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The Impact of Broadband Internet on Employment in France*

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3rd July 2018

Preliminary, comments are welcome

Abstract

The impact of broadband Internet on employment is ambiguous, but empirical evidence is still limited. In this paper, we exploit data on a massive adoption of broadband Internet in France to investigate the impact of broadband Internet on employment. Using a fuzzy difference-in-difference estimation strategy, we find that broadband Internet destroy jobs, although the unemployment rate seems not to be affected. This job destruction occurs in manufacturing activities, contrary to the service sector where broadband Internet adoption creates jobs. In addition, we find that raising the level of education in urban areas tends to alleviate the negative impact of broadband Internet on employment.

Keywords: Broadband Internet, Employment.

JEL Classification: D31, L96, O15.

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1 Introduction

As emphasized by Autor (2001), broadband Internet access transforms how firms produce and how workers search for jobs, raising issues about its effects on employment. Indeed, broadband adoption by firms could raise labor productivity, and therefore wage, inducing a process innovation and destroying jobs. However, higher wage means higher income and more demand, inducing product innovation and creating jobs. Likewise, broadband access could create jobs due to better matching online, but also destroy jobs due to skill biases.

Empirical studies such as Kolko (2012), Czernich (2014) or Ivus & Boland (2015) find no impact on employment overall, but positive for the service sector and negative for the manufacturing sector. However, none of these studies assesses the impact in France where significant investments have been made in broadband deployment and where unemployment rate remains high, compared to other OECD countries.

In this paper, we evaluate the impact of broadband Internet on employment in France, using municipality-level data from 2009 to 2013, a period that sees 5 million additional residential subscribers and 150 thousand business subscribers. We argue that, at a municipality level, these new subscriptions reflect exogenous variations stemming from the geographical latitude and signal attenuation. Therefore, we attempt to overcome potential biases in OLS estimates by using a fuzzy difference-in-difference estimation strategy, following Duflo (2001) and Chaisemartin & D’Haultefoeuille (2017).

We find that broadband Internet reduces employment, although the unemployment rate seems not to be affected due to higher workers activity. This negative effect stems from manufacturing activities, whereas broadband adoption creates job in the service sector. In addition, we also find that raising the level of education in urban municipalities in rural municipalities contributes to improving the impact of broadband Internet on employment.

The findings of this paper are related to the literature on the labor market effects of broadband Internet. Kolko (2012), Czernich (2014) and Ivus & Boland (2015) investigate the impact of broadband Internet on employment respectively in the US, Germany and Canada, but they did not highlight the negative impact on the number of employed workers. We provide additional evidence for France and use broadband quality and demand-side variable such as adoption. In addition, we highlight the complementary role of education in improving the impact of broadband Internet on employment.

The remainder of the paper is organized as follows. Section 2 summarizes the relevant literature and section 3 presents some background information about broadband adoption and employment in France. Section 4 presents the dataset along with some descriptive statistics.

Section 5 presents the econometric model and the estimation strategy. Section 6 reports the findings and section 7 concludes.

2 Related literature

The impact of broadband Internet on employment is related to the burgeoning literature on the effects of digitization. Theoretical analyses such as Acemoglu & Restrepo (2018) and Autor (2001) suggest a rather ambiguous impact of broadband Internet on employment. Broadband Internet can raise employment by improving job matching (Autor, 2001) or by increasing the demand for products due to productivity gains. However, it can also lower employment due to skill bias and improvement in labor productivity.

As reviewed by Bertschek *et al.* (2016), the empirical investigation typically shows that broadband Internet has no impact on aggregate employment, but displaces jobs from manufacture into services. In Germany, Czernich (2014) uses municipality-level data from 2002 to 2006 and finds no significant impact of broadband Internet deployment on unemployment rate. Because unemployment rate might be affected by the size of the labor force, other studies have focused on employment, measured by the number of workers or the share of the working-age adults that is employed. Kolko (2012) uses county-level data from the US and finds no impact of broadband deployment on the employment rate. Likewise, Fabling & Grimes (2016) find no effect of broadband adoption on employment in New Zealand. More specifically, Ivus & Boland (2015) use community-level data from Canada (1997-2011) and highlight a positive impact of broadband Internet on rural employment and wage growth, but only in services.

Two main mechanisms can be related to these results. Indeed, broadband Internet could improve job matching through online job search and posting. Khun & Skuterud (2002) use data from the US and find no correlation between Internet job search affects the duration of unemployment, lending support to no significant impact of broadband Internet on the unemployment rate. A second mechanism that rationalizes why broadband Internet adoption reallocates jobs from manufactures to services is its impact on labor productivity and skill complementarity. Grimes *et al.* (2012) use data from New Zealand and find positive impact of broadband adoption on labor productivity, contrary to Bertschek *et al.* (2013) who find no significant impact using data from Germany. However, Bertschek *et al.* (2016) point out a positive impact of mobile Internet access on labor productivity.

Regarding the skill complementarity of broadband Internet, Atasoy (2013) show that broadband expansion in the US increases employment mostly for college-educated workers. Akerman *et al.* (2015) use detailed firm-level data from Norway (2000-2008) and find that

the impact of broadband adoption on employment and wage is positive for skilled workers but negative for unskilled workers, lending support to a skill complementarity of broadband Internet.

3 Broadband Internet and employment in France

Very fast broadband Internet deployment in France is part of a 20 billion euros project launched in 2013 aiming at full coverage of the whole territory by 2022. The government is committed to devote 3.3 billion euros public fund to this project.¹

Historically, broadband Internet has been deployed in France since 2000. Until 2013, the majority of the broadband coverage of the territory is provided by digital subscriber line (DSL) technologies via the incumbent operator's copper network. This network consists of about 33 million lines, deployed during several decades to provide fixed telephony. It covers the entire territory and spreads over more than 15,800 local exchanges. It was, therefore, not designed to convey DSL signals and provide DSL access. Indeed, the propagation of DSL signals is weakened over long distances. This signal attenuation is measured in decibels (dB) and depends on the distance traveled and the diameter of the copper lines. The eligibility threshold for a DSL line corresponds to a maximum signal attenuation of 78 dB, allowing a nominal speed up to 512 Kilobits per second (Kbps), or slightly more than 5 km for a copper pair with a diameter of 0.4 mm.

The length of the copper line, between the local exchange and the household, has no major impact on fixed telephony. However, it introduces a wide disparity in access to broadband Internet. Thus, while households located near the local exchange can enjoy a speed of more than 20 Megabits per second (Mbps), those over 5 km away cannot benefit from broadband access. The longest lines are mostly located in rural areas, but also in areas which have been recently urbanized. At the end of 2013, less than 1% of the lines were not eligible for broadband services via DSL technology.

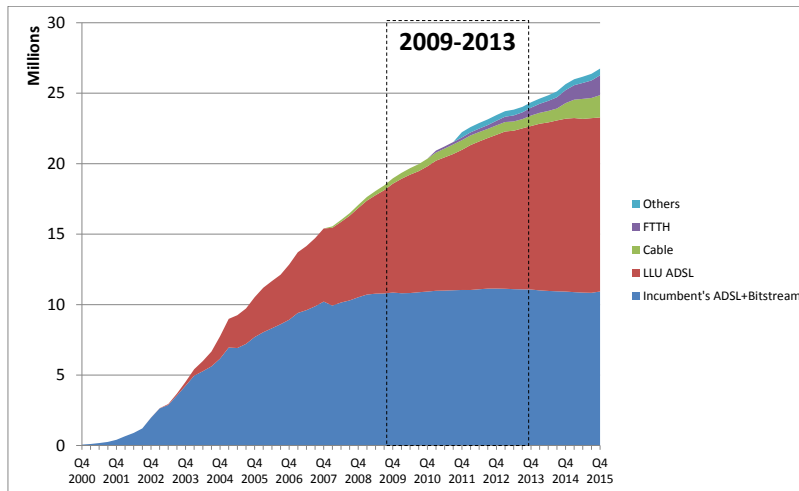
Figure 1 presents the evolution of broadband Internet penetration rate in France. ADSL is the main technology among all broadband connections. It still represents 90% of fixed broadband connections, compared to 6% for cable and 3% for fiber. More than 5 million households have adopted broadband Internet between 2009 and 2013. The total broadband subscribers have increased from 19.1 to 24.3 million during this period.

The rapid growth in broadband Internet usage is having a dramatic effect both on private and public sectors. The online environment has become a more efficient alternative to traditional

¹Plan France Tres Haut Debit.

offline setting. Broadband Internet access provides consumers with an abundance of products and services in a short amount of time. The Internet offers a centralized solution and increase the efficiency in many usages. According to a national survey conducted in France (CREDOC, 2014), 48% of interviewees use Internet for social networking, 47% to download music, 25% for job search, 51% for administrative procedures and 51% for online shopping.

Figure 1: Evolution of fixed broadband access by technology



Source: National telecoms regulator statistics (ARCEP).

Unemployment rate remains high in France, compared to other advanced countries. It stands at 10% in 2013 against 8% in the OECD, and has risen by 3 percentage points since the 2008's economic crisis. The youth, that is workers between 15 and 24, has the highest rate of unemployment, rising from 18% in 2008 to 24% in 2013.² It mainly stems from lower skills, as workers with less than high-school diploma represent 44% of the working age population but 58% of the unemployed. In 2013, the municipality-level unemployment rate ranges from 5 to 18%, but it has been rising in all municipalities since 2008.³ This trend can partly be explained by the 2008's financial crisis which translate into economic crisis, particularly in France. The GDP growth rate went from 2.4% in 2007 to 0.3% in 2013. During this period, no major labor market policy was implemented to reduce the unemployment rate.⁴

²OECD Online Statistics as of January 2017.

³INSEE

⁴Except the removal of the taxation of extra working hours.

4 Data and descriptive statistics

4.1 Data

We obtain French broadband and employment data from two sources. Broadband Internet data come from the incumbent network operator and employment data from the national office of statistics (INSEE). Both sources provide yearly data on 36,081 municipalities from 2009 to 2013.

More specifically, the broadband data include the number of residential and business subscriptions, the median download speed and the average signal attenuation. We calculate broadband penetration as the ratio of the number of residential subscriptions to the number of households. The median download speed is used as a measure of broadband quality. It is a theoretical maximal download speed established by the network operator, given the characteristics of the municipality. Signal attenuation, the ratio between the signal sent from the local exchange and the signal received by the user, expressed in decibels (dB), measures the signal power loss as a function of the distance between the emitter and the receiver. The greater the distance, the higher the attenuation value and the weaker the ADSL signal. This variable will be useful for our estimation strategy.

Regarding the employment data, it provides information on the unemployment rate as well as the number of workers employed per municipality.⁵ The employment statistics have been estimated from a declarative survey conducted by INSEE.⁶ Note that the number of workers employed is different from the number of workers residing within the municipality. The employment data is split into 38 economic activities from the manufacturing and services sectors, excluding agriculture. These activities are presented in Tables A-2 and A-1 in the Appendix.

We complement these data with socio-economic statistics provided by INSEE. They include the gross domestic product (GDP) per capita at the regional level, the average years of schooling at the department level and the share of high-school graduates at the municipality level and the share of population above 65 years old and the population density. GDP per capita serves as a proxy for production. The average years of schooling and the share of high-school graduates are proxies for the level of education. The share of population above 65 years old captures the size of the working-age population, as well as the demand for services.

⁵Nomadic workers such as taxi drivers, fishermen or itinerant traders are considered as working in their municipality of residence.

⁶According to INSEE, a worker is deemed unemployed if she declares so, unless she specifically claims not looking for a job. As a result, the unemployment rate, according to this definition, may be higher than one obtained following the standards of the International Labor Organization, as inactive workers could be declared being unemployed.

Finally, we also add the number of mobile Internet antennas in order to investigate whether its impact is similar than fixed broadband Internet.

Table 1 presents the summary statistics of the main variables. The penetration rate is greater than 100% in some municipalities due to multiple subscriptions in some households. However, the average broadband penetration stands at 53% for residential users and average number of business broadband lines is 14. The median download speed ranges from 0.3 to 20 Mbps, with an average of 6.7 Mbps. The unemployment rate goes as high as 66.7% in some municipalities, with an average at 9.4%. The number of employed workers can be nil in some municipalities, but the unemployment is neither 100% because, these municipalities have no firms, although their residents work in other municipalities. The share of active workers ranges from 25% to 100% with an average of 74%. Signal attenuation has an average of 40 decibels, with large variance. Regional GDP per capita is between 22 and 53 thousands euros, and the average year of schooling is between 9 and 13 years.

Table 1: Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Household broadband penetration	170760	0.528	0.145	0.000	2.136
Business broadband lines	170760	14.41	86.53	0.000	5007
Median download speed (Mbps)	168503	6.679	6.526	0.300	20.00
Unemployment rate	170760	0.094	0.043	0.000	0.666
Number of employed workers	170760	723.7	4973.1	0.000	297301
Share of active workers	170760	0.7399	0.0554	0.2500	1.0000
Signal attenuation (decibels)	170760	40.17	18.92	0.835	97.39
Latitude (radian)	170760	0.8210	0.0377	0.7393	0.8914
GDP per capita (euros)	170760	27371.3	5317.7	22884.5	53731.3
Average years of schooling	170760	10.080	0.486	9.206	12.762
Share of high-school graduates	170760	0.366	0.095	0.038	0.848
Share of population above 65	170760	0.189	0.067	0.000	0.741
Population density	170760	103.1	609.8	0.122	32858.5
Mobile broadband antenna	172792	1.146	6.521	0.000	914.0

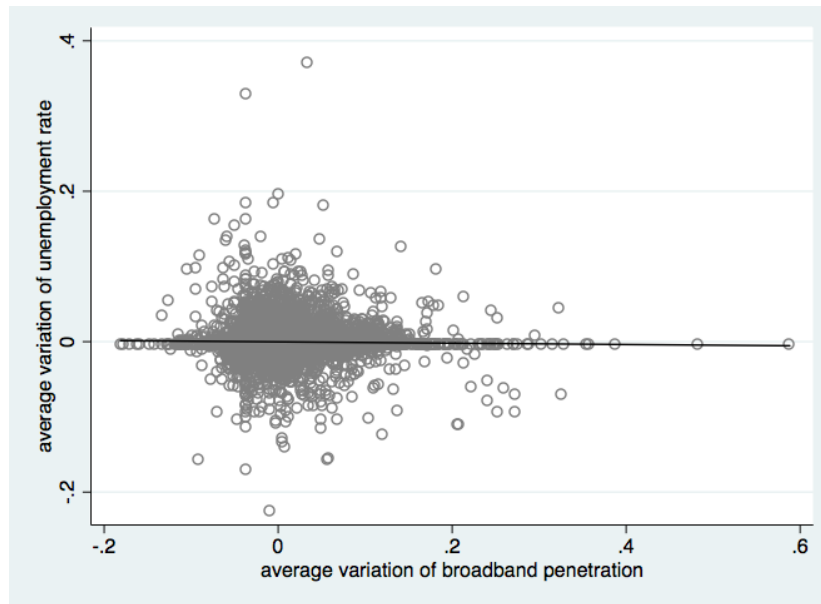
4.2 Descriptive statistics

We start by investigating the correlation between municipality-specific trends in broadband adoption and employment. We first retrieve common trend using an OLS regression of broadband adoption and employment on year fixed effects. The residuals of these regressions are first differentiated and averaged over 2009-2013 in order to obtained the average municipality-specific annual change in broadband adoption and employment. The outcomes are presented on Figures 2 and 3.

Figure 2 shows that broadband penetration is rising in most municipalities. However, at any given level of broadband penetration, the unemployment rate is rising in some municipalities and falling in others. As a result, the linear fit of the scatter plot yields a rather flat relationship between broadband penetration and unemployment rate. A similar pattern arises from Figure 3 whereby rising business broadband lines comes with increasing employment in some municipalities and decreasing in others.

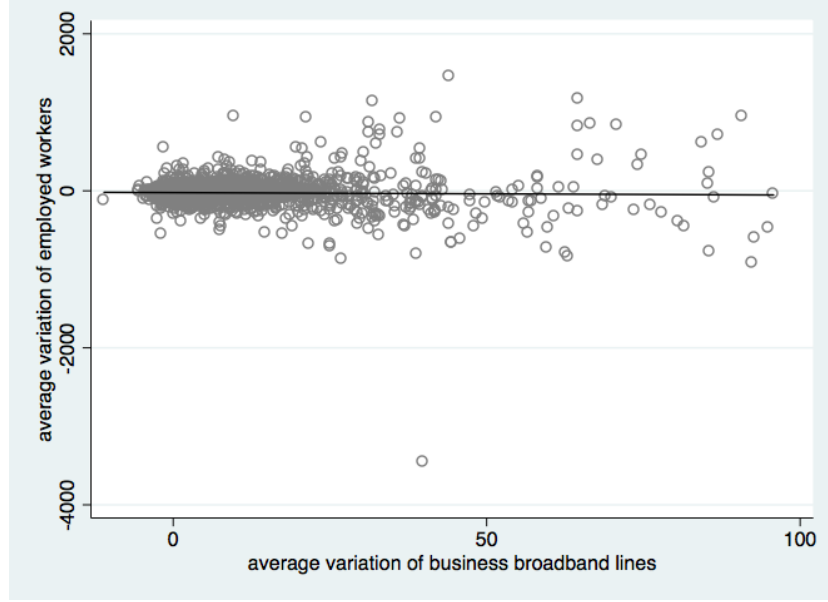
The flat relationship between broadband adoption and employment could be driven by covariates such as production, education and demographic structure. Production and education are expected to be positively correlated with employment and broadband adoption and, as a result, introduce an upward bias in the correlation between broadband adoption and employment. The effect of demographic structure is rather ambiguous. We shall account for these potential bias by including the proxies for production, education and demographic structure as controls in the regression of employment on broadband adoption. Moreover, the outcomes of Figures 2 and 3 could also be affected by a reverse causality whereby employment affects the adoption of broadband Internet. Therefore, a causal identification strategy is needed to estimate the impact of broadband adoption on employment.

Figure 2: Broadband penetration and unemployment rate



Note: Each point corresponds to the mean variations in broadband adoption and unemployment rate within a given municipality.

Figure 3: Business broadband and employment



Note: Each point corresponds to the mean variations in broadband adoption and employment (number) within a given municipality.

5 Econometric Estimation

This section presents the econometric model and the estimation strategy.

5.1 Econometric model

In order to estimate the impact of broadband Internet on employment, we specify the following linear reduced-form model:

$$Y_{it} = \alpha + \beta B_{it} + \gamma X_{it} + \mu_i + \nu_t + \epsilon_{it} \quad (1)$$

Where Y_{it} is a measure of employment, the rate of unemployment or the number of workers employed within municipality i during year t .

B_{it} is a measure of broadband Internet. We use three measures of broadband Internet, namely household broadband penetration, broadband quality and the number of broadband lines serving businesses, excluding leased lines.

X_{it} is a vector of controls. As discussed in section 4.2, we include production, education and demographic structure as control variables. Production is measured by the GDP per capita of the region a municipality belongs to. Education is measured by the average years of schooling at the department level or the share of high-school graduates at the municipality level. We use the share of population above 65 years old and population density as demographic variables.

μ_i and ν_t are respectively municipality and year fixed effects. Municipality fixed effects capture any invariant determinants of employment and broadband adoption, while the year fixed effects capture common trend in the labor markets driven by nation-wide economics shocks and public policies. ϵ_{it} is a vector of unobservable shocks.

The coefficient β corresponds to the impact of broadband Internet on employment. In spite of the inclusion of the controls and the fixed effects, Ordinary Least Squares (OLS) estimates of equation (1) is likely to be biased due to unobserved confounding variables and reverse causality. The following section lays out the estimation strategy we employ in order to obtain a causal impact of broadband Internet on employment.

5.2 Estimation strategy

We overcome a potential bias in OLS estimates by employing a fuzzy difference-in-difference estimator like in Duflo (2001) and later formalized by Chaisemartin & D’Haultfoeuile (2017). In its basic form, it can be viewed as a standard difference-in-difference estimator but with a control group that also experience a treatment, though with smaller intensity.

Let’s consider two groups i and j , and two times t and t' . Both groups are treated, but i experiences a greater treatment intensity than j , that is $B_{it} - B_{it'} > B_{jt} - B_{jt'}$. The fuzzy difference-in-difference (FDiD) estimator of the impact of the treatment B on the outcome Y can be expressed as:

$$\hat{\beta} = \frac{(Y_{it} - Y_{it'}) - (Y_{jt} - Y_{jt'})}{(B_{it} - B_{it'}) - (B_{jt} - B_{jt'})} \quad (2)$$

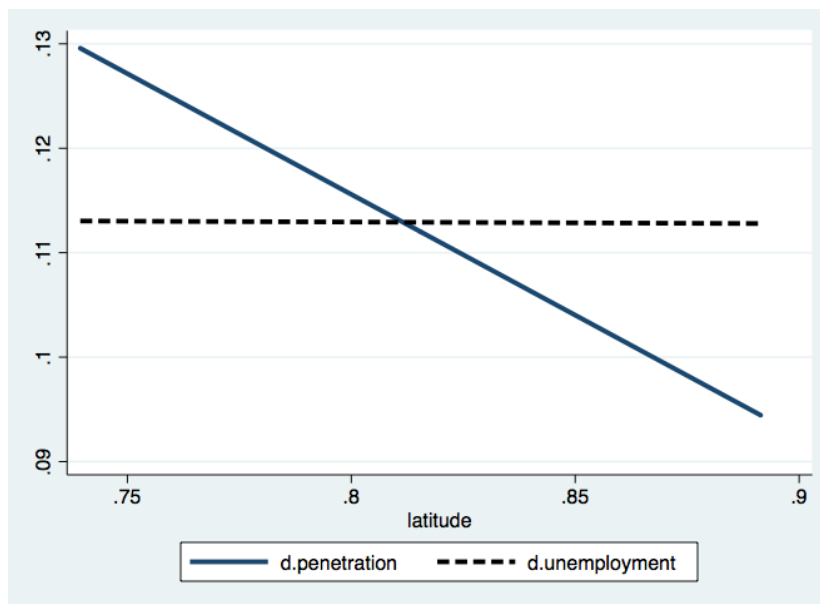
The numerator and denominator correspond to the standard difference-in-difference estimator of the outcome and treatment variables, respectively. This ratio is similar to the Wald estimator obtained from a two-stage least square estimation, with an appropriate instrument. In this case, the instrument is the interaction of time with a dummy variable that characterizes exposure to the treatment. By analogy, in presence of several groups and times, the FDiD estimator can be obtained from a two-stage least squares estimation, using the interaction between year and a treatment variable as an instrument. In our case, the groups correspond

to the 36,081 municipalities and the times corresponds to the years 2009-2013. The treatment variable remains to be defined.

We use the latitude of municipalities as the treatment variable for household broadband adoption and signal attenuation for business Internet access. As shown on Figure A-1 in the Appendix, municipalities at lower latitudes start with lower broadband penetration rates in 2009, but they eventually catch up by 2013. We argue that this delay in broadband adoption stems from weather effects and is, therefore, exogenous. At lower latitude, the weather is sunnier and more suitable for outdoor leisures. Likewise, business broadband adoption is largely dependent on signal quality. The greater the signal attenuation, the lower the signal quality and the lower the adoption by businesses.

Figure 4 below depicts the identification strategy. It turns out that municipalities at lower latitude experience larger increase in their broadband penetration rate, as they are late adopters. However, the unemployment rate seems be increasing at the same pace in all municipalities, suggesting that increasing broadband penetration has no impact on the unemployment rate. However, an econometric estimation is needed to assess the significance of this effect. The estimation results are presented in the next section.

Figure 4: Variation in broadband penetration and unemployment rate



Note: Linear fits of the difference in broadband penetration and unemployment rates between 2009 and 2013. We first net out the effects of the controls (education, income and density) by regressing unemployment rate and broadband penetration on these variables and taking the residuals.

6 Results

6.1 Main results

Table 2 reports the FDiD estimates of the impact of broadband Internet adoption on employment. Three main findings stand out from this table.

First, broadband adoption and quality have no impact on the unemployment rate. The Wald-DiD estimates are positive but not statistically significant. The estimate of the impact of broadband adoption on the unemployment rate, presented in column 1, is twice smaller than its standard error. Likewise, the coefficient of the median download speed is smaller than its standard error. Interestingly, the coefficients of the controls have the expected signs. The coefficients of the year fixed effects show that unemployment rate has been rising in all municipalities. However, it rises less in those municipalities located in regions that experience a rise in production or education, and more in municipalities with increasing share of retirees. Population density has no effect on the unemployment rate.

Second, the number of employed workers falls with the adoption of broadband Internet by businesses. More specifically, as shown in the third column of Table 2, each additional pair of business broadband lines replaces one worker. This negative impact comes on top of the general downward trend in employment in France, as suggested by the negative and increasing coefficients of the year fixed effects. However, the significance of this effect is at odds with the absence of impact on the unemployment rate. Estimates from the fourth column of Table 2 provide the rationale for this paradox. They show that broadband Internet actually increases the size of the labor market as more working-age individuals become active. A percentage point increase in the penetration rate is predicted to raise the share of active workers by 0.2 percentage point. Given that the unemployment rate is the ratio of the number of unemployed workers to the number of active workers, a rise in both parameters tends to yield a constant ratio. Intuitively, broadband Internet access is likely to raise the share of active workers as it provides an additional and less costly channel through which unless inactive workers could now search for jobs.

Third, the negative impact of broadband Internet stems from job destruction in the manufacturing sector, unlike the service sector where employment rises with broadband adoption.⁷ We first estimate the impact on employment in each of our 38 economic activities and then classify them into three groups according the sign and significance of the impact. The first group includes service-related activities such as computer and information services and administrative and support service activities. The second group encompasses manufacture-related

⁷Except in JB OZ for the manufacturing and DZ EZ for services.

activities such as textile, electrical equipment and construction. The third group includes all activities that are not affected by broadband Internet. Tables A-2 and A-1 in the Appendix present the FDiD estimate of the impact of fixed and mobile broadband on employment in each activity. We find that the coefficient of fixed broadband and mobile broadband have the same sign.

The last three columns of Table 2 report the estimates at the group level. The coefficient of broadband Internet is positive and highly significant for services-related activities, but negative and significant for manufacture-related ones. More specifically, an additional business broadband line is predicted to create 3.6 service-related jobs, while destroying 3.7 manufacture-related jobs. These effects could typically be explained by manufacturing firms going through digital transformation and outsourcing service-related activities. In the following section, we investigate how public policies could mitigate the negative impact of broadband Internet on employment.

6.2 Heterogeneous effects

Skills could affect the impact of fixed broadband Internet on employment. We test this hypothesis by interacting fixed broadband penetration with education, measured by the share of high-school graduates. Table 3 reports the outcome of the FDiD estimation.

Overall, education tend to attenuate the negative impact of broadband Internet on employment. More specifically, absent education fixed broadband Internet penetration raises unemployment rate and consistently lowers aggregate employment. However, increasing the share of high-school graduate in urban areas significantly reduces the magnitude of these negative effects.

These heterogeneous effects also hold across sectors. As shown in the second panel of Table 3, while broadband Internet still creates service-related jobs and destroys manufacture-related ones, higher share of high-school graduates in urban areas tend to amplify the former effect and weaken the later.

Table 2: Impact of broadband Internet on employment: FDiD estimates

	U	U	E	sh_activ	E_serv	E_manu	E_other
pen_FBB	0.006 (0.015)			0.212*** (0.018)			
Speed		0.000 (0.000)					
xdslb			-0.697** (0.289)		3.630*** (0.148)	-3.774*** (0.172)	-0.122 (0.076)
gdp per capita	-0.000** (0.000)	-0.000** (0.000)	0.007*** (0.001)	0.000*** (0.000)	0.002*** (0.001)	0.006*** (0.001)	0.001** (0.000)
edu	-0.013*** (0.004)	-0.011*** (0.003)	123.208*** (24.318)	0.240*** (0.010)	67.986*** (12.071)	11.618 (15.105)	12.233** (6.000)
pop_65p	0.099*** (0.007)	0.101*** (0.007)	-49.564*** (9.783)		-13.165** (5.536)	-11.811* (6.054)	-13.420*** (2.536)
density	-0.000 (0.000)	-0.000 (0.000)	0.689*** (0.255)	0.000*** (0.000)	0.051 (0.110)	0.269** (0.125)	0.172* (0.093)
y2010	0.003*** (0.001)	0.003*** (0.000)	-10.899*** (1.878)	-0.007*** (0.001)	-7.012*** (1.036)	-0.262 (1.160)	-1.292*** (0.482)
y2011	0.010*** (0.001)	0.010*** (0.001)	-26.230*** (3.684)	-0.013*** (0.002)	-14.681*** (1.969)	-5.059** (2.292)	-2.976*** (1.002)
y2012	0.014*** (0.001)	0.014*** (0.001)	-35.757*** (5.501)	-0.015*** (0.002)	-19.972*** (2.894)	-5.769* (3.440)	-4.038*** (1.427)
y2013	0.019*** (0.002)	0.018*** (0.001)	-49.255*** (7.668)	-0.015*** (0.003)	-26.794*** (4.041)	-8.218* (4.768)	-5.443*** (2.003)
Fixed effects	✓	✓	✓	✓	✓	✓	✓
Observations	170,760	168,394	170,760	170,760	170,760	170,760	170,760
R-squared	0.126	0.129	-0.012	-0.016	0.401	0.145	-0.001
Municipalities	36,081	35,511	36,081	36,081	36,081	36,081	36,081
F-stat	581.7	381.3	1104	825.2	1104	1104	1104

Table 3: Heterogeneous Effects

[illegible]

7 Conclusion

Our analysis shows that the diffusion of broadband Internet eliminates jobs, although the unemployment rate remains flat. This job destruction stems from manufacturing activities, whereas new jobs are created in service-related activities.

These findings accord well with the literature. However, they stress the negative impact of broadband Internet on employment, even though the unemployment rate seems not to be affected due to a rise in activity. Our findings suggest that the job search and income effects of broadband Internet are not strong enough to outweigh its productivity effects.

We find some room for public policies to mitigate these adverse effects of broadband Internet. Our heterogeneity analysis suggests that raising the level of education in urban municipalities tends to alleviate the negative impact of broadband Internet on employment, irrespective of the industry. Therefore, policy makers could complement their broadband Internet plans with education policy

Our findings could however be altered if we considered the long run effects of broadband Internet. The negative effects stemming from productivity improvement are effective in the short run, whereas the positive effects are more likely to emerge in the long run. Given that we focus on a five-year timer span, we could not be able to estimates the long run effects. Moreover, our assessment is not firm specific, but rather average the effects over all firms within a municipality. However, there could be firm-specific effects within the same sector. Future works should rely on longer panels and firm or worker level data in order to address these issues.

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Appendix

Table A-1: manufacture sectors

sector_manu	xds1b	nb3G4G(culossY)
BZ: Extractive Industries	-0.027***	-0.113***
CA: Manufacture of food, beverages and tobacco products	-0.161***	-0.687***
CB: Textile manu,clothing indus,leather footwear indus	-0.176***	-0.750***
CC: Woodworking, paper and printing industries	-0.262***	-1.116***
CE: Chemical Industry	-0.116***	-0.492***
CF: Pharmaceutical industry	-0.067***	-0.284***
CG: Manu of rubber & plastic prod & other non-metal mineral prod	-0.240***	-1.020***
CH: Metallurgy and manufacture of metal prod except machinery & equip	-0.302***	-1.286***
CI: Computer, Electronic and Optical Products Manufacturing	-0.142***	-0.605***
CJ: Manufacture of electrical equipment	-0.106***	-0.449***
CK: Manufacture of machinery and equipment	-0.201***	-0.855***
CL: Manufacture of transport equipment	-0.231***	-0.981***
CM: Other manu indus; repair & installation of machinery & equip	-0.288***	-1.226***
FZ: Construction	-0.540***	-2.300***
GZ: Trade; repair of automobiles and motorcycles	-0.415***	-1.769***
HZ: Transportation and warehousing	-0.345***	-1.469***
JB: Telecommunications	-0.156***	-0.665***

Table A-2: service sectors

sector_service	xds1B	nb3G4G(culossY)
IZ: Accommodation and catering	0.452***	1.923***
JC: Computer activities and information services	0.345***	1.465***
MA: Legal, Account, Manag, Archit, Engi, Contr & Tech Ana Act	0.628***	2.669***
MC: Other specialized, scientific and technical activities	0.095***	0.406***
NZ: Administrative and support service activities	0.168***	0.714***
QA: Activities for human health	0.141**	0.596**
QB: Medico-social & social housing & social act	1.342***	5.713***
RZ: Arts, Entertainment and Recreation	0.147***	0.624***
SZ: Other service activities	0.312***	1.327***

Figure A-1: Variation in broadband penetration and latitude

