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Broadband Diffusion and Firm Performance in Rural Areas: Quasi-Experimental Evidence☆

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Abstract

This article analyzes the causal impact of advanced broadband accessibility on firm performance. We exploit a unique local policy intervention of a staged broadband infrastructure installation across rural municipalities in the Province of Trento (Italy), generating a source of exogenous (spatial and temporal) variation in the provision of next-generation broadband technology (ADSL2+). Employing a difference-in-differences strategy and using longitudinal firm-level data on annual balance sheet information of corporate enterprises, we show that ADSL2+ availability is associated with a significant increase in annual sales turnover of about 40 percent and an increase in value added of roughly 25 percent over the period of two years. The positive effect is found to be rather stable for different lengths of treatment exposure and across industrial sectors. However, no significant effects are found with respect to number of employees. Placebo estimations support a causal interpretation of our results. Overall, established corporate enterprises in 'underserved' rural and remote areas appear to profit considerably from enhanced broadband delivery programs in terms of economic performance.

Keywords: Broadband internet, firm performance, quasi experiment, regional development

JEL Codes: O33, J24, L24, L26

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1. Introduction

Spatial cohesion is a paramount objective in many advanced countries. The European Union Cohesion Policy accounts for roughly one third of the EU's total budget for the programming periods 2007–2013 and 2014–2020 (European Union, 2013; European Commission, 2014b). Yet, notwithstanding the political emphasis and substantial spending on fostering local growth especially in disadvantaged regions, there is no consensus on its impact. In fact, empirical studies have provided mixed results concerning the economic impact of spatially targeted policies in Europe and the U.S. (see, e.g. the literature reviewed in Becker et al., 2010; Mohl and Hagen, 2010; Accetturo and de Blasio, 2012).

With the emergence of the EU 2020 Strategy, recent developments in EU Regional Policy have focused on "smart growth", i.e. growth based on the knowledge economy (European Commission, 2010a,b). The provision of fixed broadband infrastructure and in particular the reduction of the so-called "digital divide" between rural and urban areas play a crucial role in this regard. Despite the increased policy attention to broadband diffusion in rural areas, not much is known about its economic impact. Does broadband access improve the local economy in sparsely populated and economically disadvantaged areas?

The purpose of this paper is to contribute to the literature concerned with the impact evaluation of broadband delivery programs explicitly targeted on 'underserved' rural and sparsely populated areas. We present a rigorous econometric analysis of the causal impact of broadband availability on firm performance by exploiting a unique local broadband delivery program in Italy that creates the conditions for a quasi-experiment. More precisely, we analyze a local policy where the public authority in the autonomous Province of Trento (Italy) provided a subsidy to the telecom provider to finance the installation of broadband access points in (predominantly remote and rural) areas which were not privately supplied. Importantly, this specific policy aimed at the provision of high-speed broadband technology, i.e. connections delivering download speeds of up to 20 Mbps via ADSL 2+ technology. The staged installation of broadband infrastructures between 2011 and 2014 generated a source of exogenous (spatial and temporal) variation in advanced broadband internet provision, which enables us to provide causal estimates of broadband availability effects on firm performance. Employing a difference-in-differences approach (controlling for year and municipality fixed effects) enables us to difference away pre-existing location-specific conditions and thereby to identify the independent effect of advanced broadband access on local firm performance. Using longitudinal data on corporate enterprises' annual balance sheets, we find significant positive effects of ADSL 2+ availability on firms' annual sales turnover and value added, while there appears to be no significant impact on the number of employees employed in these firms.

Recent economic literature concerned with the overall causal impact of broadband penetration suggests generally beneficial effects in terms of GDP growth at the macro-level (Czernich et al., 2011) and an increase in the relative labor productivity of skilled versus unskilled workers at the micro-level (Akerman et al., 2015).[1] Yet, sound empirical evidence of a causal link between broadband diffusion and local economic growth in specifically rural or disadvantaged areas is extremely scant. To our knowledge, only one broadband delivery program explicitly targeting rural areas has been evaluated to date (the US Rural Broadband Loan Program), providing mixed results with positive effects on local employment, wages and firm entry being mainly driven by counties located close to metropolitan areas (Kandilov and Renkow, 2010; Kim and Orazem, 2012). More positive results emerge from studies which do not exploit specific policy interventions. Based on propensity score matching strategies, Whitacre et al. (2014) find that high levels of broadband adoption in US rural areas led to increased income growth and unemployment reduction. Kolko (2012) instruments broadband expansion in the US with terrain steepness and finds relatively stronger positive employment effects in sparsely populated areas compared with urban ones. As regards European evidence, Fabritz (2013) conducts a panel data analysis of broadband diffusion in Germany and finds overall moderate positive employment effects which are stronger in remote areas.

Our analysis extends the previous literature in several ways. To our knowledge, this is the first study to conduct an impact analysis with respect to *next-generation* broadband technologies. Note that previous causal evidence concerns the impact of the very first generation of asymmetric digital subscriber line (ADSL) technology: that is, the introduction of internet connections with download speeds exceeding 256 Kbps. In recent years, however, much faster broadband speeds of up to 20 Mbps have become standard in OECD countries, with fast and ultra-fast connections (delivering speeds of up to 30 and 100 Mbps respectively) becoming more and more popular (Digital Agenda Scoreboard, 2014). With a view to the constant improvement of infrastructure standards, policy makers are increasingly concerned with the urban-rural digital divide and the related risk that rural areas may permanently lag behind in terms of the availability and adoption of advanced broadband technology.[2]

Second, we exploit a rare local broadband delivery policy as a quasi-experiment to estimate causal effects. Generally, estimating causal effects in the context of broadband provision has

[1] Only very few studies evaluate causal effects at the micro, i.e. firm level, providing mixed evidence (see, for instance, Haller and Lyons, 2014; Bertschek et al., 2013; Colombo et al., 2013; De Stefano et al., 2014).

[2] In fact, while considerable progress has been achieved in reducing the digital divide with respect to *basic* broadband coverage, the rural-urban gap remains substantial with respect to *next-generation* fast and ultra-fast broadband technologies, with 18.1 percent rural coverage compared to 62 percent among all EU households (European Commission, 2014a).

proved difficult due to endogeneity issues. In fact, firms' broadband adoption is likely to be correlated with unobservable determinants of firm productivity that are difficult to difference away in empirical strategies. The top-down approach of a broadband delivery program may help generate exogenous variation in broadband access, which enables the estimation of causal effects. However, explicit broadband delivery programs are rare. Broadband infrastructure installation is market-led in most countries, with policy mainly focusing on issues of regulation and competition rather than supply (see the discussion in What Works Centre for Local Economic Growth, 2015). Our approach is close to that of Akerman et al. (2015), who exploit the Norwegian National Broadband Programme, in which the state-owned telecom company Telenor rolled out broadband access points across the country over the period 2000–2008.

Third, we provide an extremely rare impact evaluation of a program explicitly targeting rural and sparsely populated municipalities. The only other program evaluations of which we are aware concern the USDA Rural Broadband Loan Program in the US. To our best knowledge, we are the first to evaluate a local rural broadband initiative in Europe.

Our results suggest that established corporate enterprises in rural areas benefit substantially from access to advanced broadband technology, at least in the short- to medium-run (two years after program start). The positive effect is found with respect to annual sales turnover and value added, and it appears to be rather stable across industrial sectors. However, no significant effects are found with respect to the number of employees employed in corporate enterprises. We perform detailed robustness checks which confirm the plausibility of the common trend assumption underlying our identification strategy. Overall, our findings are consistent with the view that the impact of advanced broadband provision on local economic growth in rural and remote areas is positive and substantial.

The paper is structured as follows. Section 2 provides a detailed description of the public program, as well as tests and discussion of the key identifying assumption. Section 3 presents the empirical strategy and the data used. Section 4 sets out the results, and Section 5 concludes.

2. Institutional Background

2.1. The Policy

Decreasing the so-called 'digital divide' and the speedy diffusion of new internet technologies are among the key objectives of the EU 2020 initiative. The situation in Italy is rather diversified: while the south of the country remains well below the European average, several regions in the northern part are on a par with the most technologically developed European regions. Among these, the Province of Trento stands out with the highest percentage of broadband availability for households and firms (ISTAT, 2013). In fact, the digital divide with respect to the accessibility of *first-generation* broadband technologies (download speeds up to 2 Mbps) had already been overcome by 2010 via fixed (ADSL) or wireless infrastructure diffusion across the entire territory.

Yet, by 2010, *next-generation* ADSL 2+ broadband technology (up to 20 Mbps) had only been available in the 56 principal urban municipalities of the province (such as Trento, Rovereto or Riva del Garda). In the remaining 167 more rural and remote areas of the region, Telecom Italia – the major ICT provider in Italy – had no economic interest in investing to equip local access points with the advanced technology. In order to remedy this market failure and reach 100-percent coverage with next-generation broadband access via a service of up to 20 Mbps, the public authority decided in September 2010 (*Reg.delib.n. 2204* and *n. 2528*) to issue a public tender investing over 8.4 million euros. The tender was won by Telecom Italia, and it financed the equipment of 184 local access points serving the 167 municipalities not already provided with the ADSL 2+ technology for high speed broadband access.

It is evident from Table 1, displaying the main demographic, economic and geographic characteristics of municipalities addressed and not addressed by the policy (measured in the pre-program period), that the former are relatively less urbanized, less economically active, and geographically more remote. In what follows, our analysis focuses exclusively on firms located in the 167 municipalities addressed by the broadband diffusion policy. We therefore exclude the more urban municipalities in the Province of Trento, which, by 2010, had already been equipped with ADSL 2+ access points by private initiative. Consequently, we estimate effects of broadband diffusion on firm performance in relatively remote and rural areas.

Of particular importance in the context of this study is that the broadband expansion policy included no guidelines about roll-out timing or geographical diffusion, i.e., the local authority had neither territorial nor temporal ordering preferences with respect to the roll out. The main concern of the administration was to ensure the universal diffusion of the advanced broadband infrastructure, and to make sure that this was accomplished in a relatively short amount of time, preferably no later than December 2013 (in order for the Province to comply with the Europe 2020 objectives). Neither municipal authorities nor firms or residents in the municipalities addressed by the program could influence the roll-out timing or ordering. Moreover, Telecom Italia itself probably had no interest in an ordering that reflected the economic characteristics of municipalities since the strategically most important areas for profit purposes were already covered pre-policy, and due to the fact that all the municipalities addressed would in any case be covered within a relatively short period of time. The roll-out of broadband access points started in Spring 2011. Complete coverage was achieved by end-January 2014.

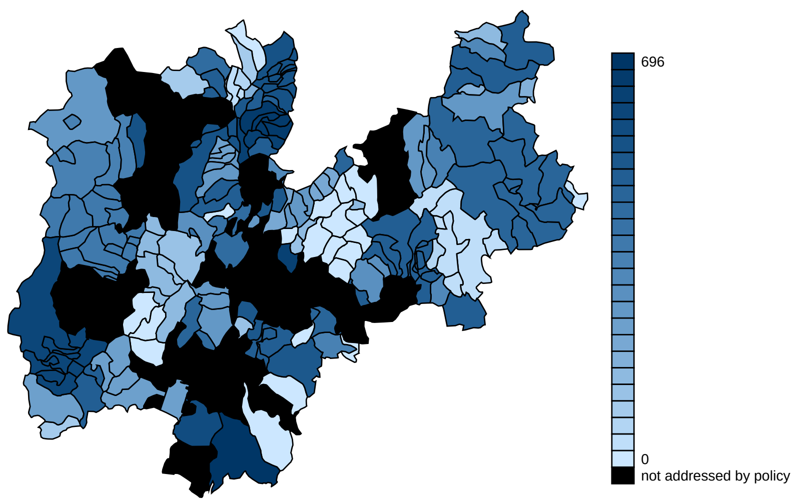
Table 1: Summary Statistics – ADSL2+ Broadband Policy and Pre-Policy Municipality Characteristics

	Municipalities not addressed by the policy		Municipalities adressed by the policy	
	mean (1)	sd (2)	mean (3)	sd (4)
Demography:				
Population density 2001	143.47	(159.69)	82.52	(231.76)
Population growth rate, 10 yrs	0.071	(0.060)	0.055	(0.078)
Population share high educated 2001	0.334	(0.049)	0.298	(0.048)
Population share aged 65 and over 2001	0.170	(0.019)	0.182	(0.037)
Employment rate 2001	0.636	(0.035)	0.630	(0.041)
Industry structure:				
Nr. firms 2001	416.84	(1225.40)	82.87	(83.99)
Empl. growth rate, 10 yrs	0.128	(0.256)	0.077	(0.359)
Empl. share in primary sector 2001	0.030	(0.054)	0.048	(0.115)
Empl. share in manufacturing 2001	0.240	(0.158)	0.212	(0.156)
Empl. share in construction 2001	0.232	(0.125)	0.244	(0.155)
Empl. share in wholesale 2001	0.175	(0.078)	0.163	(0.088)
Empl. share in services 2001	0.324	(0.150)	0.333	(0.178)
Geography:				
Municipality's altitude (m)	579.45	(307.35)	746.16	(288.98)
Distance to nearest motorway (min)	9.15	(9.59)	14.73	(11.30)
Previous ADSL technology:				
Pre-policy 7Mbps	-	-	0.665	(0.474)
Pre-policy Lite	-	-	0.186	(0.390)
ADSL2+ Broadband Access (as of 31/12/2012):				
Binary exposure	1.000	(0.000)	0.880	(0.326)
Nr. days of exposure	1,022.84	(505.69)	279.64	(184.49)
Nr. municipalities	56		167	

Source: ISTAT population & industry census 1991 & 2001, *Atlante Statistico Comuni*, Telecom Italia, own calculations.
Notes: Municipality-level data. For detailed variable description see Table A1 in Appendix.

According to Telecom Italia, the main factors determining the roll-out timing were the technical features of pre-existing internet technologies available in the municipalities addressed by the policy. As mentioned above, at the time of program start all municipalities were equipped with some sort of first-generation broadband technology, via either fixed (ADSL) or a wireless infrastructure. Technically, it was convenient for Telecom Italia to start the roll-out of next-generation broadband in those access points where a fixed ADSL infrastructure was already available. In fact, at the start of the program in spring 2011, about 85 percent of municipalities addressed by the policy had access to an ADSL infrastructure of either up to 7 Mbps (66.5 percent) or up to 1.2 Mbps (so-called ADSL-Lite) connectivity (18.6 percent) (see Table 1). Both types of infrastructures were, with respect to delivered speed, notably inferior to the ADSL 2+ technology (delivering up to 20 Mbps) installed via the public program.

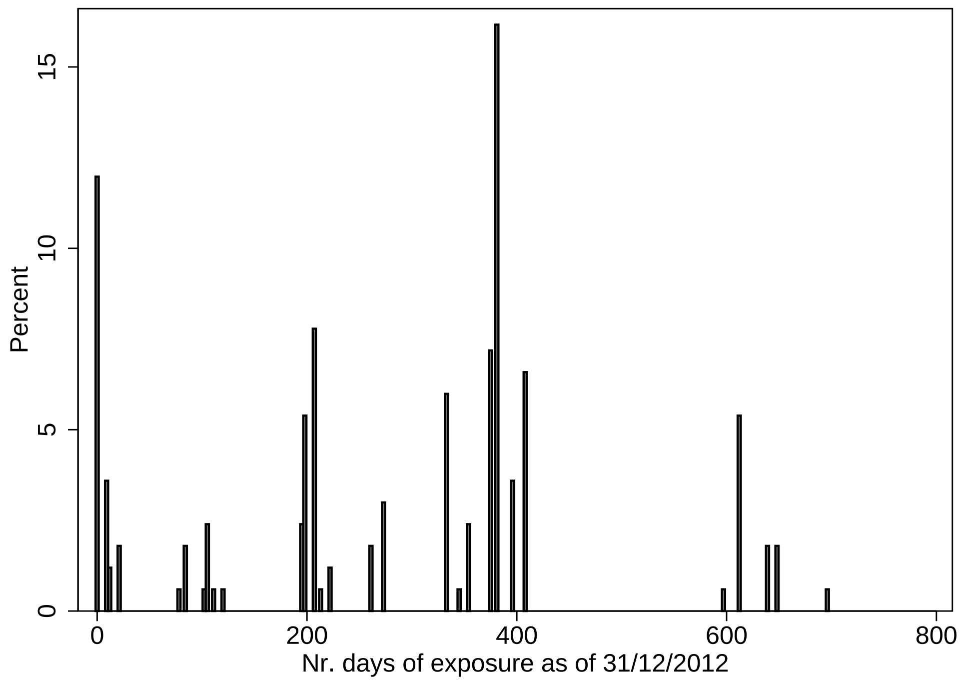
Figure 1: Nr. of Days of ADSL 2+ Broadband Exposure as of 31/12/2012 Across Municipalities in the Province of Trento



Source: Own calculations based on data from Telecom Italia.

As displayed at the bottom of Table 1, 88 percent of municipalities addressed by the policy had been ‘treated’ with an average of about 280 days of advanced broadband exposure by end-2012. Figure 1 depicts treatment status and treatment intensity across municipalities as of end-2012. In particular, treatment intensity is defined as the number of days that a municipality was exposed to ADSL 2+ broadband accessibility in the time period between program start (defined as the date of the first observed activation) and end-2012.[3] Black areas indicate municipalities that have not been subject to the broadband diffusion policy and hence are excluded from our analysis.

Figure 2: Histogram – Nr. of Days of ADSL2+ Broadband Exposure as of 31/12/2012



Source: Own calculations based on data from Telecom Italia.
Note: N =167 Municipalities

Figure 2 displays the sample distribution of treatment intensity among municipalities addressed by the policy. It evidences considerable variability in treatment intensity, with peaks of activation at around 0, 200, 400 and 600 days after the program's start.

[3]Note that each municipality can in principle be covered by more than one access point with potentially different ADSL 2+ activation dates. *De facto*, around 42 percent of the municipalities in our sample are covered by a single broadband access point. In another ca. 44 percent of the municipalities a single access point covers more than 80 percent of the municipal territory. In these cases, we assign each municipality the activation date of the access point which mainly covers the territory. In the remaining ca. 14 percent of municipalities we take a conservative approach by assigning each municipality the earliest activation date among those access points which cover at least 20 percent of the municipal territory. Note that this approach introduces, if at all, a downward bias in our estimates since we overstate the days of ADSL 2+ exposure for part of the territory.

2.2. Assessing the Exogeneity of Roll-out Timing

Although the ADSL 2+ broadband diffusion was not explicitly designed as a randomized experiment, the program features described above suggest that the roll-out timing was likely exogenous to key correlates of local firm performance: the program was implemented top-down without strategic input from the municipal authorities or Telecom Italia and with no provision for firms or residents to request earlier equipment of access points. In fact, it was clear that within a relatively short time-frame of little more than two years all municipalities addressed by the policy would be equipped with the ADSL 2+ technology. Hence, demand factors are unlikely to have played a *direct* role in roll-out timing. However, we know from Telecom Italia that a pre-existing ADSL infrastructure (which was present in the large majority of the municipalities) speeded up the physical installation of broadband access points for technical reasons. Although clearly pre-determined with respect to the ADSL 2+ policy, the pre-existing broadband infrastructure is unlikely to have been randomly allocated since – other than the policy analyzed here – the installation of previous ADSL technology was a private initiative and hence profit-oriented.

As a first step in assessing whether the data are overall consistent with exogenous roll-out timing, we examine the relationship between roll-out timing and municipalities' productive characteristics measured in the pre-policy period. In particular, we regress both a binary treatment indicator and a measure of treatment intensity on pre-policy municipality characteristics. Both variables reflect municipalities' roll-out status as of end-2012. Binary treatment indicates whether or not a municipality had been equipped with the ADSL 2+ technology by end-2012. Treatment intensity is defined as the number of days a municipality was exposed to ADSL 2+ access from program start until end-2012. The latter measure is divided by 30 throughout the analysis to ease interpretation.

The pre-policy municipality characteristics employed in this exercise include information on demography, industrial structure, geography and measures of the pre-policy presence of a previous ADSL technology. The latter indicate whether or not a municipality had access to a 7 Mbps or "Lite" (1.2 Mbps) ADSL technology by 2010. Demographic characteristics include resident population density, employment rate, share of high-educated residents and share of residents aged 65 and over. As measures of industrial structure we use the number of firms and sector-specific employment share. The geographical indicators are municipal altitude and distance to the nearest motorway. The municipality-level information on demography and industry structure are drawn from the Italian Population Census and the Italian Industry Census of 2001.[4] Besides the information from the 2001 censuses, we also include the 10-year growth rates in resident population and local employment over the pre roll-out period from 1991 to 2001.

Table 2 displays the estimated coefficients. None of the included demographic, economic or geographic pre-policy characteristics appear to be significantly correlated with the roll-out timing of the ADSL 2+ policy – neither when employing the binary treatment indicator (Column 1) nor when employing the continuous measure of treatment intensity (Column 2).[5] However, the indicators of pre-policy presence of a 7Mbps or "Lite" ADSL infrastructure appear to be positively and significantly related to earlier roll-out timing. Since the installation of pre-policy ADSL infrastructure was market-led and hence potentially non-random, we cannot exclude that roll-out timing was systematically associated with observed or unobserved local productive characteristics in ways that potentially confound a causal interpretation.

Taken together, the evidence suggests that the ADSL 2+ policy cannot exactly be treated like a randomized experiment, in which case a mean-comparison between firm outcomes in municipalities with differential roll-out timing would be sufficient to identify causal effects. Instead, any effort to measure the causal impact of advanced broadband availability must control for pre-existing location-specific fixed factors that influence the profitability of broadband provision. We consequently apply a difference-in-differences identification strategy which controls for municipality and year fixed effects. That is, we abstract from time-invariant differences across municipalities and instead exploit differences in within-municipality variation over time. This strategy allows roll-out timing to be associated with municipality characteristics that are stable over time, but it crucially relies on the assumption that ADSL 2+ roll-out timing was exogenous with respect to different underlying *trends* in economic performance across municipalities (the so-called "common-trend assumption"). In other words, we assume that – in the absence of the ADSL 2+ policy – there would have been no difference in average trends of firm-performance between municipalities with earlier or later roll-out timing. In the context of our policy of interest, this assumption seems rather plausible: whatever correlation existed between roll-out timing and relevant municipality characteristics (due to market-led installation of previous technology), it is plausible to assume that this correlation did not systematically change with the introduction of the ADSL 2+ technology.

[4]Both censuses are decennial. See summary statistics in Table 1; and for further details on data sources and variable definition see Table A1 in Appendix. We refrain from using the 2011 census to assess exogeneity since roughly 44 percent of the municipalities addressed by the policy had been equipped with ADSL 2+ by end-2011; hence 2011 cannot be treated as 'pre-policy'.

[5]Furthermore, the tests reported at the bottom of Table 2 suggest that the null-hypothesis of no joint significance of these covariates cannot be rejected.

Table 2: Was Roll-out Timing Exogenous?

	ADSL2+ exposure as of 31/12/2012	
	Binary	Nr. of Days/30
	(1)	(2)
Demography:		
Population density 2001 (log)	-0.025	-0.048
	(0.031)	(0.568)
Population growth rate, 10 yrs	0.326	-1.930
	(0.340)	(6.255)
Employment rate 2001	-0.374	7.859
	(0.600)	(11.046)
Pop. share high educated 2001	0.530	6.327
	(0.552)	(10.150)
Pop. share aged 65 and over 2001	0.399	-9.086
	(0.758)	(13.951)
Industry structure:		
Nr firms 2001 (log)	-0.023	-0.710
	(0.026)	(0.484)
Empl. growth rate, 10 yrs	-0.015	1.903
	(0.063)	(1.155)
Empl. share in manufacturing 2001	0.252	6.549
	(0.234)	(4.312)
Empl. share in construction 2001	-0.061	3.764
	(0.221)	(4.060)
Empl. share in wholesale 2001	0.174	2.714
	(0.315)	(5.786)
Empl. share in services 2001	-0.192	3.631
	(0.214)	(3.933)
Geography:		
Municipality's (log)	-0.008	-0.098
	(0.055)	(1.009)
Distance to nearest motorway (log)	-0.009	-0.075
	(0.022)	(0.408)
Previous ADSL technology:		
Pre-policy 7Mbps	0.496***	8.954***
	(0.070)	(1.282)
Pre-policy Lite	0.334***	2.957**
	(0.079)	(1.461)
N	167	167
F-test (joint sign. exc. pre-policy 7Mbps/Lite)	0.91	0.63
Prob $> F$	0.5419	0.8280

Source: ISTAT population & industry census 1991 & 2001, *Atlante Statistico Comuni Italiani*, Telecom Italia, own calculations.
Notes: Municipality-level data. Standard errors in parentheses. For detailed variable description see Table A1 in Appendix. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: Testing the Common Trend Assumption – Italian Census Data 1991 & 2001

	Log Population Density			Log Nr. Firms		
	(1)	(2)	(3)	(4)	(5)	(6)
Year=2001 × binary exposure	0.031			0.019		
	(0.029)			(0.062)		
Year=2001 × days of exposure/30		0.002	0.004		0.004	0.004
		(0.002)	(0.007)		(0.003)	(0.008)
Year=2001 × days of exposure/30 (sqrd)			-0.0001			0.0000
			(0.0003)			(0.0004)
Year=2001	-0.000	0.010	0.005	0.074	0.055*	0.056
	(0.019)	(0.015)	(0.020)	(0.060)	(0.032)	(0.041)
Municipality FE	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
N	334	334	334	334	334	334
Nr. Municipalities	167	167	167	167	167	167
F-test (joint sign. 2001×days of exp., 2001×days of exp. (sqrd))			0.51			1.05
Prob $> F$			0.6033			0.3517

Source: ISTAT population & industry census 1991 & 2001, Telecom Italia, own calculations.
Notes: Municipality-level data. Robust standard errors in parentheses. Incl. constant term. Placebo-exposure as of 31/12/2012 throughout. For detailed variable description see Table A1 in Appendix. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The common trend assumption is typically tested by examining pre-policy trends in the outcome of interest. If the common-trend assumption holds, we should observe no differential trend according to roll-out timing prior to the actual roll-out. Before turning to a more detailed test of the common-trend assumption with respect to our main outcome of interest in Section 4.2, we examine whether this assumption plausibly holds with respect to some key correlates of local economic performance. In particular, we again exploit information from the population and industrial censuses 1991 and 2001 and regress log population density as well as log number of firms on our binary (continuous) treatment variable interacted with census year, and – importantly – controlling for municipality and year fixed effects.

Table 3 reports the estimation results. Of importance as a test of the common trend assumption is the coefficient on the interaction of our respective binary and continuous measures of roll-out timing and the dummy variable for the year 2001. This coefficient indicates whether ADSL 2+ roll-out was significantly related to different pre-policy trends (1991-2001) in urbanization and size of private sector. This does not seem to be the case, which supports the common trend assumption. We also perform this exercise with respect to industrial structure, obtaining similar results (see Table A2 in Appendix).

Overall, the results reported in Table 3 and A2 lend substantial support to the argument that the policy intervention generated geographical and temporal variation in ADSL 2+ availability which was exogenous to underlying trends in local economic performance – conditional on time-invariant municipality characteristics. A further, more detailed test of the exogeneity assumption is presented in Section 4.2, where we show the zero-effects of a placebo roll out on firm performance in the pre-policy period.

3. Empirical Setup

3.1. Empirical Strategy

Our empirical approach relies upon the unique policy intervention of a staged broadband infrastructure installation across municipalities in the Province of Trento, generating a source of exogenous spatial and temporal variation in advanced broadband accessibility. We use the exogenous roll-out timing of ADSL 2+ broadband technology as a quasi-randomized experiment to avoid biased estimates due to the correlation between broadband access and unobserved determinants of firm productivity.

As discussed in Section 2.2, we exploit panel data to follow an identification strategy which controls for municipality and year fixed effects. In a first specification, we apply a difference-in-differences approach employing a binary treatment indicator. That is, we compare annual firm performance between firms located in treated and not-yet treated municipalities in the second year after program start (2012), relating them to the same firms' pre-policy performance two years previously (2010).

In a second specification, we employ a continuous treatment measure indicating the number of days that a municipality had been provided with ADSL 2+ broadband access from the start of the policy intervention until end-2012. Thus, we compare growth in outcomes between 2010 and 2012 of firms experiencing diverse levels of treatment intensity, i.e. more or fewer days of exposure to advanced broadband access. The estimation equation is specified as

$$\ln y_{imt} = \beta_0 + \beta_1 Treat_{mt} + [\beta_2 Treat_{mt}^2] + \gamma_m + \lambda_t + \omega'_{imt} + \varepsilon_{imt}, \qquad (1)$$

where $\ln y_{imt}$ represents a measure of annual performance of firm i in municipality m in year t (with $t = [2010; 2012]$). $Treat_{mt}$ indicates the treatment status of firms located in municipality m by the end of year t. Depending on the specification, we define the treatment status either in a binary way indicating whether firms located in municipality m in year t had access to ADSL 2+ broadband, or as a continuous treatment, i.e. the number of days of exposure to broadband accessibility as of the end of year t. In the case of the continuous treatment intensity measure, we also add (a) a specification including a squared term $Treat^2_{mt}$ and (b) a specification employing treatment intensity categories in order to investigate potential nonlinearities in the impact of treatment intensity.

Unobservable factors of firm performance that are fixed at the municipality level are controlled for by municipality fixed effects (γ_m); common time shocks are absorbed by the year indicator (λ_t). Our preferred specification includes firm fixed effects instead of municipality fixed effects (which does not contribute to identification of our parameter of interest because the treatment is defined at municipality level, but it helps to increase the precision of the estimate). The vector ω includes a set of industrial sector indicators (2-digit). ε_{imt} is a time-varying idiosyncratic error term. Throughout the empirical analysis, standard errors are clustered at the municipality level and robust to heteroscedasticity.

The parameter β_1 (and β_2) estimates the causal effect of interest under the common trend assumption. This parameter is identified through variation in firms' performance levels between 2010 (pre-policy) and 2012, and the comparison of this difference either between the group of firms located in municipalities with and without broadband access by end-2012 (in the case of binary treatment) or firms located in municipalities with different treatment intensity (in case of the continuous treatment measure). Note that the causal effect is thus identified by variability across municipalities since our treatment (broadband accessibility) varies at municipality level. The key identifying assumption is that the trend in outcomes would be the same for firms located in relatively earlier and later treated municipalities in the absence of treatment. We conduct a placebo analysis for the pre-policy years 2008 – 2010 to test whether the common trend assumption is plausible in this context.

3.2. Data

Our analysis employs a unique dataset which combines data from two main sources. Importantly, Telecom Italia provided us with municipality-level data on the spatial diffusion and timing of broadband infrastructure installations in the Province of Trento. Second, we use the full version of the AIDA dataset (*Analisi Informatizzata Delle Aziende*), which is a commercial database on Italian firms maintained by Bureau van Dijk. The data covers the full universe of corporate enterprises and contains detailed balance sheet information on firms' annual output (such as revenues and value added) and inputs (such as capital, labor, etc.), as well as other information on location, industry sector or year of foundation. Corporate enterprises represent roughly 13.2 percent of firms (PAT Statistical Office, 2014) and cover approximately 41.9 percent of total employees in the Province of Trento according to the ISTAT Industrial Census 2011.

The main outcome of interest is firms' annual turnover, that is, total sales income. We opt to analyze variations in annual turnover since these best capture overall changes in firm performance. Additional analysis presented in Section 4.3 provides results with respect to firms' value added and number of employees.

This analysis concerns the "non-farm" business sector: that is, we exclude corporate enterprises in agriculture and public services.[6] For the period of analysis (2008 – 2012) we then restrict our sample to firms located in those municipalities in the Province of Trento that have been addressed by the ADSL 2+ policy (see the detailed list in *Reg.delib.n. 2528 All.1*). Among those firms, we further focus on those that filed annual balance sheets in 2012 and were founded before 2006 (that is, firms that had been in business for at least 5 years in 2010) in order to prevent our results being affected by relatively higher volatility among recent start-ups. To reduce the influence of outliers, we delete firm-year observations with unusually high or low values of annual turnover (outside the 1%–99% range). Table A3 in Appendix contains the summary statistics of our final estimation sample.[7]

4. Results and Discussion

4.1. Baseline Results

Table 4 presents first evidence of an impact of the ADSL 2+ policy on firm performance. We provide results for two samples: first, an unbalanced panel (Columns 1–3) and second, a balanced sample in which we only include firms observed in 2010 as well as in 2012 (Columns 4–10). The estimations presented in Columns 4–6 include municipality fixed effects, whereas Columns 7–10 show results from models employing firm fixed effects instead of municipality fixed effects.

Columns 1, 4 and 7 of Table 4 set out the results obtained from estimating Model (1) and employing a *binary* treatment indicator. This specification corresponds to a difference-in-differences approach: while the coefficient on *Year=2012* indicates the bi-annual turnover growth experienced by firms located in (by end-2012) not-yet treated municipalities, the coefficient on the exposure dummy indicates the difference in outcome growth between the not-yet treated and treated municipalities (difference-in-differences estimate – β_1 in Model (1)). Estimates for both unbalanced and balanced sample as well as estimates with municipality or firm fixed effects are statistically

[6]Finance and insurance is also excluded due to the low number of corporate enterprises present (no more than 7 in a given year).

[7]Throughout the paper, all monetary values are fixed at 2010 level after adjusting for inflation. We used a value added deflator which stems from elaborations on regional economical accounts data and is defined at the sectoral level (see Podestà (2010) for more details).

highly significant, positive and of considerable size. Overall, the estimated effect magnitude is very similar across balanced and unbalanced samples and for models with municipality and firm fixed effects: the estimate suggests that ADSL 2+ availability is on average related to a roughly 40 percent increase in annual turnover over the period of two years. Note that this is an average effect over firms residing in 'treated' municipalities with differential exposure (treatment intensity) to broadband availability in the period 2010–2012.

The results reported in Columns 2, 5 and 8 of Table 4 employ the continuous measure of treatment *intensity* instead of a binary treatment indicator. For the unbalanced sample, these linear estimates of treatment intensity effects suggest that an additional 30 days of exposure to ADSL 2+ broadband access increased firms' annual turnover on average by about 1.5 percent within two years (Column 2). For the balanced sample, the linear estimate of treatment intensity decreases in size and is not statistically significant. However, it is apparent from Columns 3, 6, 9 and 10 that the effect is not monotonically increasing with treatment intensity, but is instead nonlinear in some way.

Nonlinearities could potentially be explained by the timing of firms' adoption behavior within municipalities. The intensive margin of ADSL 2+ adoption may become very small close to the saturation point, resulting in a nonlinear relationship of some kind between broadband infrastructure and economic benefits. For example, if relatively more motivated firms adopt the advanced broadband technology earlier than others, and if more motivated entrepreneurs also adopt more successfully, we can imagine the following situation for two municipalities A and B: at end-2012, municipality A has been treated for one month, whereas municipality B has been treated for ten months. If the most motivated entrepreneurs start adopting first, and subsequently also the less and less motivated ones, then we should expect a relatively larger share of highly-motivated entrepreneurs among the adopters in municipality A than in municipality B. If at the same time more motivated entrepreneurs gain relatively more from advanced broadband adoption, this would result in a nonlinear pattern of the positive effect of ADSL 2+ exposure. However, due to the lack of data on firms' technology adoption and its timing, this potential explanation of effect nonlinearity cannot be investigated directly and must remain tentative.

To investigate the nonlinear shape of treatment intensity effects on annual turnover, we employ both a quadratic polynomial and a 'category' specification. The latter imposes fewer assumptions about the shape of effects and contains indicator variables for five treatment intensity groups based on days of ADSL 2+ exposure by end-2012. The categories are: 1) zero exposure (base group), 2) exposure up to 6 months, 3) more than 6 months and up to 12 months, 4) more than 12 months and up to 18 months, and 5) more than 18 months of exposure (for summary statistics see Table A3 in

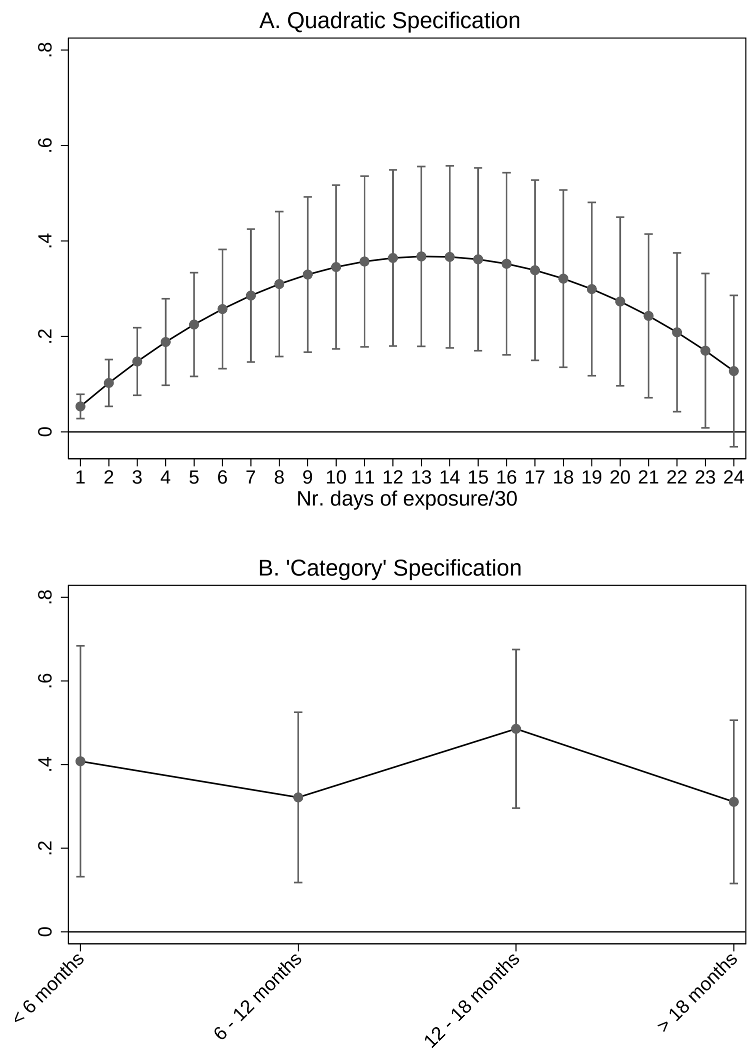
Table 4: Main Results – AIDA 2010 & 2012

Dependent variable: Annual turnover (log)										
	Unbalanced Panel			Balanced Panel						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Binary exposure	0.3991***			0.3959***			0.3959***			
	(0.0995)			(0.0981)			(0.0948)			
Nr. days of exposure/30		0.0145***	0.0375***		0.0104	0.0554***		0.0104	0.0554***	
		(0.0054)	(0.0139)		(0.0069)	(0.0140)		(0.0066)	(0.0135)	
Nr. days of exposure/30 (sqrd)			-0.0011*			-0.0021***			-0.0021***	
			(0.0006)			(0.0005)			(0.0005)	
Zero exposure (ref.)										
Exposure<=6 months										0.4079***
										(0.1409)
6 months< exp. <=12 months										0.3215***
										(0.1039)
12 months< exp. <=18 months										0.4855***
										(0.0968)
18 months< exp.										0.3109***
										(0.0996)
Year=2012	-0.4868***	-0.2764***	-0.3612***	-0.4306***	-0.1810**	-0.3455***	-0.4306***	-0.1810**	-0.3455***	-0.4306***
	(0.0928)	(0.0658)	(0.0729)	(0.0937)	(0.0833)	(0.0844)	(0.0905)	(0.0805)	(0.0815)	(0.0906)
Industry FE	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*no*	*no*	*no*	*no*
Municipality FE	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*no*	*no*	*no*	*no*
Firm FE	*no*	*no*	*no*	*no*	*no*	*no*	*yes*	*yes*	*yes*	*yes*
N	2,270	2,270	2,270	2,132	2,132	2,132	2,132	2,132	2,132	2,132
Nr. Firms	1,204	1,204	1,204	1,066	1,066	1,066	1,066	1,066	1,066	1,066

Source: AIDA 2010 & 2012, Telecom Italia, own calculations.
Notes: Robust standard errors in parentheses, adjusted for clustering at the municipality level. Incl. constant term. ADSL2+ exposure as of December 31 in the respective year. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Appendix). Columns 9 and 10 of Table 4 report the results of both specifications for the balanced sample and Figure 3 graphically illustrates the respective estimated treatment intensity effect.

Figure 3: The Shape of Treatment Intensity Effects on Annual Turnover



Source: AIDA 2010 & 2012, Telecom Italia, own calculations.
Note: Marginal effects of treatment intensity on annual turnover (log) based on Columns 9 and 10 of Table 4 with 95% confidence intervals.

First, it is apparent that effects are not short-term: they persist and are positive over the full range of exposure intensity. Moreover, the results from the category specification show that the positive effect is rather stable at around 40 percent for the different levels of exposure intensity. Hence, imposing a quadratic shape that suggests diminishing effects with increasing exposure might not be an entirely appropriate way to describe the actual shape of treatment intensity effects correctly.

Our preferred estimates set out in Table 4 are based on firm fixed effects models (Columns 7–10). With respect to models employing municipality fixed effects (see Columns 4–6), there appears to be no considerable change in the point estimates of the treatment effects (which is to be expected since treatment is defined at the municipality- and not the firm-level), yet with a slight increase in precision.

Overall the results presented in Table 4 suggest substantial and significant revenue-enhancing effects of advanced broadband accessibility. First, having or not having access in the two years from policy-start results in significant outcome differences amounting to 40 percent on average. Second, the treatment effect appears to be rather constant across different broadband exposure intensities.

At this point, it is important to bear in mind that we estimate the impact of ADSL 2+ availability exclusively for corporate enterprises and for firms located in the relatively rural and remote municipalities. Our results consequently provide some support for recent empirical evidence suggesting that rural areas may benefit from the provision of new broadband technologies (see e.g. Kolko, 2012; Fabritz, 2013; Whitacre et al., 2014); yet we cannot evaluate whether they benefit more or less strongly than urban areas do.

4.2. Placebo Test – Assessing the Common Trend Assumption

Table 5 reports the results of a placebo analysis testing the common trend assumption underlying our empirical identification strategy. The idea is to analyze turnover growth for the pre-policy years 2008 and 2010 by assigning treatment measures, both binary and continuous, as if the policy took place between 2008 and 2010 (as opposed to 2010 and 2012). We then adopt the same empirical strategy as in the main analysis described above, regressing annual log turnover on the fake measures of placebo treatment. This strategy provides a powerful test of the important identifying assumption that the effects discussed above are in fact caused by the policy intervention (providing broadband availability) and not by any other underlying difference between municipalities treated relatively later or earlier. If such underlying differences not related to the policy itself exist, we should find them also in the absence of the treatment. The placebo analysis performed in the pre-policy period is one way to test this assumption directly.

The results shown in Table 5 indeed suggest that we can rely on our identifying assumption of common trends in the outcome variable. Firms in municipalities ‘fake-treated’ earlier are not significantly different (in terms of turnover growth) from firms located in late-treated municipalities

Table 5: Placebo – Pre-reform Outcomes (AIDA 2008 & 2010)

Dependent variable: Annual turnover (log)										
	Unbalanced Panel			Balanced Panel						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Placebo–Binary exposure	0.0060			0.0371			0.0371			
	(0.1201)			(0.1027)			(0.0991)			
Placebo–Nr. days of exposure/30		0.0025	0.0044		0.0025	0.0079		0.0025	0.0079	
		(0.0055)	(0.0160)		(0.0046)	(0.0128)		(0.0044)	(0.0123)	
Placebo–Nr. days of exposure/30 (sqrd)			-0.0001			-0.0003			-0.0003	
			(0.0007)			(0.0006)			(0.0005)	
Zero exposure (ref.)										
Exposure<=6 months										0.0528
										(0.1174)
6 months< exp. <=12 months										-0.0124
										(0.1058)
12 months< exp. <=18 months										0.0774
										(0.1017)
18 months< exp.										0.0300
										(0.1184)
Year=2012	-0.0152	-0.0353	-0.0423	-0.0602	-0.0525	-0.0724	-0.0602	-0.0525	-0.0724	-0.0602
	(0.1141)	(0.0688)	(0.0822)	(0.0992)	(0.0560)	(0.0711)	(0.0957)	(0.0541)	(0.0686)	(0.0958)
Industry FE	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*no*	*no*	*no*	*no*
Municipality FE	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*no*	*no*	*no*	*no*
Firm FE	*no*	*no*	*no*	*no*	*no*	*no*	*yes*	*yes*	*yes*	*yes*
N	2,191	2,191	2,191	2,064	2,064	2,064	2,064	2,064	2,064	2,064
Nr. firms	1,159	1,159	1,159	1,032	1,032	1,032	1,032	1,032	1,032	1,032

Source: AIDA 2008 & 2010, Telecom Italia, own calculations.
Notes: Robust standard errors in parentheses, adjusted for clustering at the municipality level. Incl. constant term. Placebo-exposure as of 31/12/2012 for the year 2010 and 0 for the year 2008.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

in the actual absence of the policy, i.e. in a pre-policy period. This finding holds for the unbalanced as well as the balanced sample and for both models employing municipality fixed effects and firm-fixed effects models.

Table 6 reports the results of a similar test of the common trend assumption employing data for the full period 2008–2012. We again employ measures of binary as well as continuous treatment. However, in contrast to the above analysis, we use *time-invariant* treatment measures (binary and continuous) fixed at municipalities' treatment status by end-2012.

Before we turn to a regression-based test, Figure 4 provides graphically descriptive evidence in support of the common trend assumption. On plotting average trends in our outcome of interest separately for control and treatment municipalities (according to their binary treatment status by end-2012), we clearly see parallel trends in the pre-policy period and deviating trends in the post-policy period (2010 is the year of policy start). Note that the post-policy period coincides with a period of economic recession, which might explain the downward trend of average firm performance in control municipalities. In comparison, firms in treatment municipalities show a more stable trend in the years after policy-start.

Table 6 displays the results from firm-fixed effects models for a balanced and an unbalanced sample. The interaction of interest for assessing the common trend assumption are *"Year=2009 $\times$ exposure"* and *"Year=2010 $\times$ exposure"*. The statistical significance of the estimated coefficient on these interactions indicates whether there are differences in trends of annual turnover (with respect to base year 2008) between late- and early-treated municipalities already in years before the actual ADSL 2+ program start. We expect both groups of firms to differ only in the years after program start (in 2011) and we expect there to be no differences before program start. Indeed, the results shown in Table 6 support the common trend assumption in that the coefficients on interactions for the years 2009 and 2010 are not statistically different from zero, neither in the case of our binary treatment nor when a continuous treatment measure is employed. Overall, these results reinforce the common trend assumption and hence the causal interpretation of the estimates reported in Table 4.

4.3. Value Added and Employment

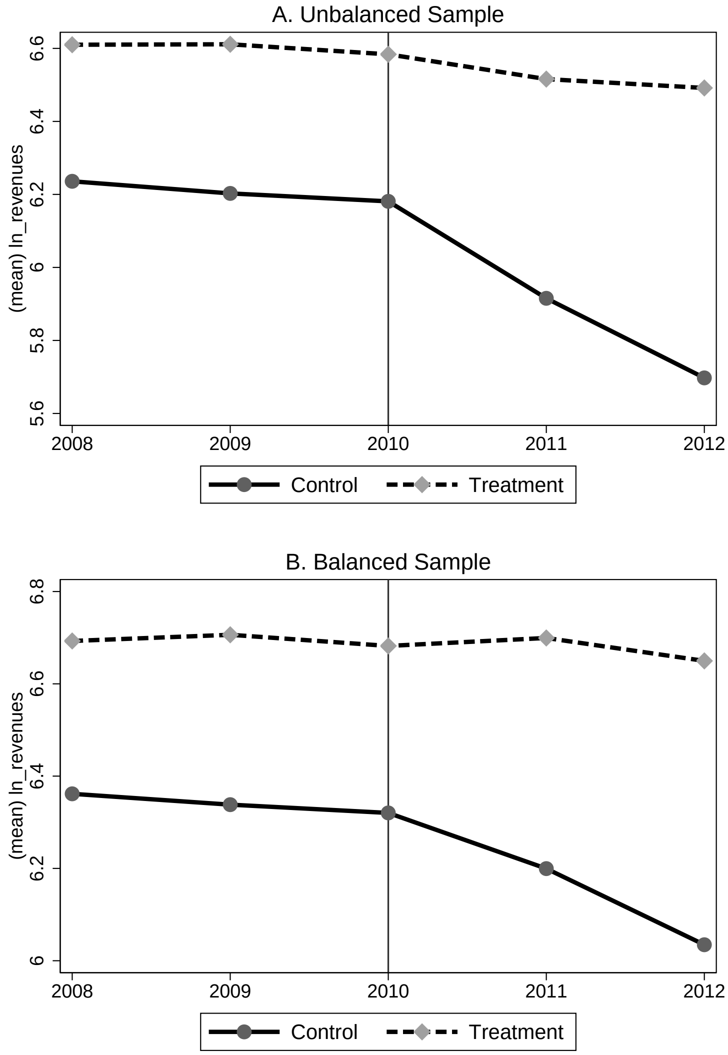
This section describes the results with respect to two additional outcomes: firms' annual value added and the number of employees. With respect to the sample employed in our main analysis of firms' annual sales turnover, we respectively discard firm-year observations with negative value added (127 observations) and observations with missing information on the number of employees (192 observations). Moreover, we present results on samples that are balanced with re-

Table 6: Testing the Common Trend Assumption (AIDA 2008–2012)

Dependent variable: Annual turnover (log)						
	Unbalanced Panel			Balanced Panel		
	(1)	(2)	(3)	(4)	(5)	(6)
Year=2008 × binary exposure (ref.)						
Year=2009 × binary exposure	0.0843			0.0369		
	(0.0862)			(0.0924)		
Year=2010 × binary exposure	0.0173			0.0306		
	(0.1015)			(0.1127)		
Year=2011 × binary exposure	0.2036			0.1686		
	(0.1235)			(0.1061)		
Year=2012 × binary exposure	0.3926***			0.2838*		
	(0.1252)			(0.1491)		
Year=2008 × days of exposure/30 (ref.)						
Year=2009 × days of exposure/30		0.0076	0.0068		0.0031	0.0042
		(0.0050)	(0.0123)		(0.0040)	(0.0114)
Year=2010 × days of exposure/30		0.0012	0.0029		0.0020	0.0080
		(0.0043)	(0.0128)		(0.0046)	(0.0134)
Year=2011 × days of exposure/30		0.0026	0.0231		0.0018	0.0259*
		(0.0062)	(0.0182)		(0.0053)	(0.0151)
Year=2012 × days of exposure/30		0.0117	0.0551***		0.0065	0.0492**
		(0.0081)	(0.0186)		(0.0086)	(0.0195)
Year=2008 × days of exposure/30 (sqrd) (ref.)						
Year=2009 × days of exposure/30 (sqrd)			0.0000			-0.0001
			(0.0006)			(0.0005)
Year=2010 × days of exposure/30 (sqrd)			-0.0001			-0.0003
			(0.0005)			(0.0006)
Year=2011 × days of exposure/30 (sqrd)			-0.0010			-0.0011*
			(0.0007)			(0.0006)
Year=2012 × days of exposure/30 (sqrd)			-0.0020***			-0.0020**
			(0.0007)			(0.0008)
Year=2008 (ref.)						
Year=2009	-0.1053	-0.1080*	-0.1045	-0.0235	-0.0220	-0.0262
	(0.0807)	(0.0581)	(0.0658)	(0.0900)	(0.0465)	(0.0643)
Year=2010	-0.0464	-0.0433	-0.0494	-0.0414	-0.0347	-0.0565
	(0.0988)	(0.0519)	(0.0721)	(0.1094)	(0.0576)	(0.0761)
Year=2011	-0.2612**	-0.1048	-0.1800*	-0.1621	-0.0289	-0.1166
	(0.1162)	(0.0849)	(0.1025)	(0.1016)	(0.0673)	(0.0826)
Year=2012	-0.4623***	-0.2294**	-0.3886***	-0.3270**	-0.1385	-0.2939***
	(0.1194)	(0.0939)	(0.1004)	(0.1446)	(0.1000)	(0.1094)
Firm FE	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
N	5,587	5,587	5,587	4,830	4,830	4,830
Nr. Firms	1,244	1,244	1,244	966	966	966

Source: AIDA 2008 – 2012, Telecom Italia, own calculations.
Notes: Robust standard errors in parentheses, adjusted for clustering at the municipality level. Incl. constant term. Exposure as of 31/12/2012 throughout. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Figure 4: Testing the Common Trend Assumption – Descriptive Evidence



Source: AIDA 2008–2012, Telecom Italia, own calculations.
Note: Treatment and control group are defined on the basis of ADSL2+ broadband exposure as of 31/12/2012: Treated= firms located in municipalities with ADSL2+ access by end-2012. Control = firms located in municipalities without ADSL2+ access by end-2012. 2011 is the starting year of the ADSL2+ policy.

gard to the respective outcome.[8] Concerning the employment estimations, we choose to employ $log(nr.employees+1)$ as the dependent variable due to the large number of firms with zero employees in the sample (roughly 50 percent).

[8]Results on unbalanced samples and employing municipality fixed effects instead of firm fixed effects are qualitatively similar and available upon request.

Table 7: Other Outcomes – Value Added and Employment

A: Main, 2010 & 2012								
	Annual value added (log)				Nr. employees (log)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Binary exposure	0.2465**				0.0287			
	(0.0999)				(0.2034)			
Nr. days of exposure/30		0.0105**	0.0262*			-0.0118	0.0187	
		(0.0046)	(0.0137)			(0.0072)	(0.0241)	
Nr. days of exposure/30 (sqrd)			-0.0007				-0.0014	
			(0.0005)				(0.0009)	
Zero exposure (ref.)								
Exposure<=6 months				0.2323**				-0.0541
				(0.1172)				(0.2472)
6 months< exp. <=12 months				0.1742*				0.2283
				(0.1040)				(0.2070)
12 months< exp. <=18 months				0.2999***				-0.0554
				(0.1024)				(0.2106)
18 months< exp.				0.2810**				-0.1728
				(0.1075)				(0.2023)
Year=2012	-0.2401**	-0.1254**	-0.1838**	-0.2401**	0.5200***	0.6668***	0.5533***	0.5200***
	(0.0977)	(0.0606)	(0.0825)	(0.0978)	(0.1987)	(0.0997)	(0.1441)	(0.1989)
Firm FE	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
N	1,964	1,964	1,964	1,964	1,756	1,756	1,756	1,756
Nr. Firms	982	982	982	982	878	878	878	878
B: Placebo, 2008 & 2010								
	Annual value added (log)				Nr. employees (log)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Placebo–Binary exposure	0.0896				-0.1465			
	(0.1217)				(0.1517)			
Placebo–Nr. days of exposure/30		0.0027	0.0138			0.0046	-0.0262	
		(0.0051)	(0.0151)			(0.0060)	(0.0176)	
Placebo–Nr. days of exposure/30 (sqrd)			-0.0005				0.0014**	
			(0.0006)				(0.0007)	
Zero exposure (ref.)								
Exposure<=6 months				0.0763				-0.0525
				(0.1528)				(0.1612)
6 months< exp. <=12 months				0.0806				-0.2943*
				(0.1241)				(0.1615)
12 months< exp. <=18 months				0.1111				-0.0860
				(0.1254)				(0.1578)
18 months< exp.				0.0582				-0.0320
				(0.1392)				(0.1636)
Year=2010	-0.0903	-0.0375	-0.0780	-0.0903	-0.1803	-0.3603***	-0.2450**	-0.1803
	(0.1191)	(0.0641)	(0.0905)	(0.1192)	(0.1465)	(0.0783)	(0.1000)	(0.1466)
Firm FE	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
N	1,922	1,922	1,922	1,922	1,628	1,628	1,628	1,628
Nr. Firms	961	961	961	961	814	814	814	814

Source: A: AIDA 2010 & 2012, B: AIDA 2008 & 2010 , Telecom Italia, own calculations.
Notes: Balanced panels. Robust standard errors in parentheses, adjusted for clustering at the municipality level. Incl. constant term. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Panel A of Table 7 presents the estimation results with respect to annual value added (Columns 1–4) and number of employees (Columns 5–6). With the difference-in-differences specification employing a binary treatment indicator, ADSL 2+ availability appears to be associated with a significant increase in value added of roughly 25 percent over the period of two years (Column 1). This is about 62 percent of the effect magnitude found for annual sales turnover. On the other hand, we find no significant effect on the number of employees (Column 5).

On employing the continuous treatment intensity measure, the estimates suggest that an additional 30 days of exposure to ADSL 2+ broadband access on average increased firms' annual value added by about 1 percent within two years (Column 3).

Further exploring nonlinearities in the treatment intensity effect, we find that the squared term of treatment intensity in the quadratic specification is not significant. Also the category specification and graphical illustrations of the effect shape displayed in Figure 5 indicate that the treatment intensity effect is slightly more linear with respect to value added than what we found for annual turnover. However, the results of the category specification (Column 4) show no *strict* monotony of treatment intensity effects. Overall, we cannot exclude constant effects of around 25 percent irrespective of treatment intensity.

No significant relationship is found in regard to employment, neither in the linear specification of treatment intensity nor with quadratic polynomials or treatment intensity categories (Columns 6–8, see also Figure 6).

Panel B Table 7 shows the results of placebo estimations analogous to the placebo analysis with respect to our main outcome annual turnover in Section 4.2. The results clearly support the common trend assumption also for the outcome of value added and the various specifications. In regard to number of employees, the common trend assumption is borne out overall. [9]

4.4. Effect Heterogeneity

In view of the substantial treatment effects thatwe find in regard to corporate enterprises' annual sales turnover and value added, it is important to analyze heterogeneous effects across several types of firms and also with respect to potentially relevant municipality characteristics. The question we attempt to answer is whether factors such as industrial sector, municipalities' degree of urbanization, or presence of a previous ADSL infrastructure are related to the extent to which firms benefit from ADSL2+ accessibility.

[9] Only the 'placebo'–treatment intensity category of 6–12 months proves to be statistically significant in the absence of actual treatment. Note, however, that statistical significance is weak (at the 10 percent-level).

Table 8: Effect Heterogeneity – Industrial Sector and Technology Intensity

A: Industrial Sector

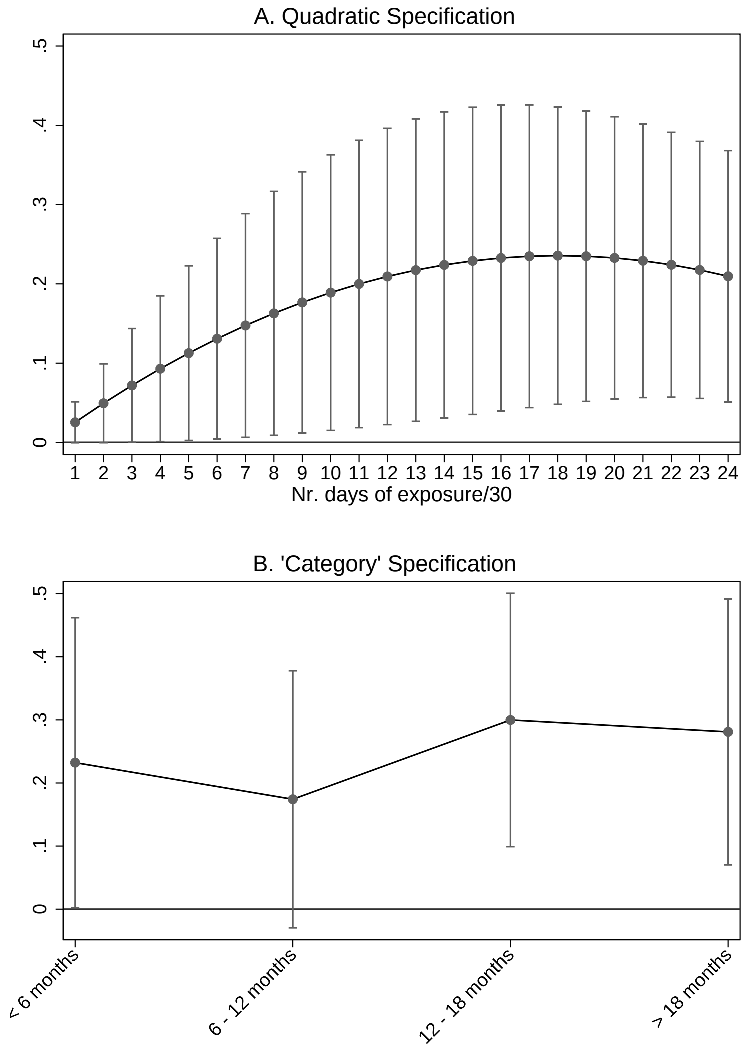
	(1) Annual turnover (log)	(2) Annual value added (log)	(3) Nr. employees (log)
Binary exposure × Manufacturing, mining (B,C)	0.3025***	0.2148**	0.0226
	(0.1026)	(0.1022)	(0.2198)
Binary exposure × Constr., electr., gas, water (D,E,F)	0.4482***	0.2749**	0.0453
	(0.1312)	(0.1083)	(0.2165)
Binary exposure × Wholesale, retail (G)	0.3341***	0.1969*	-0.2173
	(0.1017)	(0.1080)	(0.2110)
Binary exposure × Hotels, restaurants (I)	0.4942***	0.2979***	0.6303***
	(0.1019)	(0.1047)	(0.2368)
Binary exposure × Transportation, communication (H,J)	0.4363***	0.1626	0.1934
	(0.1079)	(0.1288)	(0.2340)
Binary exposure × Real estate activities (L)	0.3642*	0.2033	-0.2326
	(0.1911)	(0.1479)	(0.2197)
Binary exposure × Prof., scientific, techn. (M,N)	0.5542***	0.2860**	-0.0696
	(0.1158)	(0.1315)	(0.2391)
Binary exposure × Other services (R,S,T,U)	0.3341*	0.5391**	-0.1221
	(0.2010)	(0.2461)	(0.2442)
Firm FE	*yes*	*yes*	*yes*
N	2,132	1,964	1,756
F-test (coefficient different from *Binary exposure × Manufacturing, mining (B,C)*)			
Prob $>$ *F*:			
Binary exposure × Constr., electr., gas, water (D,E,F)	0.1565	0.3043	0.8200
Binary exposure × Wholesale, retail (G)	0.6566	0.7577	0.0668
Binary exposure × Hotels, restaurants (I)	0.0044	0.0749	0.0001
Binary exposure × Transportation, communication (H,J)	0.0983	0.5610	0.2627
Binary exposure × Real estate activities (L)	0.7238	0.9205	0.0626
Binary exposure × Prof., scientific, techn. (M,N)	0.0050	0.4606	0.5860
Binary exposure × Other services (R,S,T,U)	0.8643	0.1624	0.3889

B: Technology Intensity

	(1) Annual turnover (log)	(2) Annual value added (log)	(3) Nr. employees (log)
Binary exposure	0.3881***	0.2330**	0.0481
	(0.0953)	(0.1001)	(0.2042)
Binary exposure × High-tech sector	0.0671	0.1219	-0.1759
	(0.0778)	(0.0915)	(0.1103)
Firm FE	*yes*	*yes*	*yes*
N	2,132	1,964	1,756

Source: A: AIDA 2010 & 2012, Telecom Italia, own calculations.
Notes: Balanced panels. Robust standard errors in parentheses, adjusted for clustering at the municipality level. Incl. constant term and year indicator. Definition of high-tech sector based on EUROSTAT (2015). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

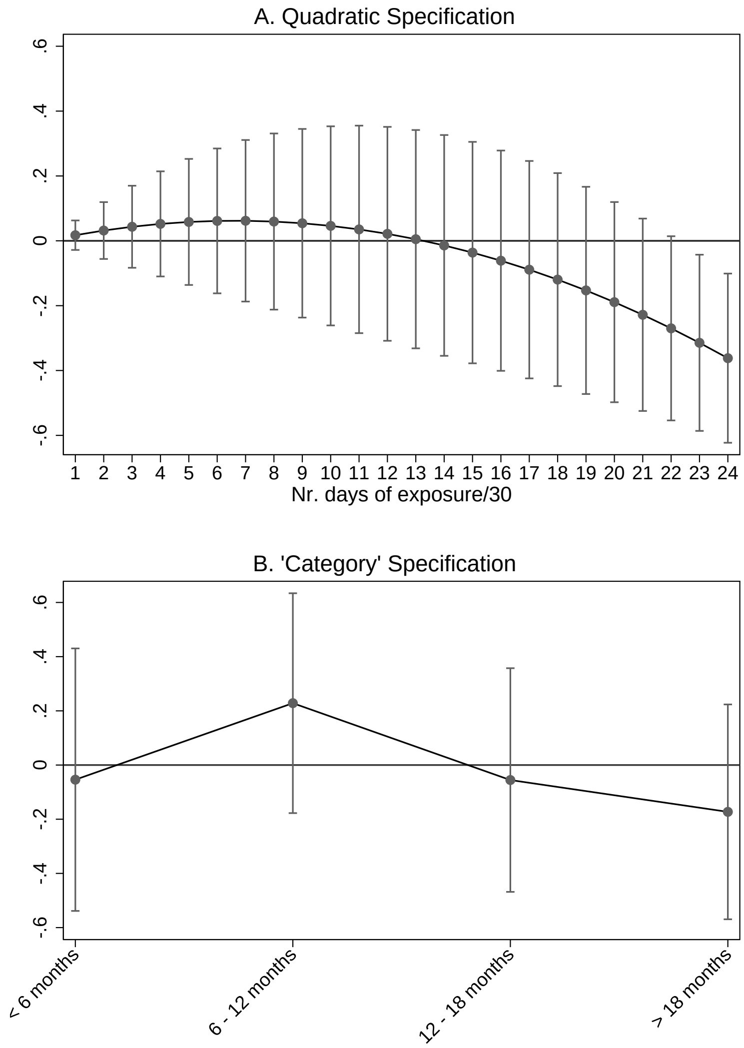
Figure 5: The Shape of Treatment Intensity Effects on Value Added



Source: AIDA 2010 & 2012, Telecom Italia, own calculations.
Note: Marginal effects of treatment intensity on value added (log) based on Columns 3 and 4 of Table 7 (Panel A) with 95% confidence intervals.

Panel A of Table 8 is concerned with effect heterogeneity with respect to firms' industrial sector. We focus on the overall treatment effect, i.e. we employ the difference-in-differences specification and estimate treatment effects for each industrial sector category separately. Estimations are performed on balanced panels and include firm fixed effects. Importantly, we allow for industry-specific treatment effects. Reported below are the results of F-tests testing the equality of each coefficient with respect to the estimated treatment effect for the sector "Manufacturing,

Figure 6: The Shape of Treatment Intensity Effects on Employment



Source: AIDA 2010 & 2012, Telecom Italia, own calculations.
Note: Marginal effects of treatment intensity on nr. of employees (log) based on Columns 7 and 8 of Table 7 (Panel A) with 95% confidence intervals.

mining (B,C)" (the most numerous sector in our sample, see Table A3 in Appendix).

In the case of annual sales turnover (Column 1), we find that ADSL2+ accessibility significantly increased sales turnover of corporate enterprises in the manufacturing sector by around 30 percent. This effect is statistically similar for most of the other sectors except "Hotels, restaurants (I)" and "Professional, scientific, technical and administrative activities (M,N)", for which we find significantly stronger effects of around 50 and 55 percent respectively. It makes intuitive sense that the hospitality/tourism sector can profit most from booking and marketing applications which require high-speed internet access. Also the finding of stronger effects for professional, scientific, technical and administrative activities is not surprising since this category likely includes high-skilled professionals whose productivity return on ADSL2+ might be substantial.

With respect to firms' annual value added (Column 2), ADSL2+ accessibility has a significant and positive effect of about 21 percent for manufacturing enterprises. F-tests confirm that the effect magnitude in other sectors is not statistically different from this estimate. The estimated effect for "Hotels, restaurants (I)" is with ca. 30 percent relatively stronger, but the difference is only marginally statistically significant at the 10-percent level. The results for number of employees (Column 3) by and large confirm the previous finding of no significant overall ADSL2+ effect for the single sectors. Once again the exception is the sector "Hotels, restaurants (I)", which appears to have experienced a very strong increase in employees of about 63 percent. This might partly be explained by the strong treatment effect that we find for this sector with respect to turnover (almost 50 percent) and value added (almost 30 percent). Additionally, the hospitality sector is traditionally relatively more reactive in terms of hiring and firing than other sectors.

In Panel B of Table 8 we report the results of interacting the treatment effect with an indicator of sectoral technology intensity. We define high-tech sectors based on 2-digit industrial sector and according to the classification described in EUROSTAT (2015). Only around 11 percent of firms in our sample are active in a high-tech sector (see also Table A3 in Appendix). In fact, with respect to annual turnover and value added (Columns 1 and 2), we find that effects of ADSL2+ accessibility are not statistically different for firms in high-tech sectors compared with others.

Table 9 shows potential interactions of the ADSL2+ treatment effect with the pre-policy presence of ADSL infrastructures of less speed (ADSL Lite and 7Mpbs) and degree of urbanization and remoteness of municipalities. The former is motivated by the assumption that firms with previous access to a fixed ADSL infrastructure, even of much lower velocity, may react differently to the introduction of access to a high-speed ADSL2+ technology than firms in locations lacking any ADSL infrastructure. We examine the association between urbanization and remoteness because previous literature for the US has shown that, particularly in rural areas, broadband effects are stronger in locations closer to metropolitan areas and with higher population density (Kandilov and Renkow, 2010; Kim and Orazem, 2012). Fabritz (2013) conversely finds for Germany that positive employment effects of broadband diffusion are stronger in remote areas.

With regard to pre-policy ADSL we find no differential treatment effects for firms in municipalities with or without previous exposure to ADSL infrastructures of minor velocity. The results concerning urbanization and remoteness are interestingly opposite in sign: whereas the

Table 9: Effect Heterogeneity – Pre-Policy ADSL, Remoteness and Urbanization

	(1) Annual turnover (log)	(2) Annual value added (log)	(3) Nr. employees (log)
A: Pre-Policy ADSL			
Binary exposure	0.3917***	0.2542**	0.0187
	(0.0954)	(0.1001)	(0.2044)
Dummy exposure × Pre-policy 7Mbps (ref.)			
Binary exposure × No pre-policy ADSL	-0.0211	-0.0648	0.0459
	(0.1138)	(0.0921)	(0.1542)
Binary exposure × Pre-policy Lite	0.0961	-0.0820	0.1364
	(0.1149)	(0.1131)	(0.1260)
Firm FE	*yes*	*yes*	*yes*
N	2,132	1,964	1,756
B: Remoteness			
Binary exposure	0.2660**	0.2408**	-0.1794
	(0.1101)	(0.1091)	(0.2167)
Binary exposure × Road distance to regional capital (min)	0.0034**	0.0001	0.0055**
	(0.0014)	(0.0012)	(0.0022)
Firm FE	*yes*	*yes*	*yes*
N	2,132	1,964	1,756
C: Urbanization			
Binary exposure	0.3806***	0.2479**	0.0470
	(0.0952)	(0.1001)	(0.2039)
Binary exposure × 2001 Population density/10	0.0136***	-0.0013	-0.0155***
	(0.0017)	(0.0022)	(0.0032)
Firm FE	*yes*	*yes*	*yes*
N	2,132	1,964	1,756

Source: AIDA 2010 & 2012 , Telecom Italia, own calculations.
Notes: Balanced panels. Robust standard errors in parentheses, adjusted for clustering at the municipality level. Incl. constant term and year indicator. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

positive effect on turnover increases significantly with road distance to the regional capital (our measure of remoteness), the effect also increases with population density (our measure of urbanization). Hence, both more urbanized and more remote (rural) areas seem to benefit relatively more strongly from ADSL2+ accessibility. There appears to be no such effect heterogeneity with respect to value added. Interestingly, in the case of employment effects, we find that the interaction term of treatment and remoteness is significant and positive, whereas the interaction of treatment and urbanization is significant and negative. We would accordingly expect positive employment effects, if at all, in the most remote and least urbanized areas, which would be in line with the findings of Fabritz (2013) in Germany.

5. Conclusions

There is substantial and increasing policy attention to public investment in broadband infrastructure. The underlying assumption in this policy debate is that the availability of broadband technology is beneficial for local economic growth. Yet there is little empirical evidence of a causal impact on economic performance at the firm level. Moreover, it is unclear whether beneficial effects would prevail (or even be stronger) in rural areas and whether there would be similar effects for the introduction of new-generation broadband technologies.

We provide micro-level evidence by exploiting a quasi-experimental setting. A unique public program in the Province of Trento (Italy) provides plausibly exogenous variation of ADSL 2+ broadband availability in relatively rural and remote areas. To control carefully for pre-existing, location-specific fixed factors, we employ a difference-in-differences strategy which controls for municipality and year fixed effects. Moreover, we conduct placebo analysis and detailed tests of the common trend assumption underlying our identification strategy.

The results are based on longitudinal balance sheet data of local corporate enterprises and suggest a strong and statistically significant impact of ADSL 2+ availability on corporate enterprises' economic performance. ADSL2+ availability appears to be associated with a significant increase in annual sales turnover of about 40 percent and an increase in value added of roughly 25 percent over the period of two years. The positive effect is found to be rather stable for different levels of treatment intensity (days of ADSL 2+ availability) and across industrial sectors (with relatively stronger benefits for the hospitality sector). Overall, no significant effects are found with respect to the number of employees employed in corporate enterprises (except for the hospitality sector).

Taken together, our findings have important implications for the ongoing policy debate on government investment in broadband infrastructure to encourage local economic growth, even (and perhaps especially) in relatively under-developed remote and rural areas.

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Appendix

Table A1: Variable Description – Municipality Characteristics

Variable	**Description**
Demography	*Source:* ISTAT (2001) 14° Censimento generale della popolazione e delle abitazioni
Population density	Total nr of residents over municipal area (in square kilometers)
Population growth rate, 10 yrs	10-year population growth rate (1991-2001)
Employment rate	Nr of employed residents over working age population (15–64)
Population share high educated	Nr of residents with upper secondary or higher education over total nr of residents
Population share aged 65 and over	Nr of residents aged at least 65 over total nr of residents
Industry structure	*Source:* ISTAT (2001) 8° Censimento dell'industria e dei servizi
Nr. firms (log)	Total nr of firms
Empl. growth rate, 10 yrs	10-year growth rate of total nr of jobs (1991-2001)
Empl. share in primary sector	Nr of jobs in the primary sector (agriculture and mining) over total nr of jobs
Empl. share in manufacturing	Nr of jobs in manufacturing over total nr of jobs
Empl. share in construction	Nr of jobs in construction and utilities (gas, water, electricity) over total nr of jobs
Empl. share in wholesale	Nr of jobs in wholesale and retail over total nr of jobs
Empl. share in services	Nr of jobs in other services over total nr of jobs
Geography	*Source:* ISTAT (2009) Atlante Statistico dei Comuni
Municipality's altitude (log)	Altitude at the city hall level (in meters)
Distance to nearest motorway (log)	Road distance of the municipality to the next motorway (in minutes)
Previous ADSL technology:	*Source:* Trentino Network
Pre-policy 7Mbps	Pre-policy availability of previous ADSL technology 7Mbps
Pre-policy Lite	Pre-policy availability of previous ADSL technology Lite

Table A2: Testing the Common Trend Assumption – Italian Census Data 1991 & 2001

	Empl. Share Manufacturing		Empl. Share Construction		Empl. Share Wholesale		Empl. Share Other Services	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Year=2001 × binary exposure	-0.017		-0.021		-0.025		-0.007	
	(0.022)		(0.031)		(0.027)		(0.028)	
Year=2001 × days of exposure/30		0.002		-0.002		-0.0005		-0.002
		(0.002)		(0.002)		(0.0013)		(0.002)
Year=2001	-0.015	-0.046***	0.058**	0.055***	-0.014	-0.031**	0.042	0.051***
	(0.020)	(0.016)	(0.029)	(0.020)	(0.026)	(0.016)	(0.027)	(0.018)
Municipality FE	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
N	334	334	334	334	334	334	334	334
Nr. Municipalities	167	167	167	167	167	167	167	167

Source: ISTAT population & industry census 1991 & 2001, Telecom Italia, own calculations.
Notes: Municipality-level data. Robust standard errors in parentheses. Incl. constant term. Placebo-exposure as of 31/12/2012 throughout. For detailed variable description see Table A1 in Appendix. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A3: Summary Statistics – AIDA 2010 & 2012

	Unbalanced Sample		Balanced Sample	
	2010	2012	2010	2012
Binary exposure	0	0.904	0	0.900
	(0)	(0.295)	(0)	(0.301)
Nr. days of exposure/30	0	10.292	0	10.231
	(0)	(6.064)	(0)	(6.089)
Zero exposure	1	0.096	1	0.100
	(0)	(0.295)	(0)	(0.301)
Exposure<=6 months	0	0.091	0	0.092
	(0)	(0.288)	(0)	(0.289)
6 months< exp. <=12 months	0	0.319	0	0.315
	(0)	(0.466)	(0)	(0.465)
12 months< exp. <=18 months	0	0.367	0	0.368
	(0)	(0.482)	(0)	(0.482)
18 months< exp.	0	0.126	0	0.125
	(0)	(0.332)	(0)	(0.331)
Revenues (in 1,000 euros)	2,087.64	2,000.56	2,055.35	2,080.26
	(3,532.93)	(3,417.34)	(3,328.80)	(3,471.59)
Firm age (in 2008)	20.86	20.74	21.16	21.16
	(23.25)	(22.88)	(23.53)	(23.53)
Industrial sector:				
Manufacturing, mining (B,C)	0.233	0.230	0.236	0.236
	(0.423)	(0.421)	(0.425)	(0.425)
Constr., electr., gas, water (D,E,F)	0.222	0.224	0.216	0.216
	(0.416)	(0.417)	(0.412)	(0.412)
Wholesale, retail (G)	0.172	0.166	0.176	0.176
	(0.378)	(0.372)	(0.381)	(0.381)
Hotels, restaurants (I)	0.116	0.119	0.115	0.115
	(0.320)	(0.324)	(0.320)	(0.320)
Transportation, communication (H,J)	0.069	0.068	0.072	0.072
	(0.254)	(0.251)	(0.259)	(0.259)
Real estate activities (L)	0.092	0.092	0.086	0.086
	(0.290)	(0.289)	(0.281)	(0.281)
Prof., scientific, techn. (M,N)	0.058	0.064	0.061	0.061
	(0.234)	(0.245)	(0.239)	(0.239)
Other services (R,S,T,U)	0.037	0.036	0.037	0.037
	(0.188)	(0.187)	(0.188)	(0.188)
High-tech sector	0.111	0.113	0.114	0.114
	(0.315)	(0.316)	(0.319)	(0.319)
Previous ADSL technology:				
Pre-policy 7Mbps	0.846	0.842	0.840	0.840
	(0.361)	(0.365)	(0.367)	(0.367)
Pre-policy Lite	0.056	0.061	0.058	0.058
	(0.229)	(0.240)	(0.234)	(0.234)
N	1,115	1,155	1,066	1,066
Value added (in 1,000 euros)	629.05	623.43	645.10	647.87
	(1,125.97)	(1,122.92)	(1,138.40)	(1,144.86)
N	1,067	1,076	982	982
Nr. employees	13.72	10.95	14.19	10.43
	(176.75)	(22.94)	(182.04)	(24.47)
N	932	1,146	878	878

Source: AIDA 2010 & 2012, Telecom Italia.
Notes: ADSL2+ exposure as of December 31 in the respective year. Definition of high-tech sector based on EUROSTAT (2015).