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An IV-estimation of the broadband effect on firms' sales and employment level

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Abstract

This study investigates the relationship between super-fast broadband and firms' sales and employment level in Sweden. It is important to learn more about this recent technological change and few studies has explored the impact of super-fast broadband on firm outcomes. We use the previous roll-out of *second-generation* internet access to identify the effect of *third-generation* internet access. The early investments in optic fiber where largely core broadband network investments paving the way for later investments in third-generation broadband technology. Municipalities choosing providers who prioritized cheap technology (broadband over telephone lines, DSL) targeting the many, thus fell behind municipalities choosing providers investing in optic fiber. We find heterogeneity in the broadband effect, but the overall effect is negative. This effect may be associated with the roll-out of 4G mobile broadband in 2011; mobile broadband services are a byproduct of optic fiber because mobile broadband is transmitted from the same high capacity fiber-optic base stations. We suggest that the negative effect found is related to internet use at work and the mixing of private and work related internet use.

JEL classification: D22, J23, O3, R5
Key words: broadband, optic fiber, firm output, employment, regional analysis

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1. Introduction

The European Commission states that being connected via reliable high-speed broadband is essential across the EU for citizens, businesses and regions to stay competitive. However, even if the digitalization of the economy, most certainly, increases national economic growth it is more ambiguous whether it affects all economic outcomes and every part of the economy in the same way (Kolko, 2012; Akerman et. al., 2015; Kim and Orazem; 2017). IT is plausibly a skill-biased technology affecting the relative productivity of skilled and unskilled workers (Akerman et. al., 2015). Also, just as broadband enhances the market of rural firms, rural firms also faces increased competition from expanding urban business. In fact, an influential study shows that internet access increases regional wage inequality (Forman et al., 2012).

Several studies have analysed the economic impact of broadband. Macro-level studies show a positive effect on national (Czernich et. al., 2011) and rural GDP growth (Whitacre et. al. ,2014; Ivus and Boland, 2015; Kolko, 2012), and (un)employment (Atasoy,2013; Crandall et. al., 2007; Fabritz 2013; Hasbi, 2017; Bai, 2017). The evidence from micro level studies is more mixed; studies find both positive results on sales, value added (Canzian et. al., 2015) and productivity (Grimes et al., 2012), and zero result on productivity (Haller and Lyons, 2015; Bertschek, et al., 2013) and economic performance in general (De Stefano, et al., 2014). There is also mixed evidence whether the broadband effect is larger in urban or rural areas; in Fabritz (2013), Kolko (2012), Atasoy (2013) and Stenberg et al. (2009) the effects are larger in rural areas, whereas in Kandilov and Renkow (2010) and Kim and Orazem (2017) the effects are larger in urban areas. For the US, Forman et al., (2012) shows that internet increased wage and employment growth only in the 6% best-of-counties.

Empirically, a main problem is that the roll-out of broadband is endogenous and often related to economic growth. Few studies use a causal identification strategy to estimate the effects of broadband and for those who do the impact of broadband is less clear. De Stefano et al. (2014) apply a fuzzy regression discontinuity design where they use a discontinuity in broadband availability in England. They find no effect on firms' outcomes. Kolko (2012) instruments broadband with slope of terrain and finds results pointing in a causal direction; a positive effect is found on economic growth but not on employment or wages. In Norway, a plausibly exogenous roll-out of broadband improves (worsens) labor market outcomes and productivity of skilled (unskilled) workers (Akerman et. al.,2015).

This study contributes by being the first study to estimate the impact of super-fast third-generation internet access (>100Mbi/s)[1] on firm's sales and employment in a presumed exogenous design. We estimate separate result for urban and rural areas and for firms in different industries. The technical shift is from DSL access to 'fiber to the premises' (FTTP) access. Hence, it is an effect over-and-above the underlying effect of having a DSL connection, which 97.8% of the population had access[2] to in 2007 (Swedish Post and Telecom Authority (PTS), 2008).

Our IV model uses previous broadband providers to instrument the uptake of broadband in 2007-2014. In Sweden, it has been acknowledged that municipalities' choice of broadband providers in 2000-2007 affected the subsequent roll-out of third-generation internet access (SOU, 2008). The procured provider received the broadband support and had to roll-out broadband in accordance with certain regulations. However, the provider could choose the preferred technology as long as the provided internet access was fast. Municipalities choosing providers prioritizing cheap technology (mainly DSL in the form of broadband over telephone lines) targeting the many in 2000-2007, fell behind municipalities choosing providers investing in optic fiber. The latter group provided six times more FTTP connections than the former group of providers (SOU, 2008). Thus, the early investments (up until 2007) where largely core

[1]The average speed is probably lower. The average speed is estimated to be five times faster than DSL (Davidsson, 2014).
[2]Actual take-up is lower, though, around 70% (Statistics Sweden, 2007).

broadband network investments paving the way for later investments in third-generation internet technology. At the national level, where regional and geographical dimensions affect the choice of a provider, the distribution of providers is not random, but within a labour market region,[3] the choice of a municipal provider is independent of pre-determined characteristics, suggesting that the choice is plausibly exogenous. Thus, if two municipalities within the same labour market region choose different providers this margin identifies our broadband effect.

Why is it important to evaluate the third-generation technology? Heterogeneity in digital technology has not received much attention in the literature. Research has, almost entirely investigated the internet and broadband effects in the era of DSL broadband, where the consumer went from a dial-up modem to DSL. It is, however, important to highlight that third-generation internet access not only provides faster internet but also offers new services and means of communication. Firms benefitting from online marketing and sales are assumed to gain from internet, but the new services may have detrimental effects as well.

Hence, this study demonstrates a negative effect on firm's sales and employment in urban areas; strikingly robust FE results (covariates and municipality-specific time dummies has no impact on the results) and the IV analysis, supports the finding. However, a heterogeneity in effect between industries is found, indicating different mechanisms. Whereas a positive effect is found in e.g. the hotel and restaurant industry, the negative effect is found in most other sectors. Since a positive (or zero) effect of broadband is in line with earlier research our focus is on the unexpected negative effect. A hypothesis explaining the negative effect is proposed below; a hypothesis supported by associative statistics.

Whereas psychologists investigate social networking and cyberloafing[4] on internet, the recent era of smartphones, ipads, super-fast internet and social media has not been evaluated with regards to economic outcomes. An exception is Duke and Montag (2017) who finds that

[3]Sweden is divided into 105 labour market regions.
[4]Cyberloafing is defined as using Internet at work for personal use while pretending to do legitimate work.

smartphones decrease self-reported labour productivity.[5] Importantly, if one cannot control for mobile broadband coverage – which is genuinely difficult to capture - while regressing third-generation broadband accessibility on different outcomes, one is likely to capture the net effect of wired broadband and mobile broadband[6]. This is because the roll-out of optic fiber also strongly determines the roll-out of mobile broadband; both connect to an internet backbone, usually a high capacity fiber-optic base station, and when an areas receives wired broadband the areas is also likely to receive mobile broadband in the nearby future. Hence, in this study, where super-fast broadband (SupB) accessibility is measured at the 250×250m grid square level and aggregated up to the SAMS (Small Areas for Market Statistics)[7] level, we acknowledge that our SupB effect captures not only firm's direct benefit of broadband, but also the indirect effect of employees total consumption of internet on firm outcomes.

Thus, studies on wired broadband accessibility need to consider the impacts of mobile broadband, or essentially, our smartphones, as well. Smartphones implies a constant stimuli of our (social) reward system which may affect our cognitive resources (see Tamir and Ward (2015) for an overview). In Britain it is reported that smartphone owners check them every 12 minutes (Ofcom. 2018), and since our brains are limited in their ability to focus, Gazzaley and Rosen (2016) argues that we have to learn to handle technology in a balanced way. Ward et al. (2017) shows that even the mere presence of our smartphone occupy resources and affects our cognitive performance negatively. Moreover, smartphone use has been associated with depression and suicide-related outcomes among adolescence (Twenge et al., 2018), sleep

[5]Other exceptions are studies by Hasbi (2017), who analyses the correlation between municipalities' investments in high-speed broadband, and Bertschek and Nibel (2016) who studies labour productivity and instruments firm's share of employees with mobile devices on the number of years the firm respondent has used a smartphone. We have exogeneity concerns about the instrument.

[6]Also, WiFi-technology is captured because a super-fast fiber connection is (almost certainly) needed for WiFi availability at firms and institutions.

[7]Sweden is divided into about 9200 SAMS areas. Larger municipalities are divided into NYKO (Nyckelkodsregistret) areas and small municipalities are divided into electoral districts.

disorder (Billari et al, 2017), decrease in exam scores (Baert, 2018) and distracted parenting causing child accidents (Palsson, 2017).

2. Previous roll-out of broadband and using providers as identifying subsequent roll-out

The second generation roll-out of internet access (but first-generation of broadband) in 2000-2007 was largely financed by governmental support at the national level, 51%, and the municipality level, 11%. Almost 7% was financed by EU's Structural funds and 30% was financed by Telecom operators. The total cost was SEK 7.6 billion.

The municipalities were responsible for the second-generation roll-out of internet access and they had to procure the service in agreement with public procurement laws. Importantly, the providers used different strategies to roll-out broadband. A general difference in strategy was that private providers prioritized to transmit broadband over cable telephone lines (DSL), whereas municipality public utilities (MPU) invested in optic fiber to a larger extent (FTTP). The former strategy provided broadband access cheaply to a large number of consumers, and the latter provided broadband access to fewer consumers, but with the up-side of being able to transform the technology into the third-generation broadband technology later (SOU, 2008). Thus, the chosen strategy also impacted the roll-out of SupB in 2007-2014. We argue that the procurement of different providers within labour market regions (which we control for) was unrelated to economic factors affecting firms' finances. Therefore we use the providers as instruments to predict SupB accessibility in 2007-2014.

Public utilities at the national and the municipality level provided broadband in 49 and 86 of the municipalities, respectively[8]. Whereas the national public utility company (Teracom) gave priority to DSL (see Figure 1: 9.5% of the firms in these municipalities had SupB in 2007), the MPU:s invested in optic fiber to a larger extend (18.6% had optic fiber in 2007). The private

[8]Community municipality networks are common in many OECD countries (Mölleryd, 2015).

providers TeliaSonera, Carlberg & Son IT, and six other small companies provided broadband in 88, 14 and 7 municipalities, respectively. They all gave priority to DSL (9.5, 2.7 and 7.8% had SupB in 2007, respectively). The county of Skåne (31 municipalities) coordinated their behavior and used the private provider Tele2 who invested in optic fiber to a larger degree than the other private providers (13.6% had SupB in 2007).

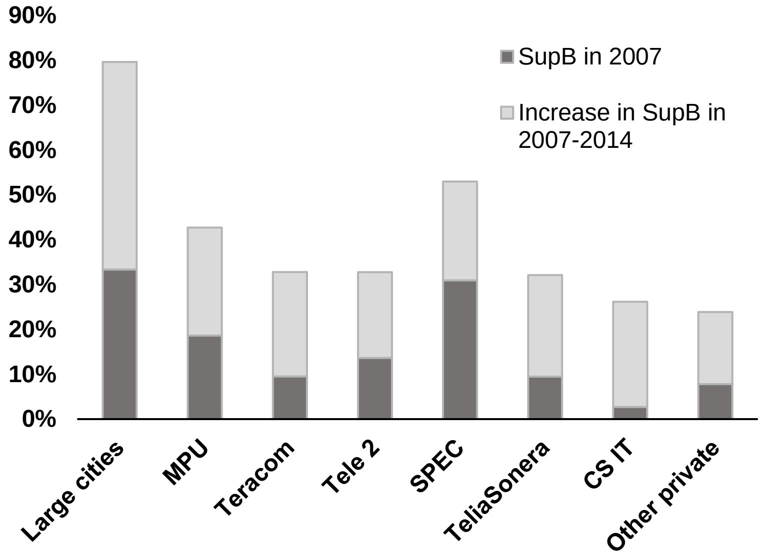
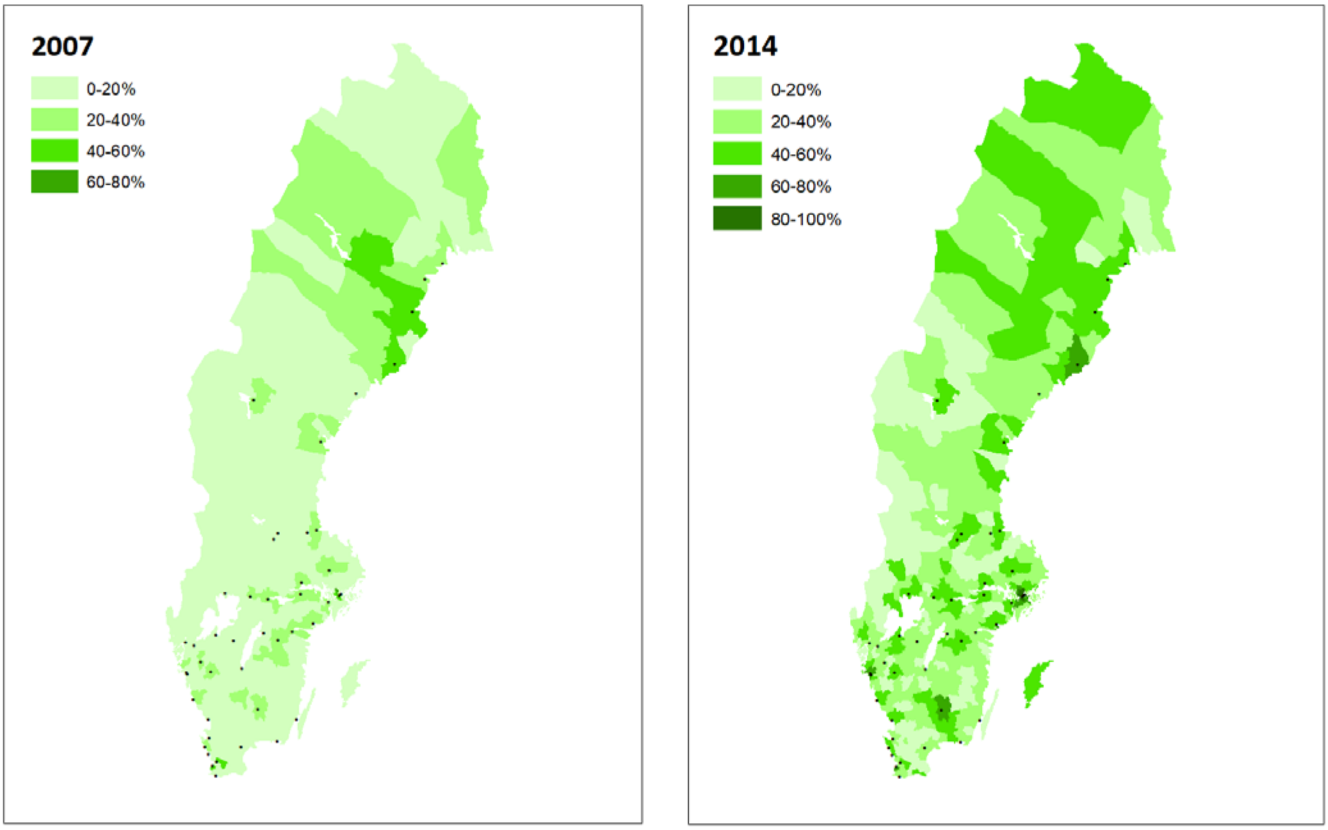


Figure 1. Coverage of superfast broadband (SupB) in 2007 and increase in superfast broadband in 2007-2014 for municipalities with different providers.

In the three largest metropolitan areas, Stockholm, Gothenburg and Malmö, where a completely unsubsidized roll-out was deemed commercially viable, no support was given. Certain providers can therefore not be distinguished. In these metropolitan the fiber coverage was, relatively, high already in 2007 (around 33.3%). Because the roll-out in the metropolitan areas differ in roll-out implementation, the metropolitan areas are removed in the IV-analysis. In 6 municipalities who used special (SPEC) solutions (in 4 municipalities there were two providers, and in 2 municipalities the roll-out was conducted by an economic association) the fiber coverage was also high in 2007 (around 30.9%). Figure 2 shows the level of SupB coverage over the country in 2007.



Figures 2 and 3. Coverage of superfast broadband in 2007 and 2014.

Figure 1 also shows the change in SupB coverage between 2007 and 2014. The municipalities who used MPU's kept investing in SupB at a higher rate (change in coverage of about 24%) than most private providers (change of around 20% for SPEC, TeliaSonera and Other private). On the other hand, for municipalities using Teracom and CS IT the investments increased (increased coverage of around 23.5%). In Skåne the increase in fiber coverage in 2007-2014 was relatively low (19%). The large cities outstripped the rest of the country even more, and in 2007-2014 fiber coverage increased with 46%. However, the SPEC municipalities who had a head start did not have a particularly high investment pace in 2007-2014 (22%). Thus, there is a large variation in fiber coverage in 2007 that seems to be associated with the choice of provider; a variation that seems to grow somewhat larger in 2007-2014. Hence, the instrument predicts both a continued high investment rate in some municipalities (MPU) and a catching up in some municipalities (Teracom and CS IT). The SupB coverage in 2014 is shown in Figure 3.

3. Data

We use data on SupB accessibility matched with Statistic Sweden's business register. Telecom operators report on a yearly basis (to the PTS) all addresses where they supply a SupB connection. We use this information and if at least one building in a 250×250 m grid square has access to SupB the square is considered to have SupB access. To receive SupB at the SAMS level we calculate the share of squares within a SAMS area that are covered. That is, if SupB access is 50%, half of the squares in a SAMS are considered covered.[9]

Since the business register contains firm's location at the SAMS level we can merge this data to our broadband accessibility measure. The business register contains firms' financial records, e.g. sales, value added, investments and workers. We also match the business data with employee data (Longitudinal Integration Database for Health Insurance and Labour Market Studies, LISA), which includes e.g. age and education level of the workers.

If an SAMS area has a population density level of 25 or above the area is classified as an urban area; otherwise we classify it as rural. However, in the IV analysis, where between municipality variation is used, the classification has to be done at the municipality level. We use SKL's (Swedish Association of Local Authorities and Regions) classification of municipalities where a municipality is considered rural if the largest city is below 40,000 inhabitants. Importantly, both methods give a similar sample of firms (and therefore 25 as our population density decision rule).

We analyse a sample of non-governmental firms with only one workplace. For firms with two or several workplaces the financial records are reported at the aggregate firm level. We also remove firms that change location; for these firms the effect of moving cannot be separated from the change in broadband coverage. Finally, a mean sales (> SEK 100,000[10]) restriction is

[9]A small share of the 250×250 m grid square are reported to have lost its broadband access. This is probably due to measurement errors in the reporting.
[10]About €10,500.

applied to remove part-time business[11]. Given these restriction we have an yearly average of 296,330 urban firms and 128,122 rural firms.[12] In the IV analysis where we cannot exploit the entire panel (see section 4.2), the sample of firms is 29% smaller.

4. Empirical specification

This study uses two different identification strategies to estimate the effect of SupB on firms output. First we present a standard firm fixed effect model using the longitudinal variation in SupB accessibility at the SAMS level to estimate the SupB effect. Thereafter we present a cross-sectional instrumental variable approach that uses a presumed exogenous variation in municipalities' choice of broadband providers in the earlier roll-out of broadband in 2000-2007. As previously explained, the provider in the earlier roll-out largely determined the choice of preferred technology (DSL or optic fiber) and this also affected the subsequent roll-out of SupB in 2007-2014 (SOU, 2008).

4.1 Fixed effect model

The FE approach – commonly used by other studies - can be described as followed: for firm *i*, located in SAMS region *s*, broadband accessibility, SupB, affects firms outcome, *Y*, in period *t* as followed:

$$Y_{ist} = \alpha_i + \gamma_t + \beta SupB_{st} + C_{mt} + \delta_{m\times t}(M_m \times T) + \varepsilon_{ist} \qquad (1)$$

α_i and γ_t are firm and time fixed effects, respectively. We also control for municipality characteristics and yearly time dummies, $M\times T$, at the municipality level. Our SupB effect, β, is an intention-to-treat (ITT) estimate which refers to an analysis based on the probability of SupB access and not actual take-up of broadband. This implies that our SupB effect is an underestimated effect of average effect of treatment.

[11]A small number of business is also removed because either municipality or fiber is lacking.
[12]

4.2. Specifying an IV model for identifying an IV-fiber effect on firm outcomes

To fulfill the exclusion restriction the choice of provider has to be uncorrelated or independent of the outcome. This is not the case here, although Figure 3 indicates a seemingly arbitrary variation in SupB coverage over the country. Probably both regional and geographical dimensions determine the choice of provider and the consequent fiber strategy. For example, in more sparsely populated areas private providers are less motivated to tender offers. On the other hand, within a labour market (LA) region we argue that the choice of provider is exogenous. Figure 4 shows for Sweden the different providers (in colour) and the *LA* regions (with lines). From eye-balling the figure, a clear pattern in the distribution of providers cannot be detected within *LA* regions. We investigate this further after specifying the econometrical model. The following IV model is used for estimating our IV-fiber effect:

$$Y_{ist} - Y_{ist-7} = LA_n + \beta Pred(SupB_{mt} - SupB_{mt-7}) + \pi U_{mt} + \rho(C_{mt} - C_{mt-7}) + \varepsilon_{imt} \quad (2)$$

Without time variation in the instrument (the set of provider-dummies) a longitudinal panel model cannot be specified. Instead we estimate the change in firm's outcome between 2007 and 2014 on the predicted level of fiber in the municipality *m*. *LA* is a set of n=105-1 labour market fixed effects. We control for an urbanity gradient, Urb_{mt} (see below), and the change in municipality characteristics, $C_{mt} - C_{mt-7}$, between 2014 and 2007. The first stage relationship, where a set of *Provider* dummies predicts the change in $SupB$ between 2007 and 2014, is:

$$SupB_{mt} - SupB_{mt-7} = LA_n + \sigma_7 Provider_{t-14} + \pi Urb_{mt} + \rho(C_{mt} - C_{mt-7}) + \varepsilon_{imt} \quad (3)$$

The predicted level of fiber is imputed in equation (2). In 24% (9%) of the *LA* regions there are more than one (two) provider(s), covering 36% (103) of the municipalities; this margin estimates our IV-fiber effect.

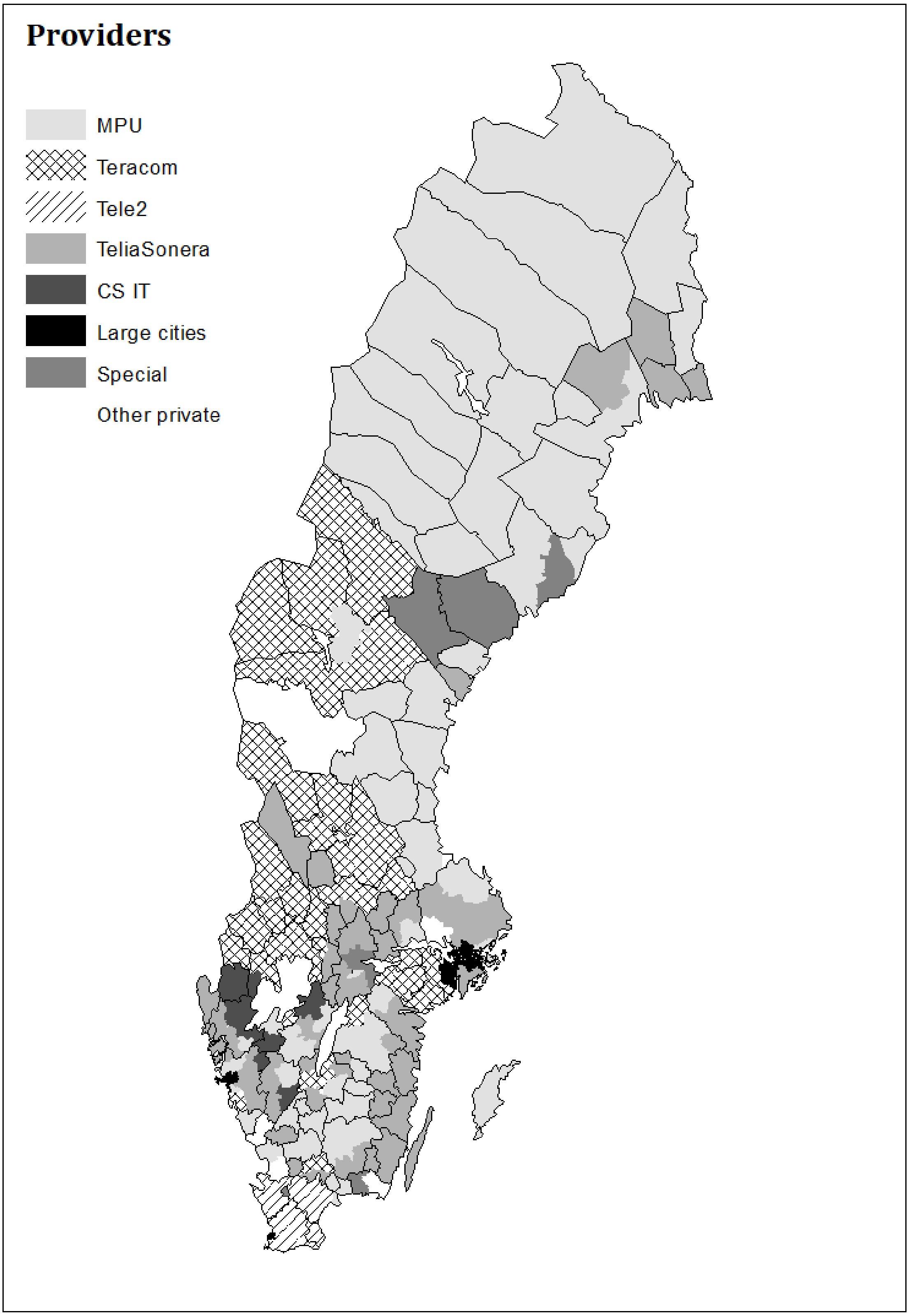


Figure 4. Providers of superfast broadband in 2000-2007. Lines show labour market regions.

In Table 1 we test with covariate balancing tests whether there are relationships between the different providers and pre-determined municipality characteristics (in 2007). The tests are executed using a *LA* fixed effect model so that it is the relevant covariate variation between municipalities that is scrutinized. This test shows, most importantly, that economical municipality characteristics: logarithmic income and employment level, are not associated to the choice of providers within *LA* regions. Only for TeliaSonera significant effects are found for the economical indicators, but these go in different direction (positive for logarithmic income and negative for employment). The overall finding is no clear relationship between the provider dummies and the covariates: we find almost the expected number of significant estimates (with 49 estimated coefficients, there should be around 5 significant estimates; we find 6). Thus, the providers do not seem to be sorted on urbanity or pre-determined municipality characteristics within *LA* regions. Nevertheless, we estimate a model where we include the urbanity measure and the change in covariates between 2007 and 2014 in our model.

Table 1. Covariate balancing tests of urbanity and pre-determined (in 2007) municipality characteristics.

	TeliaSonera	MPU	CS IT	Other private	Teracom	Tele 2	SPEC
Urbanity	-0.0250	0.0419	-0.00881	-0.00473	0.0248	-0.00886	-0.0301
	(0.0622)	(0.0455)	(0.0274)	(0.0257)	(0.0412)	(0.00947)	(0.0231)
Logarithmic income	0.837**	-0.371	-0.00279	-0.348	0.243	0.180	-0.135
	(0.399)	(0.413)	(0.106)	(0.415)	(0.476)	(0.198)	(0.128)
Employment	-0.0318*	0.00930	-0.00448	0.00515	0.00624	0.00467	-0.00318
	(0.0180)	(0.0208)	(0.00388)	(0.0170)	(0.0135)	(0.00478)	(0.0046)
Share with upper secondary education	0.0259	0.0751**	-0.0005	-0.0273	-0.0129	0.00343	0.00738
	(0.0331)	(0.0326)	(0.0145)	(0.0214)	(0.0196)	(0.0032)	(0.0086)
Share with a higher education	-0.00952	0.0106	-0.00811	-0.0002	0.00398	-0.0005	0.00687
	(0.0141)	(0.0141)	(0.00602)	(0.00451)	(0.00692)	(0.00232)	(0.00532)
Logarithmic population density	-0.140*	-0.0139	0.0182	0.00112	-0.0576*	-0.0243	-0.00601
	(0.0807)	(0.0519)	(0.0220)	(0.0158)	(0.0298)	(0.0202)	(0.00716)
Share of immigrants	0.00617	-0.0021	-0.0078**	9.08e-05	0.0102	0.000888	-0.00251
	(0.0222)	(0.0153)	(0.00369)	(0.00661)	(0.00869)	(0.00237)	(0.00299)

Notes: The dependent variables are the 7 provider dummies. The urbanity measure is an ordered variable where 1 is cities, 2 is areas closed to cities and 3 is rural areas. In each model we control for labour market fixed effects. Standard errors in parenthesis. ***Significant at 1% level. **Significant at 5% level. *Significant at 10% level.

Finally, we investigate the parallel trend assumption; hence whether the pre-treatment trends in outcomes for the treatment and control groups are similar. Thus, we examine if the trends in firms' logarithmic sales and employment level are similar for firms located in municipalities with different providers, who are assumed to differentiate in treatment. To get comparable scales that visualizes the trend before- and after 2007 we i) use the residual from a regression model where we estimate the outcomes on the LA fixed effects, and ii) divide the yearly outcomes for each group with the 2007 outcome. To decrease the number of time trends in the figure (otherwise it gets blurred) the private providers with a similar SupB coverage in 2007 are merged (TeliaSonera, CS IT, and other private providers). The metropolitan areas are, as in the econometrical analysis, removed.

Figures 5 and 6 shows that the trends are similar before and after 2007. Specifically for the groups Teracom, MPU and Private providers, who provide most of the variation to our SupB effect (combination of these providers are most often shared between LA), the trends are almost identical. Moreover, an impact of fiber is difficult to detect. The yearly variation in outcomes follows the business cycle closely. To sum up, the tests show that instrumenting broadband coverage on a set of provider dummies provides variation in internet coverage that is plausibly exogenous. Our IV-results therefore qualifies as causal results.

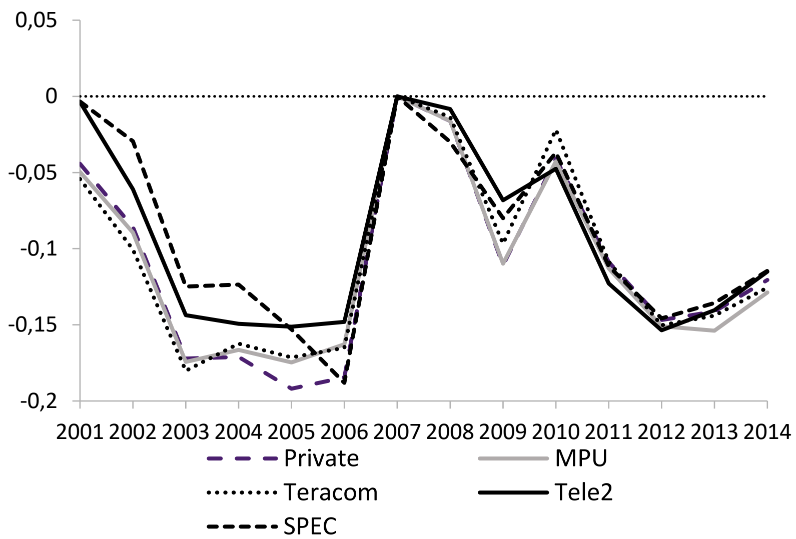


Figure 5. Parallel test for logarithmic sales.

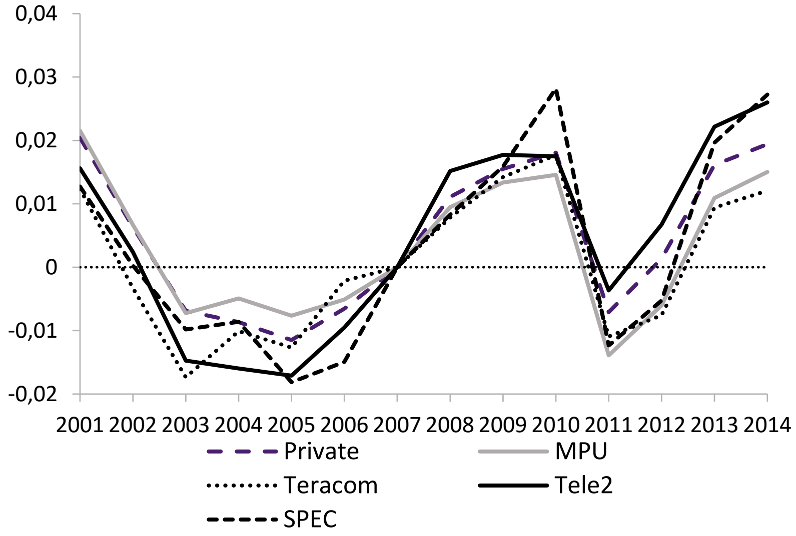


Figure 6. Parallel test for logarithmic employment.

5. Results

5.1 Fixed effect results

In Table 2, we first present FE regression results on sales and employment. In the most restrictive model (with municipality time dummies and covariates), the impact of fiber in urban areas is negative, -0.054 and -0.011 on sales and employment, respectively. For rural municipalities the impact on employment is positive. Disregarding that it is an ITT estimate, the impact of increasing coverage from 0 to 100% is about half of the decrease in firms sales caused by the Great crisis (see the change in sales between 2009-2007 in Figure 5). Adding municipality time dummies and covariates have no impact on the estimates in urban areas. In rural areas time dummies increase the positive impact on employment. The results are basically the same (see Table A1) if we use a higher mean income restriction (>SEK 500,000) or an employment restriction (>0[13] or ≥5 employees). Also, a constant sample provides the same results (not reported). The striking robustness in results, especially in urban areas, indicate exogenous variation in SupB. For a 10% increase in SupB coverage – a typical variation in

[13]Zero employed means an own-business without employees.

coverage between areas[14] – the effect translates to a decrease of 0.54% and 0.11% for sales and employment, respectively.

Table 2. Fixed effect results of the impact of SupB on sales and employment,

	Logarithmic sales		Logarithmic Employment	
	Urban	*Rural*	*Urban*	*Rural*
		Without municipality time dummies and covariates		
SupB	-0.0550***	0.00293	-0.00707***	0.00389
	(0.00776)	(0.0175)	(0.00218)	(0.00439)
		With covariates		
SupB	-0.0536***	0.00353	-0.00945***	0.00385
	(0.00782)	(0.0176)	(0.00226)	(0.00441)
		With municipality time dummies		
SupB	-0.0540***	-0.000643	-0.0113***	0.0101*
	(0.00935)	(0.0189)	(0.00274)	(0.00562)
		With municipality time dummies and covariates		
SupB	-0.0543***	-0.0016	-0.0112***	0.00979*
	(0.0094)	(0.0189)	(0.00274)	(0.00562)
Observations	2,275,147	1,122,331	2,275,147	1,122,331

Notes: The dependent variables are logarithmic sales and employment. Firm fixed are included in every specification. A national time trend is included when municipality time trends are left out. See Table 2 for the included covariates. Clustered (on municipality) standard errors in parenthesis. ***Significant at 1% level. **Significant at 5% level. *Significant at 10% level.

In Table A2 we report separate regression results for different industries. We find negative SupB effects for most industries. Largely negative (and often significant) for: Agriculture, Education, Finance, IT and Manufacturing, and small for: Transport, Commerce, Construction and Other. For, Arts, Hotel and restaurant and Health we find positive SupB effects. The positive effects are likely to be caused by an expansion of the market due to online consumer contacts. The cause of the negative effect is uncertain but in section 5.3 we propose a hypothesis that is supported with descriptive data.

5.2 IV results

Next we show the IV-result. Table 3[15] presents the IV-result for urban and rural areas, separately. Our set of instrument dummies provide a strong first-stage in urban areas: a

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[14]See e.g. Figure 1 where the SupB level is in 2014 around 42%, in municipalities where MPU is the provider, and around 32% in municipalities where either Teracom, Tele2 or Telia Sonera are providers.

[15]The first stage provider estimates are shown in Table A3. Note, for Tele2 in urban regions and SPEC in rural regions there is no provider variation at the LA level.

Kleibergen-Paap test statistics of around 30. In rural areas the weak test statistics is just barely strong, 13.[16] A rule of thumb is a weak IV-test statistic over 10.

Table 3. IV results of the impact of SupB on sales and employment when instrumenting broadband coverage with provider dummies.

	Logarithmic sales		Logarithmic Employment	
	Urban	*Rural*	*Urban*	*Rural*
		Without covariates		
SupB	-0.257***	0.225	-0.0569**	-0.172***
	(0.0717)	(0.272)	(0.0268)	(0.0566)
Weak IV-test	32.821	-	32.821	-
		With covariates		
SupB	-0.295***	0.235	-0.0697**	-0.247*
	(0.0792)	(0.348)	(0.0305)	(0.126)
Weak IV-test (Kleibergen-Paap)	26.106	13.152	26.106	13.152
Observations	117,754	87,455	117,754	87,455

Notes: The dependent variables are the change in logarithmic sales and employment between 2007 and 2014. SupB measures the change in superfast broadband coverage in 2007-2014. In the first-stage model SupB is instrumented with provider dummies in 2000-2007. Labour market fixed effect and an urbanity measure are included in every specification. See Table 2 for the included covariates. In the lower panel the change in covariates in 2007-2014 are included. Clustered (on labour market region) standard errors in parenthesis. ***Significant at 1% level. **Significant at 5% level. *Significant at 10% level.

For sales, and employment in urban regions, the IV SupB estimate is significant and large. For sales in rural regions the SupB estimate is imprecisely estimated. The covariates (see above) have no major impact on the estimates which indicates a fulfilled exclusion restriction. We also use two different classifications of LA region in Table A4. These LA are larger (73 and 60 LA regions[17], respectively) which therefore implies a less restrictive model. Except for a smaller SupB effect on employment the results are basically the same as for the more restrictive model with more LA regions. Finally, we estimate the effect for two different time periods (2007-2011 and 2010-2014) to analyse if the certain start and end years drives the results (see Table 4). Interestingly, in urban areas the SupB effect is clearly larger in the later time period. We return to this finding later.

[16]STATA report -ranktest error- when calculating weak test statistics for rural areas (without covariates).
[17]The first classification is the 2017 version of SCB's LA classification (we use the earlier version), and the second is the LA classification of the Swedish Agency for Growth Policy Analysis (also named functional regions).

Table 4. IV results of the impact of SupB on sales and employment for different time periods

	Logarithmic sales		Logarithmic Employment	
	Urban	*Rural*	*Urban*	*Rural*
			2007-2011	
SupB	-0.124	-0.448	-0.0719	0.0205
	(0.338)	(0.292)	(0.112)	(0.0808)
Weak IV-test	6.809	74.299	6.809	74.299
Observations	142,054	102,153	142,054	102,153
			2010-2014	
SupB	-0.262	0.147	-0.132**	0.0040
	(0.176)	(0.177)	(0.0564)	(0.0499)
Weak IV-test (Kleibergen-Paap)	11.324	15.676	11.324	15.766
Observations	113,805	84,425	114,645	84,994

Notes: The dependent variables are the change in logarithmic sales and employment in 2007-2011 and 2010-2014. SupB measures the change in superfast broadband coverage in 2007-2011 and 2010-2014. In the first-stage model SupB is instrumented with provider dummies in 2000-2007. Labour market fixed effect and an urbanity measure are included in every specification. Clustered (on labour market region) standard errors in parenthesis. ***Significant at 1% level. **Significant at 5% level. *Significant at 10% level.

The most important finding is that the IV model supports the sign of the FE model. Nonetheless, the substantial (about five times larger) difference in size of the SupB effect between the models has to be discussed and explored. First, IV point estimated has to be approached with caution, and secondly, a larger IV-effect is expected since the FE-effect is most likely biased in a positive direction because of a reversed link from economic growth to broadband roll-out. A third explanation, specific to our case, is the choice of models. A difference is that the IV model uses SupB variation between municipalities and the FE model uses SupB variation between SAMS areas. We analyse the importance of this by estimating a similar first-difference model as the IV-model but without instrumenting broadband coverage. Therefore we can use the same margin as the FE model, between SAMS variation (within a municipality) in broadband coverage, to estimate the SupB effect[18]. Equation (4) describes this model:

$$Y_{ist} - Y_{ist-7} = M_m + \beta(SupB_{st} - SupB_{st-7}) + \varepsilon_{imt} \quad (4)$$

[18] In contrast to the *firm* FE model, this model do not include firm FE, but by first differing the variables in (4) we capture the firm FE, and with the municipality FE we capture common changes at the municipality level (similar to the municipality time trends). Also, even if the specific start- and end years have a general impact on the results it is not causing the difference in result between the firm FE model and the municipality FE model. Another difference is that we estimate a growth model when first differing logarithmic outcomes, but even if this is conceptually important the impact on the size of the estimates is marginal.

where M_m are municipality fixed effects. The SupB effects from this model (see Table A5) are more similar to the *firm* FE-model than the IV-model. Thus, different margins between the models seem to have some impact on the results. A plausible explanation (to the stronger link between firm performance and SupB on the municipality level than the SAMS level) is that important variation in SupB takes place at a higher level than the SAMS level. In the next section we propose an explanation to this finding.

5.3 What causes the negative effect?

Hence, both models (FE and IV) indicate a negative effect of SupB on firms sales and employment in urban areas. In rural areas the results are inconclusive for employment: the FE model show a positive effect whereas the IV-model shows a negative effect. As a next step we try to investigate the potential mechanism. Although, the FE model may provide underestimated effects we need the precision of this model for slicing up the sample further. Also, we prefer to pursue with the most conservative results.

Our results differ from the literature. A mentioned earlier, this may be caused by the choice of period. A later period implies that internet has a much broader impact on our lives than before. For most people internet is always in reach, and our smartphones draw constantly attention. In line with this the IV-approach indicated larger effects in 2010-2014 than in 2007-2011. By studying three year periods where we let the period move forward by one year at the time, we analyse the time variation in effect with the FE model. The result is shown in Figure 7[19]. In 2007-2010 the effects are small, positive and insignificant, but in later periods the effects turn, large, negative and significant. There is clearly a cut-off point around 2010-2011.

[19]We choose not to divide the result on urban/rural areas because it has no major impact on the results.

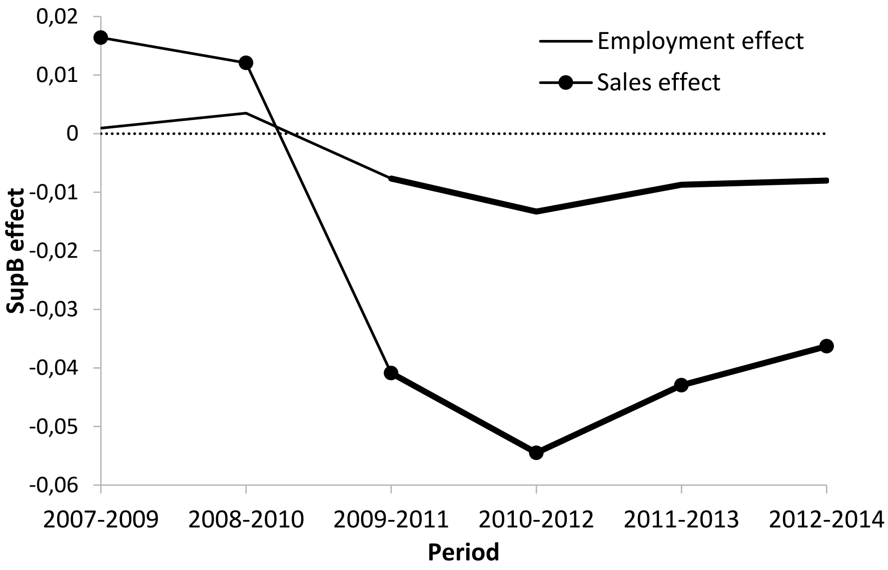

Figure 7. The effect of superfast broadband (SupB) on logarithmic sales and employment for different time periods (estimated from a firm FE model). Thick lines represent significant effects (at least at the 5%-level).

So what happens in 2011? The main technological shift related to broadband is the rollout of LTE 4G mobile broadband beginning in 2011. LTE 4G is the first mobile broadband designed specifically for data traffic and is able to transmit large amount of data. Already in 2011 the LTE 4G coverage was 48% and in 2012 the coverage reached 92% (PTS, 2015). The first smartphones using LTE 4G technology came in 2012.

If the negative impact on firms' outcomes is caused by distractions from internet and smartphones it is important to determine the main consumer of internet at the workplace. In a report (Davidsson et al., 2018) investigating the internet consumption in Sweden, it is shown that the use of internet at the workplace vary with industry. In Figure 8 we show the share using internet at work daily in each industry (y-axis)[20] and the SupB effects on sales and employment in different industries (x-axis). The reported SupB effects are from Table A2, but the industries has to be surveyed in Davidsson et al. (2018) also, which e.g. agriculture is not. A clear relationship is found between the share using internet at work daily and the SupB effect: a high use of internet at the workplace implies a larger negative impact from broadband coverage.

[20]In the figure we include the industries in the report. However, we exclude firms in arts for which there are to fem firms to estimate regressions reliably (only 113 observations).

Similar results is found in Figure 9 where we relate the SupB effect to the share mixing private and work related internet use. Scrutinizing the effect for different industries shows positive effects in the restaurant- and hotel (significant on sales) and the health industry where the use of internet is particularly low. A high internet use in finance, IT and Education are associated with negative broadband effects.

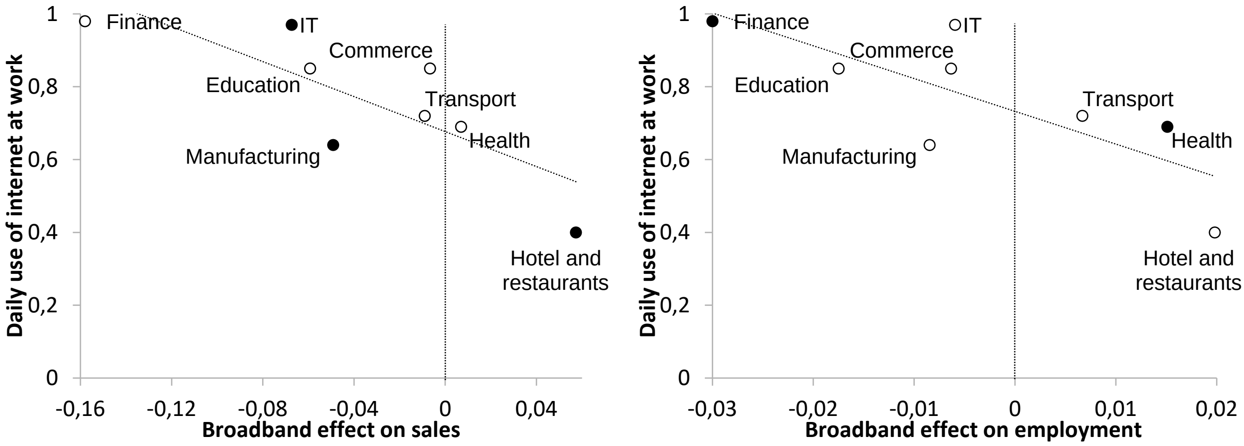

Figure 8. The relationship between the daily use of internet at work in the industry and the superfast broadband (SupB) effect in the industry.

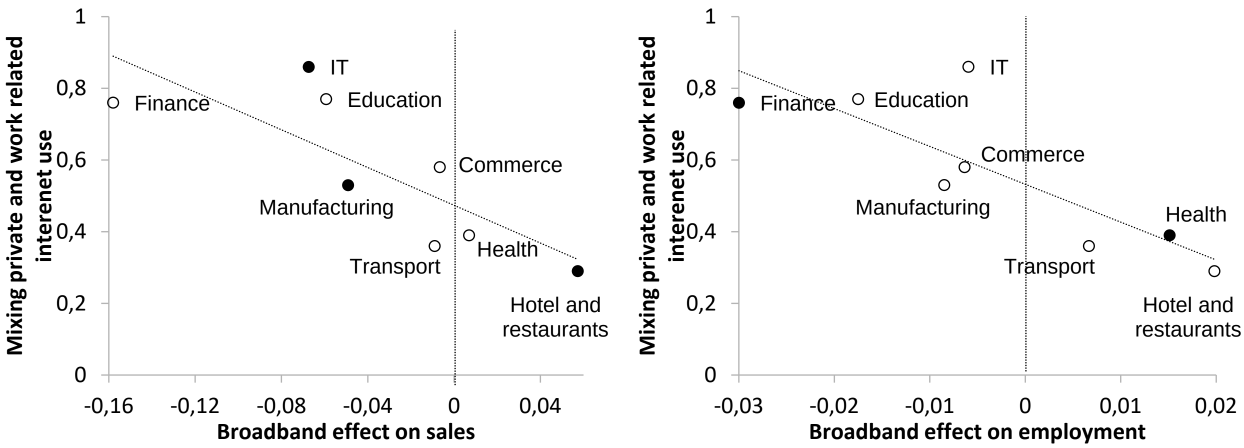

Figure 9. The relationship between the share mixing private and work related internet use in the industry and the superfast broadband (SupB) effect in the industry (filled markers represent significant effects).

Also, according to the report 90% of the university educated uses internet at work daily. Among individuals with an upper secondary or compulsory education the shares are only 65% and 50%, respectively. Moreover, it is also more common for high educated to use internet for private matters at work. The hypothesis is thus that the negative impact of broadband is larger in higher educated firms. In Figure 10 we analyse this by including separate SupB variables for firms with mainly: i) PhDs, ii) individuals with a long university education, iii) individuals with a short university education, iv) individuals with a upper-secondary education, and v) individuals with a short upper-secondary education or a compulsory education. We also control for the share of each education category, mean age of workforce at the firm and an interaction between broadband coverage and mean age at the firm. For firms above the lowest education category, Figure 8 reports a decreasing relationship between the SupB effect and the main education level at the firm. Thus, generally the internet use of different educational groups is related to the SupB effect. The exception, the negative effect for the lowest education category, may be explained by the skill-bias hypothesis; for low-skilled IT technology is negative.

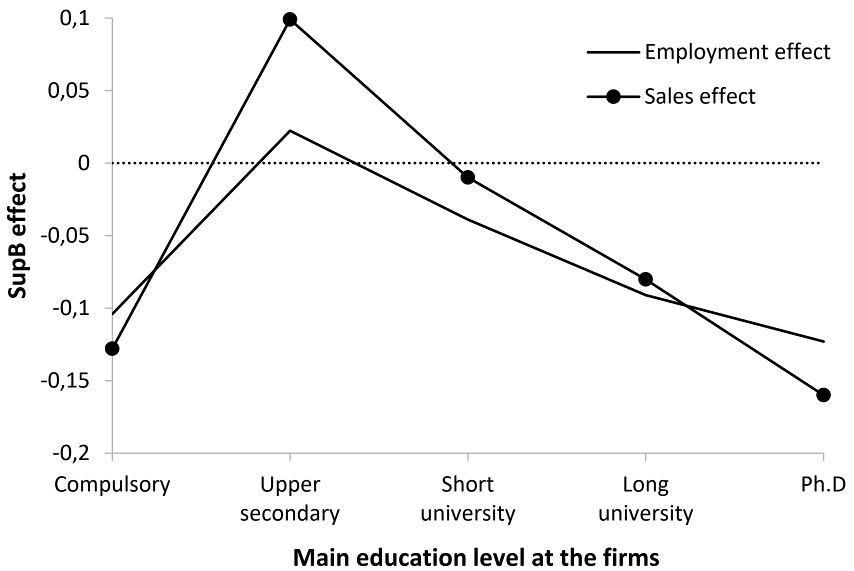

Figure 10. The effect of superfast broadband (SupB) on logarithmic sales and employment for firms with different (main) education level. (estimated from a firm FE model). All estimates besides the sales effect for upper secondary are significant (at 1%-level).

To sum up, the result suggests that (mainly) mobile internet use affects us broadly, both at home and at the work, and this may have a negative impact on firm sales and employment level. Because SupB coverage at the municipality level seems to capture this effect better than SupB coverage at the SAMS level, it agrees with the explanation; SupB coverage at the workplace does not fully capture internet accessibility at home, the shop, the playground or anywhere else where we let our smartphones distract us. Coverage at the municipality level is better in capturing this wider accessibility. Also, since the negative effect is not found in rural areas – where mobile coverage is, generally, very poor – it backs up the explanation.

6. Conclusion

The main result of this study is that we have established a robust negative correlation between the rolling out broadband and firm performance in urban areas, and our instrumental variable approach suggests that this link is causal. Although this relationship was surprising and to some extent contradicts other similar studies on other countries and time periods, it is in line with mechanisms such as the possibility that time on social media crowds-out work time.

Our negative relationship was also strongest during a time when the use of smartphones took off and it was particular pronounced in service sectors in which it was more likely to mix work and private internet time. Thus, since we cannot separate between wired and mobile broadband, our study captures the total impact of internet use on firm outcomes. That is, the cause is not, necessarily, tied to the workplace. Instead, negative impacts of overall internet use may drive our results. Also, the effect is not found in rural areas where mobile coverage is very poor.

Connecting to others is essential; social interactions and stimuli cause activity in the brain's reward system. However, the motivation to engage in social connections may lead us astray. Social networking on internet − the number one activity on the web – seem to have a positive effects for our social lives but it also implies a constant stimuli of our social reward system (see Tamir and Ward (2014) for an overview). A British report (Ofcom, 2018) finds that 20% of people spend 40 hours a week on line and say life would be "boring" without the internet. This behavior may affect our cognitive resources and cause sleeping disorder and mental ill-health. Our view is that internet and smartphones is likely to cause distraction at workplaces, and it is likely that these distractions have some consequences on firm performance; this should not be controversial. The controversial suggestion is that this negative cause is, substantially, larger than the potential positive impact found in most other studies.

However, it is far from certain that this mechanism is the sole one that explains our negative impact of broadband on firms' sales and employment, and we find positive effects for industries, and relatively low-skilled firms, with a low use of internet at work. These firms, e.g. hotels and restaurants, are also the most likely to benefit from an expansion of the market due to online consumer contacts

That said, we would like to raise some caveats regarding the causal link since it depends on whether the instrument is detached from other factors influencing firm performance. The geographical pattern of our instrument, due to its time invariant characteristic, may correlate with other long-run trends such as infrastructure investment, agglomeration of economic activity and the increased importance, concentration and internationalization of services. These mechanisms are however outside the scope of this study, and we therefore leave these additional explanations behind our negative relationship for future studies.

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Appendix

Table A1. Fixed effect results of the impact of SupB on sales and employment when using different restrictions on sales and employment.

	Logarithmic sales		Logarithmic Employment	
	Urban	*Rural*	*Urban*	*Rural*
			Sales>500,000	
SupB	-0.0678***	0.0084	-0.0145***	0.0122
	(0.0110)	(0.0246)	(0.0044)	(0.0098)
Observations	1,347,250	585,028	1,347,250	585,028
			Employment>0	
SupB	-0.0645***	-0.0400	-0.0270***	0.0175
	(0.0102)	(0.0244)	(0.00496)	(0.0134)
Observations	848,164	294,192	848,164	294,192
			Employment>4	
SupB	-0.0348***	-0.0178	-0.0201**	0.00102
	(0.0129)	(0.0279)	(0.00845)	(0.0230)
Observations	255,796	90,840	255,796	90,840

Notes: The dependent variables are logarithmic sales and employment. Firm fixed effects and time dummies at the municipality level are included in every specification. Clustered (on municipality) standard errors in parenthesis. ***Significant at 1% level. **Significant at 5% level. *Significant at 10% level.

Table A2. Fixed effect results of the impact of SupB on sales and employmentfor different industries.

	Logartitmic sales		Employment		
	Effect	Standard error	Effect	Standard error	**Observations**
Agriculture	-0,0403**	(0,0203)	-0,0065*	(0,0034)	662,824
Manufacturing	-0,0492**	(0,0227)	-0,0085	(0,0078)	229,082
Construction	-0,0124	(0,0177)	-0,0021	(0,0067)	344,394
Commerce	-0,0067	(0,018)	-0,0064	(0,0055)	422,512
Transport	-0,0090	(0,0303)	0,00667	(0,0140)	115,294
Hotel and restaurant	0,0573**	(0,0276)	0,0198	(0,0172)	114,901
Finance	-0,1580	(0,4410)	-0,310***	(0,0849)	1,872
Arts	0,6780	(0,5750)	0,269	(0,2400)	116
IT	-0,0674**	(0,0334)	-0,0060	(0,0085)	128,801
Education	-0,0593	(0,0373)	-0,0175	(0,0123)	57,835
Health	0,0069	(0,0301)	0,0151*	(0,0091)	102,342
Other	-0,0006	(0,0166)	0,0015	(0,0041)	280,724

Notes: The dependent variables are logarithmic sales and employment. Each effect is from a separate regression. Firm fixed effects and a national time trend are included in every specification. Clustered (on municipality) standard errors in parenthesis. ***Significant at 1% level. **Significant at 5% level. *Significant at 10% level.

Table A3. First-stage estimates of provider dummies on superfast broadband (SupB).

	Without covariates		With covariates	
	Urban	*Rural*	*Urban*	*Rural*
MPU	0.177***	0.179	0.164***	0.169***
	(0.0161)		(0.0173)	(0.0300)
Teracom	0.179***	0.0897	0.160***	0.0908
	(0.0343)	(0.0860)	(0.0403)	(0.0831)
Tele 2	-	0.221	-	0.208***
				(0.0271)
SPEC	0.163***	-	0.113***	-
	(0.0415)		(0.0371)	
TeliaSonera	0.162***	0.125	0.151***	0.144
	(0.0191)	(0.0847)	(0.0199)	(0.0872)
Other private	0.218***	0.131	0.222***	0.121
	(0.0600)	(0.0995)	(0.0625)	(0.0889)
Observations	117,754	87,457	117,749	87,452

Notes: The dependent variable is SupB. LA fixed effects and an urban gradient are included in every specification. Telia Sonera is the provider reference category. See Table 2 for the included covariates. Clustered (on municipality) standard errors in parenthesis. ***Significant at 1% level. **Significant at 5% level. *Significant at 10% level.

Table A4. IV results of the impact of SupB on sales and employment when instrumenting broadband coverage with provider dummies.

	Logarithmic sales		Logarithmic Employment	
	Urban	*Rural*	*Urban*	*Rural*
		Labour market regions in 2017 (N=73)		
SupB	-0.357**	0.307	-0.0528*	-0.0767
	(0.150)	(0.258)	(0.0304)	(0.0509)
Weak IV-test	14.345		14.345	
		Functional regions (n=60)		
SupB	-0.311**	0.170	-0.0371	-0.0761
	(0.139)	(0.233)	(0.0424)	(0.0626)
Weak IV-test (Kleibergen-Paap)	10.168		10.168	
Observations	117,754	87,455	117,754	87,455

Notes: The dependent variables are the change in logarithmic sales and employment between 2007 and 2014. SupB measures the change in superfast broadband coverage in 2007-2014. In the first-stage model SupB is instrumented with provider dummies in 2000-200. Labour market fixed effect and an urbanity measure are included in every specification. Clustered (on labour market region) standard errors in parenthesis. ***Significant at 1% level. **Significant at 5% level. *Significant at 10% level.

Table A5. Municipality fixed effect model.

	Logarithmic sales		Logarithmic Employment	
	Urban	*Rural*	*Urban*	*Rural*
SupB	-0.112***	-0.0132***	0.0243	0.0196
	(0.0168)	(0.0043)	(0.0432)	(0.0094)
Observations	163,023	163,023	99,335	99,335

Notes: The dependent variables are the change in logarithmic sales and employment in 2007-2014. SupB measures the change in superfast broadband coverage in 2007-2014. Municipality fixed effects are included in every specification. Clustered (on municipality) standard errors in parenthesis. ***Significant at 1% level. **Significant at 5% level. *Significant at 10% level.

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