How Broadband Internet Affects Labor Market Matching

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Abstract: This paper studies how broadband internet affects labor market matching. What makes our study feasible is the unique combination of (i) a staggered roll-out of broadband internet infrastructure in Norway over the period 2000-2009, creating plausibly exogenous variation in access to broadband internet across time and geography, and (ii) large-scale administrative and survey data on firms' recruitment efforts, workers' online search behavior, and labor market outcomes. We first document that the policy-induced increases in broadband availability enhanced the adoption rate among workers and firms, and increased their online job search and recruitment activities. Our subsequent analysis of the impacts of broadband availability yields three main results: First, we find that broadband internet improves firms recruitment process. Comparing an area with full coverage to an area with no coverage, the average duration of a job opening falls by 9 percent, the fraction of firms that report having recruitment problems falls by 14 percent, and firms' vacancy-posting increase by 20 percent. Moreover, we show that hiring a worker with more relevant industry experience is more likely – however at the expense of a corresponding increase in a firm's separation rate. Second, combining granular data on geographic locations of job seekers and hiring firms, we are the first to show how internet affects the job finding rate of unemployed workers. We show that job seekers are more likely to find new employment in firms located further away from their residence – consistent with a mechanism in which improved access to information about job openings increases job finding rates by reducing the spatial mismatch between job seekers and job vacancies. Third, we provide robust evidence that internet increases the match quality of new employment relationships among job seekers. Going from no broadband availability to full coverage increases the average starting wage and the subsequent tenure by 5-6 percent. By contrast, we find no evidence that internet improves wages after switching employer.

Keywords: Unemployment; Information; Job Search; Matching.
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1 Introduction

Nearly twenty years ago, The New York Times published a piece titled "The Internet is lowering the cost of advertising and searching for jobs". In the article, Alan Krueger argued that internet is rapidly changing the way workers search for jobs and firms recruit workers. At that time, the use of online job postings in the U.S. had taken off after Monster.com and HotJobs.com advertised during the 1999 Super Bowl. Fourteen years later almost 70 percent of U.S. job openings were posted online (Carnevale *et al.*, 2014), and the fraction job seekers using internet for job search increased from 25 to 75 percent from 2000 to 2011 (Faberman & Kudlyak, 2016). Figure 1 illustrates the same trend in online job posting for Norway: in 2002, the share accounted for about a third of the total number of vacancies, while online job posting converged to the official number of vacancies half a decade later.

The shift towards online platforms may have changed the way workers search for jobs and firms recruit in many ways. One is that firms' can announce vacancies to larger pools of applicants and to screen applications using various online employment tests. Another is by providing job seekers with readily available information about job openings previously advertised in several local newspapers on one platform. The improved access to information about available jobs could shorten job seekers' spells of unemployment, and even improve the match quality of newly formed employment relationships. As a consequence, the Beveridge curve — the negatively sloped relationship between job vacancies and unemployment — could shift towards the origin by an improvement in the aggregate job matching efficiency. However, more effective search technology could make workers and firms more selective about the quality of the relationships that they are willing to establish, leaving an ambiguous effect on unemployment and vacancy rates.

Yet, nearly twenty years after Alan Krueger's article, we still know surprisingly little about how the internet has affected the ways firms recruit and job seekers are matched to vacant employment positions.[1] This lack of knowledge is in part due to the challenge in identifying exogenous variation in the use of internet among firms and households. For example, the adoption of internet could be determined by local productivity shocks, which in turn increase labor demand and wages that have nothing to do with internet adoption. Another key challenge is measuring the availability and adoption of high-speed internet for firms and workers, as well as firms' recruitment activity (e.g., types of vacancy postings) and unemployed workers' search behavior.

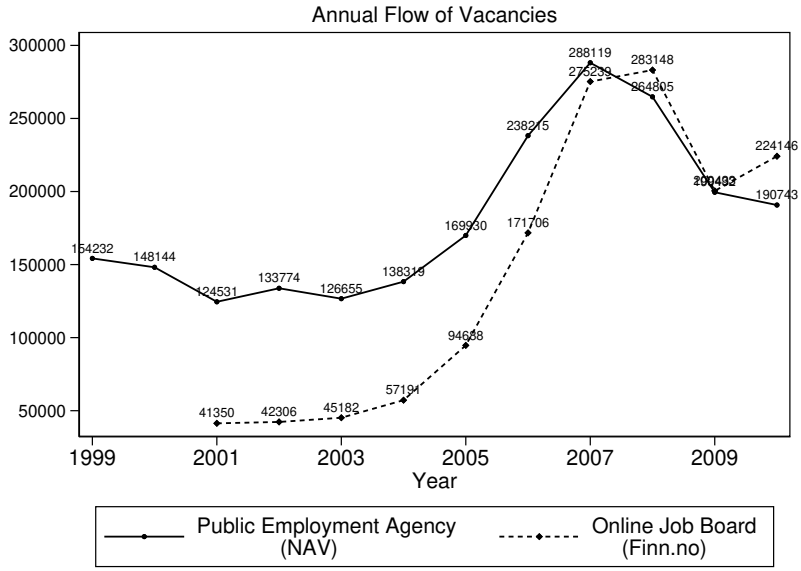
In this paper, we estimate how the availability of broadband internet affects matching in the labor market. Two features of Norwegian labor markets allow us to do so. First, we use temporal and spatial variation in broadband internet infrastructure triggered by the staggered implementation of the National Broadband Policy (as previously used in other contexts by Bhuller *et al.*, 2013 and Akerman *et al.*, 2015). Due to complex geography and limited funding, the policy generates plausibly exogenous variation in the availability of access to fast internet for households and firms.[2] Second, we have collected a wide range of survey and administrative firm- and worker-level data that overlap with the broadband infrastructure roll-out, including newly matched data on firms' vacancy-posting and job search behavior. Using these data sources, we can

[1] The small number of empirical studies (e.g. Kuhn & Skuterud, 2004, Kuhn & Mansour, 2014, Kroft & Pope, 2014) have primarily focused on the job finding rates of workers.

[2] See St.meld.nr. 38 (1997-1998) and St.meld.nr. 49 (2002-2003) for program details.

provide novel evidence on how access to broadband internet affects the way firms recruit (e.g., their use of online job board), how fast their vacancies are filled, as well as their overall labor demand and employment growth. Furthermore, we complement and expand on existing evidence by showing how the internet affects the duration of unemployment, and the quality of newly formed matches.

Figure 1: Sources of Vacancy Posting in Norway.



Notes: This figure shows the number of vacancies posted online and the number of vacancies recorded by the public employment agency. The public agency collects information about vacancies from several sources including online job boards, newspapers and directly reported by employers. FINN.no is the only major online board in Norway, established in March 2000.

The main results of our paper can be summarized in terms of three broad conclusions. First, our evidence supports the view that internet has improved firms' recruitment process: We find that firms are more likely to post vacancies on online job boards, and report less recruitment problems when internet arrives. Consistent with the predictions of a reduction in the effective recruitment cost faced by firms in the Diamond-Mortensen-Pissarides search and matching framework, going from no broadband availability to full coverage increases firms' vacancy-posting by 20 percent. Our results show that improvements in recruitment efficiency translates into a significant decrease in the duration of vacancies from 13 to 12 days on average, and a reduction in the average stock of unfilled job vacancies at the annual level. Further, broadband internet increases reallocation of workers across firms. While increases in hires and separations occur primarily among workers with lower (within-industry) levels of schooling, we show that the increase in hiring is primarily explained by hires of workers with more relevant industry experience.

Second, turning to worker-level evidence, we show that internet is likely to improve employment prospects of job seekers due to improved access to information about available jobs. Consistent with prior evidence, we first confirm that internet increases the probability that job seekers find new employment. We then show that 80 percent of the increase in employment occurs in firms that are located outside workers' own local labor markets. The evidence is consistent with a mechanism in which internet improves access to information about job openings and increases job finding rates by reducing the spatial mismatch between job seekers and

job vacancies.

Third, our evidence is consistent with the idea that internet improves the match quality of new employment relationships. We track the outcomes of job seekers exposed to different rates of broadband availability by combining employer-employee data with unemployment spell data, and estimate how the average starting wage and subsequent tenure after unemployment varies with the broadband coverage rate. Our evidence shows that the average starting wage and subsequent tenure are higher in areas that expanded the availability of broadband access points early compared to areas with later expansions. By contrast, we find no evidence that broadband coverage improves wages after switching employer.

Our empirical results should be interpreted as the intention-to-treat estimates of broadband internet on labor market matching. While our results on both sides of the market show that the exclusion restriction – that availability is only affecting workers' outcomes through their use of internet – is unlikely to hold, we take several steps to help interpret the evidence. First, we show that our measure of broadband availability significantly increases the adoption rate among firms and households by about 25-30 percent. Next, we show that the availability of broadband internet significantly increases firms' use of online marketing and job posting, and households' use of internet to browse ads and for work purposes. Our identification relies on calendar time fixed effects and municipality fixed effects to remove any systematic differences in labor market conditions across municipalities. A key threat to identification is that the broadband expansion might be related to unobserved and underlying labor demand and supply factors. We show that the timing is not systematically related to pre-determined factors that may be positively correlated with the speed of labor market matching (e.g. unemployment rate, road infrastructure, commuting time). Moreover, several robustness checks confirm that our results are qualitatively the same and quantitatively similar when we include a large number of observable labor market, firm, and worker characteristics (e.g., industry- and occupation-fixed effects).

Our findings have several important implications for policy. One pertains to the interpretation of falling rates of job-to-job mobility, a trend which has fueled a growing concern about the decline in labor market fluidity in the United States (e.g. Molloy *et al.*, 2016). Our results provide a nuanced view of the role of internet and how labor market matching is shaping these trends. We do not find any evidence of increases in mobility among workers who gain access to broadband infrastructure. However, our results show that internet has improved match quality, and therefore also dampened the need to switch employers in search for better job-specific matches. The evidence in this paper also offers a partial explanation to the inward shift in the Beveridge curve observed in several countries from the 1990s to the early 2000s. For example, our findings suggest that without the near universal adoption of internet, the unemployment rate after the Great Recession could have reached even higher levels; thus, our findings highlight the potential of labor market policies targeting the sources of matching (in)efficiency.[3]

Our paper is primarily related to a small literature that studies job search strategies and individual employment outcomes. Kuhn & Skuterud (2004) is the first and a widely cited study of the relationship between unemployment duration and internet as a method to search for jobs. These authors find that online job searchers spend a longer time unemployed than workers who use more traditional search strategies. How-

[3]For example, Shimer (2012) show that matching efficiency accounts for the bulk of unemployment fluctuations. Another implication of improvements in matching efficiency is that the natural rate of unemployment falls, which may facilitate more expansionary monetary policy.

ever, more recent descriptive evidence reveals more mixed evidence.[4] Kroft & Pope (2014) use temporal and spatial variation in the availability of a particular online marketplace across metropolitan areas in the U.S., and find that the website did not reduce local unemployment rates. Similarly, Denzer *et al.* (2018) and Gurtzgen *et al.* (2018) use variation in broadband internet availability across German municipalities to study how internet as a means of job search affected job finding probabilities. These studies find that re-employment rates increase when job seekers use internet to search out new jobs. We add to this literature in several ways. First, we confirm the positive association between internet availability and job finding rates, and then decompose this change to show that most of increase is explained by workers who find re-employment outside of their local labor market. Second, we are the first to show that workers with higher broadband coverage are more likely to find work in their previous industry and are paid higher starting wages. Third, by studying both sides of the labor market, we can show that (i) some of the increase in employment can be accounted for by an increase in the number of vacancies, and that (ii) availability of broadband infrastructure increased the probability of posting on the major online job board.

Our paper also relate to empirical studies of hiring and underlying explanations to changes in the efficiency of the recruitment process. Despite its importance for aggregate employment (see, e.g., Gavazza *et al.*, 2018), many aspects of vacancy posting and filling are poorly understood due to lack of detailed data on vacancies at the firm level. Davis *et al.* (2013) were the first to examine the factors behind time-varying and cross-sectional variation in vacancy filling rates. Their key result is that establishments with higher employment growth are also those with highest vacancy-yields, suggesting that firms use different recruitment methods to grow their workforce. To the best of our knowledge, Kettemann *et al.* (2018) is the only other study that combine administrative data on vacancies, firms and workers. Their key result is that high-paying firms fill their vacancies faster. This finding is broadly consistent with evidence from survey data or online platforms that show that vacancies that post higher wages receive more applications (e.g., Holzer *et al.*, 1991, Banfi & Villena-Roldan, 2018 and Marinescu & Wolthoff, 2016).[5] We complement this line of research by showing that the internet has similar effects on vacancy filling rates. Our result is likely explained by firms' improved ability to announce their job openings to a larger market, thereby receiving a larger pool of applicants. Finally, our paper relate to studies of the aggregate implications of mismatch between job openings and job seekers (see, e.g., Sahin *et al.*, 2014, Marinescu & Rathelot, 2018, Herz *et al.*, 2018). Our evidence is consistent with the idea that information frictions underlie spatial mismatch between job seekers and vacancies, and that improvements in the search technology may increase speed in which unemployed workers find new employment.[6]

The paper proceeds as follows. Section 2 describes the institutional background and our data sources. Section 3 presents our empirical design. Section 4 presents our evidence on firm recruitment, while we

[4] Kuhn & Mansour (2014) use a more recent sample of job seekers and find that internet usage is associated with a 25 percent reduction in unemployment duration. Stevenson (2009) uses a similar empirical strategy and finds that workers who look for jobs online have more job-to-job transitions than workers that use other strategies. Other papers focus on the employment effects of internet, which may in part come from improvements in matching among unemployed or changes in on-the-job search behavior (see, e.g., Atasoy, 2013 and Dettling, 2017).

[5] Other related studies of vacancy posting behavior use survey data (e.g. Holzer *et al.*, 1991, van Ours & Ridder, 1991, Van Ours & Ridder, 1992, Burdett & Cunningham, 1998, Davis *et al.*, 2014, Faberman & Menzio, 2018), or microdata from online job boards (e.g. Barron *et al.*, 1997, Modestino *et al.*, 2016, Hershbein & Kahn, 2018).

[6] Similarly, Belot *et al.* (forthcoming) show that online advice increase the likelihood of employment among younger job seekers.

present the evidence on worker flows and match quality based on worker-level analysis in Section 5. Lastly, Section 6 concludes.

2 Institutional Background and Data Sources

We begin this section by describing some key institutional details of labor markets in Norway. We then describe a variety of administrative and survey data sources on workers and employers, including details on the analytical samples we use.

2.1 Institutional Background

2.1.1 Labor Market Regulation

The Norwegian labor market is characterized by a combination of institutional regulation and flexibility. Virtually all private sector jobs are covered by collective bargaining agreements, and are negotiated by unions and employer associations at the industry level. Firms can fire workers when operating at a loss or are underperforming relative to their peers (see Huttunen *et al.*, 2011, for details), but are regulated by European Labor Law during mass layoffs. General agreements between employers and labor unions form the basis for selection and typically recommend tenure- and age-based selection criteria, and firms face considerable financial risks in the event of wrongful discharge. For example, if the authorities were incompletely informed about the mass layoff, or if the selection criteria are unsubstantiated, dismissed workers may file a lawsuit against the firm.

2.1.2 Unemployment Insurance

Job losers are eligible for unemployment insurance (UI) benefits after a three-day waiting period. Benefits replace about 62 percent of workers' past earnings, and all unemployed workers below retirement age are eligible for 104 weeks of benefits if their previous earnings are above a fairly low threshold (see, e.g., Røed & Zhang, 2003). To remain eligible for benefits, recipients are required to actively look for jobs and to be willing to take any type of employment (e.g. full-time and part-time) at any geographic location (e.g. within and across commuting zones). If workers don't comply with these rules, the employment agency can impose sanctions by canceling benefit payments for up to 26 weeks. The UI system is financed by payroll taxes, and there is no experience rating on the firm.

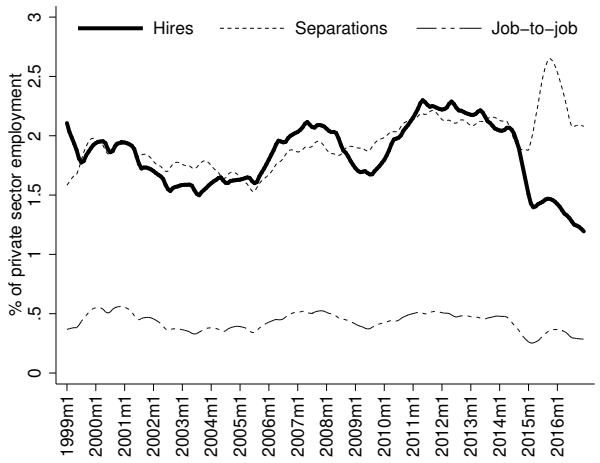
At the end of the potential benefit period, unemployed workers can apply for other mean-tested transfer programs available though the social safety net. Social assistance (i.e. traditional welfare benefits) replaces on average 30 percent of previous earnings, and eligibility requirements (activity and means-testing) vary across geographic administrative units. Vocational rehabilitation and early retirement programs provide cash transfers that cover about 60 percent of past earnings, but eligibility depends on workers' health status, educational attainment and the transferability of skills to other occupations. Other may leave the labor force for early retirement at the age of 62, or by successful applications for disability insurance benefits (see Kostol & Mogstad, 2014).

2.1.3 Comparison to the U.S.

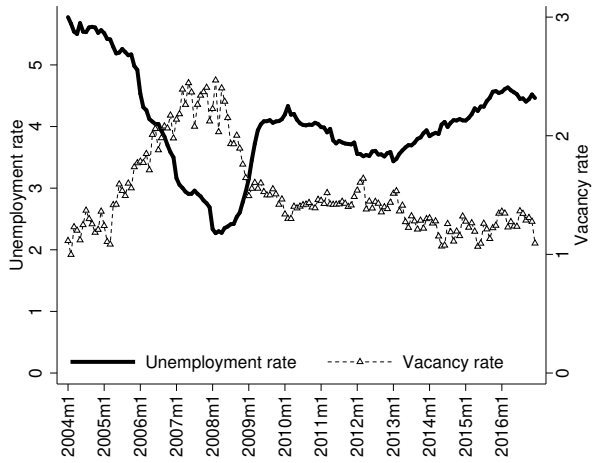
Figure 2a shows that despite a high degree of regulation and high replacement rates from UI benefits, the job turnover rates in Norway are relatively high. The rates of job creation and job destruction in the private sector are comparable to those in many other countries. For example, the turnover rate in Norway is about 20 percent lower than corresponding numbers in the US private sector (see Davis *et al.*, 2006). Figure 2b illustrates the economic environment in Norway by the co-movement between unemployment and vacancy rates over the period from 2004 to 2016. Both series are seasonally adjusted, and are divided by the labor force. The average unemployment rate over the period was among the lowest in Europe at 4 percent. Compared to the U.S., Norway had a milder experience of the Great Recession, where unemployment peaked at 4.4 percent by the end of 2009.

Figure 2: Stocks and Flows in Norwegian Labor Market.

(a) Gross Labor Market Flows



(b) Vacancy and Unemployment Rates



Notes: Figure 2a shows hires and separations in the private sector in Norway for workers aged 25-66. The time series are seasonally adjusted, and smoothed using a three month moving average. Figure 2b shows the monthly unemployment rate among workers aged 25-66, and includes workers who are partially employed and participating in active labor market programs. The vacancy rate is from the employment agency, and is divided by the labor force aged 25-66.

2.2 Data Sources

2.2.1 Administrative Datasets

Our empirical analysis combines several administrative data sources that can be linked by unique and anonymized identifiers for every resident individual and registered firm. As described below, these sources include a matched employer-employee register, a job-seeker/unemployment register, a register of vacancies and various other population-level registers. The Norwegian administrative data have several distinct advantages over data from many other countries. First, the administrative nature of our data reduces the extent of measurement errors in wages and employment relationships. Second, because individual employment histories and most income components are third-party reported (e.g., employers, financial intermediaries), the coverage and reliability are rated as exceptional by international quality assessments (see, e.g., Atkin-

son *et al.* 1995). Finally, since administrative data are a matter of public record, there is no attrition due to non-response or non-consent by individuals or firms and individuals can only exit these datasets due to natural attrition (i.e., death or out-migration), thus all resident individuals and registered or operating firms are included in our initial datasets.

Matched Employer-Employee Register. Workers' earnings and employment histories, and transitions between jobs and occupations come from the Norwegian Matched Employer-Employee Register maintained by Statistics Norway. This dataset covers virtually all employment contracts from 1995 to 2014. Every worker-level contract is reported by the employer to the authorities at the end of the year, and includes information on the dates of alterations to the contract, and the corresponding wage, industry and occupational codes, geographic location and tenure at the establishment. From this source, we construct time series of monthly earnings for each worker, and the transitions between establishments and occupations.

Job-Seeker/Unemployment Register. Information on participation in the unemployment insurance (UI) program comes from the job-seeker register, which has complete records for all individuals who entered or exited this program between 1992 and 2014. This information is maintained by Statistics Norway and builds on administrative records kept by the Norwegian Labour and Welfare Administration, cf. the public employment agency. The data includes every job-seeker, both the fully unemployed and those who have a part-time job but are looking for full-time work, as well as participants in active labor market programs. To assist workers in job search, caseworkers in the employment agency keep a record of details about workers' occupational experience, and the occupations job seekers want to work in.

Register of Job Vacancies. The public employment agency maintains a database of job vacancies used for statistical purposes and by caseworkers to match unemployed workers to potential employers. Individual vacancies are either manually collected from job boards and help-wanted ads, or are reported directly by employers.[7] These vacancies are then classified by the number of positions the establishment is trying to fill, the workplace (e.g. zip code) and corresponding four-digit occupational code. Occupational codes are based on the International Standard Classification of Occupations (ISCO). The data is available from 2002 to 2014.

Other Population Registers. To capture complete information on workers' geographic locations, annual earnings, assets, and household income, social security data is merged with longitudinal administrative registers provided by Statistics Norway and covering every Norwegian resident from 1967 to 2014. These administrative data sources contain individual demographic information (including sex, age, zip codes, and

[7]The Working Environment Act, cf. the Norwegian labor law, requires employers to report vacant positions to the public employment agency. As this rule is hard to monitor and sanction, many vacancies are not reported. The employment agency employs several data collectors that manually record vacancies from several sources. The quality of the vacancy register would naturally depend on the degree to which firms comply with the reporting requirements. A natural question is then to what extent are data recorded in the vacancy register representative of all job openings. To assess the representativeness of our data we collected additional data on job openings from Statistics Norway that is based on representative surveys of establishments from 2010 to 2016. Our comparisons reveal that data on vacancies from the employment agency tracks the time variation in aggregate job openings from the survey data on vacancies remarkably well (see Appendix Figure A3).

education) and, since 1993, all sources of annual income, including earnings, self employment income, capital income, and cash transfers. Household assets include most types of assets holdings and liabilities, such as as real estate, financial portfolio, and debt. Income data are reported in annual amounts, while the values of assets and liabilities are measured as of the last day of each year.

Data on Broadband Internet Coverage. We link our administrative data to the fraction of households covered by broadband internet in each municipality. This information is collected from the Norwegian Communications Authority, a government agency monitoring the coverage of broadband internet across Norway, which requires the suppliers of broadband access to end-users to file annual reports about the locations of their broadband infrastructure and coverage rates. Using the area signal range of each access point and detailed information on the location of households, the agency computes the overall broadband coverage rates on the municipal level for each year. In doing so they take into account that multiple suppliers may provide access to households living in the same area, so that double-counting is avoided. This coverage rate serves as our proxy for the availability of broadband internet across areas and over time in Norway. Throughout this article, broadband coverage is defined as having the possibility to connect to internet with download speed that exceeds 256 kbit/s. Earlier studies by Bhuller *et al.* (2013) and Akerman *et al.* (2015) use the same data source, with information on broadband coverage for fewer years.

2.2.2 Survey Datasets

Our empirical analysis employs several firm-level survey datasets that can be merged to the above-mentioned administrative data sources based on unique firm identifiers. As described below, the detailed nature of these survey data allows us to shed light on firms' recruitment behavior as well as on various aspects of firms' information technology use and online search behavior. Finally, access to anonymized individual-level surveys on media use allows us to assess how broadband internet coverage affects workers' information technology use and online search behavior.

Survey of Firms' Recruitment Behavior. The public employment agency has since 1994 administered annual surveys of firms' recruitment behavior. These surveys are used for various policy analyses and in predictions of labor market trends across local labor markets and industries, and are designed as repeated cross-sections, with an sample of around 20,000 representative firms drawn from the population of registered firms. The data include firm-level information on expected changes in labor demand, planned vacancy posting and recruitment challenges facing each firm is collected. Interestingly, these datasets provide information about recruitment problems facing each firm. For our analysis, we received extracts from these datasets for years 2000 to 2014, which contain responses for around 13,000 firms in each year, i.e, an average response rate of 65 percent. The data includes firm identifiers allowing us to link the survey information to the various other firm-level data sources mentioned above.

Survey of Firms' ICT Use. Statistics Norway has surveyed firms' ICT use since 1999 using repeated cross-sections. Stratified random samples by firm size and industry are drawn from the population of reg-

istered firms. There is about 4,000 surveyed firms each year. Crucial to our analysis, the surveys include information on the use of dial-up or broadband internet in firms, and moreover, whether firms have marketing websites, whether firms use online job-boards for recruitment of workers, besides a host of other measures of firms' digital presence and online search behavior. We received extracts from these datasets for years 2001 to 2014, which contain responses for around 3,800 firms in each year. Statistics Norway mandates the collection of this information for the purpose of preparing official statistics on firms' ICT use and can threaten to apply coercive fines in case of non-response; the average response rate is thus maintained at almost 95 percent.

Media Use Surveys. Statistics Norway has surveyed individuals' media use annually since 1991. These surveys are designed as repeated cross-sections, with representative survey samples of around 2-3,000 individuals drawn from the population of 9–79 year olds. Each individual is interviewed about a wide array of topics related to media use behavior, including questions on whether the individual had access to dial-up or broadband internet, used internet for work-related purposes, and a number of other measures of online search activities. We received anonymized extracts from these survey datasets from Statistics Norway for years 2000 to 2013, with an average response rate of 65 percent over these years. Even though these datasets are anonymized, identifiers for municipality of residence and time of survey were retained, which allows us to use this information in our research design.

2.2.3 Sample Construction and Summary Statistics

We use two main analytical samples – one containing firms and the other containing working-age individuals – both of which are drawn from population-wide administrative data sources discussed above. Additionally, we constructed subsamples of firms and workers containing units that could be assembled, and in most cases linked, from the various surveys described earlier. We provide details on sample restrictions and summary statistics for key variables in each of these samples below.

Firms. Our main sample of firms is restricted to establishments that employ at least one part-time worker in each year between 2000 and 2014. Applying this restriction, we retain a sample of 256,253 firms and more than 1.8 million firm-year observations. Table 1 provides means (column 1) and standard deviations (column 2) of the key variables in this sample. The average firm age is 17.5 years, average firm size is 9.5 employees, and on average workers have completed 12.5 years of education and receive an annual salary of 51,865 USD. For each year, these firm characteristics are measured in year t-1. We use these characteristics as predetermined control variables in our empirical analysis.

Next, we extract firms that are observed posting a vacancy in the employment agency's register of vacancies. Applying the same sample restriction as before, we retain 240,790 firms and more than 1.6 million firm-year observations, for which we have information on vacancy posting behavior. There are about 6 percent fewer firms in the vacancy posting sample compared to the main sample. This attrition is mainly due to the availability of data on vacancies, which is limited to from 2002 and onward. Table 1, columns 3-4, provide summary statistics for the vacancy posting sample. As expected, firms in the two samples are very

similar along these characteristics.

Table 1: Summary Statistics – Firms.

	Administrative Data				Survey Data			
	Main Sample		Vacancy Posting Sample		Recruitment Survey Sample		ICT Use Survey Sample	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Firm Characteristics:	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Firm Age	17.5	[13.5]	17.7	[13.7]	24.5	[16.3]	21.5	[13.7]
Firm Size	9.5	[47.3]	9.5	[47.5]	23.3	[103.8]	32.3	[59.6]
< 1	21.9	-	21.8	-	6.4	-	1.7	-
1-3	28.9	-	28.9	-	24.3	-	9.1	-
3-5	14.5	-	14.5	-	17.0	-	10.3	-
5-10	15.4	-	15.5	-	19.6	-	19.4	-
10-50	16.6	-	16.7	-	23.6	-	42.6	-
> 50	2.7	-	2.6	-	9.1	-	16.9	-
Average Years of Education in Firm	12.5	[2.6]	12.5	[2.7]	12.4	[2.2]	12.1	[1.9]
Average Annual Wage (2014-USD)	51,856	[72,145]	53,076	[75,250]	50,763	[41,209]	57,609	[35,985]
Number of Obs. ($B \times T$)	1,824,388		1,611,506		191,636		50,269	
Number of Firms (B)	256,253		240,790		94,472		22,476	
Time Period	2000-2014		2002-2014		2000-2014		2001-2014	

Note: Sample means and standard deviations of the firm characteristics in the samples of establishments used in the analysis. The samples are restricted to establishments with at least 1/3 FTEs. Note that ICT Survey sample consists of enterprises, and not establishments. Note that the Recruitment Survey sample consists of firms in the period 2000-2011, and of enterprises in the period 2012-2014. If an enterprise consists of more than one establishment, the control variables are averaged across establishments. Firm age is top coded to 51, while firm size measures the number of workers employed in the firm. The distribution of firms across size categories shows percentage of firms in each category. Level of education is measured in years, while the annual wage (annualized using annual wage paid and annual total number of hours) is rebased to 2014-NOK using the CPI and then converted to USD. All control variables are measured in year t-1.

In Table 1, columns 5-6 report summary statistics for firms included in the survey of firms' recruitment behavior. Applying the same sample restriction as to the main sample, we retain 94,472 firms (i.e., more than one-third) that appeared as respondents at least once in the recruitment survey sample. However, this being a repeated cross-section survey, we can only retain 191,636 firm-observations (i.e., around 10 percent) jointly across all years. Although the recruitment survey is designed as a representative survey of firms, we see some noticeable differences in firm characteristics across survey respondents (columns 5-6) and the main sample firms (columns 1-2).

Table 1, columns 7-8, further report summary statistics for firms included in the survey of ICT use. Applying the same criteria as for the other samples, we retain 22,476 firms and 50,269 firm-year observations that responded to the ICT use survey. These columns document that firms responding to the ICT use survey are bigger in size and are older compared to the main sample of firms.

Working-age Individuals. Our main sample of working-age individuals (or workers) includes 2,758,357 resident individuals aged 25–55 and 24,248,439 person-year observations. Table 2 report means (column

1) and standard deviations (column 2) of the key variables in this sample. The average age is 40 years, 49 percent are female, 60 percent are married, on average an individual has 1.04 children younger than 18 and 0.5 children aged 18 or above, and has completed 12.5 years of education. Restricting the main sample to individuals who are either full-time or part-time unemployed for at least one month, we retain 736,467 individuals and 1,339,779 person-month observations (i.e., around 5.5 percent of the working-age sample). The unemployed are on average 3 years younger, 10 percentage points less likely to be married, and have lower educational attainment (columns 3-4). Columns 5-6 provide summary statistics for a sample of workers aged 25–55 drawn from the media use surveys. There are 10,958 respondent-year observations in the media use survey. While the average age and gender distribution is comparable across the two samples, the survey respondents are more likely to be married, have older children and have completed high school than the overall working-age population.

Table 2: Summary Statistics – Working-age Individuals.

	Administrative Data				Survey Data	
	Working-age Individuals		Unemployed Workers		Media Use Survey Sample	
	(1)	(2)	(3)	(4)	(5)	(6)
Worker Characteristics:	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Age	40.0	[8.72]	37.2	[8.43]	39.6	[8.44]
Female	0.49	[0.50]	0.50	[0.50]	0.50	[0.50]
Married	0.60	[0.49]	0.50	[0.50]	0.75	[0.43]
Fraction with Young Children	0.56	[0.50]	0.57	[0.50]	0.37	[0.48]
Number of Young Children	1.04	[1.19]	1.05	[1.14]	-	-
Fraction with Old Children	0.28	[0.45]	0.19	[0.39]	0.26	[0.43]
Number of Old Children	0.50	[0.92]	0.33	[0.78]	-	-
Years of Education	12.5	[4.22]	11.1	[4.75]	-	-
High School	0.32	[0.47]	0.32	[0.47]	-	-
Some College	0.34	[0.47]	0.22	[0.42]	-	-
< 11 years	0.25	-	0.38	-	0.14	-
11-13 years	0.41	-	0.40	-	0.66	-
14-16 years	0.20	-	0.15	-	0.03	-
> 16 years	0.14	-	0.08	-	0.16	-
Number of Obs. ($N \times T$)	24,248,439		1,339,779		10,958	
Number of Individuals (N)	2,758,357		736,467		-	
Time Period	2000-2012		2000-2012		2000-2013	

Note: Summary statistics for the population of working-age individuals and the sample of unemployed workers. The samples are restricted to individuals between the ages 25-55. In the administrative data, all control variables are measured in year t-1, with t-1 $\in$ [2000,2012]. In the survey data, all control variables are measured in year t (and not year t-1), with $t \in$ [2000,2013]. Young children are children younger than 18 years, older children are children aged 18 and more.

3 Empirical Design

In this section, we describe key aspects of the Norwegian Broadband Policy and discuss our empirical design, outlining how we use the policy-generated variation to estimate the causal effects of broadband internet coverage on job search and matching.

3.1 The Norwegian Broadband Policy

Several OECD countries expanded their information and communications technology (ICT) infrastructure during the past decades. These efforts were seen as essential for retaining competitiveness and achieving high standards of living in a global economy. Norway took several steps to enhance its ICT infrastructure from the late 1990s and onward, starting with the *Policy for Regional ICT Competence* introduced by the Norwegian Parliament in 1998 (St.meld. nr. 38 (1997–1998)), followed by introduction of the *Program for High-Speed ICT (Høykom) Innovation in the Public Sector* in 1999 (Statskonsult, 2007; Bygstad & Lanestedt, 2009), and passing of the *National Broadband Policy* by the Norwegian Parliament in 2003 (St.meld. nr. 49 (2002–2003)). This section provides details about the program and describes the expansion of broadband internet.

Policy Goals and Implementation. These policies had two main goals.[8] The first was to ensure that every household and private enterprise in all parts of the country had access to broadband at a reasonable and uniform price. The second was to ensure that the public sector quickly adopted broadband internet.

The Norwegian government took several steps to reach these goals. First and foremost, it invested heavily in the necessary infrastructure. The investment in infrastructure was largely channeled through the (state-owned) telecom company Telenor, which was the sole supplier of broadband access to end-users in the early 2000s and continues to be one of the main supplier today.

Second, local governments were required to ensure access to broadband internet by 2005 to local public institutions, such as administrations, schools, and hospitals. To assist municipalities in rural areas, the government provided financial support through the *Høykom* funding program from 1999 onward. Local governments could receive funds from this program by submitting a project plan that had to be evaluated by a program board with expert evaluations. The stated aim was to ensure broadband coverage throughout the country. Once approved, financial support was provided in the initial years of broadband access, thus making it possible for public institutions to cover relatively high initial costs.

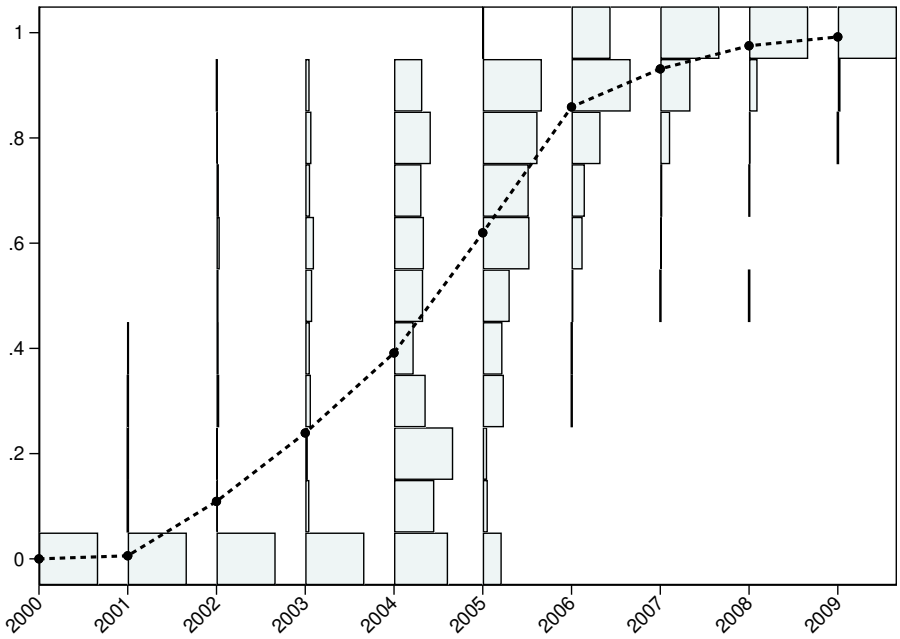
Supply and Demand Factors. The transmission of broadband signals through fiber-optic cables required installation of local access points. Since 2000, such access points were progressively rolled out, generating considerable spatial and temporal variation in broadband coverage. The staged expansion of access points was in part due to limited public funding, but also because Norway is a large and sparsely populated country.

[8] Our discussion draws on Bhuller *et al.* (2013). These policy goals are outlined in St.meld. nr. 38 (1997–1998), Section 4.5, and St.meld. nr. 49 (2002–2003), page 7.

There are often long driving distances between the populated areas, which are mostly far apart or partitioned by mountains or the fjord-broken shoreline.[9]

The main supply factors determining the timing of roll-out are topographical features and existing infrastructure (such as roads, tunnels, and railway routes). The transmission of broadband signals through fiber-optic cables required installation of local access points. In areas with challenging topography and landscapes, it was more difficult and expensive to install the local access points and the cables. Furthermore, the existing infrastructure mattered for the marginal costs of installing cables to extend the availability of broadband within a municipality and to neighboring areas. Based on our readings of the program accounts, we expect demand for broadband infrastructure to be related to public service provision, income level, educational attainment, and the degree of urbanization in the municipality.[10]

Figure 3: The Evolution of Broadband Internet Availability in Norway.



Notes: This figure shows the overall mean and distribution of broadband coverage rates across 420 municipalities for each year during the period 2000–2009. For each year, the mean broadband coverage rate across municipalities is displayed by black circles and measured as a fraction along the vertical axis. Similarly, the distribution of broadband coverage rates is displayed as a blue-shaded histogram in 11 equidistant bins for each year.

Evolution of Broadband Availability. The progressive roll-out of broadband access points generates considerable variation in broadband coverage across municipalities and over time. Figure 3 summarizes the evolution of broadband coverage rates between 2000 and 2009. In each year, we report the overall means and the distributions across municipalities. While virtually no municipalities had broadband access-points available in 2000, the average coverage rate increased to almost 40 percent by early 2004 and exceeded 80

[9]The Norwegian territory covers about 149,400 square miles, an area about the size of California or Germany, with around 13 percent and 6 percent of those regions' populations (in 2008), respectively. The country is dominated by mountainous or high terrain, as well as a rugged coastline stretching about 1,650 miles, broken by numerous fjords and thousands of islands.

[10]These factors are discussed in the several documents describing the National Broadband Policy and the roll-out of broadband access points (see St.meld.nr. 38 (1997–1998); St.meld.nr. 49 (2002–2003); Bhuller *et al.*, 2013).

percent by early 2006. By 2009 there was almost complete coverage across the country.

The geographic variation in broadband coverage across municipalities and over time is illustrated in Appendix Figure A1. By 2001, broadband transmission centrals were installed in the cities of Oslo, Stavanger, and Trondheim, as well as in a few municipalities neighboring Oslo and Trondheim. However, because of limited area signal range, broadband internet was available for less than one-third of the households in each of these municipalities. There is considerable variation in coverage rates even within municipalities over time, and few municipalities experienced abrupt changes from zero coverage to full coverage from one year to the next. In most areas the access points were progressively rolled out within and across municipalities, generating a continuous measure of coverage rates that display considerable temporal and spatial variation.

We assess how growth rates in broadband coverage vary with municipality characteristics in Appendix Figure A2. As expected, these patterns of roll-out suggest that (i) the population size and (ii) the degree of urbanization predict that a municipality had early increases in broadband coverage. However, key labor market characteristics such as local unemployment rate, average income and sector composition; socio-economic factors such as years of education, fraction of student enrollment, population age composition, immigrant population share; and other geographic features including distance to city center, travel time and road networks do not predict the patterns of roll-out. As discussed below, to account for the role of time-varying predictors of broadband roll-out we will control for these characteristics in all our regressions, besides municipality fixed effects and year dummies.

3.2 Specification

The key challenge in identifying the effects of internet on job search and matching is the lack of exogenous variation in online recruiting and job search activities. For example, the adoption of internet and the use of digital platforms for job recruitment could be determined by local productivity shocks, which in turn increase labor demand and wages, thus confounding any effects of internet. Randomizing online job search is not feasible in our application: We cannot in practice force recruiting firms or job-seekers to use digital platforms in their search and matching activities. One can, however, think of a field experiment which randomizes broadband availability at the municipality level. This randomization would break the correlation between unobserved determinants of online recruiting, job search activities and labor market outcomes. The intention of our empirical design is to mimic this experiment.

We use the staged installation of broadband infrastructure to generate plausibly exogenous spatial and temporal variation in broadband availability. To fix ideas, let's consider the following equation for an outcome y_{mt}, e.g., the hire rate of recruiting firms in year t located in municipality m:

$$y_{mt} = \delta z_{m,t-1} + x'_{mt}\beta + \alpha_m + \tau_t + \varepsilon_{mt}, \quad (1)$$

where $z_{m,t-1}$ is the lagged broadband coverage rate in municipality m measured in year *t-1*, x_{mt} is a set of time-varying covariates, α_m is a full set of municipality indicators, and τ_t are year indicators. Conditional on x_{mt}, α_m and τ_t, we maintain the assumption that $z_{m,t-1}$ is exogenous and thus uncorrelated to any unobserved determinants ε_{mt} of outcome y_{mt}. Our parameter of interest, δ, shows how a change in the lagged broadband

coverage from 0 to 100 percent affects the outcome of interest from one year to the next.[11]

In the above specification, unobservable determinants of y_{mt} at the municipality level are captured by municipality indicators α_m. Common time shocks across areas are absorbed by the year indicators τ_t. Our specification thus effectively utilizes *within* municipality changes in broadband coverage over time, while removing all changes over time in the outcome and increases in broadband coverage that are *common* across municipalities. Under the assumption of conditional independence between potential labor market outcomes and broadband infrastructure, we can identify the effects of an increase in broadband coverage on the outcome. As in a standard difference-in-differences (DiD) design, this assumption translates into an assumption of common trends in this staggered adoption design (SAD) approach.[12]

Equation (1) is our baseline specification. We estimate a slightly modified version of this specification depending on whether the outcome is measured at the firm level (y_{jmt}) or at the individual level (y_{imt}). In firm-level regressions, we will control flexibly for pre-determined characteristics of each firm j, such as industry fixed effects, firm age, firm size, and workforce composition. Similarly, in individual-level regressions, we will control for pre-determined characteristics of individual i, including (past) occupation fixed effects, age, gender, family background, and education. In all of our regressions we also control for a set of time-varying municipal characteristics that we consider to be correlates of demand and supply factors of broadband expansion (see Section 3.1). Throughout the paper, all standard errors are robust to heteroskedasticity and are clustered at the municipality level.

To further assess the validity of of our assumptions, we estimate alternative specifications where we include controls for municipality-specific trends in Equation (1) to depart from the common trends assumption, and where we include higher-order lags of broadband availability to assess sluggish or long-run responses. We also perform placebo analyses by changing the timing of the outcome variable to be before the timing of increases in broadband availability. Results from these additional analyses are available upon request.

3.3 Interpreting the Broadband Policy

We expect broadband internet access to affect labor market matching through firms' and workers' broadband adoption, as well as through the induced changes in online search and recruitment activities. In order to assess how broadband internet affects these channels, we estimate Equation (1) on firms' and workers broadband internet use and their online activity using the survey data on firms' ICT use and individuals' media use.

Table 3 presents results from this assessment. For both firms (Panel A) and workers (Panel B), we find that an increase in the broadband coverage rate from 0 to 100 percent triggers an increase in their broadband adoption rate by almost 30 percentage points (rows 1). These estimates show that firms and workers are more likely to use broadband internet (i.e., have a device with broadband installed) from one year to the next as a consequence of an increase in broadband availability in their municipality. The coefficient estimates are remarkably similar across both groups, and are highly robust to adding controls for firm (or worker) characteristics, and fixed effects for industry (or occupation). In the Appendix Table A1, we show that the

[11] Note that this specification doesn't include the contemporaneous broadband coverage rate since our analysis suggests that the adoption of new technology and changes in online activities respond to increases in broadband coverage with a short time lag.

[12] Recent comparisons of the identifying assumptions in the standard DiD design, the fuzzy DiD design, and the staggered adoption design (SAD) include de Chaisemastin & D'Haultfoeuille (2018)) and Athey & Imbens (2018).

main conclusion is robust to using analytical weights that make the survey-based estimates comparable to our main analytical samples drawn from population-wide administrative data sources.

Table 3: The Effects of Broadband Availability on Broadband Access and Online Search Activities.

	A. Firms in the ICT Use Survey			B. Working-age Individuals in the Media Use Survey		
	(1) Baseline	(2) Controls	(3) Controls + Industry FE	(4) Baseline	(5) Controls	(6) Controls + Occupation FE
Dependent Variable:	1. Has Broadband Internet Access			1. Has Broadband Internet Access		
Broadband Availability	0.309***	0.294***	0.290***	0.284***	0.282***	0.269***
(Standard Error)	(0.039)	(0.033)	(0.032)	(0.038)	(0.038)	(0.041)
[p-value]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Base Dep. Mean	0.380	0.380	0.380	0.059	0.059	0.059
Dependent Variable:	2. Has Marketing Website			2. Uses Internet for Work Purposes		
Broadband Availability	0.119***	0.103***	0.097***	0.113***	0.131***	0.142***
(Standard Error)	(0.034)	(0.026)	(0.025)	(0.032)	(0.034)	(0.032)
[p-value]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Base Dep. Mean	0.541	0.541	0.541	0.030	0.030	0.030
Dependent Variable:	3. Online Job Board Use Rate			3. Uses Internet for Browsing Ads		
Broadband Availability	0.174***	0.168***	0.171***	0.093***	0.088***	0.056*
(Standard Error)	(0.024)	(0.023)	(0.023)	(0.033)	(0.032)	(0.034)
[p-value]	[0.000]	[0.000]	[0.000]	[0.004]	[0.005]	[0.095]
Base Dep. Mean	0.284	0.284	0.284	0.022	0.022	0.022
Time FE	√	√	√	√	√	√
Municipality FE	√	√	√	√	√	√
Control variables		√	√		√	√
Occupation/industry FE			√			√
Obs. ($B\times T$ / $N\times T$)	50,619	50,619	50,269	10,958	10,958	9,180

Note: Estimation results of enterprises from the annual Survey of Firms' ICT Use for various outcomes in year t on broadband internet coverage rate in year t, with $t \in$ [2001,2014] (Panel A) and working-age individuals from the annual Media Use Survey for various outcomes in year t on broadband internet coverage rate in year t-1, with t-1 $\in$ [1999,2012] (Panel B). Results in Panel A and Panel B are based on non-weighted estimation results. Control variables for firms include firm age/size, firm composition and municipal infrastructure. Control variables for individuals include age/gender, family background, education and municipal infrastructure. The reported dependent mean is pre-assignment, i.e. when the broadband internet coverage rate equals zero. Note that sample in Panel B, outcome 3, consists of 8,612 observations (7,077 observations with occupation FE), due to data availability. *$p < 0.10$, ***$p < 0.01$.

Moreover, the coefficient estimates in Table 3, rows 2, indicate that both firms (Panel A) and workers (Panel B) increase their online presence along dimensions that are relevant to labor market outcomes, as proxied by having a marketing website (for firms) and using internet for work-related purposes (for individuals). Finally, we document an increase in online search activities in rows 3: Access to broadband internet increases the use of online job-board to as a method to announce vacancies by firms, and the use of internet to browse online advertisements among workers.[13] Taken together, our estimates reveal both significant and

[13]The regression behind Panel A, Row 3 is at the municipality level. Due to difficulties in matching digital job postings to the

sizable increases in broadband adoption, market-related online presence and online search activities from one year to the next resulting from an increase in broadband coverage in a municipality.

Finally, it is worth noting that the coefficient estimates in Table 3 could be interpreted as the first-stage coefficients in a 2SLS model where the outcome in Equation (1) is replaced by the appropriate treatment variable (e.g., broadband access or online search activity), which is instrumented using our measure of broadband coverage rate. The second-stage would estimate the effect of the treatment variable on the outcome of interest. Notably, the results in Table 3 indicates a highly significant first-stage coefficient. In that setting, our current Equation (1) could be interpreted as the reduced-form relationship between broadband coverage and any outcome of interest. Throughout our paper we present reduced form relationships as we doubt the IV exclusion restriction is likely to be satisfied in our context.[14] Thus, our estimates can be interpreted as intention-to-treat effects of broadband internet availability on labor market outcomes. Nonetheless, IV estimates of broadband access on any of our outcomes are available upon request (scaling our current estimates by around 0.3 will provide the IV estimates implied by our approach).

4 Evidence on Firm Recruitment

In this section, we estimate how firm recruitment responds to quasi-experimental variation in broadband internet availability triggered by the staggered roll-out of broadband access points over time and across different municipalities in Norway. We start by documenting the impacts on firms' vacancy creation, hires, separations, and on the fraction of surveyed firms facing recruitment problems. Next, we unpack the various margins of response, by considering heterogeneity across hired workers' past employment status, past industry and relative skill types, as well as job-to-job mobility. Finally, we consider spatial proximity between firms and newly hired workers, and assess the implications for the sizes of local labor markets.

4.1 Main Findings

Table 4 presents our evidence on how broadband availability affects firms' vacancy creation. In Panel A, we show that the probability of posting at least one vacancy in a given year (annual vacancy flow) increases by 3.1 percentage points (column 2) in response to an increase in broadband coverage from 0 to 100 percent in the previous year. Compared to the baseline dependent mean (measured at zero coverage) of 15 percent, this implies an increase in the annual vacancy posting probability of more than 20 percent. This result is consistent with the theoretical predictions from a standard search and matching model following a reduction in the costs of vacancy posting or an increase in recruiting efficiency (e.g. Davis *et al.*, 2013).

hiring establishment (the ads are often posted by recruitment and temp-agency), we aggregate these outcomes to municipality level.

[14] For instance, if broadband internet access affects a worker's outcomes through workers' own use of broadband internet as well as through firms' change in recruitment behavior.

Table 4: Firms' Vacancy Flow, Vacancy Duration and Vacancy Stock.

Dependent Variable:	A. Annual Vacancy Flow		B. Conditional Vacancy Duration		C. Normalized Vacancy Stock	
	(1)	(2)	(3)	(4)	(5)	(6)
Broadband Availability	0.033***	0.031***	-1.231***	-1.119**	-0.020***	-0.021***
(Standard Error)	(0.008)	(0.008)	(0.460)	(0.452)	(0.004)	(0.004)
[p-value]	[0.000]	[0.000]	[0.008]	[0.014]	[0.000]	[0.000]
Base Dep. Mean	0.150	0.150	12.726	12.726	0.016	0.016
Fixed Effects	√	√	√	√	√	√
Firm Characteristics		√		√		√
Obs. ($B \times T$)	1,611,506	1,611,506	358,270	358,270	1,611,506	1,611,506

Note: Estimation results of probability of posting at least one vacancy during year t (Panel A), conditional mean duration in days of vacancy postings posted during year t (Panel B), and unconditional normalized stock of vacancies posted, defined as the sum of posting-days times number of positions in each posting, divided by the total number of days in year t (Panel C) on broadband internet coverage rate in year t, with $t \in [2002,2014]$. Fixed effects include time, municipality and industry fixed effects. Firm characteristics include controls for firm age, size and composition. Firm age and size includes dummies for firm age (51 dummies) and size (6 dummies). Firm composition includes average level of education of workers in the firm and average annual wage rebased to 2014-NOK. Dependent mean is pre-assignment, i.e. when the broadband internet coverage rate equals zero. All specifications include controls for municipal infrastructure (municipal road networks (in kilometers) per capita, average travel time to municipal center (in hours) and public spending on infrastructure). Heteroskedastic robust standard errors are clustered on the municipality level. $^{**}p < 0.05$, $^{***}p < 0.01$.

In Panel B, we consider the impact of broadband internet coverage on the mean duration of vacancies posted in a given year. The sample of firms is restricted to the firms with at least one vacancy in that year. The duration of a vacancy is measured from the date the vacancy is posted to the date the vacancy is either filled or removed. Among firms that posted vacancies, we find that the baseline mean vacancy duration is 12.7 days. We find that the conditional mean vacancy duration falls by 1.1 days in response to an increase in broadband coverage, implying a decline of almost 9 percent compared to the baseline duration. This result is consistent with an increase in matching efficiency for firms experiencing an increase in broadband availability.

These results have opposite implications for how the overall stock of vacancies should respond to an increase in broadband availability. To assess the how internet affects the stock of vacancies and its potential implications on the slope and location of the Beveridge curve, we construct the average stock of vacancies in a year. Specifically, for each firm and year, we calculate an unconditional annualized stock of vacancies as the total number of posting-days summed across posted vacancies in a year divided by the number of days in that year. Table 4, Panel C, shows that the vacancy stock declines significantly in response to an increase in broadband coverage.

Table 5: Firms' Hire, Separation and Net Employment Growth.

Dependent Variable:	A. Hire Growth		B. Separation Growth		C. Net Employment Growth	
	(1)	(2)	(3)	(4)	(5)	(6)
Broadband Availability	0.006***	0.005***	0.005*	0.005*	0.001	0.000
(Standard Error)	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)
[p-value]	[0.004]	[0.004]	[0.073]	[0.065]	[0.746]	[0.906]
Base Dep. Mean	0.122	0.122	0.106	0.106	0.016	0.016
Fixed Effects	√	√	√	√	√	√
Firm Characteristics		√		√		√
Obs. ($B \times T$)	1,824,388	1,824,388	1,824,388	1,824,388	1,824,388	1,824,388

Note: Estimation results of hire growth (Panel A), separation growth (Panel B) and net employment growth (Panel C) on broadband internet coverage rate in year t, with $t \in [2000,2014]$. Construction of the outcome variables follows Davis *et al.* (2013), normalizing the change in employment/hires/separations by the firm's mean employment in the previous and current year. Fixed effects include time, municipality and industry fixed effects. Firm characteristics indicate vector of lagged controls for firm age (51 dummies), firm size (6 dummies) and firm composition (average level of education of workers in the firm and average annual wage rebased to 2014-NOK). Dependent mean is pre-assignment, i.e. when the broadband internet coverage rate equals zero. All specifications include controls for municipal infrastructure (municipal road networks (in kilometers) per capita, average travel time to municipal center (in hours) and public spending on infrastructure). Heteroskedastic robust standard errors are clustered on the municipality level. $^{*}p < 0.10$, $^{***}p < 0.01$.

In Table 5, we present evidence on how broadband availability affects firms' hiring, separation and net employment growth. We follow Davis *et al.* (2013) in measuring hire, separation and net employment growth. This is done by first calculating the annual change in hires, separations and net employment for each firm, and then normalizing the changes by each firm's mean employment in the previous and current year. The results in Panel A illustrate that firms experience a statistically significant increase in the hire growth rate by 0.5 percentage points, or around 4 percent compared to the baseline mean hire growth rate of 0.122, in response to an increase in broadband availability. However, the results in Panel B suggest that the firms also experience an increase in the separation rate of similar magnitude. As a consequence, net employment growth remains unchanged, as reflected in the point estimates reported in Panel C.

Next, we use the annual survey data on firms' recruitment behavior to further assess the impact of internet on firms recruitment behavior. The survey includes questions regarding firms' experiences from the recruitment process. To this end, we matched each firm's survey responses when asked "Have you encountered problems in recruiting staff during the last three months?" to our analytical sample utilizing the location of each firm and the timing of survey responses. Because of the large survey samples, we are able to match this information to 10.5 percent of firm-year observations in our main analytical sample. Table 6 provides evidence on how the probability that a firm reports having recruitment problems changes as a response to an increase in the broadband availability.[15] In a baseline without broadband availability, almost 25.3 percent of firms report having recruitment problems. Consistent with our findings in Tables 4-5, we now find that the probability that a firm reports experiencing a recruitment problem declines by 3.5 percentage points (column 2), which is a decline of almost 14 percent relative to the baseline response. This evidence supports the view that broadband internet increases matching efficiency.

[15]The change in broadband internet is measured three months prior to the survey date.

Table 6: Firms' Recruitment Problems.

Dependent Variable:	Firm Experienced Recruitment Problems in the Past Three Months	
	(1)	(2)
Broadband Availability	-0.034***	-0.035***
(Standard Error)	(0.012)	(0.012)
[p-value]	[0.006]	[0.003]
Base Dep. Mean	0.253	0.253
Fixed Effects	√	√
Firm Characteristics		√
Obs. ($B \times T$)	191,636	191,636

Note: Estimation results of firms from the annual Survey of Firms' Recruitment Behavior reporting recruitment problems in year t ("Have you encountered problems in recruiting staff during the last three months?") on broadband internet coverage rate in year t, with $t \in [2000,2014]$. Note that the recruitment survey sample consists of firms in the period 2000-2011, and of enterprises in the period 2012-2014. If an enterprise consists of more than one establishment, the control variables are averaged across establishments. The Recruitment Survey is conducted in the first quarter of year t, usually opening in February and closing in late March. Fixed effects include time, municipality and industry fixed effects. Firm age and size includes dummies for firm age (51 dummies) and size (6 dummies). Firm composition includes average level of education of workers in the firm and average annual wage rebased to 2014-NOK. Dependent mean is pre-assignment, i.e. when the broadband internet coverage rate equals zero. All specifications include controls for municipal infrastructure (municipal road networks (in kilometers) per capita, average travel time to municipal center (in hours) and public spending on infrastructure). Heteroskedastic robust standard errors are clustered on the municipality level. ***$p < 0.01$.

4.2 Unpacking the Margins of Response

We now move on to investigate heterogeneity in firms' recruitment responses by assessing how broadband availability differentially affects recruitment depending on workers' past (future) employment status, relative skill type, past industry, and spatial proximity to the firm. We will use this evidence on heterogeneous responses to shed light on alternative channels by which broadband may increase matching efficiency.

Table 7 decomposes firms' hire growth and separation growth by workers' past and future employment status. Panel B shows a baseline hire growth of 8.7 percent when we restrict hires to the pool of workers that were either unemployed or outside the labor force in the month before hiring (i.e., from non-job status). Compared to an overall hire growth rate of 12.2 percent (reported in Table 5, Panel A), this statistic shows that the majority of new hires are among workers without a job. The point estimate of 0.4 percentage points in Panel B moreover shows that two-third of the increase in firms' hire growth due to broadband availability also comes from the pool of workers previously without a job in the previous month. In contrast, Panel C shows that the increase in separation growth rate is primarily due to a higher rate of workers moving jobs. We interpret these results as indicating that broadband internet availability facilitates an increased hiring of both workers without a job *and* workers from other jobs. At the same time, the estimates in Panel C and D imply that internet is also increasing the rate of turnover as many workers move on to new jobs in other firms.

Table 7: Decomposing Firms' Hire and Separation Growth By Workers' Past and Future Job Status.

Dependent Variable:	A. Hire Growth From Another Job		B. Hire Growth From Non-Job Status	
	(1)	(2)	(3)	(4)
Broadband Availability	0.002**	0.002*	0.004***	0.004***
(Standard Error)	(0.001)	(0.001)	(0.001)	(0.001)
[p-value]	[0.024]	[0.066]	[0.007]	[0.007]
Base Dep. Mean	0.035	0.035	0.087	0.087
Dependent Variable:	C. Separation Growth Into Another Job		D. Separation Growth Into Non-Job Status	
	(1)	(2)	(3)	(4)
Broadband Availability	0.003**	0.003**	0.001	0.002
(Standard Error)	(0.002)	(0.002)	(0.001)	(0.001)
[p-value]	[0.033]	[0.035]	[0.266]	[0.157]
Base Dep. Mean	0.044	0.044	0.062	0.062
Fixed Effects	√	√	√	√
Firm Characteristics		√		√
Obs. ($B \times T$)	1,824,388	1,824,388	1,824,388	1,824,388

Note: Estimation results of hire growth in year t, with hires coming from another job (Panel A), hires coming from either unemployment or outside the labor force (Panel B), separations into another job (Panel C) and separations into either unemployment or outside the labor force (Panel D) on broadband internet coverage rate in year t, with $t \in [2000,2014]$. Job status is based on employment history the month before being hired. If no past employer is found, the worker is defined as coming from either unemployment or outside the labor force. Fixed effects include time, municipality and industry fixed effects. Firm age and size includes dummies for firm age (51 dummies) and size (6 dummies). Firm composition includes average level of education of workers in the firm and average annual wage rebased to 2014-NOK. Dependent mean is pre-assignment, i.e. when the broadband internet coverage rate equals zero. All specifications include controls for municipal infrastructure (municipal road networks (in kilometers) per capita, average travel time to municipal center (in hours) and public spending on infrastructure). Heteroskedastic robust standard errors are clustered on the municipality level. $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.

In Table 8, we further decompose firms' hire and separation growth by workers' relative skill type. In each case, we define a worker to be of a high-type if the worker had an above-median length of schooling compared to the industry-specific median schooling length in the previous year, and otherwise as a low-type worker. While the baseline hire and separation growth rates are substantially higher for low-type workers, the coefficient estimates reported in Panel B (column 4) and Panel D (column 4) also indicate that broadband availability increases hiring and separation growth rate for low-type workers. This finding can indicate that broadband internet is a more effective method to recruit workers with relative low skills, enhancing both their hiring and job-to-job mobility. This is also consistent with the notion that high-skill workers can use formal education as a credible signal of their ability in a job search process and/or they already have a more established network that can provide referrals in informal job search activities, such that the marginal value of increased broadband availability for them is negligible.

In Table 9, we further decompose firms' hire growth rates depending on whether the hired workers' previously worked in the same 3-digit industry as the hiring firm or in another industry. In Panels A-B, we classify hired workers by their past industry affiliation. Panel B accounts for the instances where the hired worker has previously worked in the firm's industry, while the outcome in Panel A shows the complement

Table 8: Decomposing Firms' Hire and Separation Growth By Worker Skill Types.

Dependent Variable:	A. Hire Growth High-Type Worker		B. Hire Growth Low-Type Worker	
	(1)	(2)	(3)	(4)
Broadband Availability	0.002***	0.001	0.003**	0.004***
(Standard Error)	(0.001)	(0.001)	(0.001)	(0.002)
[p-value]	[0.005]	[0.318]	[0.015]	[0.006]
Base Dep. Mean	0.040	0.040	0.082	0.082
Dependent Variable:	C. Separation Growth High-Type Worker		D. Separation Growth Low-Type Worker	
	(1)	(2)	(3)	(4)
Broadband Availability	0.001	0.000	0.003	0.005**
(Standard Error)	(0.001)	(0.001)	(0.002)	(0.003)
[p-value]	[0.124]	[0.443]	[0.103]	[0.035]
Base Dep. Mean	0.035	0.035	0.071	0.071
Fixed Effects	√	√	√	√
Firm Characteristics		√		√
Obs. ($B \times T$)	1,824,388	1,824,388	1,824,388	1,824,388

Note: Estimation results of separation growth in year t, with hires being a high-type worker (Panel A), hires being a low-type worker (Panel B), separations being a high-type worker (Panel C) and separations being a low-type worker (Panel D), on broadband internet coverage rate in year t, with $t \in [2000,2014]$. High-type is defined as the worker having an above-median education length (with the distribution of education length being industry-specific and defined in year t-1), and the worker is defined as low-type otherwise. Fixed effects include time, municipality and industry fixed effects. Firm age and size includes dummies for firm age (51 dummies) and size (6 dummies). Firm composition includes average level of education of workers in the firm and average annual wage rebased to 2014-NOK. Dependent mean is pre-assignment, i.e. when the broadband internet coverage rate equals zero. All specifications include controls for municipal infrastructure (municipal road networks (in kilometers) per capita, average travel time to municipal center (in hours) and public spending on infrastructure). Heteroskedastic robust standard errors are clustered on the municipality level. $^{**}p < 0.05$.

of hires of workers with different industry experience. Relative to the baseline industry composition of hired workers, our point estimates show that broadband availability significantly increases the hire growth of same industry workers. Moreover, Appendix Table A2 shows that the rate firms hire workers with experience from their own industry increases both among workers that weren't employed in the month before being hired (Panel A) and among workers that had another job in the same industry (Panel B). Taken together, the results indicate that broadband availability increases firms' hiring growth of workers with relevant labor market experience – which may suggest that internet facilitates better matches between workers' careers and firms' needs (e.g. Neal, 1995).

Table 9: Decomposing Firms' Hire Growth By Workers' Past Industry and Geography.

Dependent Variable:	A. Hire Growth From Different Industry		B. Hire Growth From Same Industry	
	(1)	(2)	(3)	(4)
Broadband Availability	0.002*	0.002*	0.003***	0.003***
(Standard Error)	(0.001)	(0.001)	(0.001)	(0.001)
[p-value]	[0.080]	[0.084]	[0.001]	[0.003]
Base Dep. Mean	0.094	0.094	0.028	0.028
Dependent Variable:	C. Hire Growth From Same Labor Market		D. Hire Growth From Different Labor Market	
	(1)	(2)	(3)	(4)
Broadband Availability	0.002	0.002	0.003***	0.003***
(Standard Error)	(0.001)	(0.001)	(0.001)	(0.001)
[p-value]	[0.106]	[0.120]	[0.000]	[0.000]
Base Dep. Mean	0.097	0.097	0.025	0.025
Obs. ($B \times T$)	1,824,388	1,824,388	1,824,388	1,824,388
Fixed Effects	√	√	√	√
Firm Characteristics		√		√

Note: Estimation results of hire growth in year t, with hires from a different industry (Panel A), hires from the same industry (Panel B), hires from the same industry and non-job status (Panel C) and hires from the same industry and another job (Panel D), on broadband internet coverage rate in year t, with t ∈ [2000,2014]. Past industry is based on employment history over the 11 months before being hired. If no industry affiliation is found, the worker is defined as coming from a different industry. Job status is based on employment history the month before being hired. If no past employer is found, the worker is defined as coming from either unemployment or outside the labor force (i.e., non-job status). Fixed effects include time, municipality and industry fixed effects. Firm age and size includes dummies for firm age (51 dummies) and size (6 dummies). Firm composition includes average level of education of workers in the firm and average annual wage rebased to 2014-NOK. Dependent mean is pre-assignment, i.e. when the broadband internet coverage rate equals zero. All specifications include controls for municipal infrastructure (municipal road networks (in kilometers) per capita, average travel time to municipal center (in hours) and public spending on infrastructure). Heteroskedastic robust standard errors are clustered on the municipality level. *p < 0.10, ***p < 0.01.

Next, we consider the spatial proximity to firms and hired workers and decompose firms' hire growth rates by the local labor market region of hired workers. In Panels C and D of Table 9, we decompose hire growth by whether the hired workers live in the same local labor market region as the location of the firm (Panel C) or in a different labor market (Panel D). On average, firms hire growth is primarily explained by hires of workers living in the same local labor market. The 9.7 percent baseline accounts for almost 80 percent of the overall hire growth rate at 12.2 percent (reported in Table 5, Panel A). By comparison, the baseline hire growth rate for workers from outside the firm's local labor market is only at 2.5 percent. We find that broadband availability significantly increases hire growth rate *only* for workers living outside the firm's local labor market region. As reported in Panel D, the increase in outside workers' hire growth rate of 12 percent is both statistically and economically significant.

5 Evidence on Worker Flows and Match Quality

In this section, we provide evidence on how the availability of broadband internet affects workers' transitions between unemployment, employment and non-employment, as well as their transitions between jobs,

industries and local labor markets, separately for previously unemployed and employed workers. Finally, we provide evidence on changes in match quality for newly hired workers from unemployment.

5.1 Worker Flows

To investigate how broadband internet affects workers' transitions between unemployment, employment and non-employment, we classify each worker into these three labor market states in the same period as broadband availability is measured (i.e., year *t-1*). Next, we follow workers' transitions over the ensuing two-year period, and record any entry in another labor market state as a transition event (i.e., either in year *t* and/or in year *t+1*). This approach gives the cumulative probability of entering into another labor market state over a two-year period. Because some workers may experience multiple transitions across different labor market states over a two-year period, these cumulative measures of transition events are not mutually exclusive.[16]

We classify a working-age individual as unemployed if he is observed as unemployed for at least one month in a given year. A worker is employed if he is observed with least one month of paid work in a given year, and a person who is outside the labor force for at least 6 months in a given year is classified as non-employed in that year. Table 10, Panels A-B, provides evidence on how an increase in broadband availability changes the probability that unemployed workers in year *t-1* enter employment and non-employment in year *t* and/or year *t*+1, respectively. Consistent with our firm level evidence presented in Table 7, we find that unemployed workers with higher broadband coverage are more likely to be employed within the two-year period after than workers with less coverage. Panel B shows that broadband internet does not affect the probability of leaving the labor force over the same time period. In Appendix Table A3 we assess whether broadband internet is increasing the likelihood of changing employers. We are not able to reject the null hypothesis that broadband internet does not affect job-to-job transitions. This result is robust to a wide set of specifications.

Alternative Explanation. An alternative explanation is that local productivity shocks affect some markets and increases the demand for broadband internet service in some but not in other markets. This explanation says that employment increases because of unobserved shocks that are correlated with labor demand and broadband internet infrastructure. Relatedly, a large literature shows that labor force participation is quite elastic with respect to changes in productivity (see, e.g., Nordhaus, 2005). We test this hypothesis in the data by regressing the probability of re-entering the labor force on broadband internet coverage. Panels C-D report the estimates of how broadband availability affects the probability of moving from outside of the labor force to (un)employment. We are unable to statistically reject the null hypothesis of no impact among workers outside of the labor force. To further assess the hypothesis of local productivity shocks we regress wage changes among job-to-job transitions on broadband internet coverage. The estimates are reported in Appendix Table A4. Again, we are unable to reject the null hypothesis. Taken together, the

[16] Arguably, measures of cumulative transition probabilities across labor market states provide a more comprehensive picture of labor market transitions than would transitions across mutually exclusive states measured at different points-in-time, say, e.g., at the end of each year. In addition to the findings reported here, we also performed transition analyses across mutually exclusive labor market states, which generally confirm our findings. These results are available upon request.

evidence suggests that internet is improving the labor market outcomes for workers who are actively looking for work, but has no impact on workers outside of the labor force or among those who already have an employment relationship.

Table 10: Workers' Transitions Between Unemployment, Employment and Non-Employment.

Dependent Variable:	Probability of Going from One Labor Market State to Another			
Panel:	A. Unemployment to Employment (U-E)		B. Unemployment to Non-Employment (U-N)	
	(1)	(2)	(3)	(4)
Broadband Availability	0.016**	0.012**	-0.003	-0.002
(Standard Error)	(0.007)	(0.006)	(0.007)	(0.007)
[p-value]	[0.017]	[0.038]	[0.675]	[0.766]
Base Dep. Mean	0.646	0.646	0.350	0.350
Obs. ($N\times T$)	1,339,779	1,339,779	1,339,779	1,339,779
Panel:	C. Non-Employment to Employment (N-E)		D. Non-Employment to Unemployment (N-U)	
	(1)	(2)	(3)	(4)
Broadband Availability	-0.007	-0.005	-0.005	-0.004
(Standard Error)	(0.005)	(0.004)	(0.008)	(0.008)
[p-value]	[0.136]	[0.255]	[0.518]	[0.632]
Base Dep. Mean	0.372	0.372	0.108	0.108
Obs. ($N\times T$)	6,232,398	6,232,398	6,232,398	6,232,398
Fixed Effects	√	√	√	√
Worker Characteristics		√		√

Note: Estimation results of the cumulative probability of going from unemployment in year t-1 to employment in year t or t+1 (Panel A), going from unemployment in year t-1 to non-employment in year t or t+1 (Panel B), going from non-employment in year t-1 to employment in year t or t+1 (Panel C), and going from non-employment in year t-1 to unemployment in year t or t+1 (Panel D) on broadband internet coverage rate in year t-1, with t-1 $\in$ [2000,2012. Employment is defined as at least one month of employment, unemployment is defined as at least one month of unemployment (either full-time or part-time), and non-employment is defined by the sum of number of months employed and unemployed (either full-time or part-time) within a year being 6 months or less. Worker characteristics indicate vector of controls for age/gender, family background and education. Dependent mean is pre-assignment, i.e. when the broadband internet coverage rate equals zero. All specifications include controls for municipal infrastructure (municipal road networks (in kilometers) per capita, average travel time to municipal center (in hours) and public spending on infrastructure). Heteroskedastic robust standard errors are clustered on the municipality level.

Broadband Internet and Worker Mobility. We now take a deeper look at the data to understand whether internet is changing the mobility of workers across labor markets and industries. Table 11, Panels B-C, show our estimates of how broadband availability affects the probability that job seekers find a new job in the same 3-digit industry as they previously worked in (e.g., before losing their job), and the probability that unemployed workers find a job in a different industry. The baseline two year job-finding rate is 64.6. About half of the job seekers find a job in an industry different than where they previously worked. This means that conditional on finding a job, more than 75 percent move across industries on average. While the estimates are positive, we lack the precision to draw any firm conclusion about patterns of differential changes in industry mobility due to broadband availability. In contrast, Panels D-E, reveal significant differences in geographic job mobility. On average, about 30 percent of unemployed workers find a new job outside their local labor market (i.e., 47 percent conditional on finding a job). Interestingly, almost all of the increase

in job-finding rate for unemployed workers due to broadband availability happens *outside* their local labor market. The results suggest that broadband availability increases the flow of information about available jobs outside of their local labor markets. This can be contrasted to a counterfactual scenario where workers rely on information from help-wanted ads in local newspapers or from public employment agencies. Finally, in Panel F, we further document that an increase in broadband availability does not affect the relocation of unemployed workers across labor markets, thus implying that workers that find jobs outside their local labor market are more likely to be commute.

Table 11: Unemployed Workers' Transitions Between Industries, Labor Markets and Residential Mobility.

Dependent Variable:	Probability of Being Employed (U-E)					
Panel:	A. Any Employment		B. Employed in Same Industry		C. Employed in Different Industry	
	(1)	(2)	(3)	(4)	(5)	(6)
Broadband Availability	0.016**	0.012**	0.005	0.004	0.011	0.008
(Standard Error)	(0.007)	(0.006)	(0.003)	(0.003)	(0.008)	(0.007)
[p-value]	[0.017]	[0.038]	[0.132]	[0.300]	[0.132]	[0.220]
Base Dep. Mean	0.646	0.646	0.158	0.158	0.488	0.488
Panel:	D. Employed in Same Labor Market		E. Employed in Different Labor Market		F. Relocate to Different Labor Market	
	(7)	(8)	(9)	(10)	(11)	(12)
Broadband Availability	0.002	0.002	0.014***	0.010**	0.003	0.000
(Standard Error)	(0.005)	(0.005)	(0.005)	(0.004)	(0.003)	(0.002)
[p-value]	[0.659]	[0.737]	[0.006]	[0.019]	[0.318]	[0.903]
Base Dep. Mean	0.340	0.340	0.306	0.306	0.066	0.066
Fixed Effects	√	√	√	√	√	√
Worker Characteristics		√		√		√
Obs. ($N \times T$)	1,339,779	1,339,779	1,339,779	1,339,779	1,339,779	1,339,779

Note: Estimation results of the cumulative probability of going from unemployment in year t-1 to employment in year t or t+1 (Panel A), going from unemployment in year t-1 to employment in the same 3-digit industry in year t or t+1 (Panel B), going from unemployment in year t-1 to employment in a different industry in year t or t+1 (Panel C), going from unemployment in year t-1 to employment in the same local labor market in year t or t+1 (Panel D), going from unemployment in year t-1 to employment in a different local labor market in year t or t+1 (Panel E), and relocating from year t-1 to year t or t+1 (Panel F) on broadband internet coverage rate in year t-1, with t-1 $\in$ [2000,2012]. Employment is defined as at least one month of employment and unemployment is defined as at least one month of unemployment (either full-time or part-time). Local labor market regions are defined based on the classification of Norway in 160 regions by Juvkam (2002) based on commuting patterns. Worker characteristics indicate vector of controls for age/gender, family background and education. Dependent mean is pre-assignment, i.e. when the broadband internet coverage rate equals zero. All specifications include controls for municipal infrastructure (municipal road networks (in kilometers) per capita, average travel time to municipal center (in hours) and public spending on infrastructure). Heteroskedastic robust standard errors are clustered on the municipality level.

5.2 Match Quality

Our evidence indicates that broadband availability allows firms (i) to fill posted vacancies faster at a higher rate, (ii) hire workers from the pool of previously unemployed workers more effectively, (iii) reduces firms' reported recruitment problems, and (iv) facilities the hiring of workers from outside local labor markets by increasing the flow of information about available jobs. We also found evidence that suggests that firms are more likely to find workers with relevant experience (i.e., workers that previously had a job in the same industry). A natural follow-up question is to what extent broadband availability also improves the match

quality of employment relationships that are formed after the installation of broadband internet access points (i.e., worker-firm-specific wage).

Table 12: Unemployed Workers' Match Quality.

Dependent Variable:	A. Tenure in First Job		B. Wage in First Job		C. Unemployed One Year After Finding Job	
	Un-conditional	Conditional	Un-conditional	Conditional	Un-conditional	Conditional
	(1)	(2)	(3)	(4)	(5)	(6)
Broadband Availability	0.315***	0.285**	807***	688***	-0.007	-0.010
(Standard Error)	(0.094)	(0.113)	(242)	(258)	(0.006)	(0.006)
[p-value]	[0.001]	[0.012]	[0.001]	[0.008]	[0.245]	[0.123]
Base Dep. Mean	6.435	9.996	14,581	22,558	0.187	0.196
Fixed Effects	√	√	√	√	√	√
Worker Characteristics	√	√	√	√	√	√
Obs. ($N \times T$)	1,339,779	882,569	1,339,779	882,569	1,339,779	882,569

Note: Estimation results of tenure length in the first firm measured in months (Panel A), starting monthly wage level measured in 2014-NOK (Panel B) and probability of unemployment (at least one month of unemployment, either full-time or part-time) one year after finding job (Panel C) on broadband internet coverage rate in year t-1, with t-1 $\in$ [2000,2012]. Note that tenure is set to zero if tenure is equal or greater than 4 years (48 months). For unconditional outcomes, the outcome is not conditional on finding a job in either year t or t+1, and tenure and entry wage level is set to zero for non-job outcomes while unemployment is measured in year t+2 for non-job outcomes. For conditional outcomes, the outcome variable is conditional on finding a job in either year t or t+1. Fixed effects include time, municipality and occupation fixed effects. Worker characteristics indicate vector of controls for age/gender, family background and education. Dependent mean is pre-assignment, i.e. when the broadband internet coverage rate equals zero. All specifications include controls for municipal infrastructure (municipal road networks (in kilometers) per capita, average travel time to municipal center (in hours) and public spending on infrastructure). Heteroskedastic robust standard errors are clustered on the municipality level. $^{**}p < 0.05$, $^{***}p < 0.01$.

Because the evidence provided in Section 5.1 suggests that broadband availability primarily facilitates an increased job-finding for previously unemployed workers, we focus on new jobs after spells of unemployment. We follow Card *et al.* (2007), Schmieder *et al.* (2016) and Nekoei & Weber (2017) in proxying for match quality by using starting wages and subsequent tenure. In Table 12, we provide evidence on how broadband availability affect match quality. Panel A reports how broadband availability affects tenure in the first job measured in months for previously unemployed workers. In column (1) we report the impact on the unconditional mean (e.g., including extensive margin), and column (2) reports the impact on average tenure among those who successfully find a new job (which happens for around 65 percent over a two-year period). Our estimates show that broadband internet increases average tenure in the first job after unemployment, which is consistent with an improvement in match quality. In Panel B, we report our estimates of how broadband internet affects starting monthly wage for previously unemployed workers. The estimates provide additional suggestive evidence in support of the view that internet is improving the match quality. The increase in starting wage exceeds 5 percent of the unconditional mean. Finally, Panel C, reports estimates of how broadband internet affects the probability of experiencing another unemployment spell within a year after finding a job. While point estimates are negative and consistent with the evidence in Panels A-B, we lack the statistical precision to draw a firm conclusion. Taken together, our evidence suggests that broadband availability increases the match quality for unemployed workers.

6 Conclusion

In this paper we have studied how internet affects labor market matching. We were able to do this because of two unique features of Norwegian labor markets. The first was a staggered expansion in broadband internet infrastructure that generated plausibly exogenous variation in availability of high-speed internet to firms and workers. The second was the availability of a wide range of survey and administrative datasets covering firms and workers that overlap with the broadband infrastructure roll-out, including newly matched data on firms' vacancy-posting and job search behavior. Combined, the data allows us to estimate how an increase in availability of broadband internet affects workers and firms use of broadband internet as well online job search and recruitment activities. These data sources also allowed us to study how broadband internet affects firms' recruitment and hiring and workers' job search behavior. Using matched employer-employee data, we estimated the effects of internet on job seekers' starting wage, tenure, and subsequent unemployment risk.

We began our analysis of documenting substantial increases in the use of broadband internet among both firms and households following the staggered roll-out of internet access-points. Focusing first on firms, we found that firms with better access to broadband internet respond by increasing their use of online marketing and online vacancy posting. Our survey data further shows that firms are less likely to report problems with recruitment, and administrative vacancy-data shows that vacancies are filled at a faster rate. Consistent with a reduction in the recruitment cost and increase in recruitment efficiency, we find that firms post more vacancies as broadband internet arrives. Our further evidence shows an increase in the hire growth which is offset by an equal increase in the separation rate, which suggests that internet is increasing the efficiency of the recruitment process, as well as increasing the rate of turnover of workers across firms.

We then turned to worker-level evidence, and found that workers are more likely to use internet for work-activities and browsing ads when broadband internet access-points arrive. Next, we confirmed previous evidence on the association between internet use and job search outcomes, and found that broadband internet increases the rate that job seekers find new employment. The detailed geographical identifiers for firms and workers allowed us to investigate the extent to which internet increases the effective size of labor markets by providing information about job openings outside their own local labor markets. The evidence shows that nearly 60 percent of the increase in job finding rates could be accounted for by hires outside workers' local labor markets. The evidence thus suggests that internet may have shifted the locus of the Beveridge curve, and reduced the spatial mismatch between job seekers and vacancies. Finally, we studied how internet affected the match quality for job seekers, and found an economically and statistically significant increase in starting wages and tenure in new employment relationships. These results speak to the debate about falling rates of worker mobility, and suggests that internet has lowered the need to reallocate in search of better employment relationships.

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A1 Appendix

A1.1 Additional Tables and Figures

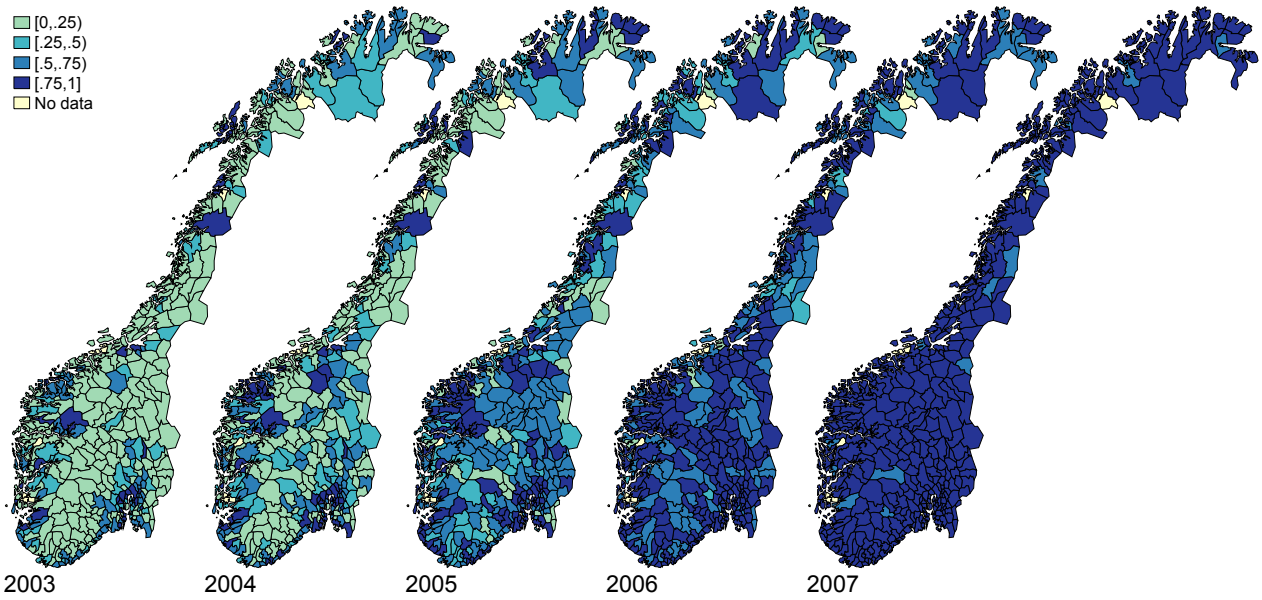


Figure A1: The Geographical Dispersion of Broadband Internet Coverage Rates across Norway.

Notes: The figures show the geographical distribution of broadband internet coverage rates across Norway in each year from 2003-2007. For each municipality and year, broadband internet coverage rate is plotted, with different colors indicating different levels of coverage.

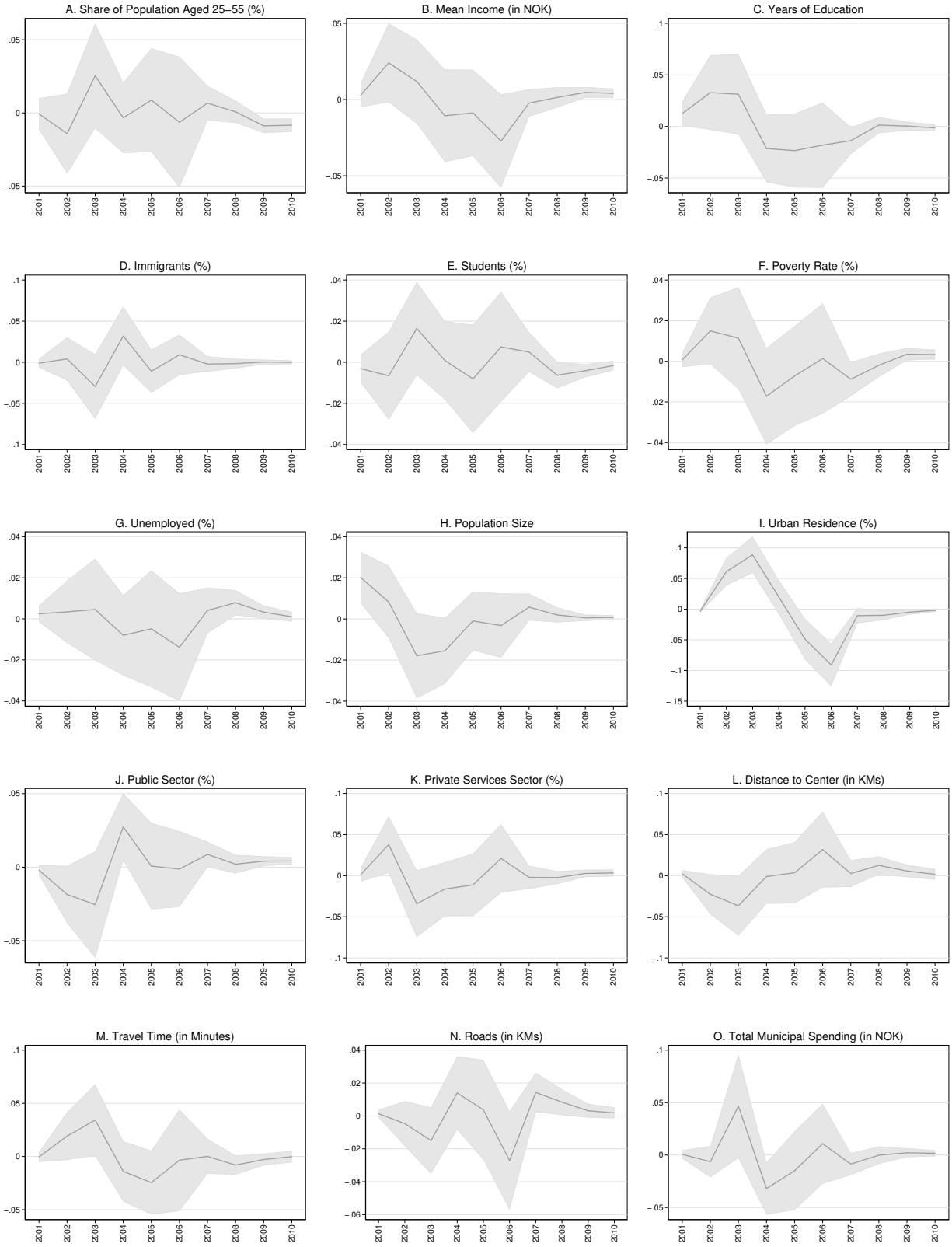


Figure A2: The Expansion of Broadband Internet by Baseline Municipality Characteristics.

Notes: Figures display the change in broadband internet coverage rate, Δz_{mt}, regressed on baseline municipality characteristics. In order to construct these plots, we regress changes in coverage rates on municipality specific baseline characteristics interacted with time dummies, while controlling for the overall time effects. The figures plot the interaction terms for each variable, along with the associated 95 percent CIs.

Table A1: The Effects of Broadband Availability on Access and Online Activities – Analytical Weights.

	A. Firms in the ICT Use Survey		B. Working-age Individuals in the Media Use Survey	
	(1) Unweighted	(2) Analytical Weights	(3) Unweighted	(4) Analytical Weights
Dependent Variable:	1. Has Broadband Internet Access		1. Has Broadband Internet Access	
Broadband Availability	0.290***	0.290***	0.282***	0.295***
(Standard Error)	(0.032)	(0.032)	(0.038)	(0.040)
Base Dep. Mean	0.380	0.380	0.059	0.059
Dependent Variable:	2. Has Marketing Website		2. Uses Internet for Work Purposes	
Broadband Availability	0.097***	0.098***	0.131***	0.121***
(Standard Error)	(0.025)	(0.025)	(0.034)	(0.031)
Base Dep. Mean	0.541	0.541	0.030	0.030
Dependent Variable:	3. Online Job Board Use Rate		3. Uses Internet for Browsing Ads	
Broadband Availability	0.171***	0.171***	0.088***	0.087***
(Standard Error)	(0.023)	(0.023)	(0.032)	(0.033)
Base Dep. Mean	0.284	0.284	0.022	0.022
Obs. ($B\times T$ / $N\times T$)	50,269	50,269	10,958	10,118

Note: OLS estimation results of enterprises from the annual Community Survey on ICT usage of various outcomes in year t on broadband internet coverage rate in year t, with $t \in$ [2001,2014] (Panel A) and households from the annual Media Usage Survey reporting recruitment on various outcomes in year t on broadband internet coverage rate in year t-1, with t-1 $\in$ [1999,2012] (Panel B). Results in Panel A and Panel B are based on non-weighted estimation results. Control variables for firms include firm age/size, firm composition and municipal infrastructure. Control variables for individuals include age/gender, family background, education and municipal infrastructure. The reported dependent mean is pre-assignment, i.e. when the broadband internet coverage rate equals zero. Note that sample in Panel B, outcome 3 consists of 8,612 observations (7,077 observations with occupation FE), due to data availability. *$p < 0.10$, ***$p < 0.01$.

Table A2: Decomposing Firms' Hire Growth By Workers' Past Industry.

Dependent Variable:	A. Hire Growth From Same Industry and Non-Job Status		B. Hire Growth From Same Industry and Another Job	
	(1)	(2)	(3)	(4)
Broadband Availability	0.002**	0.002**	0.002***	0.002***
(Standard Error)	(0.001)	(0.001)	(0.001)	(0.001)
[p-value]	[0.015]	[0.018]	[0.002]	[0.005]
Base Dep. Mean	0.017	0.017	0.011	0.011
Fixed Effects	√	√	√	√
Firm Characteristics		√		√
Obs. ($B \times T$)	1,824,388	1,824,388	1,824,388	1,824,388

Note: Estimation results of hire growth in year t, with hires from a different industry (Panel A), hires from the same industry (Panel B), hires from the same industry and non-job status (Panel C) and hires from the same industry and another job (Panel D), on broadband internet coverage rate in year t, with t ∈ [2000,2014]. Past industry is based on employment history over the 11 months before being hired. If no industry affiliation is found, the worker is defined as coming from a different industry. Job status is based on employment history the month before being hired. If no past employer is found, the worker is defined as coming from either unemployment or outside the labor force (i.e., non-job status). Fixed effects include time, municipality and industry fixed effects. Firm age and size includes dummies for firm age (51 dummies) and size (6 dummies). Firm composition includes average level of education of workers in the firm and average annual wage rebased to 2014-NOK. Dependent mean is pre-assignment, i.e. when the broadband internet coverage rate equals zero. All specifications include controls for municipal infrastructure (municipal road networks (in kilometers) per capita, average travel time to municipal center (in hours) and public spending on infrastructure). Heteroskedastic robust standard errors are clustered on the municipality level. *p < 0.10, ***p < 0.01.

Table A3: Broadband Availability and Job-to-Job Mobility.

Dependent variable:	Probability of Job-to-Job Movement			
	(1)	(2)	(3)	(4)
Broadband Availability	-0.003	-0.002	-0.002	-0.002
(Standard Error)	(0.002)	(0.002)	(0.002)	(0.002)
p-value	[0.116]	[0.219]	[0.236]	[0.290]
Time FE	√	√	√	√
Municipality FE	√	√	√	√
Age/gender		√	√	√
Family background			√	√
Education				√
Adjusted R^2 (ITT)	0.002	0.017	0.017	0.018
Dep. mean (pre-assign)	0.080	0.080	0.080	0.080
Obs. ($N \times T$)	18,961,171	18,961,171	18,961,171	18,961,171

Note: Reduced form estimation results of cumulative job-to-job transition probability of individuals employed in year t-1 (indicator variable equal to one if performing a job-to-job movement in year t and/or year t+1, and zero otherwise) on broadband internet coverage rate in year t-1, with t-1 ∈ [2000,2012]. Job-to-job movements are defined based on employment history in the past month before being hired, and equals one if coming from another firm and zero otherwise. Employment in year t-1 is defined as at least one month of employment. Age/gender includes dummies for female and age (31 dummies). Family background includes dummy for marital status and dummies for number of young and old children (12 dummies). Education includes dummies for education length (18 dummies). Dependent mean is pre-assignment, i.e. when the broadband internet coverage rate equals zero. All specifications include controls for municipal infrastructure (municipal road networks (in kilometers) per capita, average travel time to municipal center (in hours) and public spending on infrastructure). Heteroskedastic robust standard errors are clustered on the municipality level.

Table A4: Broadband Availability, Job-to-Job Mobility and Starting Monthly Wages.

Dependent variable:	Starting Monthly Wage with Job-to-Job Movement			
	(1)	(2)	(3)	(4)
Broadband Availability	171	205	209	100
(Standard Error)	(767)	(764)	(761)	(708)
p-value	[0.824]	[0.789]	[0.785]	[0.888]
Time FE	√	√	√	√
Municipality FE	√	√	√	√
Age/gender		√	√	√
Family background			√	√
Education				√
Adjusted R^2 (ITT)	0.008	0.018	0.018	0.027
Dep. mean (pre-assign)	28,720	28,720	28,720	28,720
Obs. ($N \times T$)	18,961,171	18,961,171	18,961,171	18,961,171

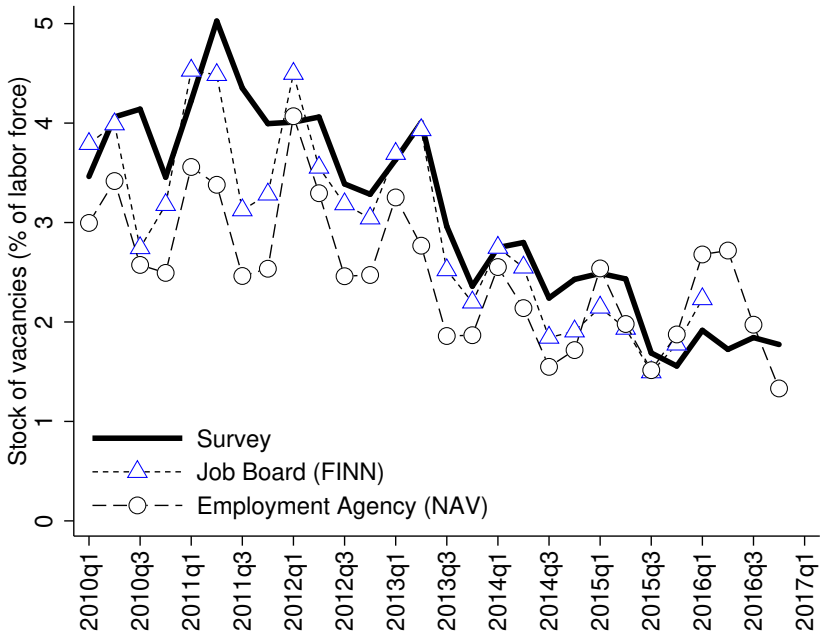
Note: Reduced form estimation results of monthly starting wage of individuals employed in year t-1 (measured in 2014-NOK) of a job-to-job movement in year t or t+1 (being registered as a new hire during year t or t+1) on broadband internet coverage rate in year t-1, with t-1 $\in$ [2000,2012]. Job-to-job movements are defined based on employment history in the past month before being hired, and equals one if coming from another firm and zero otherwise. Employment in year t-1 is defined as at least one month of employment. Monthly starting wage is set to the mean monthly wage of the individual if the individual does not perform a job-to-job movement. Age/gender includes dummies for female and age (31 dummies). Family background includes dummy for marital status and dummies for number of young and old children (12 dummies). Education includes dummies for education length (18 dummies). Dependent mean is pre-assignment, i.e. when the broadband internet coverage rate equals zero. All specifications include controls for municipal infrastructure (municipal road networks (in kilometers) per capita, average travel time to municipal center (in hours) and public spending on infrastructure). Heteroskedastic robust standard errors are clustered on the municipality level.

A1.2 Quality Assessment of the Register of Posted Vacancies

The Register of Posted Vacancies is a dataset covering years 2002 to 2014 and is based on employer-filled reports of vacant positions sent to the Norwegian Labour and Welfare Administration (NAV), cf. the public employment agency. The quality of this vacancy register would naturally depend on the degree to which firms comply with the reporting requirements. To assess the quality and representatives of the employment agency's vacancy data, we first (i) aggregate vacancies using ad-level data, to occupation, municipality and month in which job vacancy was created, (ii) create stocks of vacancy stocks based on the duration of each vacancy, and next, (iii) compare the vacancy stocks to two alternative sources of vacancy data.

First, we use a representative sample performed by Statistics Norway, which includes vacancies for 8,000 establishments, i.e, almost 5 percent of all establishments. The definition of a vacant position in this survey is that it can start within 30 days, recruitment must be from outside the firm, and full-time, part-time, permanent, temporary, and short-term job openings are included. The survey arguably provides the most reliable data on the aggregate level of vacancies, and includes the number of vacant positions and establishment identifiers. Next, we also collected vacancy data from the largest Norwegian online job-board (Finn.no), with an online market share fairly close to 100 percent. Unfortunately, the Finn.no data do not include establishment identifies for all online vacancy postings, limiting the scope for a direct use of this dataset in our main analysis.

Figure A3: Trends in Vacancy Stocks Across Three Sources of Data on Vacancies.



Notes: This figure shows the aggregate trend of vacancy rates using three data sources on vacant jobs. The total number of vacancies is divided by the labor force.

Figure A3 displays the aggregate trends of quarterly stocks of vacancies, starting in 2010, from when the survey data are available. The stock of vacancies is divided by the labor force, comprising every worker aged between 25 to 66 who is either employed or unemployed but actively looking for work. The time pattern shows a clear seasonality in the vacancy postings: the survey shows a distinct peak in the second quarter, while the two other sources have peaks that vary between the first two quarters of the year. More importantly, the graph shows that the three sources track each other well over time when the relative differences between the sources are stable over time.[17]

[17] The aggregate numbers from NAV and FINN are approximately 20 percent below the survey at their respective peaks.