	(0.060)
	N	2,114	1,216	898
Skill composition				
Share of low-skilled		−0.015**	−0.020**	−0.006
Source: SIAB		(0.006)	(0.009)	(0.007)
	N	2,184	1,255	929
Share of medium-skilled		0.017	0.043***	−0.020
Source: SIAB		(0.012)	(0.013)	(0.022)
	N	2,184	1,255	929
Share of high-skilled		−0.001	−0.022**	0.025
Source: SIAB		(0.011)	(0.010)	(0.021)
	N	2,184	1,255	929

This table shows the results from the fixed-effects difference-in-differences estimation with 1996 to 2000 as pre-treatment period and 2001 to 2005 as the treatment period. The estimation equation is: $y_{i,t} = \beta_0 + \beta_1 \,\mathsf{DSL\ access}_i\, D_{post,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{post,t}$ is an indicator variable for the treatment period from 2001 on. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 2 and 3.5 km from the MDF and zero for firms located between 4.2 and 5.7 km from the MDF. The table reports the results for β_1. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

B.2 Main results of speed upgrades

Table B.5: Impact of speed upgrades on performance, non-manufacturing firms

	log revenues	log(VA)	Shr. of Inputs	log(rev. p. FTE)	log(rev. p. empl.)
$D_{DSL} \times D_{2001}$	0.008	0.120	−0.004	0.019	−0.043
	(0.055)	(0.088)	(0.024)	(0.067)	(0.055)
$D_{DSL} \times D_{2002}$	0.028	0.124	−0.016	−0.018	−0.035
	(0.052)	(0.087)	(0.023)	(0.073)	(0.059)
$D_{DSL} \times D_{2003}$	0.128**	0.210**	−0.009	0.120	0.061
	(0.053)	(0.100)	(0.025)	(0.079)	(0.060)
$D_{DSL} \times D_{2004}$	0.168***	0.296***	−0.025	0.108	0.083
	(0.057)	(0.096)	(0.026)	(0.074)	(0.060)
$D_{DSL} \times D_{2005}$	0.138**	0.222**	−0.035	0.063	0.039
	(0.060)	(0.097)	(0.025)	(0.081)	(0.067)
$D_{DSL} \times D_{2006}$	0.147**	0.304***	−0.048*	0.072	0.037
	(0.061)	(0.099)	(0.029)	(0.082)	(0.069)
$D_{DSL} \times D_{2007}$	0.191***	0.324***	−0.021	0.069	0.058
	(0.064)	(0.106)	(0.031)	(0.078)	(0.069)
$D_{DSL} \times D_{2008}$	0.150**	0.192*	0.005	0.075	0.034
	(0.061)	(0.106)	(0.029)	(0.077)	(0.068)
$D_{DSL} \times D_{2009}$	0.158**	0.242**	−0.009	0.076	0.105
	(0.063)	(0.103)	(0.032)	(0.080)	(0.067)
$D_{DSL} \times D_{2010}$	0.161**	0.255**	−0.008	0.072	0.093
	(0.063)	(0.103)	(0.032)	(0.081)	(0.064)
$D_{DSL} \times D_{2011}$	0.168**	0.277***	−0.039	0.084	0.112
	(0.066)	(0.101)	(0.029)	(0.093)	(0.072)
R-squared	0.973	0.944	0.699	0.925	0.822
Obs.	6,274	5,054	5,189	5,472	5,455

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\,\mathsf{DSL\ access}_i\, D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 0.5 and 2 km from the MDF and zero for firms located between 2.8 and 4.2 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Information on revenues, value added, share of inputs, and total employment retrieved from survey data. The number of full-time employees (FTE) is calculated based on social-security data.

Table B.6: Firm size and skill composition

	log(employment)		log(wage sum)		skill shares		
	full-time	total	daily	survey	low	med.	high
$D_{DSL} \times D_{2001}$	−0.019	0.069	0.015	0.070	−0.015	0.001	0.013
	(0.055)	(0.049)	(0.056)	(0.066)	(0.010)	(0.018)	(0.016)
$D_{DSL} \times D_{2002}$	0.046	0.065	0.052	0.066	−0.007	0.013	−0.006
	(0.058)	(0.049)	(0.057)	(0.066)	(0.009)	(0.019)	(0.017)
$D_{DSL} \times D_{2003}$	0.017	0.078	0.047	0.094	−0.005	0.003	0.005
	(0.061)	(0.052)	(0.060)	(0.069)	(0.009)	(0.021)	(0.018)
$D_{DSL} \times D_{2004}$	0.062	0.119**	0.101	0.205***	−0.008	0.026	−0.018
	(0.064)	(0.058)	(0.064)	(0.074)	(0.011)	(0.019)	(0.016)
$D_{DSL} \times D_{2005}$	0.059	0.132**	0.120*	0.191***	0.005	0.007	−0.008
	(0.062)	(0.058)	(0.064)	(0.074)	(0.010)	(0.020)	(0.018)
$D_{DSL} \times D_{2006}$	0.083	0.118**	0.107*	0.123*	−0.008	0.030*	−0.018
	(0.061)	(0.056)	(0.062)	(0.072)	(0.009)	(0.017)	(0.015)
$D_{DSL} \times D_{2007}$	0.087	0.100*	0.110*	0.143*	−0.006	0.042**	−0.031*
	(0.061)	(0.055)	(0.061)	(0.075)	(0.010)	(0.021)	(0.018)
$D_{DSL} \times D_{2008}$	0.069	0.124**	0.090	0.198**	−0.001	0.040*	−0.039*
	(0.067)	(0.058)	(0.067)	(0.079)	(0.010)	(0.023)	(0.020)
$D_{DSL} \times D_{2009}$	0.066	0.107*	0.114*	0.198**	−0.016	0.054**	−0.037*
	(0.065)	(0.059)	(0.066)	(0.083)	(0.011)	(0.022)	(0.020)
$D_{DSL} \times D_{2010}$	0.077	0.103*	0.083	0.118	−0.025*	0.059***	−0.031*
	(0.070)	(0.059)	(0.073)	(0.077)	(0.015)	(0.023)	(0.018)
$D_{DSL} \times D_{2011}$	0.078	0.131**	0.115	0.102	−0.019	0.067**	−0.045*
	(0.091)	(0.066)	(0.091)	(0.077)	(0.015)	(0.030)	(0.026)
R-squared	0.951	0.978	0.960	0.971	0.762	0.809	0.833
Obs.	6,274	6,274	6,274	6,068	6,274	6,274	6,274

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\, \mathsf{DSL\ access}_i\, D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 0.5 and 2 km from the MDF and zero for firms located between 2.8 and 4.2 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * p $<$ 0.10, ** p $<$ 0.05, *** p $<$ 0.01. Information on total employment and monthly wage sum retrieved from survey data. Information on skills reported in social security data. Low-skilled employees do not have any vocational training. Medium-skilled employees have vocational training. High-skilled employees have at least a college degree. The sample only contains non-manufacturing firms.

B.3 Results of speed upgrades incl. donut in manufacturing

Table B.7: Performance

	log revenues	log(VA)	Shr. of Inputs	log(rev. p. FTE)	log(rev. p. empl.)
$D_{DSL} \times D_{2001}$	0.008	0.120	−0.004	0.019	−0.043
	(0.055)	(0.088)	(0.024)	(0.067)	(0.055)
$D_{DSL} \times D_{2002}$	0.028	0.124	−0.016	−0.018	−0.035
	(0.052)	(0.087)	(0.023)	(0.073)	(0.059)
$D_{DSL} \times D_{2003}$	0.128**	0.210**	−0.009	0.120	0.061
	(0.053)	(0.100)	(0.025)	(0.079)	(0.060)
$D_{DSL} \times D_{2004}$	0.168***	0.296***	−0.025	0.108	0.083
	(0.057)	(0.096)	(0.026)	(0.074)	(0.060)
$D_{DSL} \times D_{2005}$	0.138**	0.222**	−0.035	0.063	0.039
	(0.060)	(0.097)	(0.025)	(0.081)	(0.067)
$D_{DSL} \times D_{2006}$	0.147**	0.304***	−0.048*	0.072	0.037
	(0.061)	(0.099)	(0.029)	(0.082)	(0.069)
$D_{DSL} \times D_{2007}$	0.191***	0.324***	−0.021	0.069	0.058
	(0.064)	(0.106)	(0.031)	(0.078)	(0.069)
$D_{DSL} \times D_{2008}$	0.150**	0.192*	0.005	0.075	0.034
	(0.061)	(0.106)	(0.029)	(0.077)	(0.068)
$D_{DSL} \times D_{2009}$	0.158**	0.242**	−0.009	0.076	0.105
	(0.063)	(0.103)	(0.032)	(0.080)	(0.067)
$D_{DSL} \times D_{2010}$	0.161**	0.255**	−0.008	0.072	0.093
	(0.063)	(0.103)	(0.032)	(0.081)	(0.064)
$D_{DSL} \times D_{2011}$	0.168**	0.277***	−0.039	0.084	0.112
	(0.066)	(0.101)	(0.029)	(0.093)	(0.072)
R-squared	0.973	0.944	0.699	0.925	0.822
Obs.	6,274	5,054	5,189	5,472	5,455

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\,\mathsf{DSL\ access}_i\, D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 0.5 and 2 km from the MDF and zero for firms located between 2.8 and 4.2 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Information on revenues, value added, share of inputs, and total employment retrieved from survey data. The number of full-time employees (FTE) is calculated based on social-security data.

Table B.8: Firm size

	log(employment)			log(wage sum)	
	full-time	total	prod.	daily	survey
$D_{DSL} \times D_{2001}$	−0.019	0.069	−0.043	0.015	0.070
	(0.055)	(0.049)	(0.059)	(0.056)	(0.066)
$D_{DSL} \times D_{2002}$	0.046	0.065	0.015	0.052	0.066
	(0.058)	(0.049)	(0.062)	(0.057)	(0.066)
$D_{DSL} \times D_{2003}$	0.017	0.078	−0.017	0.047	0.094
	(0.061)	(0.052)	(0.066)	(0.060)	(0.069)
$D_{DSL} \times D_{2004}$	0.062	0.119**	0.036	0.101	0.205***
	(0.064)	(0.058)	(0.068)	(0.064)	(0.074)
$D_{DSL} \times D_{2005}$	0.059	0.132**	0.049	0.120*	0.191***
	(0.062)	(0.058)	(0.067)	(0.064)	(0.074)
$D_{DSL} \times D_{2006}$	0.083	0.118**	0.050	0.107*	0.123*
	(0.061)	(0.056)	(0.066)	(0.062)	(0.072)
$D_{DSL} \times D_{2007}$	0.087	0.100*	0.064	0.110*	0.143*
	(0.061)	(0.055)	(0.065)	(0.061)	(0.075)
$D_{DSL} \times D_{2008}$	0.069	0.124**	0.047	0.090	0.198**
	(0.067)	(0.058)	(0.072)	(0.067)	(0.079)
$D_{DSL} \times D_{2009}$	0.066	0.107*	0.029	0.114*	0.198**
	(0.065)	(0.059)	(0.071)	(0.066)	(0.083)
$D_{DSL} \times D_{2010}$	0.077	0.103*	0.047	0.083	0.118
	(0.070)	(0.059)	(0.081)	(0.073)	(0.077)
$D_{DSL} \times D_{2011}$	0.078	0.131**	−0.120	0.115	0.102
	(0.091)	(0.066)	(0.128)	(0.091)	(0.077)
R-squared	0.951	0.978	0.939	0.960	0.971
Obs.	6,274	6,274	6,274	6,274	6,068

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\,\mathsf{DSL\ access}_i\, D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 0.5 and 2 km from the MDF and zero for firms located between 2.8 and 4.2 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Information on total employment and monthly wage sum (last column) retrieved from survey data.

Table B.9: Shares of skill groups

	low-skill	medium-skill	high-skill
$D_{DSL} \times D_{2001}$	0.004	-0.007	0.004
	(0.008)	(0.015)	(0.012)
$D_{DSL} \times D_{2002}$	-0.000	-0.010	0.010
	(0.008)	(0.014)	(0.011)
$D_{DSL} \times D_{2003}$	-0.000	-0.021	0.020^{*}
	(0.009)	(0.014)	(0.011)
$D_{DSL} \times D_{2004}$	0.012	-0.050^{***}	0.038^{***}
	(0.008)	(0.015)	(0.013)
$D_{DSL} \times D_{2005}$	0.004	-0.049^{***}	0.039^{***}
	(0.008)	(0.015)	(0.013)
$D_{DSL} \times D_{2006}$	0.001	-0.042^{***}	0.037^{***}
	(0.008)	(0.015)	(0.013)
$D_{DSL} \times D_{2007}$	-0.006	-0.034^{**}	0.035^{***}
	(0.008)	(0.015)	(0.012)
$D_{DSL} \times D_{2008}$	-0.003	-0.033^{**}	0.027^{**}
	(0.009)	(0.015)	(0.011)
$D_{DSL} \times D_{2009}$	-0.020^{*}	-0.028^{*}	0.040^{***}
	(0.011)	(0.016)	(0.013)
$D_{DSL} \times D_{2010}$	-0.008	-0.023	0.020
	(0.009)	(0.016)	(0.013)
$D_{DSL} \times D_{2011}$	-0.021	-0.003	0.015
	(0.014)	(0.020)	(0.018)
R-squared	0.824	0.801	0.771
Observations	6,117	6,117	6,117

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\,\mathsf{DSL\ access}_i\, D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 0.5 and 2 km from the MDF and zero for firms located between 2.8 and 4.2 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Information on skills reported in social security data. Low-skilled employees do not have any vocational training. Medium-skilled employees have vocational training. High-skilled employees have at least a college degree.

B.4 Robustness checks on introduction of the broadband internet

Table B.10: Other robustness checks for introduction of the broadband internet

Dependent variable		(1)	(2)	(3)	(4)	(5)
Performance						
Log(revenues)		−0.006	−0.208	−0.440**	−0.043	0.066
Source: survey		(0.123)	(0.152)	(0.185)	(0.081)	(0.099)
	N	572	381	211	1,179	793
Log(value added)		0.050	−0.073	−0.389*	−0.011	0.172
Source: survey		(0.168)	(0.233)	(0.194)	(0.109)	(0.136)
	N	428	319	164	1,179	626
Log(revenues per full-time employee (FTE))		0.161	0.060	−0.028	−0.102	0.207
		(0.170)	(0.211)	(0.224)	(0.111)	(0.143)
Sources: survey and SIAB	N	506	354	199	1,054	704
Log(revenues per employee)		0.154	0.134	−0.126	0.144**	0.131
Source: survey		(0.110)	(0.087)	(0.255)	(0.061)	(0.083)
	N	505	354	198	1,052	702
Employment						
Log(total employment)		−0.067	−0.217	−0.393	−0.098	−0.036
Source: survey		(0.159)	(0.157)	(0.331)	(0.107)	(0.150)
	N	572	381	211	1,179	793
Log(full-time employment)		−0.061	−0.139	−0.126	−0.087	0.043
Source: SIAB		(0.113)	(0.100)	(0.211)	(0.071)	(0.096)
	N	572	381	211	1,179	793
Log(wage sum)		−0.144	−0.252*	−0.423	−0.127	−0.075
Source: SIAB		(0.190)	(0.151)	(0.316)	(0.112)	(0.158)
	N	572	381	211	1,179	793
Log(wage sum)		−0.174	−0.207*	−0.275	−0.158*	−0.074
Source: survey		(0.129)	(0.110)	(0.296)	(0.082)	(0.104)
	N	553	373	211	1,140	793
Skill composition						
Share of low-skilled		−0.020	0.002	0.026	−0.016	−0.023
Source: SIAB		(0.028)	(0.009)	(0.028)	(0.016)	(0.021)
	N	572	381	211	1,179	793
Share of medium-skilled		0.038	0.043	−0.024	0.033*	0.052*
Source: SIAB		(0.030)	(0.048)	(0.040)	(0.018)	(0.030)
	N	572	381	211	1,179	793
Share of high-skilled		−0.016	−0.051	−0.021	−0.016	−0.029
Source: SIAB		(0.012)	(0.046)	(0.014)	(0.012)	(0.025)
	N	572	381	211	1,179	793

The table shows the results from the fixed-effects difference-in-differences estimation with 1996 to 2000 as pre-treatment period and 2001 to 2005 as the treatment period. The estimation equation is: $y_{i,t} = \beta_0 + \beta_1 \,\mathsf{DSL\ access}_i\, D_{post,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{post,t}$ is an indicator variable for the treatment period from 2001 on. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 2 and 3.5 km from the MDF and zero for firms located between 4.2 and 5.7 km from the MDF. The table reports the results for β_1. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All samples only contain non-manufacturing firms. Samples are further restricted by robustness check. Column (1) contains firms that did not invest in ICT in 2000. Column (2) contains firms that invested in ICT in 2000. Column (3) contains firms in Western Germany. Column (4) contains firms in municipalities with at least one household with DSL access in 2005. Column (5) contains firms founded in 1992 or before.

B.5 Robustness check on introduction: 2-3.5 km to 3.5-5 km

Table B.11: Regression results comparing 2-3.5 km to 3.5-5 km

	Pooled	Non-manuf.	Manuf.
Performance			
log(revenues)	-0.064^{**}	-0.072^{*}	-0.057
	(0.030)	(0.041)	(0.042)
	2,359	1,381	978
log(value added)	-0.034	-0.107^{*}	0.048
	(0.053)	(0.065)	(0.086)
	1,874	987	792
log(revenues per FTE)	-0.023	-0.020	-0.024
	(0.039)	(0.057)	(0.053)
	2,115	1,123	894
log(revenues per employee)	-0.006	0.016	-0.031
	(0.034)	(0.051)	(0.044)
	2,110	1,121	892
Employment			
log(total employment)	-0.040	-0.038	-0.050
	(0.033)	(0.048)	(0.041)
	2,359	1,381	978
log(full-time employment)	-0.045^{*}	-0.038	-0.061^{*}
	(0.024)	(0.035)	(0.032)
	2,359	1,381	978
log(wage sum, soc. sec.)	-0.041	-0.060	-0.025
	(0.033)	(0.047)	(0.045)
	2,359	1,381	978
log(wage sum, survey)	-0.040	-0.124^{***}	0.051
	(0.033)	(0.044)	(0.050)
	2,268	1,329	939
Skill composition			
share of low-skilled	-0.006	-0.001	-0.012^{**}
	(0.005)	(0.009)	(0.005)
	2,359	1,381	978
share of medium-skilled	0.003	0.003	0.002
	(0.010)	(0.011)	(0.018)
	2,359	1,381	978
share of high-skilled	0.001	-0.003	0.007
	(0.009)	(0.007)	(0.017)
	2,359	1,381	978

This table shows the results from the fixed-effects difference-in-differences estimation with 1996 to 2000 as pre-treatment period and 2001 to 2005 as the treatment period. The estimation equation is: $y_{i,t} = \beta_0 + \beta_1 \textsf{DSL access}_i D_{post,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{post,t}$ is an indicator variable for the treatment period from 2001 on. $\textsf{DSL access}_i$ is an indicator variable equal to one if the firm is located between 2 and 3.5 km from the MDF and zero for firms located between 3.5 and 5 km from the MDF. The table reports the results for β_1. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

B.6 Robustness checks speed upgrades: 0.5-2 km vs. 2-3.5 km

Table B.12: Non-manufacturing sample comparing 0.5-2 km to 2-3.5 km: firm size

	log(employment)		log(wage sum)	
	full-time	total	daily	survey
$D_{DSL} \times D_{2001}$	−0.014	0.021	0.018	0.035
	(0.087)	(0.030)	(0.083)	(0.039)
$D_{DSL} \times D_{2002}$	0.022	−0.002	0.037	0.005
	(0.089)	(0.030)	(0.084)	(0.041)
$D_{DSL} \times D_{2003}$	0.082	0.010	0.107	0.040
	(0.078)	(0.031)	(0.074)	(0.042)
$D_{DSL} \times D_{2004}$	0.109	0.007	0.156*	0.090**
	(0.086)	(0.032)	(0.083)	(0.043)
$D_{DSL} \times D_{2005}$	0.176*	0.019	0.216**	0.077*
	(0.106)	(0.035)	(0.098)	(0.044)
$D_{DSL} \times D_{2006}$	0.145	−0.007	0.165	0.005
	(0.106)	(0.033)	(0.101)	(0.043)
$D_{DSL} \times D_{2007}$	0.106	−0.045	0.120	0.011
	(0.108)	(0.032)	(0.102)	(0.045)
$D_{DSL} \times D_{2008}$	0.043	−0.043	0.065	0.010
	(0.089)	(0.036)	(0.086)	(0.048)
$D_{DSL} \times D_{2009}$	0.035	−0.050	0.068	0.012
	(0.087)	(0.038)	(0.083)	(0.052)
$D_{DSL} \times D_{2010}$	0.041	−0.020	0.054	0.023
	(0.089)	(0.039)	(0.085)	(0.051)
$D_{DSL} \times D_{2011}$	0.019	0.011	0.058	0.018
	(0.107)	(0.044)	(0.104)	(0.052)
R-squared	0.947	0.979	0.958	0.974
Obs.	7854	7854	7854	7605

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\, \mathsf{DSL\ access}_i\, D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 0.5 and 2 km from the MDF and zero for firms located between 2 and 3.5 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Information on total employment and monthly wage sum (last column) retrieved from survey data.

Table B.13: Non-manufacturing sample comparing 0.5-2 km to 2-3.5 km: performance

	log revenues	log(VA)	Shr. of Inputs	log(rev. p. FTE)	log(rev. p. empl.)
$D_{DSL} \times D_{2001}$	0.013	0.073	−0.009	0.000	−0.016
	(0.036)	(0.066)	(0.018)	(0.100)	(0.043)
$D_{DSL} \times D_{2002}$	0.011	−0.048	0.000	−0.028	−0.024
	(0.035)	(0.066)	(0.018)	(0.108)	(0.045)
$D_{DSL} \times D_{2003}$	0.065*	0.057	−0.001	−0.041	0.072
	(0.036)	(0.068)	(0.019)	(0.094)	(0.045)
$D_{DSL} \times D_{2004}$	0.104***	0.052	0.013	−0.027	0.103**
	(0.037)	(0.064)	(0.019)	(0.102)	(0.046)
$D_{DSL} \times D_{2005}$	0.050	−0.024	−0.007	−0.193	0.059
	(0.039)	(0.066)	(0.019)	(0.122)	(0.048)
$D_{DSL} \times D_{2006}$	0.061	0.084	−0.020	−0.103	0.067
	(0.039)	(0.063)	(0.019)	(0.122)	(0.050)
$D_{DSL} \times D_{2007}$	0.057	0.063	−0.018	−0.104	0.073
	(0.041)	(0.069)	(0.020)	(0.121)	(0.051)
$D_{DSL} \times D_{2008}$	0.059	0.070	−0.012	−0.010	0.124**
	(0.042)	(0.071)	(0.020)	(0.100)	(0.050)
$D_{DSL} \times D_{2009}$	0.058	0.074	−0.000	0.001	0.154***
	(0.041)	(0.072)	(0.023)	(0.101)	(0.051)
$D_{DSL} \times D_{2010}$	0.080*	0.032	0.004	−0.019	0.107**
	(0.041)	(0.074)	(0.023)	(0.105)	(0.051)
$D_{DSL} \times D_{2011}$	0.068	0.116	−0.023	0.013	0.132**
	(0.044)	(0.078)	(0.024)	(0.104)	(0.052)
R-squared	0.977	0.950	0.686	0.922	0.829
Obs.	7854	6334	6503	6859	6842

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\, \mathsf{DSL\ access}_i\, D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 0.5 and 2 km from the MDF and zero for firms located between 2 and 3.5 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01. Information on revenues, value added, share of inputs, and total employment retrieved from survey data. The number of full-time employees (FTE) is calculated based on social-security data.

B.7 Other outcome variables

Table B.14: Outcome variable: firms exits

	Non-manuf.	Manuf.	Pooled
$D_{DSL} \times D_{2001}$	-0.002	-0.000	-0.001
	(0.002)	(0.000)	(0.001)
$D_{DSL} \times D_{2002}$	-0.006^{*}	-0.001	-0.004^{**}
	(0.003)	(0.001)	(0.002)
$D_{DSL} \times D_{2003}$	0.002	-0.004	0.000
	(0.006)	(0.003)	(0.004)
$D_{DSL} \times D_{2004}$	-0.007	-0.009	-0.008
	(0.020)	(0.014)	(0.013)
$D_{DSL} \times D_{2005}$	-0.016	-0.002	-0.009
	(0.024)	(0.013)	(0.015)
$D_{DSL} \times D_{2006}$	-0.013	-0.009	-0.011
	(0.024)	(0.017)	(0.015)
$D_{DSL} \times D_{2007}$	-0.012	0.001	-0.007
	(0.027)	(0.015)	(0.017)
$D_{DSL} \times D_{2008}$	-0.022	-0.000	-0.014
	(0.030)	(0.016)	(0.019)
$D_{DSL} \times D_{2009}$	-0.020	0.001	-0.012
	(0.030)	(0.017)	(0.019)
$D_{DSL} \times D_{2010}$	0.000	0.005	0.002
	(0.030)	(0.018)	(0.019)
$D_{DSL} \times D_{2011}$	-0.014	0.020	-0.000
	(0.030)	(0.020)	(0.019)
R-squared	0.511	0.405	0.484
Observations	8,720	6,501	15,275

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\,\mathsf{DSL\ access}_i\,D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 0.5 and 2 km from the MDF and zero for firms located between 2.8 and 4.2 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B.15: Outcome variable: firm invests in ICT, panel 1996-2005

	Pooled	Non-manufacturing	Manufacturing
$D_{DSL} \times D_{post}$	-0.024	0.037	0.017
	(0.047)	(0.052)	(0.077)
R-squared	0.489	0.450	0.456
Observations	2,027	1,255	929

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\,\mathsf{DSL\ access}_i\, D_{post} + \alpha_i + \alpha_t + u_{it}$, where D_{post} is an indicator variable for the post-treatment period. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 0.5 and 2 km from the MDF and zero for firms located between 2.8 and 4.2 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Investments in ICT retrieved from survey data. Firms are asked whether they invested in ICT. Samples are split by firms reporting to invest in ICT in 2000 or not.

Table B.16: Outcome variable: firm invests in ICT, panel 2000-2011

	Pooled	Non-manufacturing	Manufacturing
$D_{DSL} \times D_{2001}$	0.031	−0.062	−0.031
	(0.038)	(0.057)	(0.049)
$D_{DSL} \times D_{2002}$	−0.003	−0.076	0.014
	(0.040)	(0.058)	(0.050)
$D_{DSL} \times D_{2003}$	−0.059	0.075	0.037
	(0.045)	(0.064)	(0.055)
$D_{DSL} \times D_{2004}$	−0.053	0.072	0.060
	(0.045)	(0.066)	(0.056)
$D_{DSL} \times D_{2005}$	−0.011	−0.014	0.024
	(0.049)	(0.068)	(0.062)
$D_{DSL} \times D_{2006}$	−0.066	0.002	0.102*
	(0.047)	(0.068)	(0.061)
$D_{DSL} \times D_{2007}$	−0.042	0.008	0.061
	(0.049)	(0.068)	(0.066)
$D_{DSL} \times D_{2008}$	0.050	−0.038	−0.092
	(0.053)	(0.073)	(0.069)
$D_{DSL} \times D_{2009}$	−0.036	0.018	0.039
	(0.052)	(0.075)	(0.067)
$D_{DSL} \times D_{2010}$	0.051	−0.042	−0.098
	(0.055)	(0.073)	(0.072)
$D_{DSL} \times D_{2011}$	−0.043	−0.041	0.091
	(0.061)	(0.080)	(0.083)
R-squared	0.506	0.463	0.457
Observations	11,345	6,274	6,117

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\, \mathsf{DSL\ access}_i\, D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 0.5 and 2 km from the MDF and zero for firms located between 2.8 and 4.2 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Investments in ICT retrieved from survey data. Firms are asked whether they invested in ICT. Samples are split by firms reporting to invest in ICT in 2000 or not.

B.8 Other robustness checks

Table B.17: Distance: firm size

	log(employment)		log(wage sum)	
	full-time	total	daily	survey
$Distance \times D_{2001}$	-0.016	-0.058	-0.025	-0.049
	(0.040)	(0.037)	(0.040)	(0.048)
$Distance \times D_{2002}$	-0.058	-0.083^{**}	-0.056	-0.065
	(0.042)	(0.037)	(0.041)	(0.049)
$Distance \times D_{2003}$	-0.063	-0.114^{***}	-0.073^{*}	-0.098^{*}
	(0.045)	(0.040)	(0.044)	(0.052)
$Distance \times D_{2004}$	-0.148^{***}	-0.168^{***}	-0.148^{***}	-0.200^{***}
	(0.047)	(0.043)	(0.045)	(0.055)
$Distance \times D_{2005}$	-0.146^{***}	-0.165^{***}	-0.158^{***}	-0.185^{***}
	(0.044)	(0.042)	(0.044)	(0.052)
$Distance \times D_{2006}$	-0.120^{***}	-0.154^{***}	-0.133^{***}	-0.153^{***}
	(0.046)	(0.043)	(0.046)	(0.054)
$Distance \times D_{2007}$	-0.139^{***}	-0.158^{***}	-0.161^{***}	-0.184^{***}
	(0.045)	(0.043)	(0.044)	(0.056)
$Distance \times D_{2008}$	-0.103^{**}	-0.162^{***}	-0.110^{**}	-0.180^{***}
	(0.049)	(0.044)	(0.049)	(0.058)
$Distance \times D_{2009}$	-0.084^{*}	-0.150^{***}	-0.119^{**}	-0.177^{***}
	(0.048)	(0.045)	(0.047)	(0.061)
$Distance \times D_{2010}$	-0.109^{**}	-0.146^{***}	-0.129^{**}	-0.117^{**}
	(0.051)	(0.043)	(0.052)	(0.057)
$Distance \times D_{2011}$	-0.108	-0.144^{***}	-0.124	-0.103^{*}
	(0.076)	(0.046)	(0.077)	(0.060)
Constant	1.851^{***}	2.999^{***}	6.054^{***}	10.181^{***}
	(0.018)	(0.014)	(0.018)	(0.017)
R-squared	0.950	0.977	0.959	0.971
Obs.	6,352	6,352	6,352	6,145

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\,\mathsf{Distance}_i\,D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{Distance}_i$ is a continuous variable indicating the distance between the firm and the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01. Information on total employment and monthly wage sum (last column) retrieved from survey data.

Table B.18: Distance: performance

	log(revenues)	log(VA)	Shr. of Inputs	log(revenues p. FTE)	log(revenues p. empl.)
$Distance \times D_{2001}$	0.018	−0.046	0.007	0.026	0.060
	(0.045)	(0.067)	(0.017)	(0.051)	(0.044)
$Distance \times D_{2002}$	−0.043	−0.103	0.022	−0.012	0.042
	(0.041)	(0.071)	(0.018)	(0.055)	(0.047)
$Distance \times D_{2003}$	−0.105**	−0.204***	0.016	−0.048	−0.008
	(0.043)	(0.077)	(0.018)	(0.058)	(0.049)
$Distance \times D_{2004}$	−0.116**	−0.226***	0.021	0.008	0.010
	(0.046)	(0.076)	(0.019)	(0.058)	(0.049)
$Distance \times D_{2005}$	−0.126***	−0.220***	0.034*	0.006	0.028
	(0.047)	(0.079)	(0.020)	(0.061)	(0.054)
$Distance \times D_{2006}$	−0.128***	−0.256***	0.054***	−0.012	0.075
	(0.048)	(0.076)	(0.019)	(0.062)	(0.053)
$Distance \times D_{2007}$	−0.124**	−0.252***	0.035*	0.044	0.075
	(0.049)	(0.083)	(0.020)	(0.057)	(0.051)
$Distance \times D_{2008}$	−0.118**	−0.194**	0.016	−0.027	0.057
	(0.048)	(0.082)	(0.020)	(0.059)	(0.053)
$Distance \times D_{2009}$	−0.121**	−0.245***	0.034	−0.033	−0.009
	(0.049)	(0.079)	(0.022)	(0.061)	(0.053)
$Distance \times D_{2010}$	−0.124**	−0.279***	0.044*	−0.035	−0.006
	(0.049)	(0.081)	(0.024)	(0.063)	(0.050)
$Distance \times D_{2011}$	−0.139***	−0.258***	0.055**	−0.003	0.022
	(0.051)	(0.082)	(0.022)	(0.087)	(0.055)
Constant	13.906***	13.235***	0.420***	11.983***	11.160***
	(0.016)	(0.027)	(0.007)	(0.021)	(0.018)
R-squared	0.972	0.943	0.700	0.924	0.813
Obs.	6,352	5,111	5,247	5,538	5,520

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\,\mathsf{Distance}_i\, D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{Distance}_i$ is a continuous variable indicating the distance between the firm and the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Information on revenues, value added, share of inputs, and total employment retrieved from survey data. The number of full-time employees (FTE) is calculated based on social-security data.

Table B.19: Distance: performance

	low-skill	medium-skill	high-skill
$Distance \times D_{2001}$	0.003	−0.004	0.003
	(0.008)	(0.012)	(0.009)
$Distance \times D_{2002}$	−0.007	−0.010	0.017*
	(0.008)	(0.013)	(0.010)
$Distance \times D_{2003}$	−0.007	−0.003	0.008
	(0.009)	(0.013)	(0.010)
$Distance \times D_{2004}$	−0.010	−0.007	0.018*
	(0.009)	(0.013)	(0.010)
$Distance \times D_{2005}$	−0.019**	−0.000	0.019*
	(0.009)	(0.014)	(0.011)
$Distance \times D_{2006}$	−0.011	−0.007	0.019*
	(0.008)	(0.013)	(0.010)
$Distance \times D_{2007}$	−0.012	−0.000	0.013
	(0.010)	(0.015)	(0.010)
$Distance \times D_{2008}$	−0.025**	0.010	0.022**
	(0.010)	(0.015)	(0.011)
$Distance \times D_{2009}$	−0.007	−0.006	0.014
	(0.010)	(0.015)	(0.012)
$Distance \times D_{2010}$	−0.006	−0.003	0.010
	(0.015)	(0.018)	(0.012)
$Distance \times D_{2011}$	−0.002	−0.021	0.028
	(0.013)	(0.022)	(0.017)
Constant	0.073***	0.815***	0.101***
	(0.004)	(0.006)	(0.004)
R-squared	0.758	0.810	0.835
Observations	6,352	6,352	6,352

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\,\mathsf{Distance}_i\,D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{Distance}_i$ is a continuous variable indicating the distance between the firm and the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Information on skills reported in social security data. Low-skilled employees do not have any vocational training. Medium-skilled employees have vocational training. High-skilled employees have at least a college degree.

Table B.20: Founded 1992 or later: firm size

	log(employment)		log(wage sum)	
	full-time	total	daily	survey
$D_{DSL} \times D_{2001}$	−0.042	0.026	−0.004	−0.009
	(0.074)	(0.048)	(0.074)	(0.067)
$D_{DSL} \times D_{2002}$	0.032	0.020	0.044	−0.016
	(0.079)	(0.048)	(0.077)	(0.068)
$D_{DSL} \times D_{2003}$	−0.038	0.011	−0.000	−0.007
	(0.083)	(0.052)	(0.080)	(0.071)
$D_{DSL} \times D_{2004}$	0.044	0.045	0.096	0.096
	(0.086)	(0.060)	(0.086)	(0.079)
$D_{DSL} \times D_{2005}$	0.028	0.075	0.110	0.131
	(0.084)	(0.062)	(0.086)	(0.085)
$D_{DSL} \times D_{2006}$	0.081	0.052	0.137*	0.067
	(0.080)	(0.054)	(0.081)	(0.075)
$D_{DSL} \times D_{2007}$	0.094	0.043	0.118	0.109
	(0.079)	(0.053)	(0.079)	(0.076)
$D_{DSL} \times D_{2008}$	0.085	0.086	0.115	0.200**
	(0.089)	(0.057)	(0.087)	(0.083)
$D_{DSL} \times D_{2009}$	0.121	0.077	0.169**	0.182**
	(0.084)	(0.058)	(0.086)	(0.088)
$D_{DSL} \times D_{2010}$	0.142	0.084	0.147	0.098
	(0.089)	(0.062)	(0.090)	(0.086)
$D_{DSL} \times D_{2011}$	0.132	0.112	0.178	0.081
	(0.118)	(0.073)	(0.119)	(0.085)
R-squared	0.941	0.972	0.951	0.965
Obs.	4,182	4,182	4,182	4,046

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\,\textsf{DSL access}_i\, D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\textsf{DSL access}_i$ is an indicator variable equal to one if the firm is located between 0.5 and 2 km from the MDF and zero for firms located between 2.8 and 4.2 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Information on total employment and monthly wage sum (last column) retrieved from survey data. The sample only contains firms founded 1992 or later.

Table B.21: Founded 1992 or later: performance

	log revenues	log(VA)	Shr. of Inputs	log(rev. p. FTE)	log(rev. p. empl.)
$D_{DSL} \times D_{2001}$	0.012	0.176*	−0.038	−0.000	−0.002
	(0.057)	(0.098)	(0.027)	(0.078)	(0.065)
$D_{DSL} \times D_{2002}$	0.011	0.191**	−0.046*	−0.027	0.001
	(0.057)	(0.095)	(0.025)	(0.086)	(0.069)
$D_{DSL} \times D_{2003}$	0.070	0.169	−0.032	0.108	0.064
	(0.059)	(0.109)	(0.027)	(0.090)	(0.070)
$D_{DSL} \times D_{2004}$	0.099	0.257***	−0.050*	0.034	0.094
	(0.060)	(0.099)	(0.029)	(0.085)	(0.070)
$D_{DSL} \times D_{2005}$	0.061	0.194*	−0.065**	−0.013	0.045
	(0.062)	(0.104)	(0.028)	(0.087)	(0.074)
$D_{DSL} \times D_{2006}$	0.099	0.357***	−0.098***	0.006	0.056
	(0.064)	(0.107)	(0.032)	(0.089)	(0.077)
$D_{DSL} \times D_{2007}$	0.170**	0.291***	−0.022	0.024	0.157*
	(0.069)	(0.111)	(0.035)	(0.088)	(0.084)
$D_{DSL} \times D_{2008}$	0.152**	0.245**	−0.024	0.038	0.105
	(0.069)	(0.122)	(0.036)	(0.083)	(0.077)
$D_{DSL} \times D_{2009}$	0.131*	0.257**	−0.027	−0.053	0.115
	(0.072)	(0.117)	(0.038)	(0.088)	(0.075)
$D_{DSL} \times D_{2010}$	0.189***	0.331***	−0.028	0.032	0.163**
	(0.072)	(0.116)	(0.039)	(0.099)	(0.078)
$D_{DSL} \times D_{2011}$	0.210***	0.345***	−0.061*	0.068	0.186**
	(0.073)	(0.115)	(0.035)	(0.111)	(0.090)
R-squared	0.973	0.940	0.713	0.916	0.830
Obs.	4,182	3,378	3,468	3,619	3,608

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\,\mathsf{DSL\ access}_i\, D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 0.5 and 2 km from the MDF and zero for firms located between 2.8 and 4.2 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01. Information on revenues, value added, share of inputs, and total employment retrieved from survey data. The number of full-time employees (FTE) is calculated based on social-security data. The sample only contains firms founded 1992 or later.

Table B.22: Founded 1992 or before: firm size

	log(employment)		log(wage sum)	
	full-time	total	daily	survey
$D_{DSL} \times D_{2001}$	0.008	0.098*	0.033	0.108
	(0.060)	(0.059)	(0.060)	(0.082)
$D_{DSL} \times D_{2002}$	0.053	0.098*	0.058	0.112
	(0.065)	(0.059)	(0.063)	(0.080)
$D_{DSL} \times D_{2003}$	0.069	0.117*	0.083	0.140*
	(0.063)	(0.062)	(0.061)	(0.084)
$D_{DSL} \times D_{2004}$	0.050	0.093	0.080	0.169*
	(0.069)	(0.065)	(0.069)	(0.088)
$D_{DSL} \times D_{2005}$	0.042	0.130*	0.095	0.157*
	(0.067)	(0.067)	(0.068)	(0.091)
$D_{DSL} \times D_{2006}$	0.032	0.122*	0.047	0.100
	(0.067)	(0.067)	(0.066)	(0.093)
$D_{DSL} \times D_{2007}$	0.055	0.110*	0.087	0.105
	(0.065)	(0.066)	(0.066)	(0.097)
$D_{DSL} \times D_{2008}$	0.097	0.140**	0.105	0.187*
	(0.071)	(0.069)	(0.070)	(0.099)
$D_{DSL} \times D_{2009}$	0.064	0.150**	0.087	0.199**
	(0.071)	(0.071)	(0.067)	(0.098)
$D_{DSL} \times D_{2010}$	0.095	0.129*	0.099	0.159*
	(0.074)	(0.069)	(0.075)	(0.091)
$D_{DSL} \times D_{2011}$	0.198**	0.176**	0.230**	0.137
	(0.098)	(0.075)	(0.100)	(0.094)
R-squared	0.962	0.984	0.969	0.978
Obs.	4,062	4,062	4,062	3,932

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\, \mathsf{DSL\ access}_i\, D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 0.5 and 2 km from the MDF and zero for firms located between 2.8 and 4.2 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01. Information on total employment and monthly wage sum (last column) retrieved from survey data. The sample only contains firms founded 1992 or earlier.

Table B.23: Founded 1992 or before: performance

	log revenues	log(VA)	Shr. of Inputs	log(rev. p. FTE)	log(rev. p. empl.)
$D_{DSL} \times D_{2001}$	0.010	0.154	−0.004	0.010	−0.036
	(0.067)	(0.108)	(0.032)	(0.070)	(0.058)
$D_{DSL} \times D_{2002}$	0.056	0.103	0.014	0.003	−0.028
	(0.061)	(0.102)	(0.028)	(0.081)	(0.065)
$D_{DSL} \times D_{2003}$	0.150**	0.250**	0.004	0.095	0.069
	(0.060)	(0.125)	(0.035)	(0.083)	(0.062)
$D_{DSL} \times D_{2004}$	0.196***	0.297**	−0.006	0.111	0.071
	(0.068)	(0.121)	(0.034)	(0.083)	(0.066)
$D_{DSL} \times D_{2005}$	0.160**	0.236**	−0.023	0.107	0.082
	(0.070)	(0.116)	(0.031)	(0.092)	(0.077)
$D_{DSL} \times D_{2006}$	0.154**	0.333***	−0.047	0.136	0.052
	(0.072)	(0.121)	(0.037)	(0.092)	(0.077)
$D_{DSL} \times D_{2007}$	0.203***	0.378***	−0.020	0.111	0.085
	(0.078)	(0.130)	(0.043)	(0.089)	(0.081)
$D_{DSL} \times D_{2008}$	0.152**	0.207	0.026	0.040	0.034
	(0.070)	(0.140)	(0.044)	(0.087)	(0.073)
$D_{DSL} \times D_{2009}$	0.211***	0.304**	0.010	0.156+	0.142*
	(0.070)	(0.130)	(0.044)	(0.087)	(0.072)
$D_{DSL} \times D_{2010}$	0.173**	0.240*	0.003	0.046	0.042
	(0.070)	(0.131)	(0.047)	(0.084)	(0.068)
$D_{DSL} \times D_{2011}$	0.167**	0.281**	−0.015	−0.018	0.082
	(0.072)	(0.117)	(0.034)	(0.111)	(0.078)
R-squared	0.975	0.948	0.699	0.939	0.848
Observations	4,062	3,272	3,354	3,554	3,546

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\,\mathsf{DSL\ access}_i\, D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 0.5 and 2 km from the MDF and zero for firms located between 2.8 and 4.2 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses. Constant and year dummies included but now shown. Information on revenues, value added, share of inputs, and total employment retrieved from survey data. The number of full-time employees (FTE) is calculated based on social-security data. The sample only contains firms founded 1992 or before.

Table B.24: West Germany: firm size

	log(employment)		log(wage sum)	
	full-time	total	daily	survey
$D_{DSL} \times D_{2001}$	0.040	0.196	0.071	0.248
	(0.069)	(0.129)	(0.074)	(0.157)
$D_{DSL} \times D_{2002}$	0.046	0.191	0.030	0.288*
	(0.080)	(0.134)	(0.091)	(0.174)
$D_{DSL} \times D_{2003}$	0.127	0.209	0.141	0.292*
	(0.086)	(0.140)	(0.095)	(0.176)
$D_{DSL} \times D_{2004}$	0.105	0.288*	0.132	0.463**
	(0.084)	(0.147)	(0.099)	(0.189)
$D_{DSL} \times D_{2005}$	0.117	0.263*	0.132	0.324**
	(0.087)	(0.148)	(0.093)	(0.164)
$D_{DSL} \times D_{2006}$	0.157*	0.276*	0.079	0.236
	(0.090)	(0.152)	(0.100)	(0.182)
$D_{DSL} \times D_{2007}$	0.098	0.204	0.073	0.215
	(0.100)	(0.154)	(0.114)	(0.193)
$D_{DSL} \times D_{2008}$	0.064	0.145	0.038	0.219
	(0.105)	(0.155)	(0.115)	(0.193)
$D_{DSL} \times D_{2009}$	0.025	0.139	0.066	0.254
	(0.104)	(0.156)	(0.104)	(0.206)
$D_{DSL} \times D_{2010}$	−0.076	0.105	−0.085	0.149
	(0.101)	(0.142)	(0.121)	(0.173)
$D_{DSL} \times D_{2011}$	−0.068	0.140	−0.052	0.110
	(0.138)	(0.144)	(0.133)	(0.169)
R-squared	0.965	0.984	0.969	0.975
Obs.	2,600	2,600	2,600	2,495

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\,\textsf{DSL access}_i\, D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\textsf{DSL access}_i$ is an indicator variable equal to one if the firm is located between 0.5 and 2 km from the MDF and zero for firms located between 2.8 and 4.2 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Information on total employment and monthly wage sum (last column) retrieved from survey data. The sample only contains firms in West Germany.

Table B.25: West Germany: performance

	log revenues	log(VA)	Shr. of Inputs	log(rev. p. FTE)	log(rev. p. empl.)
$D_{DSL} \times D_{2001}$	0.001	0.008	0.096**	0.081	−0.149
	(0.119)	(0.174)	(0.041)	(0.139)	(0.110)
$D_{DSL} \times D_{2002}$	0.068	0.067	0.019	0.019	−0.149
	(0.120)	(0.192)	(0.041)	(0.158)	(0.118)
$D_{DSL} \times D_{2003}$	0.227*	0.343	0.004	0.108	−0.023
	(0.122)	(0.233)	(0.042)	(0.167)	(0.113)
$D_{DSL} \times D_{2004}$	0.272**	0.421*	0.003	0.207	0.009
	(0.135)	(0.216)	(0.041)	(0.156)	(0.114)
$D_{DSL} \times D_{2005}$	0.343**	0.360*	−0.005	0.257	0.043
	(0.143)	(0.212)	(0.040)	(0.187)	(0.152)
$D_{DSL} \times D_{2006}$	0.328**	0.332	0.000	0.212	0.072
	(0.143)	(0.204)	(0.039)	(0.187)	(0.144)
$D_{DSL} \times D_{2007}$	0.305**	0.561**	−0.074*	0.208	−0.103
	(0.139)	(0.222)	(0.043)	(0.172)	(0.116)
$D_{DSL} \times D_{2008}$	0.251**	0.284	0.014	0.196	−0.010
	(0.127)	(0.208)	(0.039)	(0.181)	(0.151)
$D_{DSL} \times D_{2009}$	0.289**	0.280	0.008	0.342**	0.224*
	(0.127)	(0.190)	(0.038)	(0.171)	(0.133)
$D_{DSL} \times D_{2010}$	0.214*	0.263	−0.009	0.261*	0.080
	(0.127)	(0.197)	(0.040)	(0.154)	(0.122)
$D_{DSL} \times D_{2011}$	0.178	0.288	−0.030	0.248	0.114
	(0.129)	(0.195)	(0.039)	(0.180)	(0.127)
R-squared	0.968	0.940	0.679	0.928	0.781
Obs.	2,600	2,056	2,123	2,274	2,267

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\,\mathsf{DSL\ access}_i\, D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 0.5 and 2 km from the MDF and zero for firms located between 2.8 and 4.2 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Information on revenues, value added, share of inputs, and total employment retrieved from survey data. The number of full-time employees (FTE) is calculated based on social-security data. The sample only contains firms in West Germany.

Table B.26: Excluding municipalities without broadband internet access: firm size

	log(employment)		log(wage sum)	
	full-time	total	daily	survey
$D_{DSL} \times D_{2001}$	−0.009	0.082	0.026	0.090
	(0.056)	(0.051)	(0.057)	(0.068)
$D_{DSL} \times D_{2002}$	0.048	0.076	0.054	0.080
	(0.060)	(0.051)	(0.059)	(0.068)
$D_{DSL} \times D_{2003}$	0.013	0.077	0.047	0.098
	(0.063)	(0.054)	(0.062)	(0.072)
$D_{DSL} \times D_{2004}$	0.051	0.112*	0.100	0.208***
	(0.066)	(0.061)	(0.066)	(0.077)
$D_{DSL} \times D_{2005}$	0.052	0.124**	0.119*	0.189**
	(0.064)	(0.060)	(0.066)	(0.077)
$D_{DSL} \times D_{2006}$	0.078	0.100*	0.107*	0.099
	(0.062)	(0.058)	(0.064)	(0.073)
$D_{DSL} \times D_{2007}$	0.064	0.077	0.089	0.137*
	(0.062)	(0.057)	(0.063)	(0.078)
$D_{DSL} \times D_{2008}$	0.052	0.101*	0.068	0.171**
	(0.069)	(0.060)	(0.069)	(0.082)
$D_{DSL} \times D_{2009}$	0.058	0.086	0.105	0.188**
	(0.066)	(0.062)	(0.067)	(0.086)
$D_{DSL} \times D_{2010}$	0.061	0.076	0.065	0.094
	(0.071)	(0.060)	(0.074)	(0.079)
$D_{DSL} \times D_{2011}$	0.074	0.114*	0.113	0.095
	(0.091)	(0.068)	(0.091)	(0.078)
R-squared	0.951	0.978	0.960	0.971
Obs.	5,956	5,956	5,956	5,760

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\ \mathsf{DSL\ access}_i\ D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 0.5 and 2 km from the MDF and zero for firms located between 2.8 and 4.2 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * p $<$ 0.10, ** p $<$ 0.05, *** p $<$ 0.01. Information on total employment and monthly wage sum (last column) retrieved from survey data. Firms in municipalities where no household has DSL access in 2005 or later years are excluded. Information on the share of household with DSL access retrieved from BMWi (2009).

Table B.27: Excluding municipalities without broadband internet access: performance

	log revenues	log(VA)	Shr. of Inputs	log(rev. p. FTE)	log(rev. p. empl.)
$D_{DSL} \times D_{2001}$	0.007	0.109	0.001	0.008	−0.043
	(0.057)	(0.091)	(0.026)	(0.069)	(0.058)
$D_{DSL} \times D_{2002}$	0.029	0.111	−0.011	−0.016	−0.049
	(0.054)	(0.091)	(0.024)	(0.076)	(0.064)
$D_{DSL} \times D_{2003}$	0.123**	0.190*	−0.004	0.120	0.058
	(0.055)	(0.104)	(0.026)	(0.082)	(0.063)
$D_{DSL} \times D_{2004}$	0.158***	0.288***	−0.026	0.107	0.076
	(0.060)	(0.099)	(0.027)	(0.077)	(0.063)
$D_{DSL} \times D_{2005}$	0.122*	0.201**	−0.035	0.054	0.031
	(0.062)	(0.100)	(0.026)	(0.083)	(0.070)
$D_{DSL} \times D_{2006}$	0.125**	0.262**	−0.041	0.051	0.037
	(0.063)	(0.102)	(0.031)	(0.084)	(0.071)
$D_{DSL} \times D_{2007}$	0.166**	0.253**	−0.005	0.072	0.051
	(0.066)	(0.108)	(0.033)	(0.081)	(0.072)
$D_{DSL} \times D_{2008}$	0.127**	0.108	0.019	0.077	0.031
	(0.063)	(0.104)	(0.030)	(0.079)	(0.071)
$D_{DSL} \times D_{2009}$	0.155**	0.208**	−0.002	0.078	0.116*
	(0.065)	(0.105)	(0.034)	(0.083)	(0.070)
$D_{DSL} \times D_{2010}$	0.156**	0.229**	−0.004	0.075	0.096
	(0.065)	(0.105)	(0.033)	(0.083)	(0.067)
$D_{DSL} \times D_{2011}$	0.159**	0.257**	−0.035	0.079	0.122*
	(0.067)	(0.103)	(0.030)	(0.093)	(0.074)
R-squared	0.973	0.944	0.703	0.924	0.823
Obs.	5,956	4,799	4,925	5,194	5,178

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\, \mathsf{DSL\ access}_i\, D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 0.5 and 2 km from the MDF and zero for firms located between 2.8 and 4.2 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Information on revenues, value added, share of inputs, and total employment retrieved from survey data. The number of full-time employees (FTE) is calculated based on social-security data. Firms in municipalities where no household has DSL access in 2005 or later years are excluded. Information on the share of household with DSL access retrieved from BMWi (2009).

Table B.28: Excluding counties with VDSL till 2008: firm size

	log(employment)		log(wage sum)	
	full-time	total	daily	survey
$D_{DSL} \times D_{2001}$	−0.063	0.073	−0.035	0.056
	(0.050)	(0.051)	(0.044)	(0.079)
$D_{DSL} \times D_{2002}$	0.055	0.083	0.055	0.052
	(0.075)	(0.060)	(0.071)	(0.087)
$D_{DSL} \times D_{2003}$	0.009	0.076	0.050	0.085
	(0.079)	(0.068)	(0.072)	(0.088)
$D_{DSL} \times D_{2004}$	0.051	0.128	0.110	0.236**
	(0.087)	(0.078)	(0.087)	(0.106)
$D_{DSL} \times D_{2005}$	0.086	0.157*	0.157*	0.222**
	(0.089)	(0.080)	(0.094)	(0.103)
$D_{DSL} \times D_{2006}$	0.074	0.144*	0.128	0.170*
	(0.090)	(0.084)	(0.091)	(0.103)
$D_{DSL} \times D_{2007}$	0.112	0.149*	0.154*	0.178*
	(0.089)	(0.083)	(0.089)	(0.098)
$D_{DSL} \times D_{2008}$	0.096	0.159*	0.130	0.228**
	(0.092)	(0.087)	(0.091)	(0.110)
$D_{DSL} \times D_{2009}$	0.062	0.133	0.105	0.200*
	(0.095)	(0.091)	(0.099)	(0.120)
$D_{DSL} \times D_{2010}$	0.060	0.135	0.061	0.125
	(0.101)	(0.092)	(0.105)	(0.117)
$D_{DSL} \times D_{2011}$	0.019	0.158	0.054	0.109
	(0.124)	(0.102)	(0.128)	(0.114)
Constant	1.839***	2.917***	6.018***	10.049***
	(0.026)	(0.021)	(0.026)	(0.027)
R-squared	0.943	0.972	0.952	0.965
Obs.	4,349	4,349	4,349	4,177

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\,\mathsf{DSL\ access}_i\, D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 0.5 and 2 km from the MDF and zero for firms located between 2.8 and 4.2 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Information on total employment and monthly wage sum (last column) retrieved from survey data. The sample contains non-manufacturing firms in counties in which VDSL was not introduced till 2008.

Table B.29: Excluding counties with VDSL till 2008: performance

	log revenues	log VA	Shr. of Inputs	log(rev. p. FTE)	log(rev. p. empl.)
$D_{DSL} \times D_{2001}$	0.003	0.107	−0.001	0.039	−0.026
	(0.037)	(0.087)	(0.022)	(0.071)	(0.061)
$D_{DSL} \times D_{2002}$	0.049	0.171*	−0.012	−0.007	−0.010
	(0.063)	(0.101)	(0.027)	(0.097)	(0.069)
$D_{DSL} \times D_{2003}$	0.123*	0.177	0.002	0.094	0.024
	(0.074)	(0.126)	(0.026)	(0.095)	(0.074)
$D_{DSL} \times D_{2004}$	0.171**	0.241**	−0.007	0.084	0.047
	(0.081)	(0.123)	(0.026)	(0.104)	(0.077)
$D_{DSL} \times D_{2005}$	0.169*	0.222*	−0.022	0.053	0.053
	(0.093)	(0.128)	(0.028)	(0.122)	(0.095)
$D_{DSL} \times D_{2006}$	0.175*	0.306**	−0.046	0.077	0.031
	(0.099)	(0.137)	(0.028)	(0.125)	(0.099)
$D_{DSL} \times D_{2007}$	0.194*	0.299*	−0.024	−0.002	−0.028
	(0.104)	(0.156)	(0.044)	(0.113)	(0.086)
$D_{DSL} \times D_{2008}$	0.115	0.161	0.009	−0.017	−0.068
	(0.096)	(0.153)	(0.042)	(0.099)	(0.088)
$D_{DSL} \times D_{2009}$	0.112	0.208	0.002	0.018	0.021
	(0.095)	(0.157)	(0.045)	(0.111)	(0.084)
$D_{DSL} \times D_{2010}$	0.151	0.261*	−0.016	0.084	0.060
	(0.102)	(0.150)	(0.046)	(0.114)	(0.090)
$D_{DSL} \times D_{2011}$	0.162	0.235	−0.033	0.136	0.074
	(0.101)	(0.146)	(0.040)	(0.131)	(0.101)
Constant	13.805***	13.158***	0.410***	11.903***	11.141***
	(0.023)	(0.038)	(0.009)	(0.029)	(0.024)
R-squared	0.969	0.936	0.703	0.905	0.814
Obs.	4,349	3,526	3,631	3,789	3,776

This table shows the results from the fixed-effects difference-in-differences estimation with 2000 to 2002 as pre-treatment period, small speed upgrades in 2003 to 2005 and a major upgrade to ADSL2+ in 2006. The estimation equation is: $y_{i,t} = \beta_0 + \beta_{1,t}\,\mathsf{DSL\ access}_i\, D_{year,t} + \alpha_i + \alpha_t + u_{it}$, where $D_{year,t}$ is an indicator variable for each year. $\mathsf{DSL\ access}_i$ is an indicator variable equal to one if the firm is located between 0.5 and 2 km from the MDF and zero for firms located between 2.8 and 4.2 km from the MDF. The table reports the results for $\beta_{1,t}$. To adjust for different numbers of firms in the treatment and control groups by three-digit sector, I use the weights suggested by Iacus et al. (2009). Number of observations reported for each regression. Standard errors clustered at the firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Information on revenues, value added, share of inputs, and total employment retrieved from survey data. The number of full-time employees (FTE) is calculated based on social-security data. The sample contains non-manufacturing firms in counties in which VDSL was not introduced till 2008.