

Effect of Residential Broadband Internet Diffusion on Industry Composition: Evidence from Japan

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Abstract

In this paper, we estimate the effect of broadband internet roll-out in Japan on industrial structure through its impact on labor force participation and wages by industry. Using the instrumental variable method, which focuses on regional differences in the geographic characteristics that constrain broadband internet supply, we find that the diffusion of broadband internet increased the probability of labor force participation and wages, particularly in the wholesale and service industries. Possible reasons for this include the spread of online shopping, telework, and the potential for improved job match quality.

Keywords: Broadband Internet, Labor Supply, Wages, Online Shopping, Telework

JEL Codes: J20, J21, J22

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1 Introduction

The internet has permeated our lives and has altered when, how, and where we conduct our activities. As the internet is used in many different ways, its potential effects are multidimensional. From the perspective of workers, while technological progress has facilitated employment in some occupations and industries, it may have reduced the supply of labor in markets where technology and labor are substitutes (Acemoglu and Autor, 2011). From the perspective of consumers, while some of us may have had fewer opportunities to meet friends or family in person due to the coronavirus pandemic, we can interact with them through video calls and chat systems even when we are far away (Gershuny, 2007; Nowland, Necka and Cacioppo, 2018). The coronavirus pandemic has also revealed and strengthened pre-existing trends that have been facilitated by broadband internet such as the increased use of streaming platforms such as YouTube or Netflix to watch movies instead of going to the cinema (Chiang and Hsiao, 2015; Jackson, Amin, Fu, Gilbert and Martin, 2015), and shopping online instead of going to physical stores (Pérez-Hernández and Sánchez-Mangas, 2011; Akhter, 2015).

Economists have long recognized the groundbreaking effect of the internet on our lives (Autor, 2001), and prior research on its spread has shown a range of effects. In the labor market, Dettling (2017) finds that women's labor supply increased due to increased flexibility for women through telework, and Akerman, Ingvil and Mogstad (2015) find that wages for high-skilled workers increased, while wages for low-skilled workers decreased, while Bhuller, Kostøl and Vigtel (2019) and Gürtzgen, né Nolte, Pohlan and van den Berg (2021) find improved job search quality. Beyond the labor market, the impact has ranged from increased sex crime (Bhuller, Havnes, Leuven and Mogstad, 2013) to higher voter turnout (Falck, Gold and Heblich, 2014), and Bauernschuster, Falck and Woessmann (2014) have also found that the internet has increased participation in volunteer activities and increased social capital.

Based on these studies and the recognition that the internet has substantially changed the lives of consumers and businesses, various factors that affect labor supply and demand may

have also changed, and so our analysis will focus on the effect of the internet on industrial structure. In doing so, we will not limit our study to the direct impact of the internet on the labor market, but will also investigate the possibility that changes in consumer behavior may have had an indirect impact on the provision of goods and services and, in turn, industrial structure. To the best of our knowledge, no research to date has analyzed the impact of the broadband internet on the industrial structure through the mechanism of changes in both worker and consumer behavior, and so this study aims to fill this gap.

One of the challenges of analyzing the impact of internet diffusion is the endogeneity of internet usage. Due to the lack of exogenous internet *usage* data, it is difficult to identify causal effects if, for example, more educated or higher income individuals use the internet more than others. To address this challenge, some studies have used the internet *coverage* rate for the analysis, taking advantage of the fact that internet diffusion was delayed in some regions due to exogenous factors (Akerman, Ingvil and Mogstad, 2015; Bhuller, Kostøl and Vigtel, 2019), while others have used an instrumental variable (IV) methodology to take advantage of the fact that, for technical reasons, the internet line speed slows down rapidly when the distance from the base station exceeds a certain threshold (Falck, Gold and Heblich, 2014; Gürtzgen, né Nolte, Pohlman and van den Berg, 2021).

This paper contributes to the literature by adopting broadband internet diffusion as a new instrumental variable, with mountainous areas a geographical source of exogenous variation in the broadband coverage rate. Because of regional difficulties that increased construction costs, access to broadband internet could not initially be implemented in mountainous areas of Japan, so in our analysis, we use the ratio of mountainous areas as our IV and a unique Japanese data set to exploit the spatial and temporal variation in the availability of broadband internet to estimate its effect on industrial structure.

Our main findings are that broadband internet diffusion increased the probability of labor force participation and wages, particularly in the wholesale and service industries, changed the industrial structure due to the spread of online shopping and telework, and improved

job match quality. Additionally, following Akerman, Ingvil and Mogstad (2015), we also estimated the causal effects of broadband internet on labor force participation and wages by level of education, and found that broadband internet increased the probability of labor force participation for highly educated more than less educated individuals, both for males and females. The analysis by educational background also confirmed an increase in the percentage of workers engaged in the wholesale and service industries.

This study also contributes to the large and growing literature on the effects of information and communication technologies (ICTs) on productivity and labor market outcomes by strengthening the claim made in some prior work that technological changes are important in explaining better labor market outcomes (Jorgenson, Ho and Stiroh, 2008; Syverson, 2011; Bloom, Sadun and Van Reenen, 2012). While recent studies have focused on the impact that technological developments such as artificial intelligence (AI) and robotics have had on labor demand (Acemoglu and Restrepo, 2019, 2020; Aghion, Antonin and Bunel, 2019; Frank, Autor, Bessen, Brynjolfsson, Cebrian, Deming, Feldman, Groh, Lobo, Moro, Wang, Youn and Rahwan, 2019), this study examines the internet, which is a more familiar and widespread technology that has the potential to change many aspects of our lives.

The paper proceeds as follows: Section 2 describes the expansion of broadband internet in Japan. Section 3 describes our datasets and Section 4 discusses our empirical strategy. Sections 5 and 6 present and discuss our main estimation results, and Section 7 concludes the paper.

2 Broadband Internet Diffusion in Japan

2.1 Background on Broadband Internet Diffusion

Since the days of dial-up internet, as applications have become more sophisticated, there has been a continued interest in improving internet access and speeds. What is commonly known as broadband internet actually consists of a range of technologies, from CATV provided

by incumbent cable TV companies to DSL through telephone wires and fiber-to-the-home (FTTH). As in many countries, the Ministry of Internal Affairs and Communications (2010) explains that broadband internet service in Japan consisted first of CATV and DSL, and then increased in speed and capacity through FTTH.

So-called dial-up internet, using a non-dedicated portion of the telephone line, was the main internet system before broadband internet service was introduced. CATV was introduced in 1996 as Japan's first broadband internet,¹ but despite the appeal of broadband, dial-up remained more prevalent for a number of years, with 11 million dial-up subscribers compared to 140,000 for CATV in 2000, for example.

The nationwide diffusion of broadband internet infrastructure started in 2000 with the enactment in November 2000 of the *Basic Act on the Formation of an Advanced Information and Telecommunications Network Society* (*kodo-johotshushin-network-shakai-kihonho* in Japanese), which defined an “e-Japan” strategy (*e-Japan senryaku*) to develop high-speed access. DSL began service in 2000 and FTTH in 2001, providing speeds of 100 Kbps - 3 Mbps (for uploading)/1.5 - 40 Mbps (for downloading) and 100 Mbps - 1 Gbps (for both uploading and downloading), respectively. Though both of these technologies are considered broadband, their speed differences substantially affect people's daily lives, taking about an hour to download a movie with DSL but only about five minutes with FTTH, for example. In any case, the e-Japan strategy worked, with broadband internet subscriptions exploding from 140,000 in 2000 to 33 million in 2010, consisting of 6, 8.5, and 18.5 million subscribers for CATV, DSL, and FTTH, respectively (Figure 1).

Since dial-up internet technology relied on the non-dedicated use of the telephone line, there was no regional variation in the internet coverage rate at that time, as all regions had equal access to low-quality internet over the legacy telephone wires and the coverage rate was virtually 100 percent. However, since broadband internet infrastructure, and FTTH in particular, requires new construction, the rollout of broadband infrastructure began to show

¹This service was called “Musashino-Mitaka Cable TV”, and was available only in one city in the Tokyo metropolis.

regional variation, allowing us to use prefectural variation in the speed of FTTH broadband internet development as the identification strategy for this study. As FTTH development depends not only on available financing but also on geographical features that make construction difficult, it could not be rolled out simultaneously across Japan but instead was started first in plains areas and was introduced much later in mountainous areas and far-flung islands. We follow the literature by exploiting these exogenous geographical characteristics (Olken, 2009; Bhuller, Havnes, Leuven and Mogstad, 2013; Bhuller, Kostøl and Vigtel, 2019) to estimate the causal effects of FTTH broadband internet access on labor market outcomes and industry composition.

While the literature has tended to use the DSL coverage rate for an identification strategy (Dettling, 2017; Gürtzgen, né Nolte, Pohlen and van den Berg, 2021), we use the FTTH coverage rate in our analysis, for three main reasons. First, since DSL is easily transmitted over existing telephone lines with an ADSL modem installed in the home, it did not require the huge construction projects required of introducing FTTH. Second, due to data limitations, we have access only to the prefectural level internet coverage rate, but DSL internet speed depends intrinsically on distance from base stations, so prefectural level data is not sufficiently fine-grained. FTTH internet speed, on the other hand, does not depend on distance from a base station, so we can analyze the effect of FTTH precisely even with prefectural level data. Third, DSL was already highly diffused in 2011 with almost a 100% coverage rate in many prefectures, so regional variation cannot be used as an identification strategy during this period. FTTH, on the other hand, shows substantial regional variation in 2011 as seen in Figure 2, so FTTH is an appropriate identification strategy for our analysis.

The coverage rate of FTTH broadband internet for each prefecture, Cov_{pt} , is calculated as follows:

$$Cov_{pt} = \frac{BBhh_{pt}}{hh_{pt}}, \quad (1)$$

where $BBhh_{pt}$ is the number of households of prefecture p in year t that have access to FTTH internet and hh_{pt} is the total number of households in prefecture p at year t .

Figure 3 shows the FTTH diffusion rate by prefecture from 2006 to 2016. We can see that diffusion rates in 2006 were high in prefectures with large government-ordinance-designated cities such as Tokyo, Aichi, and Fukuoka and lower in less populated prefectures. However, we note that the diffusion rate for Wakayama was also high even though the prefecture does not have a government-ordinance-designated city. As discussed in the previous section, the construction of broadband internet infrastructure depends on geographical characteristics such as mountainous areas and island areas. This is discussed in the next section.

While prefectures such as Tottori, Kagawa, Kochi, Kumamoto, Kagoshima, and Okinawa had a lower diffusion rate in 2006, the Basic Act on the Formation of an Advanced Information and Telecommunications Network Society caused broadband infrastructure development to accelerate, and we can see that each prefecture reached a 90-100% diffusion rate in 2016. It is this spatial and temporal variation in the broadband internet diffusion rate that we use for our identification strategy.

2.2 Determinants of the Broadband Internet Diffusion Rate

In the previous section, we discussed our use of the FTTH broadband internet coverage rate as our identification strategy. This section confirms that regional differences in internet coverage are due to geographic factors.

Geographic factors proliferate in the literature as one of the reasons for observed regional differences in internet coverage. From a geographic perspective, the digital divide is particularly noteworthy in disadvantaged areas such as mountainous regions, remote islands, and marginal areas of the country, and in the early days of the internet, organizations and residents in disadvantaged areas had limited access. (Arai, Naganuma and Satake, 2012). It is further pointed out that the initial cost of broadband development in mountainous areas is high due to, for example, long installation distances and the need to install new stations and poles (Ministry of Internal Affairs and Communications, 2007).

Figure 2 shows the coverage rate by prefecture in 2006, 2011, and 2016, and we can

see not only prefectural variation but also intertemporal changes in broadband even among prefectures of similar cultural, economic and geographic zones. Ibaraki, Tochigi, and Gunma prefectures in the northern Kanto region, for example, are considered to belong to the same economic, cultural and geographic zone to the north of Tokyo. In 2006, Tochigi had the highest coverage rate, but by 2011, Tochigi and Gunma had similar coverage, indicating that Ibaraki was lagging behind in 2011. As another example, Akita prefecture in the Tohoku region showed higher coverage rate than Iwate prefecture in the same region in 2006 but by 2011, they were at the same level. In these examples, we can see that similar prefectures belonging to the same region with similar economic and cultural characteristics show differences in the diffusion rate, so it can be inferred that some other factor affected the internet coverage rate in Japan. In this study, we focused on geographical factors; specifically, the mountainous area ratio.

According to the Broadband Infrastructure Development Status (BIDS) survey of the Ministry of Internal Affairs and Communications (MIC), although there were regional differences in the broadband diffusion rate in 2006, the diffusion rate had reached close to 100% in most regions of Japan by 2016. Between 2006 and 2016, when broadband internet spread nationwide, the change in the coverage rate is considered to be larger in mountainous areas which had previously lagged and smaller in the plains areas which have fewer geographical barriers and which had already had a high coverage rate 10 years earlier.

In order to confirm that the coverage rate is indeed determined by geographic characteristics, we calculated the correlation between the coverage rate and the percentage of mountainous areas by prefecture. For the coverage rate, using BIDS data, we took the first difference of the coverage rate between 2006 and 2016. For the percentage of mountainous areas, we used data from the Census of Agriculture and Forestry. Since geographical characteristics are regarded as constant, we used the most recent data which was collected in

2000. The estimation equation is the following:

$$DiffCov_{pt} = \gamma_1 Mountain_p + \gamma_2 X_{pt} + v_{pt}, \quad (2)$$

where $DiffCov_{pt}$ is the first difference in the coverage rate between 2006 and 2016, $Mountain_p$ is the ratio of mountainous areas in prefecture p in 2000, which is considered to be constant over time, and X_{pt} are control variables in 2006 covering an index of financial strength, log of income per capita, unemployment rate, log of population, log of total production, log of average revenues, and log of average wage.

First, we drew a scatterplot of the correlation of the first difference in the internet coverage rate and percentage of mountainous areas. As shown in Figure 4 and Table 2, the two variables are positively correlated and statistically significant. Even after we include the control variables, the correlation remains statistically significant, so we can conclude that the prefectural variation in the rollout of broadband internet does indeed depend on geographical characteristics.

3 Data

To estimate the impact of broadband internet diffusion on labor force participation and wages, we used four data sources. These are the Broadband Infrastructure Development Survey (BIDS), Labor Force Survey (LFS) and Survey on Time Use and Leisure Activities conducted by the Ministry of Internal Affairs and Communications (MIC), and the Basic Survey on Wage Structure conducted by the Ministry of Health, Labour and Welfare (MHLW), all of which are described further below.

3.1 Broadband Infrastructure Development Survey

As a measure of regional development, the Ministry of Internal Affairs and Communications has surveyed the broadband internet coverage rate for each municipality in Japan every

year since 2006. Although the survey is conducted at the municipal level, for reasons of confidentiality, we were provided access only to prefectural level data, and so we used this prefectural level coverage rate for our analysis.

3.2 Labor Force Survey

To investigate labor force participation, we used the Labor Force Survey (LFS) also conducted by the Ministry of Internal Affairs and Communications (MIC). LFS is a monthly survey which collects information on all household members aged 15 or older in households dwelling in the sampled units. The LFS adopts a rotating sampling structure that surveys the same household for two consecutive months, and then after a 10-month break, it again surveys the same households for two months. The annual sample size is about 240,000 individuals from 120,000 households, and this survey provides the most detailed large sample labor force survey data in Japan.

The LFS collects information on household members, including each member's labor-force status and hours worked during the last week of each survey month, age, education, and annual labor earnings. The survey also records the highest educational attainment as follows: (1) junior-high school, (2) high school, (3) junior college and technical college, and (4) four-year college and graduate school. We use individual data on labor force participation, and Table 1 shows summary statistics for the key variables.

3.3 Basic Survey on Wage Structure

The Basic Survey on Wage Structure (BSWS), which is one of the major data sources of our study, is an annual establishment survey conducted by Ministry of Health, Labour and Welfare (MHLW), which collects individual worker data on payroll records via a random sampling of establishments.

Establishments are randomly sampled according to the Establishment and Enterprise Census (EEC), which lists all establishments in Japan, and the sample is constructed to be

representative of the prefecture and industry share and establishment size of the EEC. Then, each sampled establishment randomly chooses a certain number of workers from the pool of employees by using a sampling probability which depends on the industry and establishment size. We use the individual sampling weight, which is included in the BSWS, for our analysis.

All types of workers, including full- and part-time workers and regular and temporary workers,² are surveyed when they are directly hired by randomly selected establishments. The sample does not cover (1) workers at establishments with less than 5 workers, and (2) agriculture, fishery, and the legislative, administrative, and judicial branches of local and national governments. The survey is conducted every June, and the sample size is about 1,570,000 workers at 7,000 randomly sampled establishments.

BSWS collects establishment information (firm size, industry, location, number of regular workers, and number of new graduates hired) and employee information (employment status, type of employment, occupation, gender, age, education (only for regular workers), seniority, years of experience, number of working days, scheduled hours, overtime hours, contractual cash earnings, and annual special earnings) for each sampled worker from payroll records. For our analysis, we calculated hourly wages using the following equation and weighted them by the BSWS individual sampling weight:

$$w = (e_c + \frac{e_s}{12}) / (h_s + h_o), \quad (3)$$

where w is hourly wages, e_c contractual cash earnings, e_s annual special earnings, h_s scheduled hours, and h_o overtime hours.

²Workers are classified as regular workers if workers are: (1) on contracts that do not clearly specify a contractual time period; (2) on contracts that last more than one month; or (3) on contracts that last less than one month, but on which the workers worked 18 or more days in the last two months. Part-time workers as well as full-time workers can be classified as regular workers if at least one of the above criteria is satisfied.

3.4 Survey on Time Use and Leisure Activities

The Survey on Time Use and Leisure Activities is used in our study for a detailed analysis of behavioral changes. This survey has collected the time allocation of the Japanese general public every 5 years since 1976, so it has a repeated cross-sectional data structure. The sample size is around 190 thousand each survey year, providing the most detailed large sample time allocation survey data in Japan.

The survey is fielded over a nine-day period including two weekends in October, and each respondent is given two days to reply. Each household member aged 10 or older reports their activities in 15-minute intervals from among 20 kinds of activities.³ In addition, each respondent is also asked to select an answer to the question “Did you use the internet?” for each 15-minute interval. We use both components of this data (the measure of activity and the internet use) for our detailed analysis of activity, such as online shopping and telework.

4 Model

We examined the effects of the FTTH broadband internet on labor force participation and wages using data from the Labor Force Survey and Basic Survey on Wage Structure. Due to concerns about the potential endogeneity of internet *usage*, we followed the literature (Bhuller, Havnes, Leuven and Mogstad, 2013; Bhuller, Kostøl and Vigtel, 2019) and estimated the intention-to-treat effects using the internet *coverage* rate. Because the Broadband Infrastructure Development Survey was first conducted in 2006, the period of our analysis is 2006-2016, and the observation unit is individual-prefecture-year. Furthermore, we restricted the sample to adults of working age between 20 and 59. This is because few people work full-time in Japan prior to adulthood at age 20, and retirement begins at the age of 60.

³The possible activities are: 1. Work, 2. Schoolwork, 3. Commuting to/from school or work, 4. Studying and Researching, 5. Housework, 6. Child Care, 7. Shopping, 8. Sleep, 9. Personal Care, 10. Meals, 11. Medical Examination or Treatment, 12. TV, Radio, Reading, 13. Rest and Relaxation, 14. Hobbies and Amusements, 15. Sports, 16. Volunteer and Social Activities, 17. Social Life, 18. Travel Other than Commuting, 19. Caring and Nursing, and 20. Other Activities.

Although some retirees in Japan are rehired, their wages often drop and their jobs change, with most retirees shifting from full-time to part-time positions.

To investigate the effect of broadband diffusion on labor market outcomes, we used ordinary least squares to estimate the following equation:

$$y_{ist} = \gamma_1 Cov_{pt} + \gamma_2 X_{ist} + \lambda_i + \theta_t + \eta_s + \eta_s t + \delta R_{st} + v_{ist}, \quad (4)$$

where y_{ist} denotes outcome variables such as a labor force participation dummy variable and log wages for individual i in municipality s in year t , Cov_{pt} is the share of the population of prefecture p that resided in a housing unit that was covered by broadband FTTH internet in year t , X_{ist} is a vector of demographic variables including education, age, and gender,⁴ λ_i denotes industry, occupation, and firm size fixed effects,⁵ θ_t year fixed effects, η_s municipality fixed effects, t a linear trend, R_{st} a vector of prefecture characteristics including an index of financial strength, log of income per capita, unemployment rate, log of population, log of total production, log of average revenues, log of average wage bill, and v_{ist} is the error term. Standard errors are clustered at the prefecture level.

4.1 Identification Strategy

The coefficient of interest is γ_1 , which indicates the effect of the broadband coverage rate on the outcome variables. As Akerman, Ingvil and Mogstad (2015) discuss, the key threat to the identification of γ_1 is that the timing of the diffusion of broadband internet might be related to different underlying trends in labor market outcomes. Our identification strategy controls for municipality and year fixed effects, and it also relies on two features of the policy

⁴We use the following categories for each demographic dummy variable: junior-high school, high school, junior college or technical college, and four-year college or graduate school for education; and full-time worker or part-time worker for employment status.

⁵Industry fixed effects consist of a 2 digit classification with 82 categories, and occupation fixed effects consist of a 2 digit classification with 54 categories.

⁶We use the following categories for firm size fixed effects: number of employees is either 1, 2-4, 5-9, 10-29, 30-99, 100-499, 500-999, more than 1000, or unknown.

to expand broadband internet availability. First, most of the time-variant factors for internet availability tend to change very little over time. Second, the timing of the diffusion does not correlate with key correlates of labor market outcomes.

First, in order to check whether the data are consistent with the first feature, we estimated the following equations:

$$Cov_{pt} = \theta_t + \eta_p + v_{pt}, \quad (5)$$

$$Cov_{pt} = \theta_t + \eta_p + \delta R_{pt} + v_{pt}, \quad (6)$$

where θ_t denotes year fixed effects, η_p prefecture fixed effects, R_{pt} prefecture characteristics such as index of financial strength, log of income per capita, unemployment rate, log of population, log of total production, log of average revenues, and log of average wage bill. The R^2 for equation (5) and (6) are 0.85 and 0.87, indicating that 85 percent of the variation in broadband internet availability can be attributed to time-invariant prefecture characteristics and common time effects, while 2 percent of the variation can be attributed to a large set of time-varying variables.

Second, we examined the relationship between the timing of broadband diffusion and baseline prefecture characteristics using the following estimation equation:

$$\Delta Cov_{pt} = \eta_p + [\theta_t \times R_p]' \psi_t + v_{pt}, \quad (7)$$

where $\Delta Cov_{pt} = Cov_{pt} - Cov_{p,t-1}$, θ_t is a vector of year fixed effects, and R_p is the same vector of prefecture characteristics in the year 2000. Figure 5 shows the estimated coefficients and 95 percent confidence intervals of the vector ψ_t for every t . As the timing of the expansion does not correlate with baseline characteristics, this supports our identification strategy.

4.2 Instrumental Variable Estimation

However, even though in our OLS estimation we controlled for municipality and year fixed effects and a time trend, and notwithstanding that time-variant factors in each prefecture do not correlate with the timing of broadband internet diffusion, we still have concerns about potential endogeneity caused by unobserved time-variant factors. In order to deal with this concern, we used the interaction term between the ratio of mountainous area by prefecture and year fixed effects as an instrumental variable, since the ratio of mountainous area is expected to lead to differences in the trends in broadband internet availability across prefectures. For our IV estimation, we used the following first stage estimation equation:

$$Cov_{pt} = \mu_1 Mountain_p * \theta_t + \mu_2 X_{ist} + \theta_t + \eta_s + \delta R_{st} + v_{ist}, \quad (8)$$

where $Mountain_p$ is the percentage of mountainous area in prefecture p in 2000 which is considered to be constant over time and Cov_{pt} , X_{ist} , θ_t , η_s , R_{st} , and v_{ist} are the same as in the OLS estimation.

Because of regional difficulties and the large construction cost, FTTH broadband infrastructure in mountainous areas could not be conducted easily, so $Mountain_p * \theta_t$ year fixed effects should be relatively more negative in the earlier years of the sample than the later years. The coefficients μ_1 are expected to be negative with their magnitude decreasing over time and we omitted $Mountain_p * \theta_{t=2016}$ for the identification. Table 3 presents the first stage estimation results which exhibit the expected relationship. Therefore, we conclude that variations in the diffusion of broadband internet infrastructure over time do depend on geographical characteristics.

The second stage estimation equation is the same as that for the OLS estimation:

$$y_{ist} = \gamma_1 Cov_{pt} + \gamma_2 X_{ist} + \lambda_i + \theta_t + \eta_s + \eta_s t + \delta R_{st} + v_{ist}. \quad (9)$$

While it is not possible to test the exclusion restriction directly, we can test this assump-

tion by performing a placebo test of the reduced form effect of the instrument on labor force participation before FTTH broadband internet was available. If the ratio of mountainous areas correlates with the trend in labor supply at that time, then the exclusion restriction would have been violated during the period when the FTTH broadband internet was available. In this placebo test, we focused on the period from 1995 to 2000, as FTTH broadband internet was not available until 2001. Figure 6 shows the results of the reduced form analysis from 1995 to 2000, which includes all the control variables discussed above. As there is no significant impact of mountainous areas on labor force participation rates in any of the years shown, and the results also do not show any clear trend or pattern, this suggests that the exclusion restriction is satisfied.

5 Estimation Results

Although our research interest is to examine the impact of the diffusion of FTTH broadband internet on industry composition, we first estimated its impact on labor participation and wages across all industries, and also performed a subsample analysis by gender.

5.1 Effect on Labor Force Participation

First, we estimated the effect of broadband internet on labor force participation, and the results are shown in Table 4. Column 1 is the OLS estimation result and shows that the probability of labor force participation was increased by broadband availability. When the coverage rate increases by 10%, the probability of participating in the labor force increases by 0.21%, which is statistically significant at the 1% level.

Column 2 of Table 4 shows the IV estimation results. When the internet coverage rate increases by 10%, the probability of participating in the labor force increases by 0.42%, which is marginally statistically significant at the 10% level. Compared to the OLS estimates, the magnitude of the IV estimates is larger, indicating that the OLS estimation results are

negatively biased. As the first-stage F-Statistic is 91.24, there is no concern about the power of the instrumental variable.

Columns 3-6 of Table 4 show the estimation results by gender. For both men and women, we see statistically significant results at the 1% level for labor force participation, but the effect is larger for women than men. When the internet coverage rate increases by 10%, the probability of labor force participation for women increases by 0.51% (OLS) and 2.11% (IV) and for men it increases by 0.07% (OLS) and 0.70% (IV).

The reasons for these observed results could be an increase in wages and a decrease in reservation wages. For example, telework facilitated by broadband internet availability could increase wages by increasing productivity due to reduced commuting times or workplace distractions. Broadband availability could also decrease reservation wages by providing opportunities to work from home, reducing childcare expenses and the psychological costs of being away from home. We estimate the effects of broadband internet diffusion on wages in the next subsection to clarify the reason for increased labor force participation, and estimate the impact on telework in the next section.

5.2 Effect on Wages

Next, we estimated the effect of broadband internet coverage on wages by using the MHLW Basic Survey on Wage Structure in order to clarify the reason for the observed increase in potential labor force participation. The results are presented in Table 5, and Column 1 shows the full sample OLS estimate. When the broadband internet coverage rate increases by 10%, wages decrease by 0.18%, which is statistically significant at the 5% level. Column 2 shows the IV result, and we see that when the broadband coverage rate increases by 10%, wages increase by 0.61%, which is also statistically significant at the 5% level. As the magnitude of the IV estimate is larger than the OLS estimate, this indicates that the OLS estimation result shows a negative bias. The first-stage F-Statistic is 98.54, indicating that our IV is sufficiently strong.

Columns 3 - 6 in Table 5 show the result of subsample analysis by gender. Columns 3 and 5 show our OLS estimates, and indicate that broadband coverage expansion decreases both male and female wages. The IV estimates are shown in columns 4 and 6, and while the effect on female wages is not significant, when the broadband coverage rate increases by 10%, male wages increase by 0.85%, which is statistically significant at the 5% level.

Taking the labor market effects together, we have found statistically significant effects for both men and women in the likelihood of labor market participation, though the magnitude of the effect is larger for women, and a statistically significant result only for men in terms of wages. Thus, we can state that the effects of broadband internet diffusion seems to have rewarded males mostly with higher wages and women through more opportunities to participate in the labor force through new platforms such as online shopping and telework.

5.3 Effect on Industry Composition

After having estimated the effect of broadband internet diffusion on labor force participation and wages aggregated across all industries above, we now in this section present the results of our main analysis, which are the effects by industry. For this analysis, we used the same estimation equation, but the outcome variables are labor force participation and log wages for each industry. From the results, we can estimate the impact of broadband internet diffusion on industry composition by analyzing the industry-level effects on potential labor force participation and wages.

Figures 7 to 9 present the estimation results of the effect on labor force participation. From Figure 7, which shows the OLS estimates, we can see that broadband internet increased employment potential in some industries such as manufacturing; electricity, gas and water utilities; wholesale trade; finance and insurance, and services. We also found statistically significant negative results for information and communications, transport and postal activities, retail trade, school education, and compound services. The IV estimates in Figure 7 indicate statistically significant effects in some industries including electricity, gas, and

water utilities; information and communications; wholesale and retail trade; medical welfare; school education; services and compound services. While the probability of engaging in wholesale trade increased, that of retail trade decreased. This result would be consistent with the spread of online shopping that has caused the physical retail sector to shrink but the wholesale sector to expand. In the next section, we will explore further the reasons for this finding.

We also conducted a subsample analysis by gender. Figure 8 shows the results for males, and while the OLS estimates in Figure 8 show statistically significant effects of broadband in many industries, the IV results in Figure 8 isolate only a few industries, with increased chances of working in wholesale trade; electricity, gas, and water utilities; and services, while the potential was decreased in information and communication, school education and compound services. While at first it may seem counterintuitive that broadband internet diffusion reduced the opportunities for employment in the information and communication industry, also included in this industry are broadcasting and film, video and animation production, which might have been negatively affected by broadband access. In addition, since the compound services industry includes postal services, it is understandable that broadband internet availability might have reduced the demand for postal services in favor of alternatives such as e-mail and video calls for communicating.

Figure 9 shows similar results for females, especially in wholesale trade and services. The IV results in Figure 9 show an increased potential for employment in wholesale trade, finance and insurance, and services, and decreased opportunities in retail trade, accommodations, restaurant businesses, medical welfare, and school education.

Regarding the effects on wages, the estimation results by industry are presented in Figure 10, and we see statistically significant results from the OLS estimation in several industries, but the IV estimates in Figure 10 show that wages in the electricity, gas and water and services industries were increased by the expansion in broadband internet availability, and these effects were experienced for both males and females, as we see in the IV results presented in

Figures 11 and 12.

We note that the OLS and IV estimates were different in all estimations. We conjecture that this is due to unobserved time-variant factors that are correlated with the broadband internet coverage rate, causing the OLS estimates to be biased.

5.4 Subsample Analysis by Level of Educational Attainment

It has been pointed out that the impact of technological progress is felt differently between high-skilled and low-skilled workers (Autor, Levy and Murnane, 2003), so we also investigated the impact of educational attainment in this study. For this analysis, we used data on the highest level of educational attainment from the Labor Force Survey and the Basic Survey on Wage Structure. The LFS and the BSWS ask respondents to choose among the following categories: (1) junior-high school, (2) high school, (3) junior college and technical college, and (4) four-year college and graduate school. For our analysis, we combined groups 1 and 2 into a new group with high school or below as their highest level of educational attainment, creating three educational attainment groups instead of four. We did not combine groups 3 and 4 because of the highly gendered nature of these two higher education choices. The rate of enrolment at junior colleges in Japan is very high for women, where even women with the academic ability to enter a four-year university have chosen to instead attend junior colleges for reasons of better employment or marriage. Below, we first discuss the effect of education on labor force participation and wages across industries before moving to the results by industry.

5.4.1 Labor Force Participation

First, we estimated the effects of broadband internet availability by level of educational attainment and by gender using the instrumental variable method. The results are shown in Table 6 and, for males, we see negative but statistically insignificant effects for those with junior or senior high school as their highest level of educational attainment, but statistically

significant positive effects for graduates of junior college/technical college and four-year college/graduate school. When the broadband coverage rate increases by 10%, the probability of labor force participation increases by 0.48% for junior college/technical college graduates and 1.69% for four-year college/graduate school graduates. In general, the effects of broadband internet availability are monotonically increasing for males by level of educational attainment, but substantial effects are only seen for those who have completed college or better.

For females, we see a similar monotonically increasing effect of education on probability of labor force participation, with the magnitudes of the effect larger than that for males so that the effect for females is positive and statistically significant for all levels of educational attainment. When the broadband coverage rate increases by 10%, the probability of labor force participation increases by 1.31% for junior-high school/high school graduates, 1.64% for junior college/technical college graduates, and 3.87% for four-year college/graduate school graduates. Taking all the results together, we can see that each higher level of educational attainment accrues greater benefits from the availability of broadband internet on the probability of labor force participation for everyone, but for each level of educational attainment, the effects are larger for women than for men. For example, only graduating junior-high school/high school is not statistically significant for men but still positive and statistically significant for women. Also, the effect on women with junior college/technical college is almost the same as men with college degrees. Furthermore, women with college degrees benefitted most from the broadband internet expansion. Therefore, taking all these together, it seems that women have unambiguously benefitted more from the diffusion of broadband internet.

5.4.2 Wages

Next, we estimated the effects of broadband availability on wages by gender and level of educational attainment. The results of the IV estimation are shown in Table 7, and for

females, although the results are not statistically significant, the relationship is monotonically increasing by education level. This is not the case for males, and significance is achieved only for the most highly educated group. When the broadband coverage rate increases by 10%, wages increase by 1.57% for graduates of four-year college or graduate school, and this is statistically significant at the 1% level. These results are consistent with the literature (e.g. Akerman, Ingvil and Mogstad (2015)), which shows that broadband internet improves the wages of skilled workers but not unskilled workers.

5.4.3 Discussion

These results indicate that broadband internet diffusion benefitted both men and women through an increased potential for labor force participation and higher wages, though the wage effect was stronger for men and the participation effect larger for women. In addition, broadband availability monotonically increased the potential for labor force participation by level of educational attainment, with the positive effects stronger for women than for men at each level of education. As for wages, we see a similar, though not statistically significant, monotonically increasing effect of broadband availability on wages by level of educational attainment for women, but this pattern does not hold for men. For men, the relationship is not monotonically increasing, though we see statistically significant positive effects for the most highly educated men.

Drawing on the literature, Bartel, Ichniowski and Shaw (2007) show that adoption of new information technology reduces production time and improves efficiency, and Autor, Levy and Murnane (2003) and a growing literature suggests that ICTs substitute for workers performing routine tasks but complement workers executing non-routine abstract tasks. Our results are consistent with the literature in that our finding that broadband expansion increased wages, and that the effect was larger for the more highly educated, suggests that this might have been the result of increased productivity. Further, we did find negative effects of broadband availability on the wages of the least educated females and on

the potential for labor force participation for the least educated males, these results were not statistically significant. One possible reason for this is that the life time employment system, while weakening, remains a key feature of the Japanese employment system (Kato and Morishima, 2002; Moriguchi and Ono, 2004), and so it is conceivable that firms could not replace unskilled workers easily even with the technological advancement.

The results also suggest that broadband internet diffusion gave women more options for labor force participation, regardless of their level of education. This finding is consistent with the previous literature Dettling (2017), which finds that women's labor force participation increased due to increased work-family balance for women through saving time in home production and telework. We estimate the mechanism behind the increased female labor force participation by focusing on online shopping and telework in the next section.

5.4.4 Effect on Industry Composition

We next estimated the impact of broadband internet diffusion on industrial structure by educational attainment and gender. The IV results are shown in the Figures 13 to 16.

First, looking at the impact on the probability of labor force participation by industry for males, which is shown in the Figure 13, we see that for the least educated group, the probability of working in the electricity, gas, and water industry and the transport and postal activities industry increased, while the probability decreased for school education (including schools, head offices or branches for administrative work of school education, libraries, museums, zoos, botanical gardens, aquariums, vocational training facilities, cram schools, music classes, calligraphy classes, flower arrangement and tea ceremony classes, abacus classes, foreign language conversation classes, and sports and health classes) and compound services (including post offices, agricultural cooperatives, and other cooperatives). For men who graduated from junior college or technical college, potential employment increased in wholesale trade but, like the least educated group, decreased in school education and compound services. The probability of being engaged in the wholesale trade, as well as the service

industry, also increased for men who graduated from university or graduate school, while the probability of being engaged in accommodation and restaurant business, school education, and compound service industries decreased. These results indicate that although there are some differences in the effect of increased broadband availability by level of educational attainment, there is a tendency for the probability of engaging in the wholesale trade and service industries to increase, and that of school education and compound service industries to decrease with levels of educational attainment.

As a potential cause of the observed decline in the probability of engaging in school education, the spread of online video-based cram schools and online foreign language conversation may have made it possible to reduce the number of teachers. It is also possible that the spread of the internet has caused the labor-intensive work of less-educated people hired to promote cram schools and lessons has shifted to less expensive online advertising. In addition, the probability of engaging in compound services may have decreased because the number of postal services has decreased due to the spread of the internet, and the number of mail carriers and postal clerks may have also decreased.

Next, looking at the IV results for women, shown in Figure 14, we see that for women who graduated from junior high school or high school, the probability of engaging in the service industry increased, while the probability of engaging in the retail, school education, and compound service industries decreased. For women who graduated from junior college or technical college, the probability of engaging in wholesale trade increased, while the probability of engaging in the electricity, gas, and water supply, and medical welfare industries decreased. Finally, for women who graduated from universities and graduate schools, the probability of being engaged in the wholesale trade and service industries increased, while that of the retail trade, accommodation/restaurant business, medical welfare, school education, and compound service industries decreased. Altogether, these effects are similar to those for men, with the probability of engaging in the wholesale trade and service industries increasing and that of education and learning support and the compound service industries

decreasing, though there are some differences by educational background.

Turning to the effects on wages, Figures 15 and 16 show the IV estimates by industry. For the least educated males, wages rose in the wholesale trade and electricity, gas, and water supply industries, but fell in the construction, information and communication, and medical welfare industries. For men who graduated from junior college or technical college, wages rose in the accommodation and food services and the service industries, but fell in the construction industry. For the most highly educated males, wages increased in the electricity, gas and water supply and service industries, but decreased in the accommodation and restaurant industry.

For women, the least educated saw their wages increase in the wholesale industry, while wages in the medical welfare industries declined. For women who graduated from junior or technical colleges, wages increased in the information and communication, transportation, and real estate and service industries. For the most highly educated women, wages increased in the electricity, gas and water supply, transportation, and service industries, and decreased in the mining industry.

For both males and females, wages in the service sector increased among junior or technical colleges and college or graduate school graduates, and the reason for this may be higher wages due to higher productivity and job match quality resulting from the spread of the broadband internet. Also, for both men and women, the wages of wholesale workers in the less-educated group increased, which may have been brought about by the spread of online shopping. Furthermore, the less-educated group is more likely to be engaged in labor-intensive industries, which may be the reason for the decline in wages seen in the construction and health and welfare industries.

6 Mechanism for Change in Wages and Industry Composition

We have found that broadband internet diffusion increased wages and potential employment for many workers and also changed the industry composition. In this section, we discuss the possible reasons underlying our findings. In particular, we consider three potential mechanisms: 1. increase in online shopping, 2. increase in telework, 3. improved job search quality.

6.1 Increase in Online Shopping

First, we estimate the effect of increased broadband internet availability on online shopping. The expansion of the internet has dramatically changed consumer behavior in many ways, one of these being an increase in online shopping, with Amazon, Rakuten, and other online shopping platforms used regularly. Because we found that potential engagement in wholesale trade increased, but retail trade decreased, our hypothesis is the increase in online shopping due to broadband diffusion caused retail trade to shrink but wholesale trade to expand.

To test this hypothesis, we used the MIC Survey on Time Use and Leisure Activities. In Questionnaire B of the survey, respondents choose from a list of twenty categories which activity they performed each 15 minute interval over a period of 24 hours. In addition, respondents also answer whether or not they used the internet during each of these 15 minute intervals. Thus, for our analysis, we considered a respondent to have been shopping online if they chose both shopping as the activity and yes for internet usage, and we calculated the sum of online shopping minutes per day. Similarly, we considered a respondent to be shopping offline if they chose shopping and no for internet usage, and calculated the total number of minutes of shopping offline. This allowed us to analyze the impact of both online and offline shopping, and we predicted that the increase in online shopping may decrease offline shopping.

We estimated the following IV regression equation:

$$y_{ist} = \gamma_1 Cov_{pt} + \gamma_2 X_{ist} + \theta_t + \eta_s + \delta R_{st} + v_{ist}, \quad (10)$$

where y_{ist} is the outcome variable and denotes either online shopping minutes or offline shopping minutes, Cov_{pt} is the percentage of the population of prefecture p that resided in a housing unit that was covered by broadband internet at year t , X_{ist} is a vector of demographic variables including education, income, age, gender, and family type,⁷ θ_t and η_s are year and municipality fixed effects, R_{st} is a vector of prefecture characteristics including an index of financial strength, log of income per capita, unemployment rate, log of population, log of total production, log of average revenues, and log of average wage bill, and v_{ist} is the error term. Time period t is 2006 and 2011 in this analysis. Standard errors are clustered at the prefecture level.

Our IV results appear in Tables 8 and 9. When the internet coverage rate increased by 10%, the online shopping minutes for people in their twenties increased by 15.1 minutes, and their offline shopping minutes decreased by 3.7 minutes, with both of these results statistically significant at the 1% level. On the other hand, we did not find any statistically significant results for those in their thirties, forties, and fifties. Online shopping was common only among the younger generation in our data period, both in 2006 and in 2011. From these results, we can conclude that broadband diffusion increased online shopping for those in their twenties, and this is consistent with our findings of increased labor force participation in wholesale trade and decreased labor force participation in retail trade.

⁷We used the following categories for each demographic dummy variable: 9, 12, 14 and more than 14 years for education; less than 1 million JPY, 1-1.99 million JPY, 2-2.99 million JPY, 3-3.99 million JPY, 4-4.99 million JPY, 5-5.99 million JPY, 6-6.99 million JPY, 7-7.99 million JPY, 8-8.99 million JPY, 9-9.99 million JPY, 10-14.99 million JPY, and greater than or equal to 15 million JPY for income; individual years of age dummy variables for age 10-112; couple, couple and children, couple and their parents, couple and their single parent, couple with children and both parents, couple with children and a single parent, motherless family, fatherless family, single, others, and older couple for family type.

6.2 Telework

The second potential mechanism for the observed impact of broadband expansion on wages and industry composition is an increase in telework, as Dettling (2017) finds that telework spread out in tandem with internet expansion in the US. In order to test this hypothesis, we used telework minutes, which we have defined as working minutes that do not have any associated commuting minutes in the Survey on Time Use and Leisure Activities. In addition, we estimated the effect of broadband diffusion on commuting minutes as an outcome variable, using the following equation:

$$y_{ist} = \gamma_1 Cov_{pt} + \gamma_2 X_{ist} + \theta_t + \eta_s + \delta R_{st} + v_{ist}, \quad (11)$$

where y_{ist} indicates either working minutes when not commuting at all or commuting minutes, and all other variables are the same as in the previous estimations.

The IV estimation results are shown in Tables 10 and 11, with Column 1 of Table 10 showing the estimate of telework minutes for the full sample analysis. When the coverage rate increased by 10%, telework minutes increased by 9.3 minutes, which is statistically significant at the 1% level. As columns 2 and 3 show, when the broadband coverage rate increased by 10%, telework minutes increased by 12.8 minutes for males but we did not find any statistically significant result for females.

The IV estimation results for commuting minutes are shown in Table 11, and we see that the results are statistically significant. When the broadband coverage rate increased 10%, commuting minutes decreased by 10.3 minutes for the full sample, and 11.6 minutes for males. We did not find any statistically significant results for females here as well.

Together, these results show that telework has become more widespread and commuting time has decreased with the diffusion of broadband internet. Considering our main results, it is therefore plausible that an increase in telework may have encouraged labor force participation and, moreover, may have increased productivity and wages, especially for males.

6.3 Job Search Quality Improvement

The third potential mechanism we consider is an improvement in the quality of job search activities. We assume that the widespread use of the internet has increased the probability of changing or obtaining jobs because of a reduction in the cost of job search that has increased the opportunity to find a job easily. Hence, the quality of job search activities may have improved, leading to increased labor force participation and higher wages.

In order to test this hypothesis, we estimated the effect of broadband internet diffusion on job tenure, using data from the Basic Survey on Wage Structure. If job search costs have fallen and people have become more active in changing jobs and looking for work, then the number of people with shorter job tenure will have increased. The estimation equation is as follows:

$$DummyTen_{ist} = \beta_1 Cov_{pt} + \beta_2 X_{ist} + \lambda_i + \theta_t + \eta_s + \eta_s t + \delta R_{st} + v_{ist}, \quad (12)$$

where $DummyTen_{ist}$ indicates tenure dummy variables, which are categorized into 0-5 years, 6-10 years, 11-15 years, 16-20 years, and over 20 years. All other variables are the same as previous estimations.

The results are shown in Table 12, and we see that broadband internet diffusion increased the probability of shorter tenure categories (0-5 years, 6-10 years, and 11-15 years) but was not significant for longer categories. This is consistent with the hypothesis that broadband internet diffusion improved job search quality, as this may have lowered job search costs and increased job-seeking behavior, stimulating job changes and raising wages.

From the results of the analysis by industry which showed a substantial impact on the wholesale and retail industries, the increase in online shopping appears to be the most important mechanism. Beyond trade, other industries were also affected by the spread of the broadband internet, but this is presumably due to the increase in telework and improvements in job search quality, which caused job changes between industries.

7 Conclusion

This paper examined the impact of broadband internet diffusion on industrial structure, focusing on labor participation rates and wages by educational attainment and gender. Using the instrumental variable method and a unique Japanese dataset, we found that increased broadband internet availability did increase the potential for labor force participation by level of education for both men and women and in terms of increased wages, particularly for men. At the industry level, we found a substantial increase in wholesale trade and a decrease in retail trade, and it was confirmed that there was also an increase in online shopping and telework as well as an improvement in job search quality.

One of the limitations of the paper is that we were only given permission to access prefecture-level broadband internet coverage rates due to the confidentiality of the Japanese government data. With access to the municipal-level coverage rates, a more fine-grained analysis would be possible, including using DSL as well as FTTH coverage rates. We would hope to pursue this more detailed analysis using municipal-level data in the future.

Also for our future work, it would be interesting to estimate the effects of other technological advancements on labor market composition. Historically, we have experienced many technological advancements such as the washing machine and electrical cleaning appliances. Using an ultra-long-term dataset, we would like to compare the impact of these other technological advances on labor market outcomes. This would help contextualize the relative importance of the internet and ICTs more generally on labor market composition.

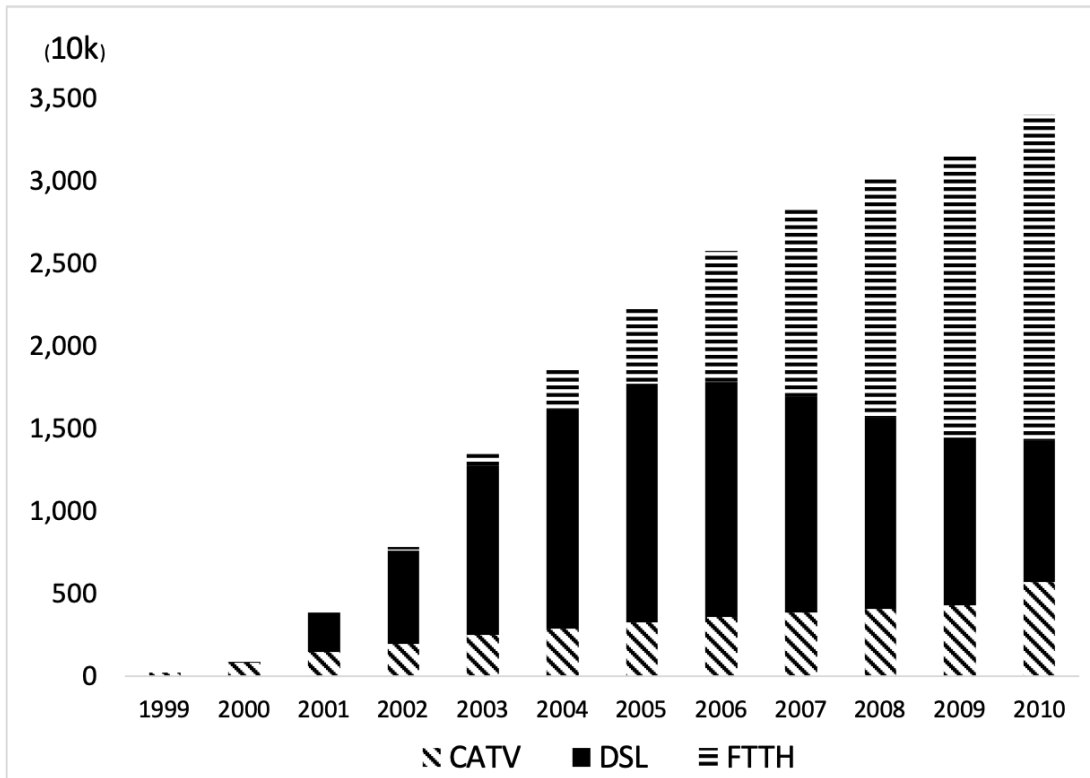


Figure 1: Broadband Internet Subscribers

Source: Broadband Infrastructure Development Survey, Ministry of Internal Affairs and Communications (2010)

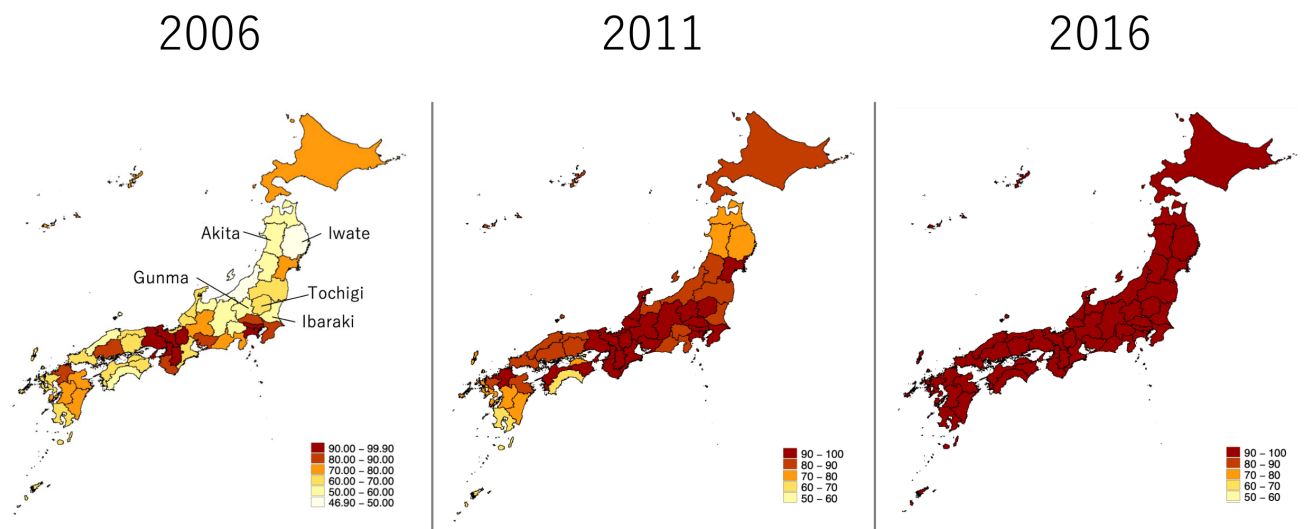


Figure 2: Coverage Rate of FTTH by Prefecture in 2006, 2011, and 2016

Source: Broadband Infrastructure Development Survey, Japan Ministry of Internal Affairs and Communications

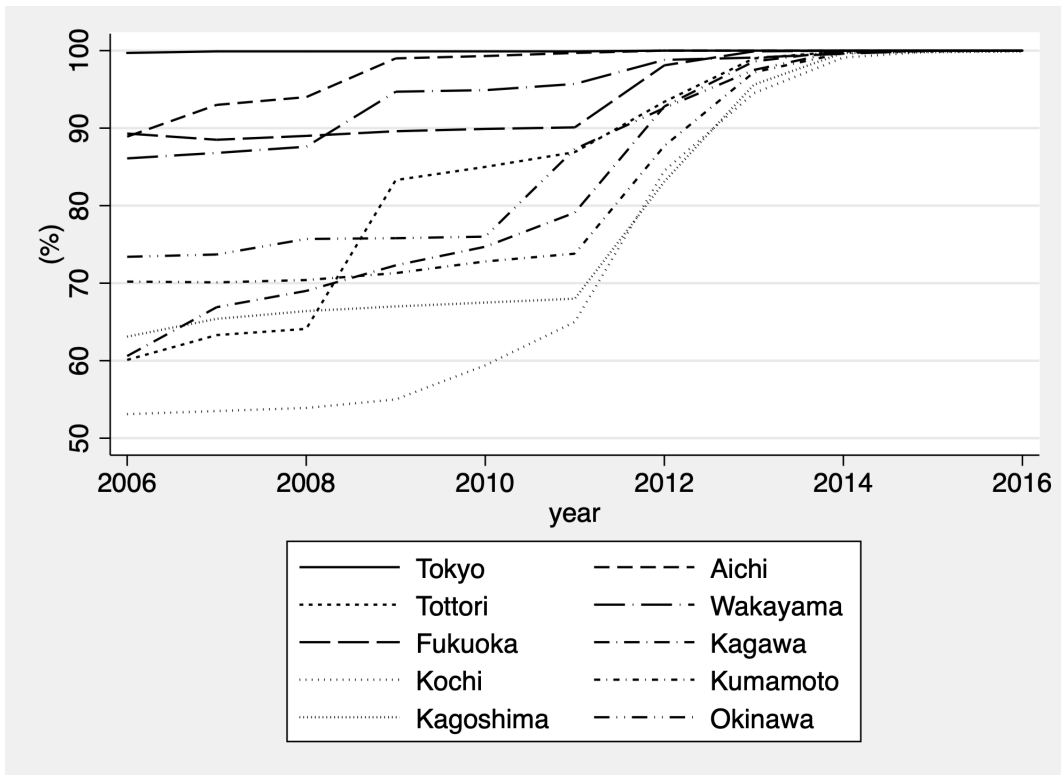


Figure 3: Diffusion Rate of FTTH by Prefecture

Source: Broadband Infrastructure Development Survey, Japan Ministry of Internal Affairs and Communications

Notes: This figure reports the diffusion rate of FTTH broadband internet for 10 selected prefectures.

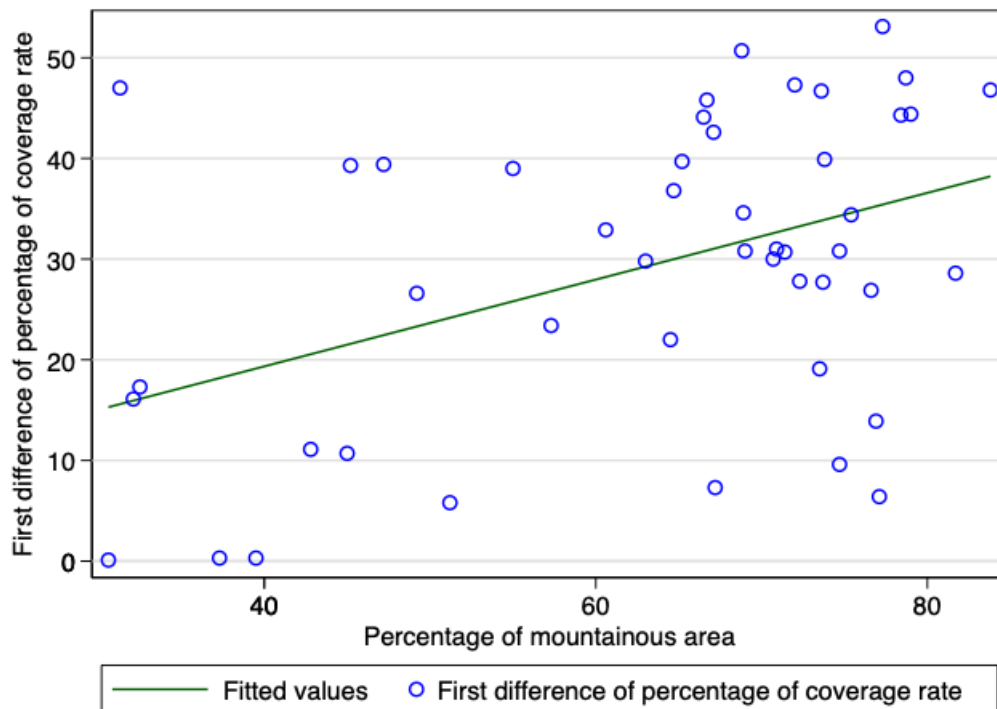


Figure 4: Correlation of Coverage Rate and Percentage of Mountainous Area

Source: Census of Agriculture and Forestry

Notes: This figure shows the scatterplot of the correlation of the first difference in the coverage rate between 2006 and 2016 and percentage of mountainous areas.

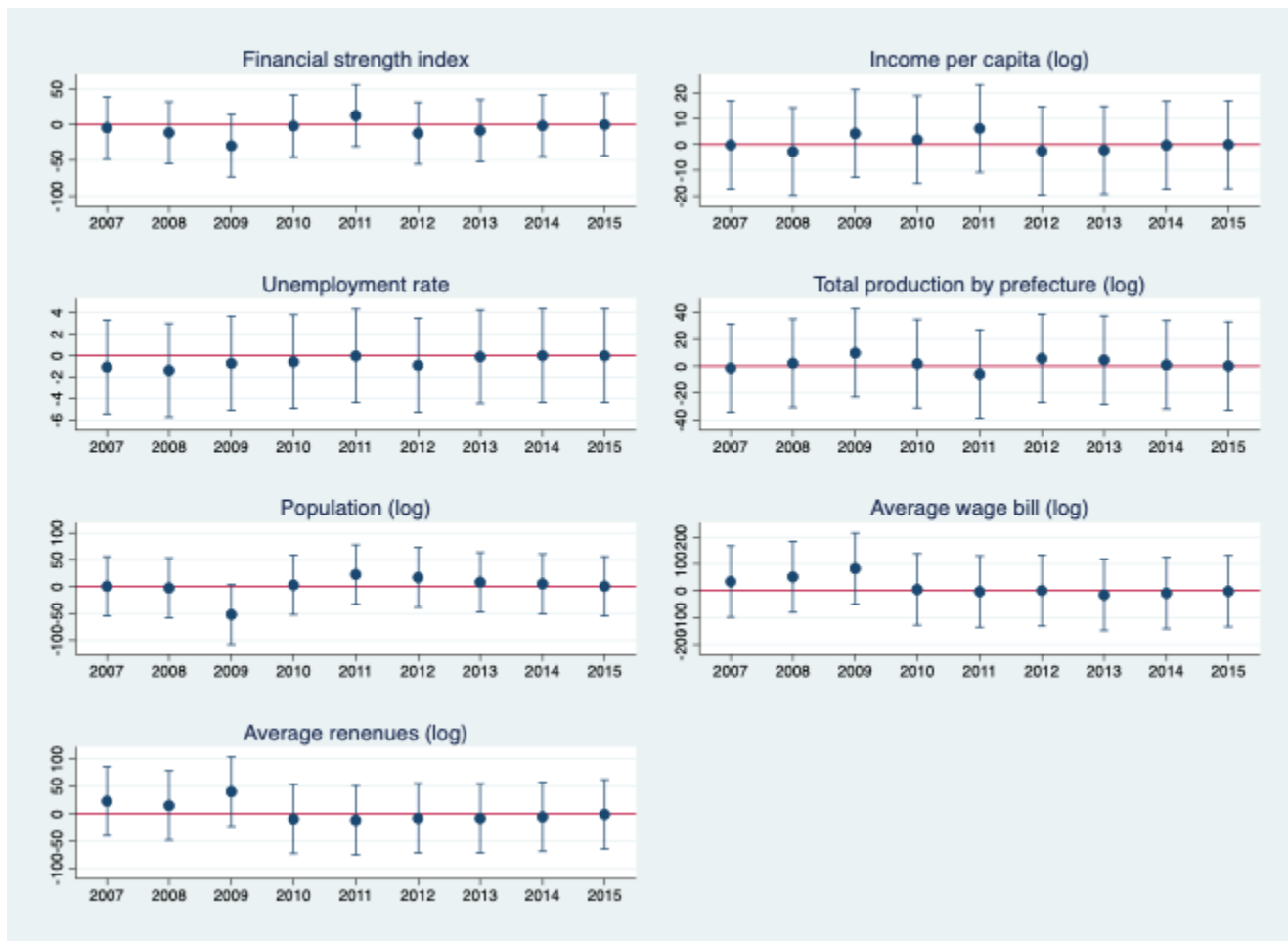


Figure 5: Timing of Broadband Internet Diffusion by Prefecture Characteristics

Notes: This figure reports the estimated coefficients and 95 % confidence intervals of the vector ψ for each year from 2007-2015.

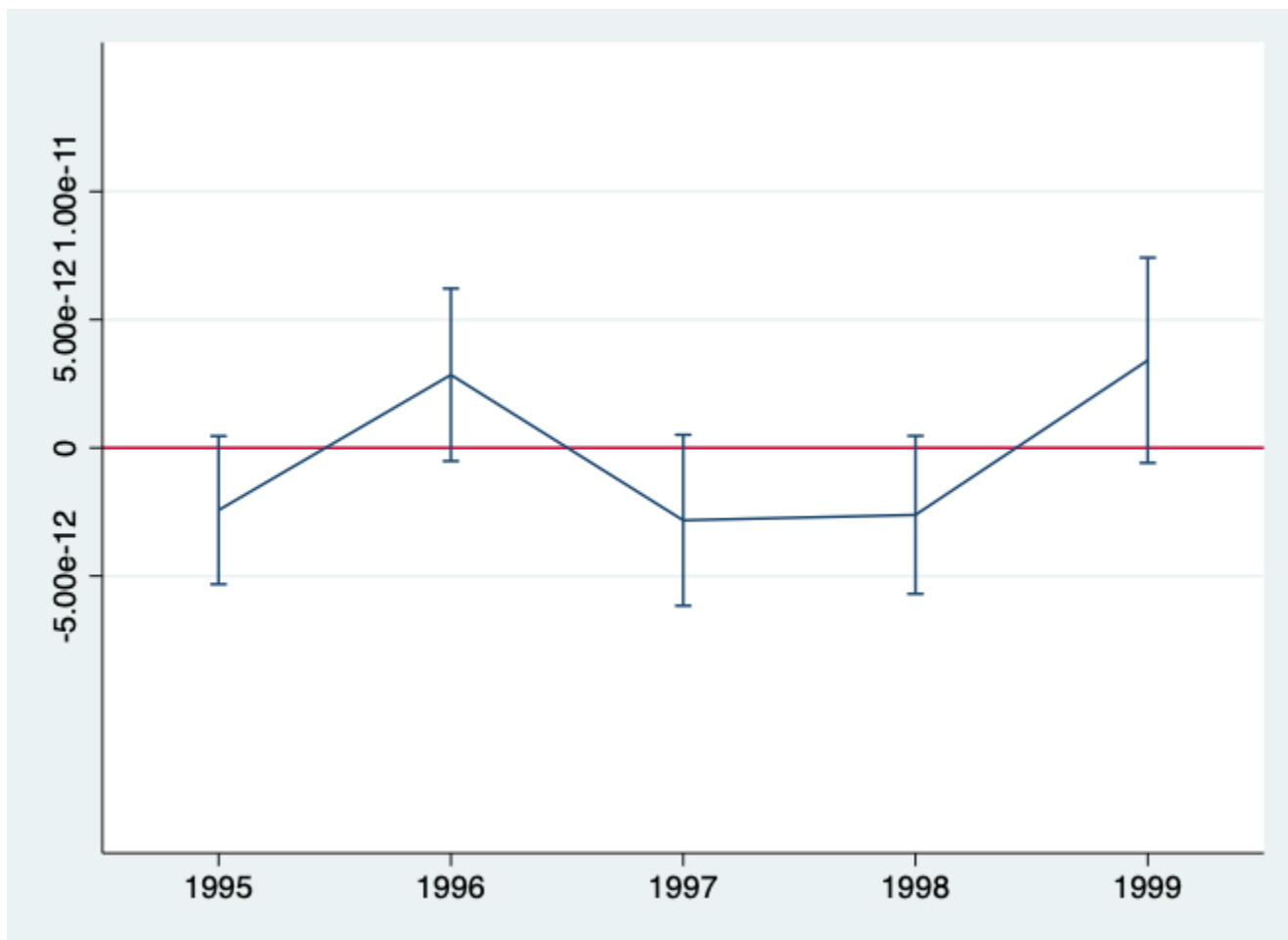


Figure 6: Reduced-Form Relationship between Percentage of Mountainous Area and Labor Supply, 1995-2000

Notes: This figure reports the coefficients and 95% confidence intervals of the vector $Mountain_p * \theta_t$ from the reduced form estimation, including all control variables. Coefficients are relative to the base year of 2000. The period 1995 to 2000 is prior to the introduction of broadband FTTH internet access.

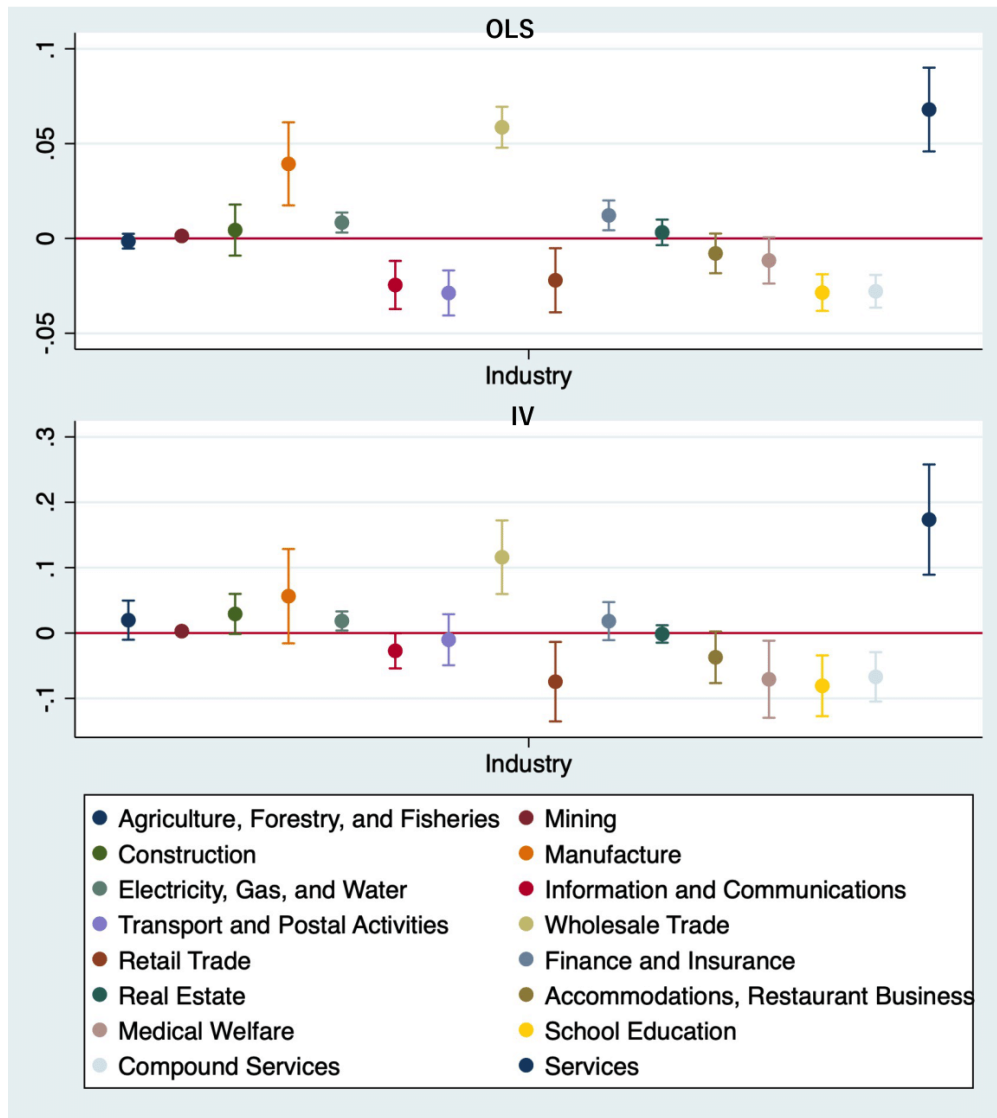


Figure 7: Effects of FTTH Broadband Internet Coverage on Labor Force Participation by Industry (Full Sample)

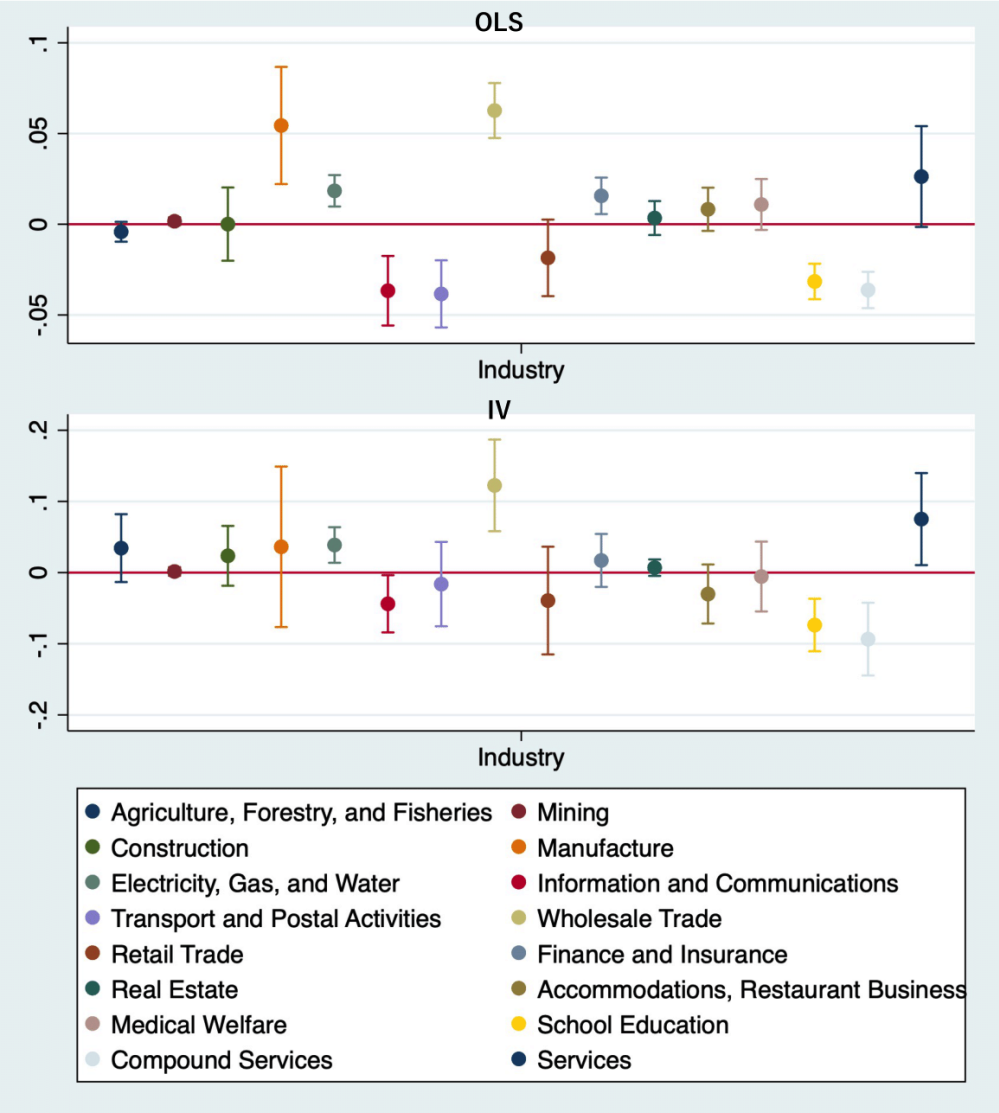


Figure 8: Effects of FTTH Broadband Internet Coverage on Labor Force Participation by Industry (Male)

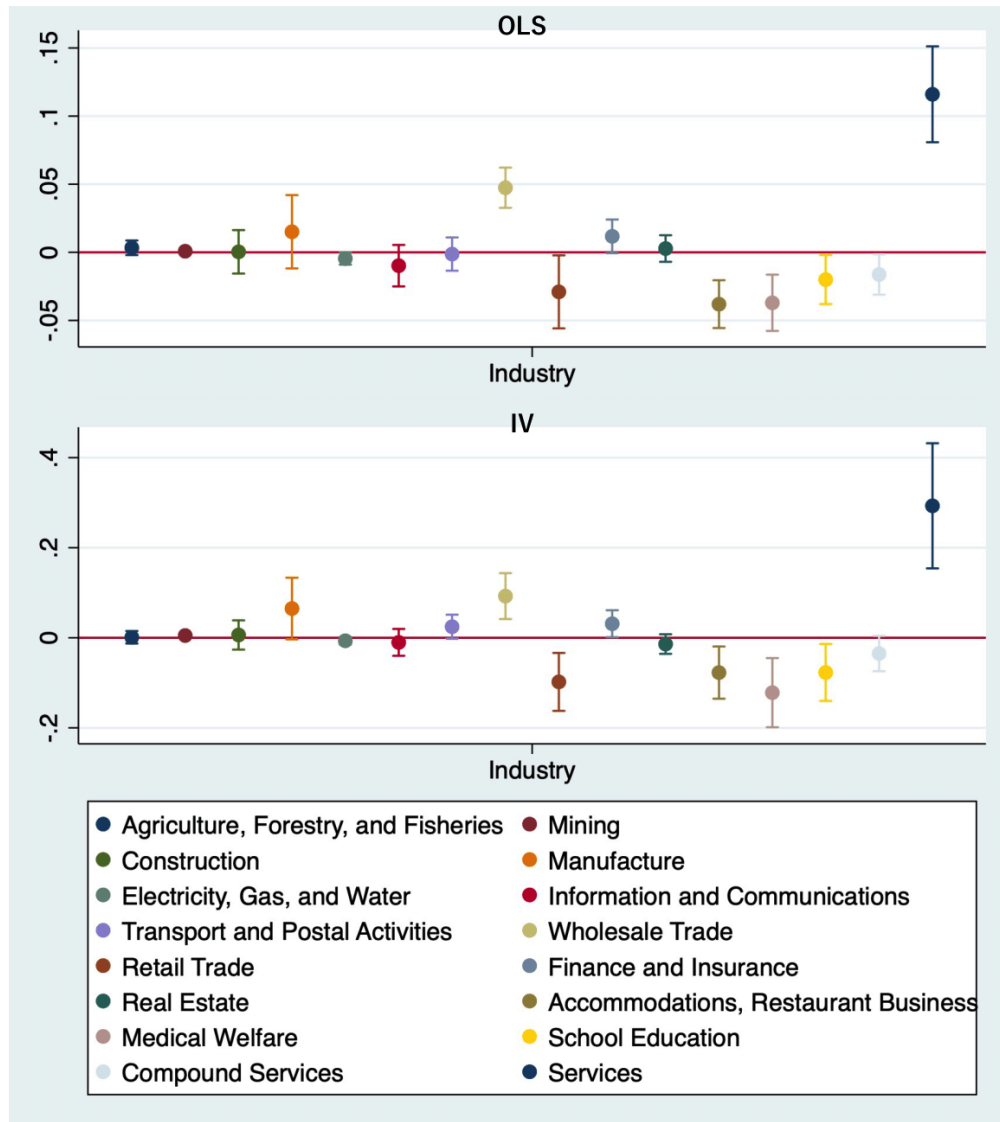


Figure 9: Effects of FTTH Broadband Internet Coverage on Labor Force Participation by Industry (Female)

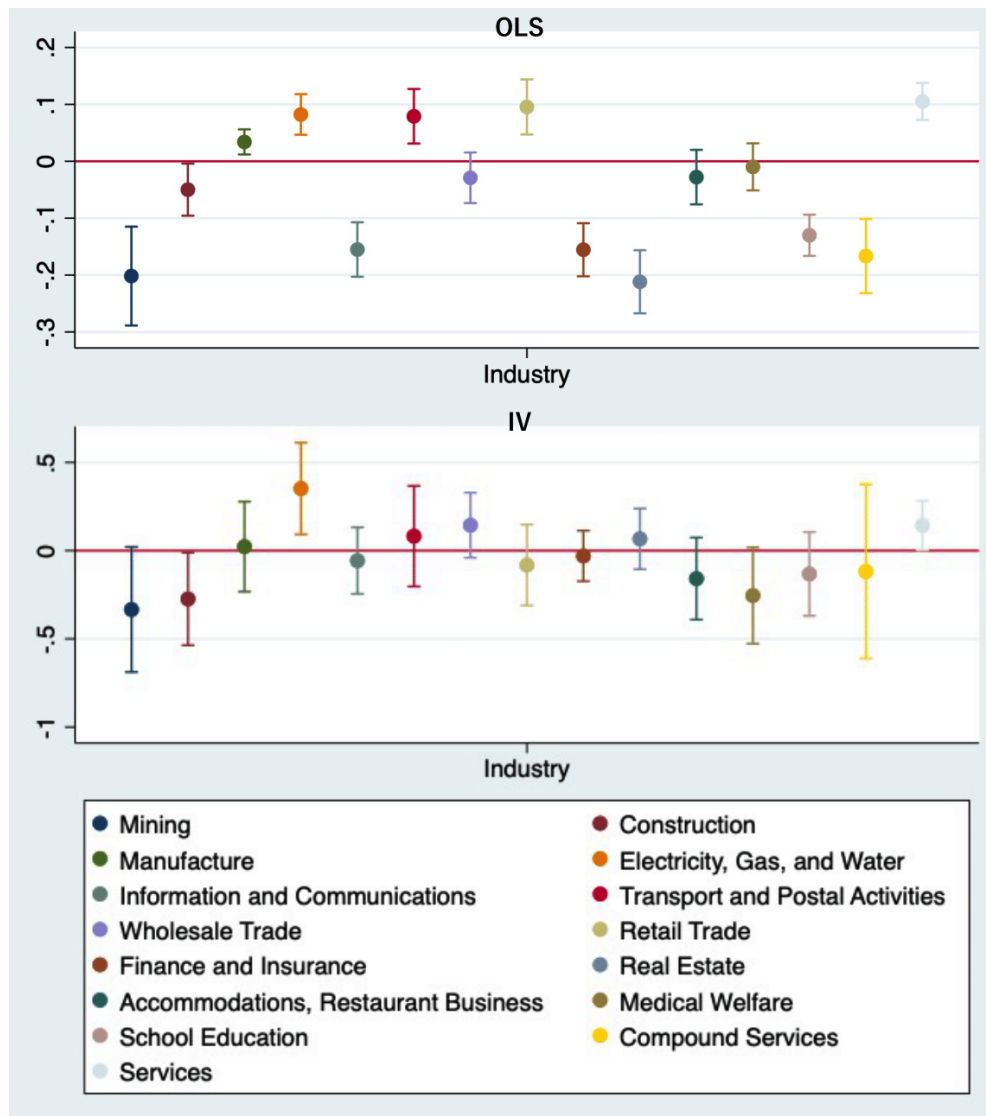


Figure 10: Effects of FTTH Broadband Internet Coverage on Wages by Industry (Full Sample)

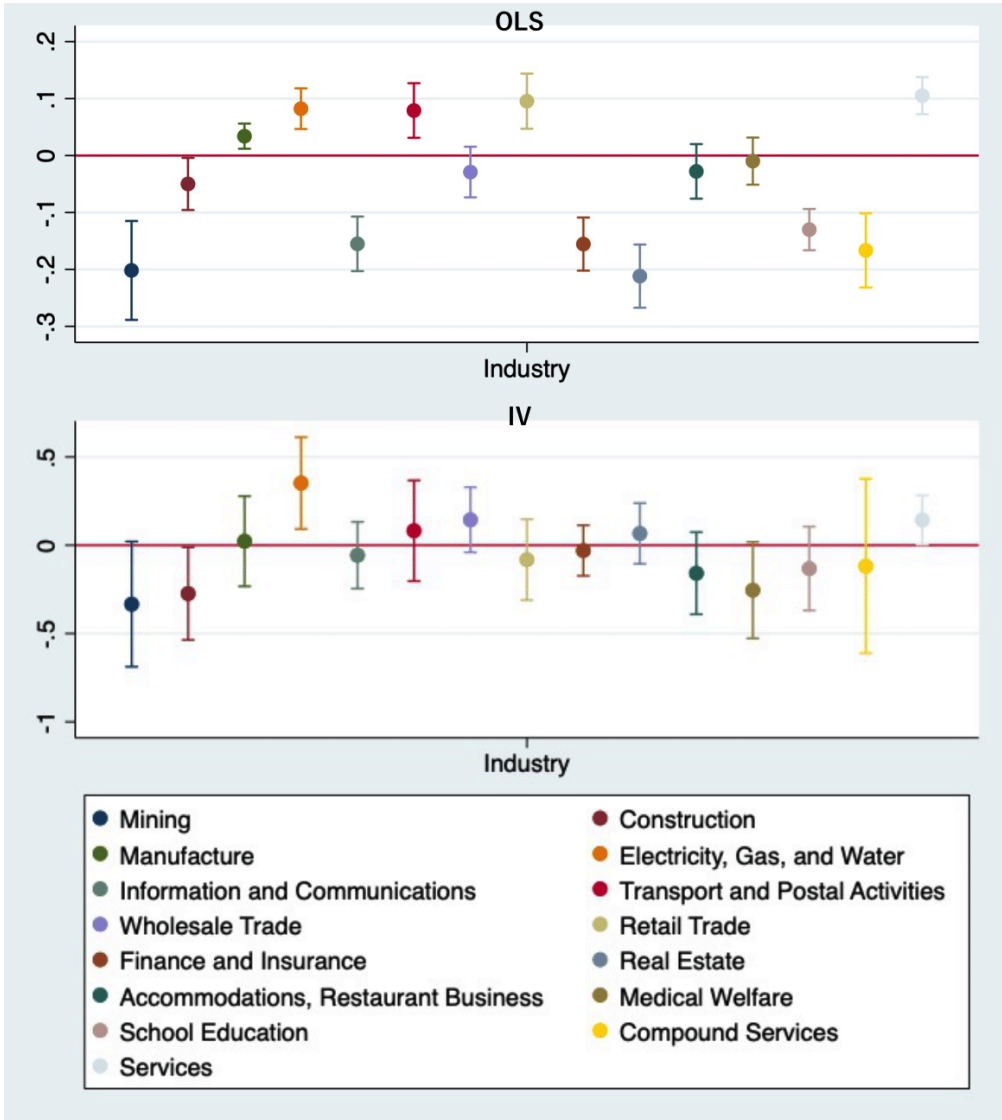


Figure 11: Effects of FTTH Broadband Internet Coverage on Wages by Industry (Male)

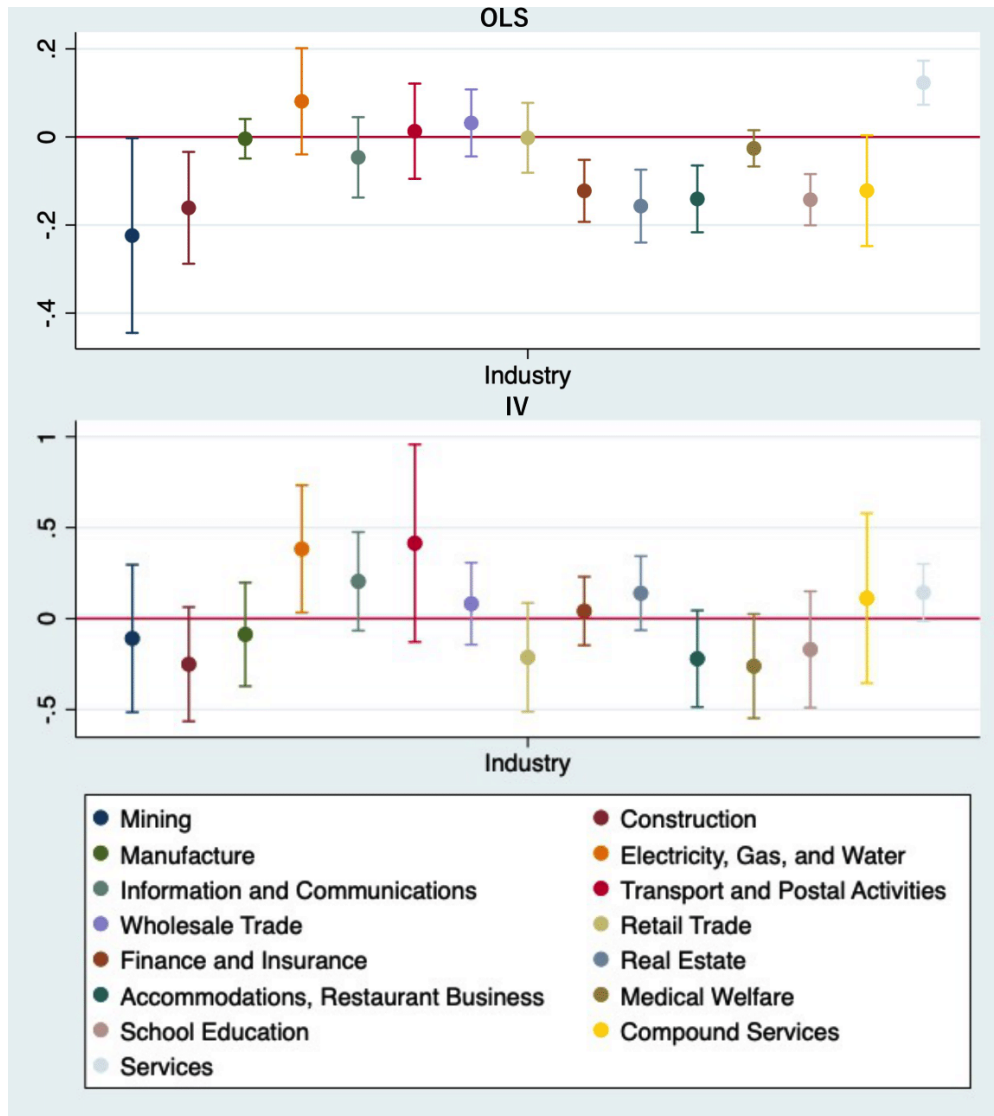


Figure 12: Effects of FTTH Broadband Internet Coverage on Wages by Industry (Female)

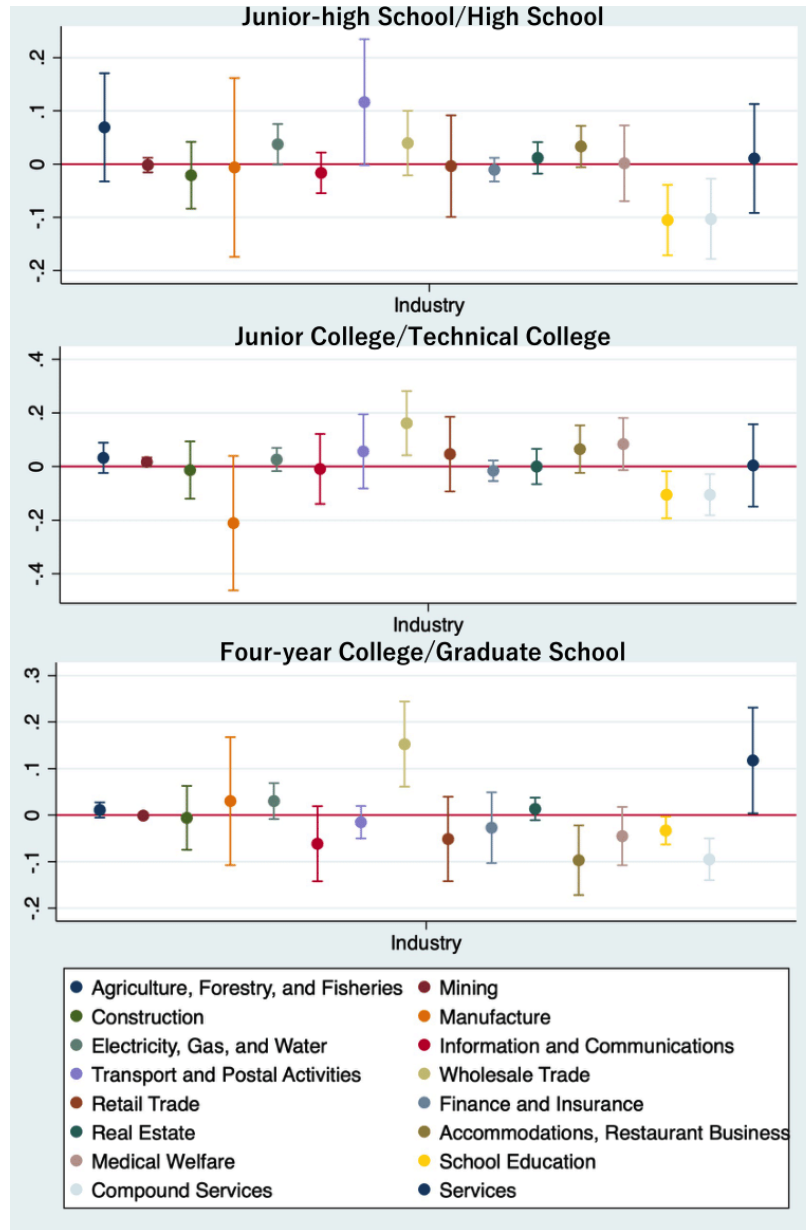


Figure 13: Effects of FTTH Broadband Internet Coverage on Labor Force Participation by Industry (Male, by Education)

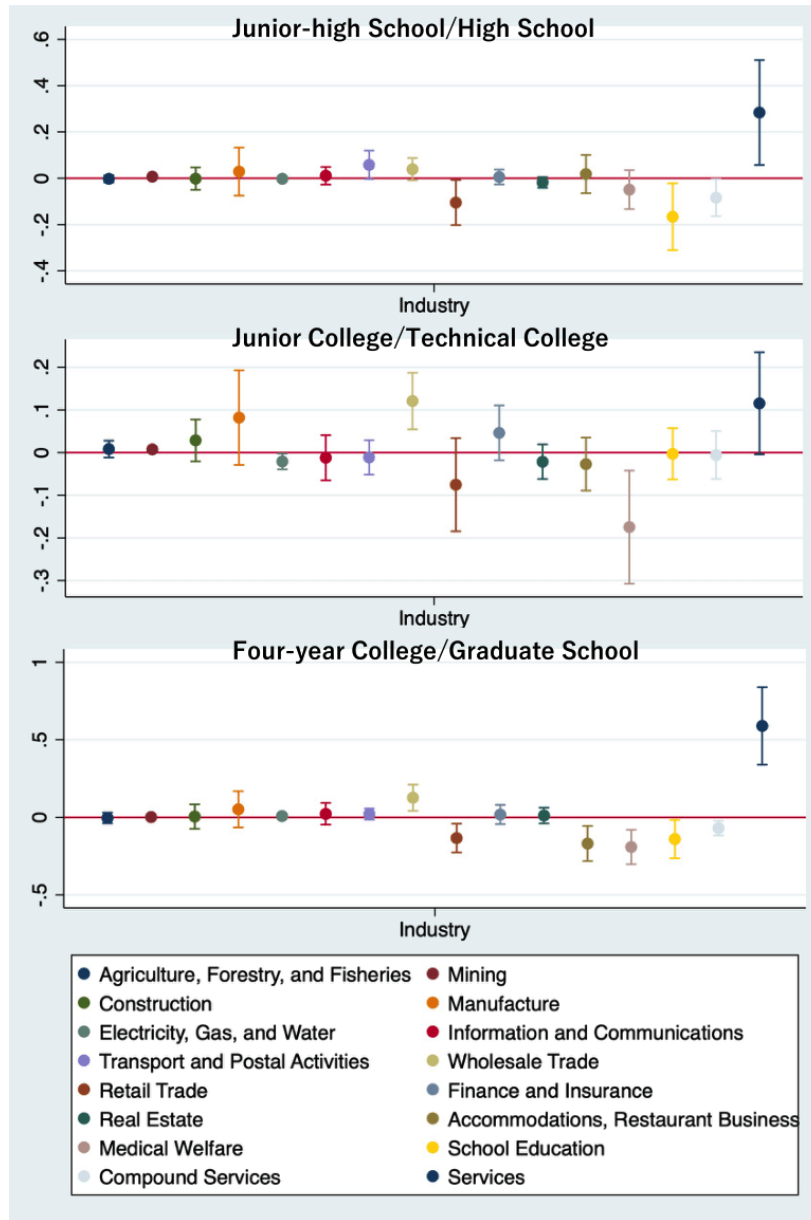


Figure 14: Effects of FTTH Broadband Internet Coverage on Labor Force Participation by Industry (Female, by Education)

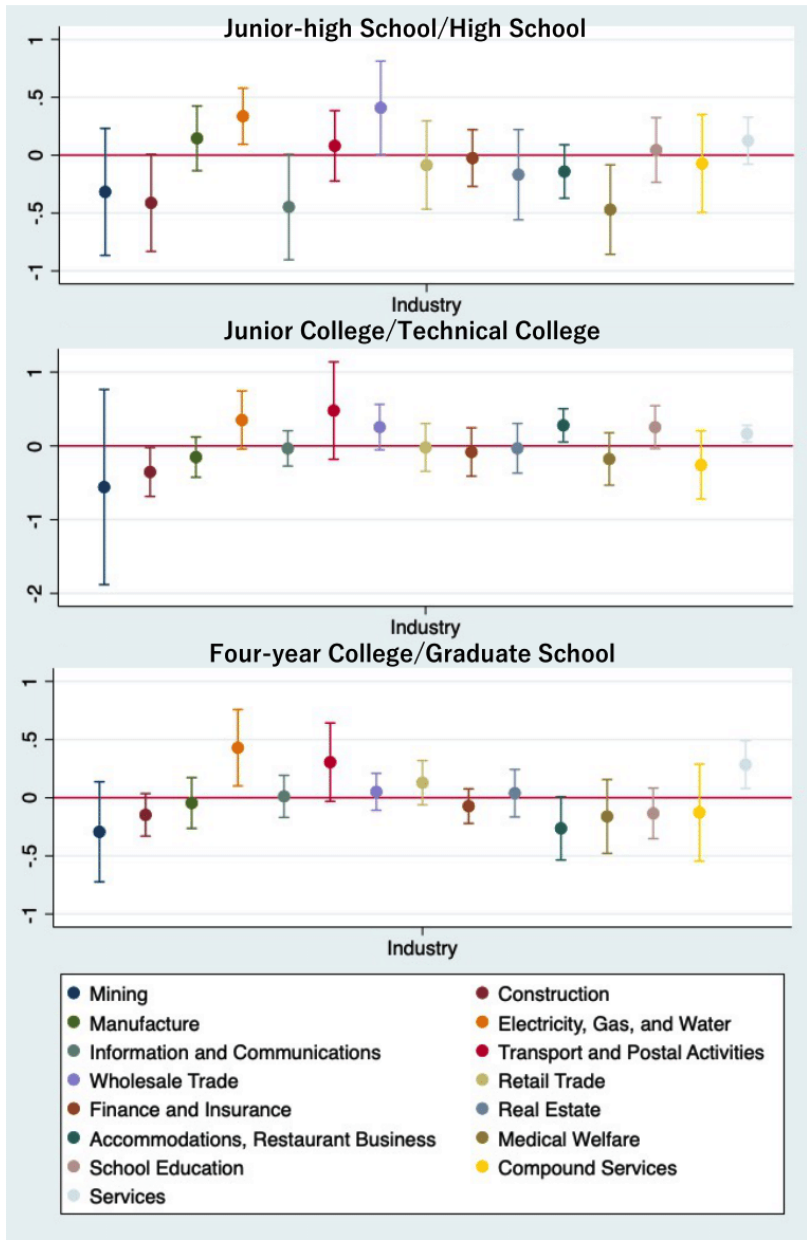


Figure 15: Effects of FTTH Broadband Internet Coverage on Wages by Industry (Male, by Education)

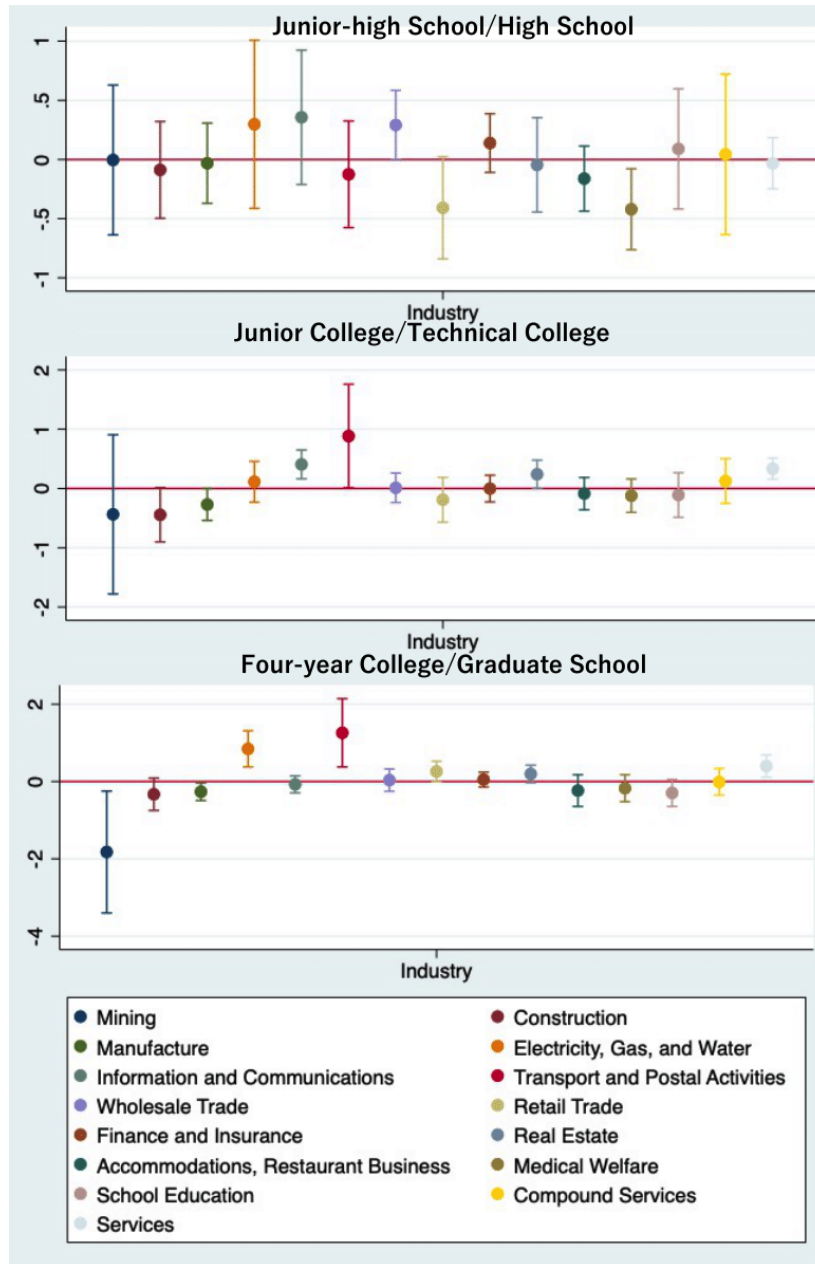


Figure 16: Effects of FTTH Broadband Internet Coverage on Wages by Industry (Female, by Education)

Table 1: Summary Statistics

		Mean	SD
FTTH broadband coverage			
	2006	0.706	0.149
	2007	0.739	0.133
	2008	0.778	0.119
	2009	0.839	0.109
	2010	0.865	0.100
	2011	0.886	0.089
	2012	0.956	0.044
	2013	0.988	0.013
	2014	0.998	0.002
	2015	0.999	0.001
	2016	0.999	0.001
Labor force participation		0.781	0.413
	Male	0.891	0.311
	Female	0.670	0.469
Number of individuals, aged 20-59		1,253,382	
Log hourly wages (in JPY)		7.265	0.496
	Male	7.442	0.484
	Female	7.109	0.397
Number of workers, aged 20-59		9,978,148	
Age		40.20	11.23
Male		0.502	0.499
Education			
	Junior-high school/High school	0.518	0.499
	Junior college/Technical college	0.202	0.402
	Four-year college/Graduate school	0.278	0.448

Sources: FTTH broadband coverage from Status of Development of Broadband Infrastructure, Ministry of Internal Affairs and Communications. Labor force participation rate from Labor Force Survey, Ministry of Internal Affairs and Communications. Log hourly wages from Basic Survey on Wage Structure, Ministry of Health, Labour and Welfare.

Notes: The sample is limited to adults ages 20 to 59.

Table 2: Correlation of Coverage Rate and Percentage of Mountainous Area

	First difference of coverage rate	First difference of coverage rate
Ratio of mountainous area	0.431*** (0.132)	0.266* (0.154)
Financial strength index		Y
Income per capita (log)		Y
Unemployment rate		Y
Population (log)		Y
Total production (log)		Y
Average revenues (log)		Y
Average wage bill (log)		Y
Observations	47	47
R-squared	0.191	0.564

Notes: We took the first difference of the coverage rate between 2006 and 2016. We used the data in 2000 for ratio of mountainous area. All other control variables are data in 2006. Robust standard errors in parentheses.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 3: First Stage Estimates

Dependent variable: coverage rate	
Ratio of mountainous area*2006	-0.0739*** (0.0053)
Ratio of mountainous area*2007	-0.0718*** (0.0054)
Ratio of mountainous area*2008	-0.0657*** (0.0050)
Ratio of mountainous area*2009	-0.0574*** (0.0053)
Ratio of mountainous area*2010	-0.0528*** (0.0042)
Ratio of mountainous area*2011	-0.0346*** (0.0042)
Ratio of mountainous area*2012	-0.0237*** (0.0031)
Ratio of mountainous area*2013	-0.0134*** (0.0023)
Ratio of mountainous area*2014	-0.0021** (0.0011)
Ratio of mountainous area*2015	-0.0015 (0.0011)
Observations	1,253,382

Notes: We controlled for the following variables: demographic characteristics including education, age, gender, industry, occupation, and firm size; year and municipality fixed effects; linear trend; and prefectural characteristics including an index of financial strength, log of income per capita, unemployment rate, log of population, log of total production, log of average revenues, and log of average wage bill. Standard errors in parentheses are clustered at the prefecture level.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 4: Effects of FTTH Broadband Internet Coverage on Labor Force Participation

	(1) Full sample OLS	(2) Full sample IV	(3) Male OLS	(4) Male IV	(5) Female OLS	(6) Female IV
Coverage rate	0.021*** (0.002)	0.042* (0.022)	0.007*** (0.001)	0.070*** (0.011)	0.051*** (0.001)	0.211*** (0.055)
F-Statistic		91.24		83.28		79.83
Observations	1,253,382	1,253,382	701,067	701,067	552,315	552,315

Notes: We controlled for the following variables: demographic characteristics including education, age, gender, industry, occupation, and firm size; year and municipality fixed effects; linear trend; and municipal characteristics including an index of financial strength, log of income per capita, unemployment rate, log of population, log of total production, log of average revenues, and log of average wage bill. Standard errors in parentheses are clustered at the prefecture level.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 5: Effects of FTTH Broadband Internet Coverage on Wages

	(1) Full sample OLS	(2) Full sample IV	(3) Male OLS	(4) Male IV	(5) Female OLS	(6) Female IV
Coverage rate	-0.018** (0.008)	0.061** (0.030)	-0.022** (0.009)	0.085** (0.043)	-0.024** (0.013)	0.019 (0.035)
F-Statistic		98.54		82.29		73.18
Observations	9,978,148	9,978,148	6,821,983	6,821,983	3,156,165	3,156,165

Notes: We controlled for the following variables: demographic characteristics including education, age, gender, industry, occupation, and firm size; year and municipality fixed effects; linear trend; and municipal characteristics including an index of financial strength, log of income per capita, unemployment rate, log of population, log of total production, log of average revenues, and log of average wage bill. Standard errors in parentheses are clustered at the prefecture level.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 6: Effects of FTTH Broadband Internet Coverage on Labor Force Participation by Gender and Education

Male	(1)	(2)	(3)
	Junior-high school/High school	Junior college/Technical college	Four-year college/Graduate school
Coverage rate	-0.012 (0.182)	0.048*** (0.023)	0.169** (0.092)
F-Statistic	54.68	52.97	53.49
Observations	387,688	73,947	239,432

Female	(1)	(2)	(3)
	Junior-high school/High school	Junior college/Technical college	Four-year college/Graduate school
Coverage rate	0.131*** (0.064)	0.164** (0.091)	0.387*** (0.174)
F-Statistic	68.78	69.32	76.54
Observations	309,996	152,305	90,014

Notes: We controlled for the following variables: demographic characteristics including education, age, gender, industry, occupation, and firm size; year and municipality fixed effects; linear trend; and municipal characteristics including an index of financial strength, log of income per capita, unemployment rate, log of population, log of total production, log of average revenues, and log of average wage bill. Standard errors in parentheses are clustered at the prefecture level.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 7: Effects of FTTH Broadband Internet Coverage on Wages by Gender and Education

Male	(1)	(2)	(3)
	Junior-high school/High school	Junior college/Technical college	Four-year college/Graduate school
Coverage rate	0.273 (0.261)	0.289 (0.345)	0.157*** (0.046)
F-Statistic	45.71	43.87	50.81
Observations	3,353,810	676,002	2,491,937

Female	(1)	(2)	(3)
	Junior-high school/High school	Junior college/Technical college	Four-year college/Graduate school
Coverage rate	-0.408 (0.312)	0.321 (0.445)	0.744 (0.591)
F-Statistic	52.89	55.87	56.41
Observations	1,523,887	853,795	680,287

Notes: We controlled for the following variables: demographic characteristics including education, age, gender, industry, occupation, and firm size; year and municipality fixed effects; linear trend; and municipal characteristics including an index of financial strength, log of income per capita, unemployment rate, log of population, log of total production, log of average revenues, and log of average wage bill. Standard errors in parentheses are clustered at the prefecture level.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 8: Effects of FTTH Broadband Internet Coverage on Online Shopping Minutes

	Twenties	Thirties	Forties	Fifties
Coverage rate	150.9*** (71.9)	18.71 (22.91)	-17.35 (41.33)	12.31 (13.28)
F-Statistic	23.98	19.31	22.83	18.38
Observations	1,733	3,585	3,833	4,509

Notes: We controlled for the following variables: demographic characteristics including education, income, age, gender, and family type; year and municipality fixed effects; municipal characteristics including an index of financial strength, log of income per capita, unemployment rate, log of population, log of total production, log of average revenues, and log of average wage bill. Standard errors in parentheses are clustered at the prefecture level.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 9: Effects of FTTH Broadband Internet Coverage on Offline Shopping Minutes

	Twenties	Thirties	Forties	Fifties
Coverage rate	-36.98*** (13.51)	13.09 (21.43)	9.683 (17.41)	8.865 (13.50)
F-Statistic	23.98	19.31	22.83	18.38
Observations	1,733	3,585	3,833	4,509

Notes: We controlled for the following variables: demographic characteristics including education, income, age, gender, and family type; year and municipality fixed effects; municipal characteristics including an index of financial strength, log of income per capita, unemployment rate, log of population, log of total production, log of average revenues, and log of average wage bill. Standard errors in parentheses are clustered at the prefecture level.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 10: Effects of FTTH Broadband Internet Coverage on Telework Minutes

	(1) Full sample	(2) Male	(3) Female
Coverage rate	93.27*** (13.53)	127.6*** (24.56)	11.22 (14.30)
F-Statistic	92.38	89.88	85.42
Observations	214,555	115,291	102,467

Notes: We controlled for the following variables: demographic characteristics including education, income, age, gender, and family type; year and municipality fixed effects; municipal characteristics including an index of financial strength, log of income per capita, unemployment rate, log of population, log of total production, log of average revenues, and log of average wage bill. Standard errors in parentheses are clustered at the prefecture level.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 11: Effects of FTTH Broadband Internet Coverage on Commuting Minutes

	(1) Full sample	(2) Male	(3) Female
Coverage rate	-103.4*** (33.89)	-116.7*** (35.01)	47.05 (35.13)
F-Statistic	95.51	90.23	88.52
Observations	382,489	214,852	173,137

Notes: We controlled for the following variables: demographic characteristics including education, income, age, gender, and family type; year and municipality fixed effects; municipal characteristics including an index of financial strength, log of income per capita, unemployment rate, log of population, log of total production, log of average revenues, and log of average wage bill. Standard errors in parentheses are clustered at the prefecture level.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 12: Effects of FTTH Broadband Internet Coverage on Tenure Categories

	(1) 0-5 years	(2) 6-10 years	(3) 11-15 years	(4) 16-20 years	(5) Over 21 years
Coverage rate	0.226** (0.097)	0.083** (0.043)	0.035* (0.021)	0.008 (0.035)	-0.359 (0.321)
F-Statistic	98.65	98.65	98.65	98.65	98.65
Observations	1,721,379	1,721,379	1,721,379	1,721,379	1,721,379

Notes: We controlled for the following variables: demographic characteristics including education, age, gender, industry, occupation, and firm size; year and municipality fixed effects; linear trend; and municipal characteristics including an index of financial strength, log of income per capita, unemployment rate, log of population, log of total production, log of average revenues, and log of average wage bill. Standard errors in parentheses are clustered at the prefecture level.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Appendix

The time series graphs of key labor market outcomes of our study are presented in Figures 17 and 18. Figure 17 indicates that the male labor force participation rate has been stable over the last four decades while the female labor force participation rate has increased. Figure 18 shows the wage trend for men and women in Japan. Wages for males increased until around 1990, and then stabilized and slowly declined over time, while wages for females increased after 1990, though the growth rate slowed slightly over time.

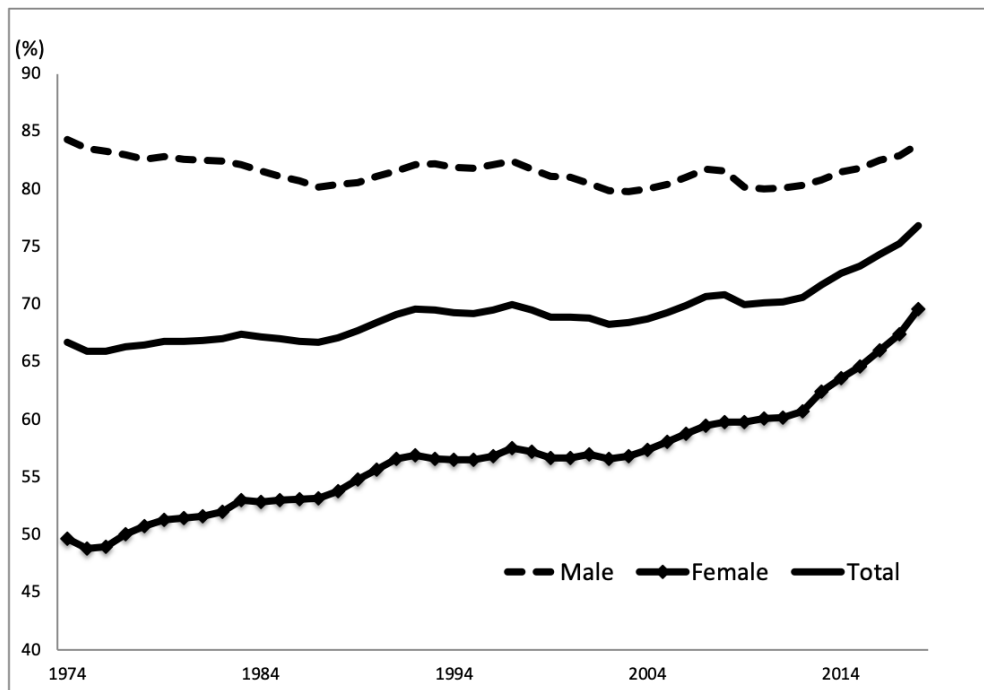


Figure 17: Labor Force Participation Rate (15-64 years old)

Source: Labor Force Survey, Japan Ministry of Health and Welfare

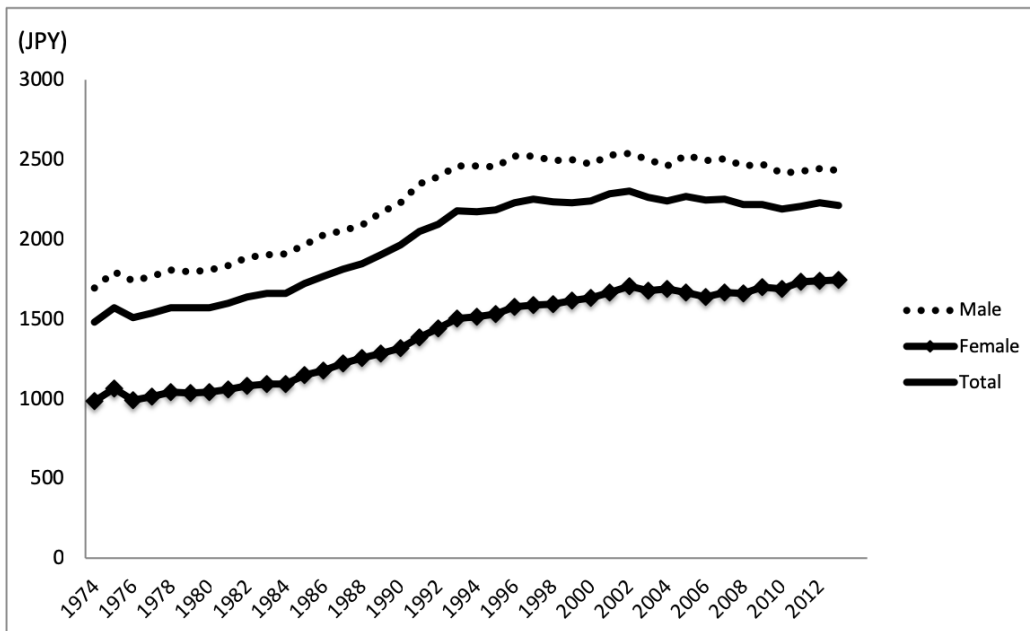


Figure 18: Real Wages in Japan, 1974-2012

Source: Basic Survey on Wage Structure. Real values are calculated using the CPI.

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Effect of Residential Broadband Internet Diffusion on Industry Composition: Evidence from Japan

本論文では、日本におけるブロードバンドインターネットの普及が産業構造へもたらした影響を、産業別の労働力人口と賃金への影響を通じて推定している。ブロードバンドインターネットの普及の制約となった地理的特性の地域差に注目した操作変数法を用いた結果、ブロードバンドインターネットの普及は、特に卸売・サービス業の労働参加を増加させ賃金を上昇させることを明らかにした。また、オンラインショッピングの普及、テレワーク、ジョブマッチングの質の向上などについても分析を行い、背景の検討を行なっている。