Impact of high-speed broadband access on local establishment dynamics

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Abstract

The aim of this study is to examine the relationship between high-speed fibre broadband access and establishment dynamics at the municipality level. Special emphasis is placed on micro as well as on small and medium-sized establishments in contracting areas. Data cover information on 290 municipalities in Sweden for the period 2010-2018. Results of Fixed Effects and Spatial Durbin models reveal a significant but rather small direct effect of lagged high-speed broadband access, driven by the micro establishments. However, when the proportion of establishments with high-speed broadband access is combined with the local presence of university educated employees and researchers, a stronger indirect relationship appears. There is also some evidence that the broadband availability in neighbouring municipalities has a spillover effect. A high degree of heterogeneity is found in the results, where the relationship is far weaker in contracting municipalities and in those with a low-skilled workforce.

JEL: L25, O30

Keywords: high-speed broadband access, high-skilled employees, municipalities, Sweden, Spatial econometric models.

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1. Introduction

While there is rich evidence that broadband infrastructure investments relate positively to economic outcomes at the aggregate level, their quality is less investigated (Kongaut and Bohlin, 2017; Briglauer and Gugler, 2018; Abrardi and Cambini, 2019; Vu, Hanafizadeh and Bohlin, 2020). There is also mixed evidence of effects on firms and regions (Holt and Jamison, 2009; Grimes, Ren and Stevens, 2012; Hagsten, 2016; Haller and Lyons, 2019; see also Bertschek et al., 2015; Draca, Martin and Sanchis-Guarner, 2018, for literature reviews). High-speed broadband access may enable access to or delivery of new internet contents, applications and services (such as e-commerce and e-learning) as well as a more efficient organisation of production activities (Bertschek and Kaiser, 2004, for instance), and thus are indispensable for firm growth and business competitiveness (European Court of Auditors, 2018). By some, broadband access is even considered an all-purpose technology that permits better communication and improved connectivity (Majumdar, Carare and Chang, 2010). Although Briglauer et al. (2019) consider broadband access as a measure to combat depopulation and Ivus and Boland (2015) find that broadband can offset location as a barrier to growth, literature does not give a clear picture of impacts on establishment dynamics across size classes in expanding or contracting regions, that is, those with an increasing or a decreasing population.

This study aims to investigate the relationship between high-speed broadband access and establishment dynamics, based on detailed official municipality-level data for Sweden. Particular attention is paid to micro, small and medium-sized establishments and those in contracting municipalities. Estimations are performed by use of standard Fixed Effects as well as by spatial econometric models. The latter is meant to control for possible inter-regional spillover effects of the high-speed broadband access.

As opposed to common studies on regional effects of broadband access, this analysis does not only take into account the possible impact on overall establishment dynamics, but also

investigates the relationships for micro establishments. By using information on establishments (workplaces) instead of firms, there is a guarantee that the presumptive effects can be tied to the local area in question, since an establishment is geographically, not legally defined. This means that issues related to ownership, mergers and acquisitions do not affect the analysis. Another advantage of the study is the exploration of both direct and indirect effects of high-speed broadband access for expanding as well as contracting municipalities. By using this distinction, assumptions about rural areas, for instance, as automatically having certain characteristics, can be avoided. Finally, the broadband variable relates to the establishment access to modern fibre technology of a minimum speed, something which is rarely used in literature.

The study is structured as follows: Section 2 introduces the conceptual background, Section 3 presents the empirical model while Section 4 describes the dataset. The empirical results are revealed in Section 5 and Section 6 concludes.

2. Conceptual background

There are several studies on the impact of broadband access at the regional level although a strong focus is held on employment (Kolko, 2012, Atasoy 2013; Whitacre, Gallardo and Strover, 2014; Ford, 2018, for instance) rather than on firm dynamics or performance (Audretsch, Heger and Veith, 2015; McCoy et al., 2018; Canzian, Poy and Schuller, 2019; Hasbi, 2020). Most likely, this relates to issues with data deficits or availability. Studies on the regional performance of firms requires operational data for each local establishment, linked to local broadband internet supply, something which is not always at disposal.

Numerous studies on the link between broadband access and regional employment growth are based on data for North America. Some find clear significant correlations between local broadband coverage, defined by speed, and employment growth (Kolko, 2012; Atasoy, 2013),

while others report no positive impact on jobs from the availability of broadband or from a speed upgrade (Whitacre et al., 2014; Ford, 2018). Deployment of broadband in Canada is found to promote rural wage growth and employment in services, but not in manufacturing industries (Ivus and Boland, 2015). Results of studies on European data appear to show similar heterogeneity. According to Stockinger (2019), access to the first generation of broadband (DSL) decreases employment growth in certain industries and areas but in others not. Briglauer et al. (2019) evaluate the impact of a state aid programme on broadband deployment in Bavaria, Germany, and demonstrate that extended coverage of broadband raises the number of persons employed living in the aid-receiving area, although the number of employees are unaffected. Carthy and Lyons (2019) pursue a relationship between broadband access and local employment growth in Irish firms, without success, even when educational attainment is taken into account. Opposite results for the United Kingdom are found by DeStefano et al. (2018), where broadband infrastructure to some extent affects firm size when region is controlled for.

Not only studies on the relationship between regional employment and broadband access, but also those investigating the association with performance render mixed results. De Stefano et al. (2014) discover that broadband access in rural areas in the United Kingdom does not relate to firm performance, while productivity effects are found in a study on the region of Trento in Italy (Canzian, Poy and Schuller, 2019). Another study on Brazilian data reports positive productivity effects from access to broadband of a certain speed, although there is a variation across regions, where the least productive ones gain the most (Jung and Lopez-Bazo, 2020). Mack and Faggian (2013) show that broadband internet only has a positive impact on productivity in the United States areas with high levels of human capital or skilled occupations. What is more, in an analysis of the Cardiff-city region, Jones and Henderson (2019) conclude that productive impacts of broadband technologies are contingent on factors such as firm size, sector and human capital.

Literature investigating the impact of broadband access on the number of firms or business start-ups is increasing, although evidence based on detailed establishment data are scarce. Tranos and Mack (2016) demonstrate that a good broadband internet infrastructure leads to an increase in the number of knowledge-intensive service firms in the same country. There is, however, also evidence of spatial heterogeneity in the relationship between firm formation and broadband access in certain regions in the United States (Parajuli and Haynes, 2015). According to Kim and Orazem (2017) broadband access is positively and significantly related to the location choice of new firms in the United States rural areas, although the effect varies with agglomeration. Similar effects for urban regions outside the capital city in Ireland are found by McCoy et al. (2018), who demonstrate that broadband access is a determinant of the location of new business establishments and that this effect is larger in areas with higher educational attainments.

There is also evidence that areas with high-speed broadband access in France is more attractive for new firms, especially in combination with a certain level of education of the local population (Hasbi, 2020). Audretsch et al. (2015) follow suit and conclude that start-up activities in Germany are particularly enhanced by specific infrastructures, such as broadband. A review of 16 studies for the United Kingdom concludes that the expansion of broadband infrastructure in an area may have a positive impact not only on the number of firms, but also on firm productivity and employment (What Works Centre for Local Economic Growth, 2015). However, these presumptive effects vary across industries and depend on the skills level of the employees as well as on other complementary investments such as on-the-job training, re-organisation and new sales systems and strategies.

Needless to say, broadband access is not the only factor that might affect the dynamics of firms in specific regions. Armington and Acs (2002), report that industry intensity, population growth, income growth and the proportion of colleague graduates are crucial factors while

Delfmann et al. (2014) demonstrate that there is a relationship between firm formation and population change. Audretsch, Lehmann and Warnings (2005) show that the number of firms located close to a university is positively affected by the knowledge capital of the region as well as the output of the university and Audretsch et al. (2015) conclude that different kinds of infrastructure are relevant, even if broadband is the most crucial one. McCoy et al. (2018) confirm that most studies only encompass partial factors of importance for regional business count and make an attempt to provide a remedy to this by including physical infrastructure, agglomeration, human capital and unemployment as controls besides broadband in their estimations. Still, local investments are not mentioned, but Bennett (2019), for instance, finds that public investments tend to impede new businesses while private investments do not.

Thus, literature reveals ambiguous results on the relationship between regional growth in general and broadband access but is somewhat more consistent when it comes to firm formation. Part of the differences could be explained by variations in time periods studied, measures of broadband access and estimation methods used. Still, the importance of skilled human capital appears to be a consistent theme running through several of the studies in that it makes regions more attractive for firms and that it complements advanced technological infrastructure (high-speed broadband access, for instance). There are also indications that the broadband infrastructure benefits the economy differently due to the local context such as population change and knowledge capital in general. The local investment climate may also be related to the attractiveness of a region for firms.

Although this analysis is based on a deeper level of detail than is commonly investigated (establishment instead of firm), an assumption is made that expectations of general relationships outlined in literature are still valid. Consequently, a direct relationship between high-speed broadband access and establishment dynamics is expected to occur when other regional characteristics such as innovativeness, public investments, human capital and population

change are taken into account. The relationship may also appear indirectly if there is a complementarity between broadband access and skills, for instance, or if the establishments are dependent on the number of firms or broadband access among neighbours, collaborators or affiliates. Declining municipalities could exhibit a different pattern than growing ones.

Due to the mixed modes for financing of fast broadband roll-out in Sweden; private, private-public or public (Swedish Post and Telecom Authority, PTS, 2019), the analysis by-pass factors of importance for adoption and focuses directly on impact of access.

Empirical approach

Literature reveals a variety of approaches to study the link between broadband access and regional dynamics, such as count data models (McCoy et al., 2018; Hasbi, 2020) difference-in-differences methods (Ford, 2018; Briglauer et al., 2019; Canzian, Poy and Schuller, 2019), labour demand (Ivus and Boland, 2015) or production functions (Jung and Lopez-Bazo, 2020). In this study, the establishment dynamics *Y* is modelled as a function of high-speed broadband access, presence of inhabitants with tertiary university or research degrees, public investments at the municipal level and number of patents. Presumptive indirect effects of the high-speed broadband are investigated by interaction terms for the two skills variables and by spatial regressions. Thus, the following specification can be estimated by the static Fixed Effects model for each size class:

$$LnY_{sit} = \beta_{1s} HighspeedBB_{it} + \beta_{2s} SH\_Unigraduates_{it} +$$
$$\beta_{3s} SH\_Uniresarchgraduates_{it} + \beta_{4s} HighspeedBB_{it} * SH\_Unigraduates_{it} +$$
$$+\beta_{5s} HighspeedBB_{it} * SH\_Uniresearchgraduates_{it} + \beta_{6s} \ln (PublicInvestment)_{it} +$$
$$\beta_{7s} Patents_{it} + \theta_{ts} + \alpha_{is} + \varepsilon_{its}, \quad (1)$$

where *i*=1,..,290 municipalities, *t*=2010,..2018, *s* stands for the total number of establishments or four different size classes (0, 1-9, 10-49 or 50-249 employees) and *ln( )* is the natural

logarithm. The dependent variable *Y* represents the number of establishments and the broadband infrastructure variable, *HighspeedBB,* is measured as the proportion of workplaces (establishments) in the municipality with broadband access nearby. Skills is illustrated by the proportion of the local population with higher educational achievements; $SH\_Unigraduates$ and $SH\_Uniresearchgraduates$. Variables *PublicInvestments* and *Patents* indicate the level of public investments and innovativeness, the latter measured as the number of patents in the municipality, θ_{ts} encompasses time dummies, α_{is} denotes the municipality fixed effects and ε_{is} is the error term. Establishment dynamics may not only depend on the broadband access within the local administrative domain but could as well relate to the status in neighbouring municipalities due to backward and forward interactions among establishments. To allow geographical spillover effects of high-speed broadband access the spatial Durbin Model (SDM) is employed (Elhorst, 2010, Belotti, Hughes, and Mortari, 2017):

$$LnY_{sit} = \tilde{\rho}_s WLnY_{it}^S + \tilde{\beta}_{1s} HighspeedBB_{it} + \tilde{\beta}_{2s} WHighspeedBB_{it} + Z_{1it}\tilde{\beta}_{3s} + \tilde{\theta}_{ts} + \tilde{\alpha}_{is} + \upsilon_{its} \quad , \qquad (2)$$

where *W* is the spatial weight matrix based on the geographical distance between one core district of a municipality to another. The term $\tilde{\alpha}_{is}$ represents the time-invariant regional fixed effects, $\tilde{\theta}_{ts}$ corresponds to the time dummy variables, and the vector Z_{1it} contains the same control variables as in Specification 1. Parameters $\tilde{\beta}_{1s}$ and $\tilde{\beta}_{2s}$ measure the direct as well as the indirect relationship between high-speed broadband access and the number of establishments, the latter reflecting the status in the neighbouring municipalities. The extent to which the dynamics is dependent on the number of establishments in the neighbouring municipalities is indicated by parameter $\tilde{\rho}_s$.

In order to include interaction terms, a generalised version of the spatial autoregressive model with spatially autocorrelated errors (SAC) is also used:

$$LnY_{sit} = \tilde{\tilde{\rho}}_s WLnY_{it}^S + \tilde{\tilde{\beta}}_{1s} HighspeedBB_{it} + \tilde{\beta}_{2s} SH\_Unigraduates_{it} +$$

$$\tilde{\beta}_{3s} SH\_Uniresarchgraduates_{it} + \tilde{\beta}_{4s} HighspeedBB_{it} * SH\_Unigraduates +$$

$$+\tilde{\beta}_{5s} HighspeedBB_{it} * SH\_Uniresearchgraduates_{it} + Z_{2it}\tilde{\tilde{\beta}}_{2s} + \tilde{\tilde{\theta}}_{ts} + \tilde{\tilde{\alpha}}_{is} + \tilde{\tilde{v}}_{its}, \quad (3)$$

$$v_{its} = \lambda_s W v_{its} + \tilde{\varepsilon}_{is}.$$

All specifications are estimated separately by size-class as well as for the total number of establishments. Issues related to possible time-delayed reactions to the high-speed broadband access are captured by the lagged level of this variable in all models.

Although the study relies on the main assumption that broadband access, as opposed to adoption, is exogenous (Haller and Lyons, 2019, for instance), the presence of endogeneity cannot be neglected. Because of this, one of the robustness checks will introduce a system GMM estimation of the baseline model where high-speed broadband access is treated as predetermined.

Data and stylised facts

This analysis uses a database that consists of detailed information from official sources on establishments, educational achievements, public investments, patents, population and high-speed broadband access for all 290 Swedish municipalities during the period 2010-2018. The dependent variable is the total number of establishments or four different size-classes (0, 1-9, 10-49 or 50-249 employees) based on data from RAPS (a regional database held by Statistics Sweden and the Swedish Agency for Economic and Regional Growth, https://tillvaxtverket.se/statistik/regional-utveckling/regionalt-analys-och-prognossystem-raps/raps---ris.html). Although the untransformed series are strongly skewed, where only a few municipalities have a large number of establishments, the standard normal distribution is a good approximation when the data are transformed to the natural logarithm (Appendix, Figure A1).

Data on fibre broadband supply, defined as the proportion of workplaces (establishments) with access to a minimum speed of 100mbit/second within 250 metres, originate from the Swedish Post and Telecom Authority (https://statistik.pts.se/mobiltaeckning-och-bredband/statistik/). A region is considered contracting if the average population change over the period of time studied is decreasing. These calculations are based on population data from Statistics Sweden (http://www.statistikdatabasen.scb.se/pxweb/sv/ssd/START__BE__BE0101__BE0101A/BefolkningNy/X). Statistics Sweden also holds the education register of the population (https://www.statistikdatabasen.scb.se/pxweb/sv/ssd/START__UF__UF0506/UtbBefRegionR/). Information on public investments at the municipal level is received from Kommunivest of Sweden (https://kommuninvest.se/en/) and patent data by municipality originate from the Swedish Patent Office (https://www.prv.se/en/). Swedish support regions are regulated by law: Zone A regions are those most highly eligible for support and these areas are mainly found in the middle and north of Sweden, except some coastal areas (Regulation SFS 1999:1382).

The spatial weight matrix is calculated using the Haversine distance measure between geographical coordinates, where calculations of latitudes and longitudes for the core district of the municipality is based on information from Google maps (Drukker et al., 2013). The Stata command *spmat* is applied as well as non-truncated and truncated distance matrixes with a cut-off point of 100 kilometres.

On average, there are 4193 establishments over municipality and time included in the analysis, with almost 70 percent having no and a quarter 1-9 employees (Table 1).[1] The proportion of establishment with access to high-speed broadband nearby is 45 per cent on average with a wide variation. Slightly more than one fourth of the workforce (16-74 years) has a tertiary degree (three or four years) and the proportion of university research graduates is 0.5 per cent.

[1] Most micro firms (0-10 employees) have one establishment, while some small and medium-sized firms have several (https://www.scb.se/vara-tjanster/foretagsregistret/aktuell-statistik-fran-foretagsregistret/).

Table 1: Descriptive statistics Swedish municipalities

	All municipalities					
	Observations	Mean	Median	Std. Dev.	Min	Max
Number of establishments	2610	4193	2239	9997	342	165970
Number of establishments 0 employees	2610	2880	1619	6484	228	105647
Number of establishments 1t9 employees	2610	1037	465	2788	75	48426
Number of establishments 10t49 employees	2610	225	97	597	8	9570
Number of establishments 50t249 employees	2610	46	18	128	2	2038
Broadband access 100 mbps (t), %	2610	45	45	25		98
Proportion of university graduates (t), %	2610	27	25	8	14	62
Proportion of university research graduates (t), %	2610	0.5	0.0	1.0	0.0	6
Number of patents (t-1)	2610	6.2	1.0	24.9	0	364
Public investments, SEK million (t-1)	2610	1536	663	3249	4	41000
	Contracting municipalities (population decline 2010-2018)					
	Observations	Mean	Median	Std. Dev.	Min	Max
Number of establishments	477	1529	1307	836	406	3785
Number of establishments 0 employees	477	1181	1003	651	296	2867
Number of establishments 1t9 employees	477	282	218	161	87	782
Number of establishments 10t49 employees	477	56	44	34	14	161
Number of establishments 50t249 employees	477	10	8	6	2	29
Broadband access 100 mbps (t), %	477	41	37	26	0.0	91
Proportion of university graduates (t), %	477	20	20	3	14	32
Proportion of university research graduates (t), %	477	0.2	0.2	0.2	0.0	1
Number of patents (t-1)	477	0.8	0.0	1.2	0	7
Public investments, SEK million (t-1)	477	355	292	252	4	1185
	Expanding municipalities (population growth 2010-2018)					
	Observations	Mean	Median	Std. Dev.	Min	Max
Number of establishments	2133	4792	2535	10960	342	165970
Number of establishments 0 employees	2133	3262	1888	7108	228	105647
Number of establishments 1t9 employees	2133	1207	553	3056	75	48426
Number of establishments 10t49 employees	2133	263	119	654	8	9570
Number of establishments 50t249 employees	2133	54	22	140	2	2038
Broadband access 100 mbps (t), %	2133	46	46	25	0.0	98
Proportion of university graduates (t), %	2133	28	26	8	15	62
Proportion of university research graduates (t), %	2133	0.6	0.4	0.7	0.0	6
Number of patents (t-1)	2133	8.3	2.0	28.8	0	364
Public investments, SEK million (t-1)	2133	1799	832	3537	0	41000

Source: Statistics Sweden, Swedish Agency for Economic and Regional Growth, Swedish Post and Telecom Authority, Swedish Patent office and Kommuninvest of Sweden.

Contracting municipalities exhibit characteristics that partly differ from those of the expanding ones, although the proportion of establishments with access to broadband nearby is only slightly higher in expanding municipalities. There are larger discrepancies for the proportions of the population with higher degrees and number of patents. Public investments are also smaller in contracting municipalities, but this needs to be seen from the perspective of size (municipalities in population decline are often small). The proportion of micro firms is larger in municipalities with declining populations.

Table 2: Evolution of variables over time

All municipalities

Average number of establishments by size-class (employees)

	Total	Zero	1-9	10-49	50-249	250+
2010	3626	2455	913	210	42	5
2011	4095	2872	961	214	43	5
2012	4152	2881	1002	219	44	5
2013	4121	2825	1025	221	45	5
2014	4227	2905	1046	225	45	5
2015	4286	2941	1065	229	46	5
2016	4370	3012	1073	233	47	5
2017	4410	3011	1108	236	48	5
2018	4457	3019	1143	240	49	5

	Broadband access 100 mbps; %	Share of university graduates, %	Share of university research graduates	Public investment, SEK million
2010	23	24	0.5	1214
2011	28	25	0.5	1253
2012	33	25	0.5	1351
2013	37	26	0.5	1436
2014	43	27	0.5	1520
2015	47	27	0.5	1622
2016	55	28	0.6	1739
2017	65	28	0.6	1802
2018	72	29	0.6	1893

Contracting municipalities

Average number of establishments by size-class (employees)

	Total	Zero	1-9	10-49	50-249	250+
2010	1322	985	272	54	10	1
2011	1530	1188	277	55	10	1
2012	1544	1192	285	56	10	1
2013	1501	1149	287	55	10	1
2014	1558	1207	285	56	10	1
2015	1569	1218	285	56	10	1
2016	1576	1228	282	56	9	1
2017	1576	1227	283	56	10	1
2018	1585	1232	286	56	9	1

	Broadband access 100 mbps; %	Share of university graduates, %	Share of university research graduates, %	Public investment, SEK million
2010	19	19	0.2	328
2011	26	19	0.2	335
2012	30	20	0.2	343
2013	34	20	0.2	351
2014	42	21	0.2	355
2015	42	21	0.2	360
2016	48	21	0.2	362
2017	58	22	0.2	378
2018	65	22	0.2	383

Expanding municipalities

Average number of establishments by size-class (employees)

	Total	Zero	1-9	10-49	50-249	250+
2010	4141	2784	1056	245	50	6
2011	4668	3249	1114	249	51	6
2012	4735	3259	1163	256	52	6
2013	4707	3200	1190	258	52	6
2014	4823	3285	1216	263	53	6
2015	4905	3335	1242	268	54	6
2016	4995	3410	1250	273	56	6
2017	5043	3411	1293	276	57	6
2018	5112	3429	1338	280	58	6

	Broadband access 100 mbps, %	Share of university graduates, %	Share of university research graduates	Public investment, SEK million
2010	24	26	0.6	1412
2011	29	26	0.6	1458
2012	33	27	0.6	1576
2013	37	27	0.6	1679
2014	43	28	0.6	1781
2015	48	29	0.6	1898
2016	57	29	0.6	2046
2017	67	30	0.6	2121
2018	74	30	0.7	2222

Notes: Averaged across all 290 municipalities. Source: Statistics Sweden, Swedish Agency for Economic and Regional Growth, Swedish Post and Telecom Authority and Kommuninvest of Sweden.

Over time, the total number of establishments is growing, especially so the micro ones (Table 2). The proportion of establishments with high-speed broadband access nearby expands by a factor three over the period of time studied. In addition, the proportion of university graduates is increasing by four percentage points while the proportion of university research graduates is only slightly changing over time. Public investment in current prices is also growing.

Just like in the expanding municipalities, the number of establishments is growing in the contracting ones, although with a slower speed. There is no clear difference in the development of broadband access, but the change over time in the proportion of the workforce with university degrees is more pronounced in thriving municipalities.

Empirical results

Fixed Effects estimations show a positive relationship between the proportion of establishments with high-speed broadband access nearby (lagged one year) and the number of establishments (Table 3, Panel A). The relationship is most pronounced for micro establishments with 1-9 employees. No contemporaneous link is found, indicating that some time is needed before improved broadband access attracts new establishments. The coefficients for the broadband variable can be interpreted as semi-elasticities. This means, for instance, that a 1 percentage point increase in high-speed broadband access is associated with a 0.05 per cent increase in the number of micro establishments and a 0.023 per cent change in the total number of establishments, ceteris paribus. Given the increase in the proportion of establishments with high-speed broadband access by almost 50 percentage points over the period of time studied, approximately one tenth of the growth in the number of micro establishments can be explained by this access (coefficient of 0.055 times increase in broadband supply of 0.489 divided by the growth of micro enterprises of 0.25=25 percent).

The number of establishments is strongly related to the skills level of the population in the municipality (graduate or post-graduate university degrees). Public investments are generally not significantly different from zero. The ratio of patent applications (lagged by one year) to number of establishments is also not significant at conventional levels in any of the specifications and thus excluded from the final specification.

Results from the spatial autoregressive model (with spatially autocorrelated errors and fixed effects) show that there is a significant relationship between the number of establishments in the size class 1-9 employees and high-speed broadband access lagged one year with a coefficient of 0.028 (Table 3, Panel B). However, the significance level is lower than in the Fixed effects model, five instead of one per cent. The two skills variables appear significant for the total number of establishments and the proportion of university graduates is also highly significant as well across all size classes. As indicated by the spatial Durbin model with fixed effects, the relationship between the number of establishments and the weighted proportion of establishments with high-speed broadband access is also significant (Table 3, Panel C). For the group of establishments with 1-9 employees, the coefficient is 0.043 and thus slightly higher than the direct effect of 0.03. This implies that there are some spillovers from high-speed broadband access in neighbouring areas. Additionally, the number of establishments in a given municipality is strongly related to that of the spatially weighted average of the neighbouring regions with coefficients ranging between 0.2 and 0.43.

Table 3: Determinants of number of establishments by size class, panel data estimations

	All establishments			0 employees			1-9 employees			10-49 employees			50-249 employees		
Panel A: Fixed Effects estimations															
	Coeff.		t-stat	Coeff.		t-stat	Coeff.		t-stat	Coeff.		t-stat	Coeff.		t-stat
Broadband 100mbps t, %	-0.017		-1.61	-0.020	*	-1.73	0.003		0.19	0.014		0.59	-0.045		-1.29
Broadband 100mbps t-1, %	0.023	**	2.57	0.011		1.14	0.055	***	4.04	0.023		1.21	0.015		0.47
University graduates t, %	1.250	***	4.89	0.227		0.75	4.227	***	8.49	1.584	***	3.25	4.510	***	4.72
University research graduates t, %	8.54	***	3.35	7.532	***	2.89	12.427	**	2.50	6.571		1.14	10.272		1.22
Ln public investment t-1	-0.002		-0.66	-0.004		-1.64	0.002		0.18	0.014	*	1.92	0.010		0.89
Year dummy variables	Yes			Yes			Yes			Yes			Yes		
Constant	7.361	***	118.4	7.281	***	101.1	5.094	***	41.59	4.157	***	32.65	1.808	***	8.21
R^2 within	0.828			0.819			0.567			0.173			0.083		
Number of observations	2,610			2,610			2,610			2,610			2,610		
Number of municipalities	290			290			290			290			290		
Wald test Broadband 100mbps t= Broadband 100pbps t-1=0, p-value	0.033			0.210			0.000			0.291			0.410		
Hausman specification test, p-value	0.000			0.000			0.000			0.000			0.000		
Panel B: Spatial autoregressive model with spatially autocorrelated errors and Fixed Effects (SAC)															
	All establishments			0 employees			1-9 employees			10-49 employees			50-249 employees		
	Coeff.		z-stat	Coeff.		z-stat	Coeff.		z-stat	Coeff.		z-stat	Coeff.		z-stat
Broadband 100mbps t, %	-0.007		-0.71	-0.009		-0.83	0.000		0.03	0.018		0.81	-0.043		-1.23
Broadband 100mbps t-1, %	0.009		1.23	0.001		0.11	0.028	**	2.50	0.014		0.78	0.007		0.20
University graduates t, %	1.168	***	4.93	0.738	***	2.72	2.414	***	5.61	1.127	**	2.29	3.503	***	3.69
University research graduates t, %	5.474	**	2.34	4.620	**	2.00	8.806	**	2.24	5.889		1.02	8.878		1.04
Ln public investment t-1	0.002		0.44	0.001		0.16	0.002		0.48	0.015	**	2.33	0.010		1.01
Year dummy variables	Yes			Yes			Yes			Yes			Yes		
Number of establishment spatially weighted, ρ	0.429	***	12.15	0.288	***	3.40	0.380	***	6.81	0.201	*	1.66	0.366	***	7.36
Spatial autocorr. parameter λ	0.570	***	124.4	0.569	***	111.0	1.097	***	50.05	0.257	**	2.26	-0.130		-1.17
Error variance σ	0.000	***	16.10	0.001	***	16.18	0.001	***	20.64	0.004	***	12.70	0.012	***	11.83
Pseudo R^2	0.99			0.991			0.999			0.997			0.99		
Number of observations	2,610			2,610			2,610			2,610			2,610		
Number of municipalities	290			290			290			290			290		
Wald test Broadband 100mbps t= Broadband 100mbps t-1=0, p-value	0.46			0.68			0.04			0.41			0.47		
Hausman specification test, p-value	0.000			0.000			0.000			0.000			0.000		
Panel C: Spatial Durbin model with Spatial Fixed-Effects (SPD)															
	All establishments			0 employees			1-9 employees			10-49 employees			50-249 employees		
	Coeff.		z-stat	Coeff.		z-stat	Coeff.		z-stat	Coeff.		z-stat	Coeff.		z-stat
Broadband 100mbps t, %	-0.017		-1.60	-0.020	*	-1.73	0.006		0.46	0.016		0.68	-0.049		-1.40
Broadband 100mbps t-1, %	0.018	**	2.18	0.014		1.44	0.032	***	2.85	0.015		0.83	-0.011		-0.32
Broadband 100mbps t-1 spatially lagged, %	0.020	*	1.93	-0.019		-1.61	0.043	**	2.05	0.010		0.30	0.190	***	3.04
University graduates t, %	0.977	***	3.73	0.383		1.27	2.310	***	5.27	1.011	**	2.02	2.927	***	2.84
University research graduates t, %	8.384	***	3.34	7.520	***	2.87	10.05	**	2.26	6.099		1.08	10.42		1.21
Ln public investment, t-1	-0.003		-0.94	-0.004		-1.36	0.000		0.07	0.014	**	2.32	0.007		0.82
Year dummy variables	Yes			Yes			Yes			Yes			Yes		
No. of establishment spatially weighted, ρ	0.074	*	1.86	-0.030		-0.66	0.470	***	11.75	0.288	***	4.51	0.169	**	2.46
Error variance σ	0.000	***	15.20	0.001	***	15.43	0.001	***	17.88	0.003	***	11.27	0.011	***	10.61
Pseudo R^2	0.999			0.999			0.914			0.875			0.822		
Number of observations	2,610			2,610			2,610			2,610			2,610		
Number of municipalities	290			290			290			290			290		
Wald test Broadband 100mbps t=Broadband 100mbps t-1= Broadband 100mbps t-1 spatially lagged, p-value	0.026			0.119			0.001			0.626			0.019		
Hausman specification test, p-value	0.000			0.000			0.000			0.000			0.000		

Notes: Asterisks ***, ** and * denote significance at the 1, 5 and 10 per cent levels. Standard errors are adjusted for 290 clusters in municipality. Estimates are conducted using the *xsmle* and *spmat* commands for Stata (Belotti et al., 2017). To test the value of the lagged broadband access coefficient compared to that of all size-classes, a Wald test is conducted. The results show that the coefficient is significantly higher (at the one per cent level) for the group 1-9 employees and lower for all other size-classes. These results are valid for Panel A and B. However, estimates of the SDM model (Panel C) for the total number

and the size-class 1-9 employees are not significant at the 5 per cent level. The Hausman test implies that a random effects model is rejected in favour of fixed effects.

Since the independent variables are scaled differently, the effect of a one standard deviation change on the dependent variable can be calculated. Thus, a change in the proportion of establishments with high-speed broadband access (increase of 25 percentage points) affects the number of establishments by 0.7 percent. The corresponding impact of the proportion of university graduates is 20 per cent (based on an increase of one standard deviation of 8 percentage points) and the proportion of university research graduates is 6 per cent (given an increase in one standard deviation equal to 0.7 percentage points). Overall, these results show that the direct link between high-speed broadband access and the number of establishments is negligible and that the dynamics are largely determined by the presence of a highly skilled local workforce and the presence of research personnel.

To investigate if and to what extent high-speed broadband access is an enabler, that allows indirect rather than direct effects, the variable is interacted with the proportion of the workforce with university graduate or research degrees. These results show that broadband access in combination with higher skills strongly relates to the number of establishments (Figure 1 and Figure 2), suggesting that high-speed broadband access is a prerequisite for establishment dynamics, more markedly so in combination with higher skills than by itself. High-speed broadband access in municipalities with a low skilled structure does not attract an increase in the number of establishments. The marginal effects of high-speed broadband access appear significant above a certain threshold of university graduates. This threshold relates to a proportion of between 20 and 25 per cent (Figure 1), and is lowest for the micro establishments with 1-9 employees and higher for the remaining size-classes. Given that the median proportion of the university graduated employees is 25 per cent (see Table 1), the establishment dynamics are significantly dependent on high-speed broadband access in more than half of the municipalities. Although this study provides a more detailed level of analysis, some of the

results coincides with earlier literature, particularly relating to business start-ups, where tangible as well as intangible infrastructures (access to high-speed broadband and advanced knowledge, for instance) of a region is emphasised (Audretsch et al., 2005; Audretsch et al. 2015; Tranos and Mack, 2016; McCoy et al., 2018; Hasbi, 2020).

Still, the average results do not tell whether the relationships are valid for both contracting and expanding municipalities, where the former often are targeted for preferential subsidies, such as innovation support and investments in broadband infrastructures. Fixed Effects estimates show that broadband access in declining municipalities are insignificant for the number of establishments (Table 4).

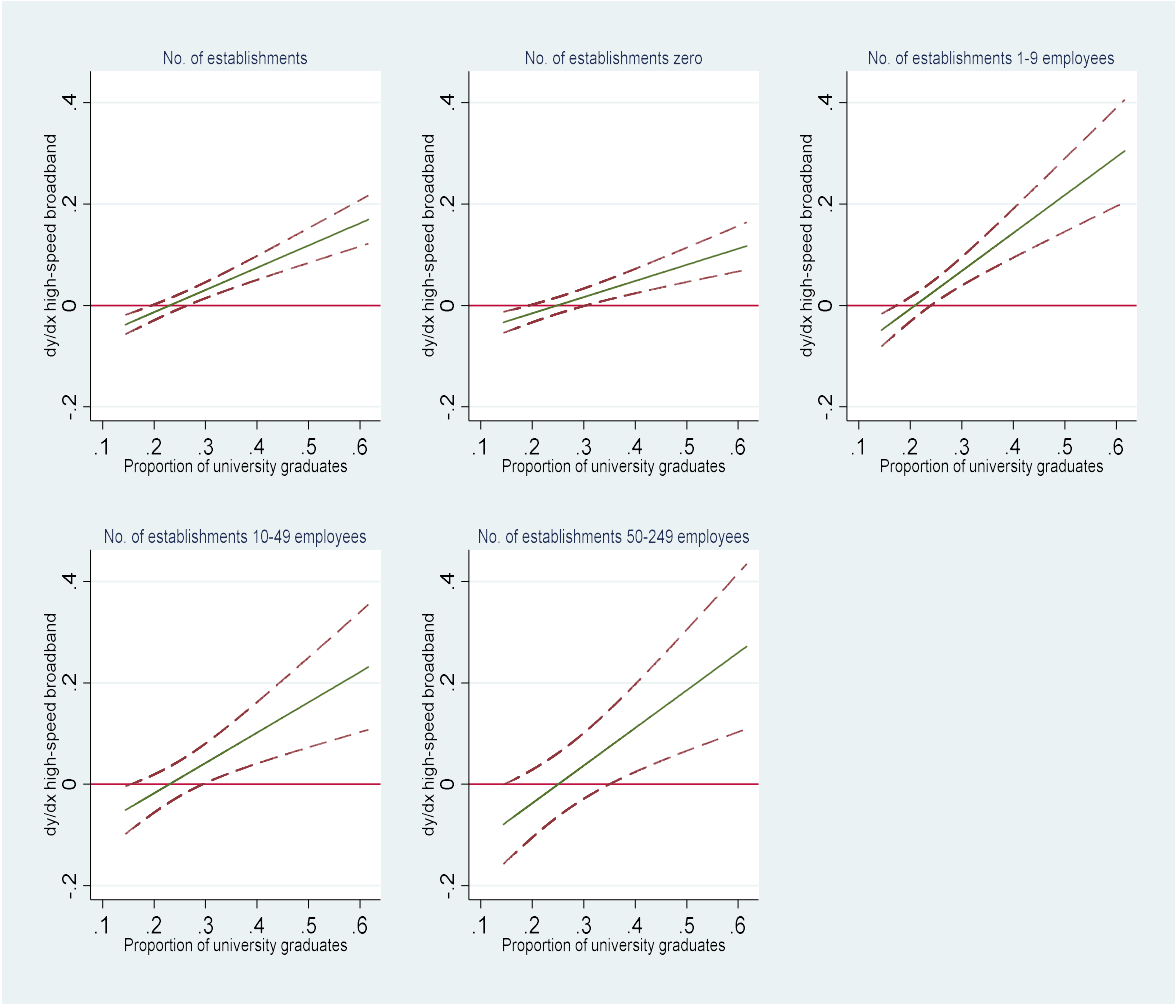
Table 4: Determinants of number of establishments by size class in contracting regions, Fixed effects panel estimations

	All establishments					Establishments 1-9 employees				
	(i)			(ii)		(iii)			(iv)	
	coeff.		t-stat	coeff.	t-stat	coeff.		t-stat	coeff.		t-stat
Broadband 100mbps t, %	0.036	**	2.03	0.010	0.40	-0.020		-0.67	0.002		0.07
Broadband 100mbps t-1, %	-0.021		-1.29			0.044		1.27			
University graduates t, %	1.021	***	3.88	2.999	*** 7.09	0.149		0.27	0.901	**	2.17
Constant	6.988	***	138.20	6.572	*** 84.03	5.464	***	54.20	5.313	***	68.01
Number of observations	424			477		424			477		
Number of municipalities	53			53		53			53		
R^2 within	0.29			0.42		0.02			0.06		

Notes: Asterisks ***, ** and * denote significance at the 1, 5 and 10 per cent levels. Standard errors are adjusted for 290 clusters in municipality.

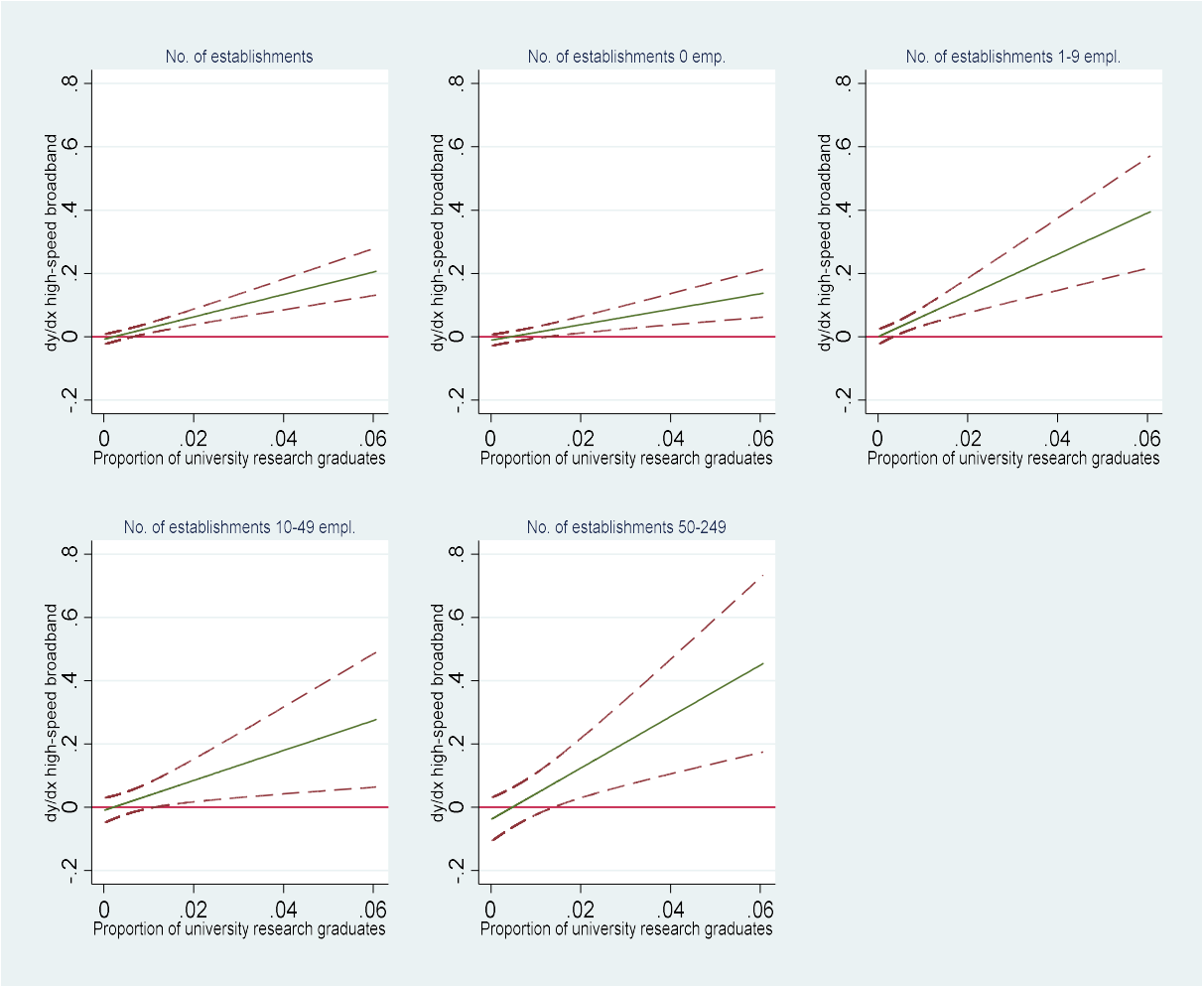
There is also no significant association between the proportion of university graduates and number of establishments, nor an indirect link where broadband is the enabler (Appendix, Figure A2). Thus, this stands in contrast to the findings for all municipalities. Possible explanations include an underlying lack of skills in the local workforce in contracting regions. Highly skilled individuals tend to be extra sensitive to career opportunities and because of this also more geographically mobile than others (Brandén, 2013).

Figure 1: Marginal effect of high-speed broadband access on number of establishments in combination with the proportion of university graduates



Notes: The calculations are conducted using SAC with spatial fixed-effects and the Delta method.

Figure 2: Marginal effect of high-speed broadband access on number of establishments in combination with the proportion of university research graduates



Notes: Calculations are conducted using SAC with spatial fixed-effects and the Delta method.

Several robustness checks are conducted. Separate estimation for the 38 municipalities in Zone A regions (entitled the highest amount of public support) reveal that the link between number of establishments and broadband access is on average only weakly significant and not at all for micro-establishments (results are available upon request). Due to the small number of observations these results need to be interpreted with caution.

Although an assumption is made that the broadband access variable is external to the establishment, the possibility of endogeneity cannot be fully neglected. Another aspect that might induce endogeneity is the high degree of persistence in the number of establishments. To make sure that these two additional sources of endogeneity are controlled for, the System

Generalized Method of Moments (GMM) estimator is applied to the dataset. Lags of both the dependent and independent variables are used as instruments, and the number of instruments employed is below the number of groups (municipalities) as recommended by Roodman (2009). The Hansen tests do not reject the null hypothesis of valid instruments at the five per cent level, indicating that the instruments do not correlate with the error term. Estimations reveal that the coefficient of high-speed broadband access is significant at the five percent level (Appendix, Table A1), but the time delay in the reaction is longer than that given by the Fixed Effects model. Results are stable, independently of treating all explanatory variables or only the lagged dependent variable as predetermined (Appendix, Table A1, Specifications i and ii). The importance of higher skills are also verified, implying that the estimates are not sensitive to how the broadband and skills variables are treated, as predetermined or exogenous.

Conclusions

This study investigates the relationship between high-speed broadband access and establishment dynamics, based on detailed official municipality-level data for Sweden. Particular attention is paid to micro as well as small and medium-sized establishments and those in contracting municipalities. The broadband variable measures the number of establishments with access to fibre broadband of a minimum speed nearby.

Estimates using fixed effects and spatial econometric models show that the direct relationship between high-speed broadband access and the total number of establishments is significant but of a small magnitude, except for micro establishments where the strength is twice as large. Instead, the establishment dynamics are largely determined by the local presence of university (or research) educated persons, with broadband access possibly functioning as an enabler. The magnitude of the relationship increases significantly with the proportion of the local population with graduate or post-graduate university degrees. A stronger link to smaller establishments is

not completely unexpected because it is in this group most start-ups occur, which supposedly pay extra attention to beneficial business surroundings. There is no significant relationship between high-speed broadband access and establishment dynamics in contracting regions, neither directly nor indirectly.

The findings are somewhat alarming, since establishments (or firms) in declining regions are commonly entitled to the most extensive public support, investments in broadband infrastructure, for instance. If a possible high-speed broadband access cannot be combined with sufficient skills, the resulting dynamism in the business sector may remain low. This indicates that the capacity to absorb different policy interventions may be restricted.

Certain limitations of the study should be noted. Regional characteristics are not always changing over time, and thus cannot be included in dynamic modelling. There is also a possibility of omitted variable bias that is not fully controlled for due to non-measurable factors of importance at the regional level. Establishment data is particularly suitable for regional analysis since they are geographically, not legally, defined. However, these establishments may be affiliated across regional or country borders, although this information is not available in the dataset analysed. Instead, the horizontal dependency is expected to be controlled for at least partly by the spatial estimations.

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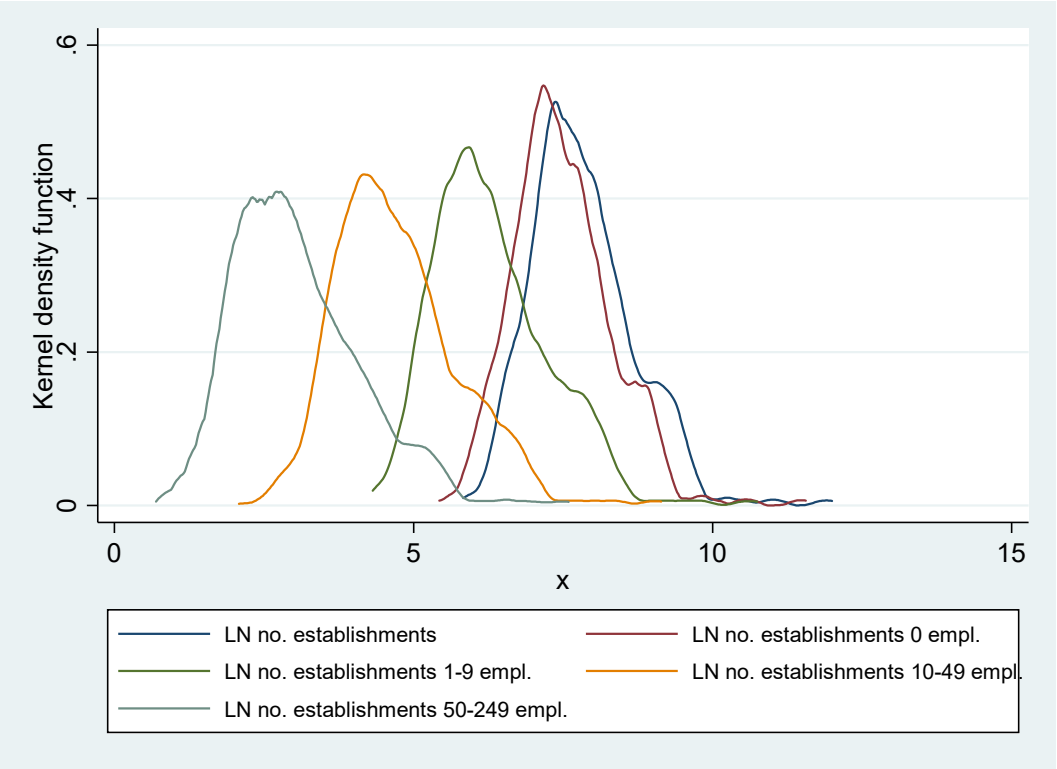
Appendix

Figures A1: Distribution of the universe of establishments (measured in logarithms), Kernel density estimates



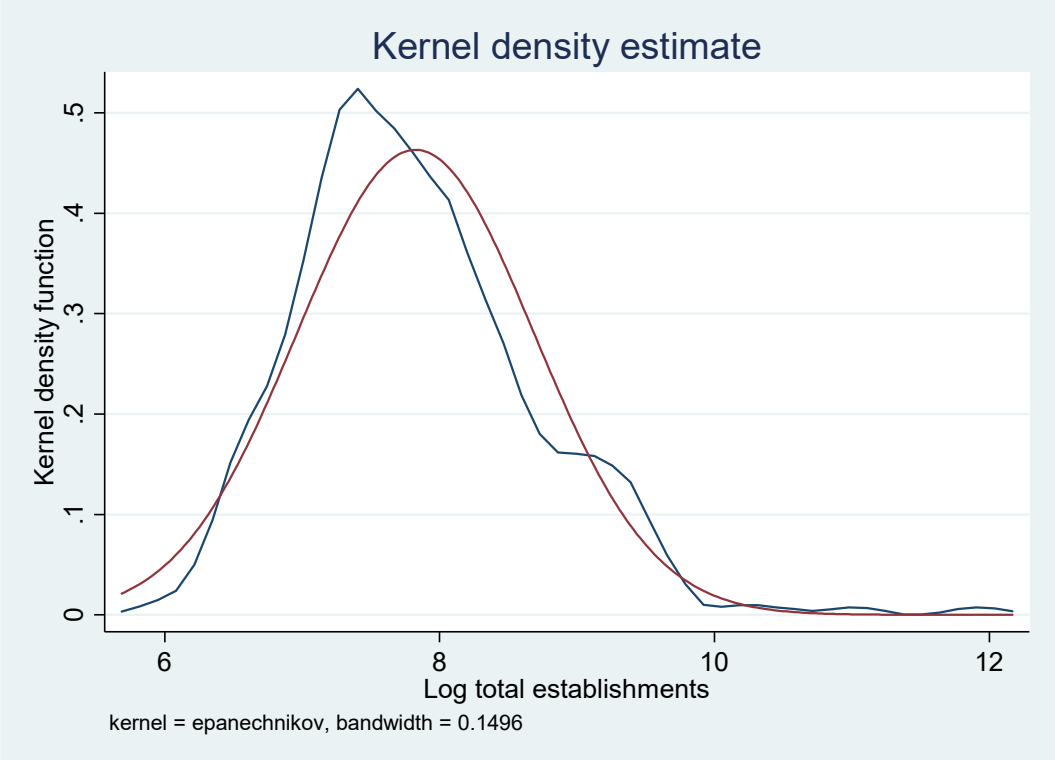
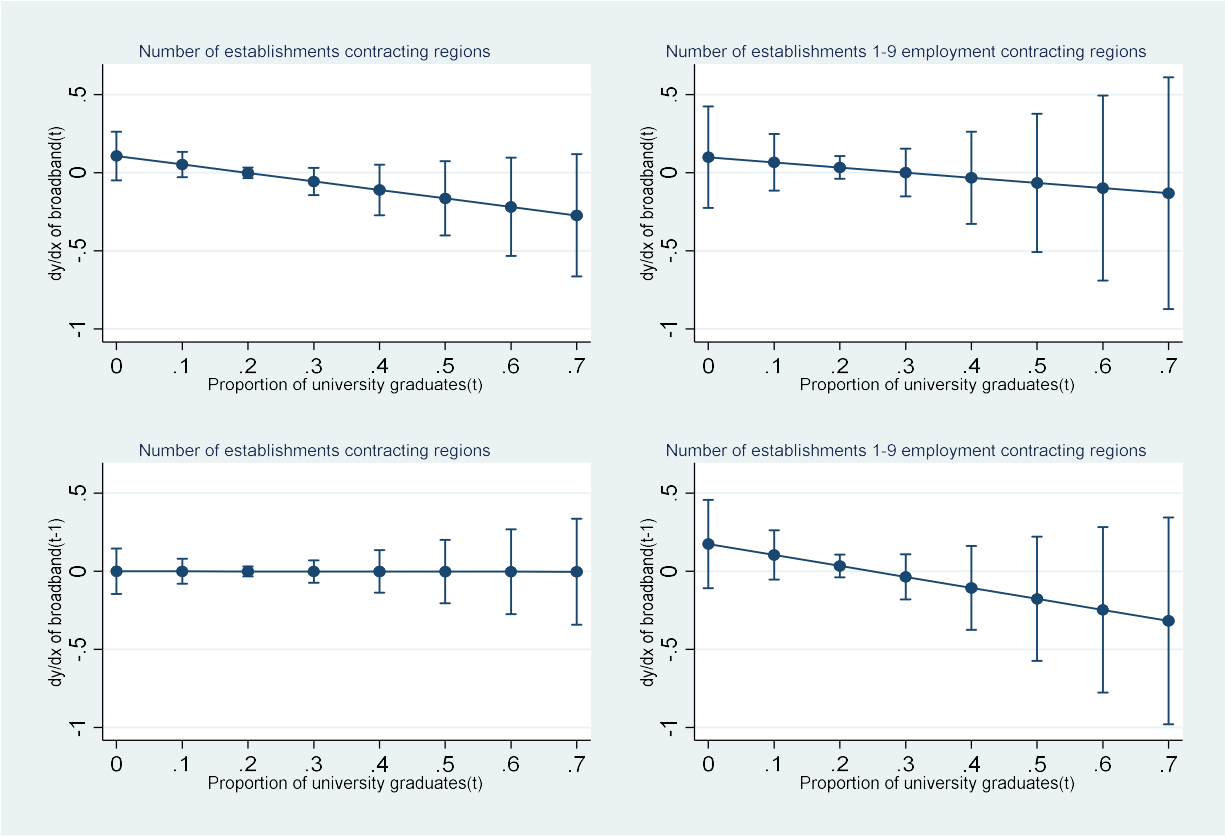


Figure A2: Marginal effect of high-speed broadband access on number of firms in combination with the proportion of university graduates in contracting municipalities



Notes: Calculations are based on the Fixed Effects model, Panel A in the main body of the study.

Table A1: 5 Determinants of the number of establishments, System GMM estimations

	(i)			(ii)		
	Coeff.		t-stat	Coeff.		t-stat
Ln number of establishments t-1	0.959	***	43.66	0.957	***	44.96
Ln number of establishments t-2	0.042	*	1.95	0.040	*	1.95
Broadband 100mbps t-1, %	0.000		0.05	-0.004		-0.71
Broadband 100mbps t-2, %	-0.005		-0.89	-0.006		-1.06
Broadband 100mbps t-3, %	0.010	**	2.42	0.010	**	2.57
University graduates t, %	0.070	***	4.06	0.092	***	5.08
Ln public investment t-1	-0.001		-1.45	-0.001		-1.55
Ln public investment t-2	0.002	**	2.45	0.002	**	3.32
Ln public investment t-3	0.000		0.26	0.000		0.50
Year dummy variables	Yes			Yes		
Constant	-0.015		-1.12	0.001		0.08
Number of observations	2030			2030		
Number of municipalities	290			290		
AR(1), p-value	0.026			0.000		
AR(2), p-value	0.898			0.298		
Hansen test, p-value	0.089			0.175		
Number of instruments	185			202		
Broadband, university graduates, public investment are treated as predetermined	Yes			No		
Wald test Broadband 100pbps t-1, t-2, t-3=0, p-value	0.065			0.043		
Long run coefficient Broadband 100mbps t-3	0.259	***	4.68	0.219	***	5.18

Notes: Asterisks ***, **, and * indicate the significance at 1, 5, and 10 per cent, respectively. The dependent variable is the logarithm of the number of establishments. The significance is based on the t-test with the robust standard errors from the two-step GMM estimator. The p-values are reported for the Arellano-Bond, Hansen and Wald tests. T-values for the long run coefficients are based on non-robust standard errors.