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ABSTRACT

We study the effects of broadband internet use on the portfolio selection of individual investors. A public program in Norway provides plausibly exogenous variation in internet use. Our instrumental variables estimates show that internet use causes a substantial increase in stock market participation, driven primarily by increased fund ownership. Existing investors increase the fraction of their portfolios held in funds and do not increase their trading activity in stocks. Access to fast internet seems to induce individual investors to make better financial decisions and hence leads to a "democratization of finance".

Keywords: equity market participation, investor welfare, portfolio selection, stock market participation.

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I. Introduction

Does internet use spur a "democratization of finance" (Shiller (2007)), meaning better portfolio choices by households, or does it amplify behavioral biases? Pioneering studies by Barber and Odean (2002) and Choi et al. (2002) suggest the latter: In the 1990s, online stock trading platforms were adopted primarily by young males who increased their trading activity and trading costs without any apparent increase in risk-adjusted returns.

In this paper, we study the effects of the roll-out of broadband internet on the portfolio choices of individual investors in Norway in the 2000s. In addition to the policy shift, Norway offers extraordinary data opportunities through detailed common stock and equity fund records for the entire population. Our main finding is that increased internet usage, induced by the broadband roll-out, led to a substantial increase in stock market participation. In contrast to Barber and Odean (2002) and Choi et al. (2002), we do not find detrimental effects of internet usage on the welfare of established investors.

Standard asset allocation theory suggests that if markets are complete, risk tolerance is the only individual characteristic that determines stock market participation (Merton (1969); Mossin (1968); Samuelson (1969)): A less wealthy individual's portfolio should be a scaled-down version of a more wealthy individual's portfolio. However, entering the stock market involves fixed costs (Vissing-Jørgensen (2002); Campbell (2006)) such as becoming aware of stock market opportunities (Guiso and Jappelli (2005)), setting up an investor account and becoming acquainted with trading solutions (e.g., Barber and Odean (2001)), and acquiring financial competence (e.g., Lusardi and Mitchell (2014); Lusardi et al. (2017)). It is plausible that faster internet would facilitate these activities and thus increase stock market participation rates. On the other hand, faster internet reduces the cost of leisure-related activities, such as social networking or watching movies,

which could crowd out individuals' focus on personal finance.[1]

We use data on common stock and fund transactions made by Norwegian individual investors between 2000 and 2010, obtained from the Norwegian Central Securities Depository (NCSD). Each transaction contains an individual ID that can be linked to data on investor age, gender, education, and other sociodemographic variables. As a source of exogenous variation in internet use, we exploit a program rolled out by the Norwegian government in the 2000s that aimed at ensuring broadband internet access throughout the country. We use the spatial and temporal variation in broadband build-out across municipalities in an instrumental variables (IV) setup: We instrument the fraction of households with a broadband internet subscription in a given year with the fraction of households that are covered by broadband infrastructure.[2] In additional analyses, we use data from two national surveys on internet usage to inform the main results.

Our main empirical finding is that broadband internet use leads to increased stock market participation, driven by an increase in the fraction of the population investing in equity funds; we find no effect of internet use on the fraction of the population holding common stocks. The effects are economically significant: A 15 percentage point increase in broadband use in a given year increases the stock market participation rate by about 7.5 percent, as measured relative to the pre-reform stock market participation rate. The results are robust to a number of alternative specifications.

Following Imbens and Angrist (1994), we interpret our IV estimates as the local

[1]For example, Brown et al. (2020) show that market trading activity increases on days with Blackberry outages, consistent with the internet being an attention-diverting activity.

[2]Existing papers that use the Norwegian broadband data, and a very similar empirical methodology, include Bhuller et al. (2013), who study the effects of broadband internet use on sex crime, Akerman et al. (2015), who study the effects of broadband internet on worker productivity, and Bhuller et al. (2020), who study the effects of broadband internet on labor market matching. Additional details on the Norwegian broadband reform can be found in these papers.

average treatment effect of internet use on stock market participation for the part of the population that is induced to use internet because of the broadband reform. It is possible that the complier group consists mostly of young males, as in Barber and Odean (2002) and Choi et al. (2002), and that the large IV estimates are due to a strong response among this subgroup. Using data from a nationally representative survey on broadband user rates, we construct IV estimates for subgroups by age, gender, and education. We find little evidence suggesting that our results are driven by the responses of young males; the effects are statistically significant for most subgroups.

We also study whether broadband internet use affects the trading behavior of individuals that are already established stock market participants. Access to broadband internet reduces the cost of acquiring information about individual companies, which may increase investors' belief that they can beat the market by being well informed and thus lead to increased trading activity and possibly decreased diversification.[3] We find that established investors on average do not increase their trading activity in stocks following the introduction of broadband internet (although there is a slight tendency for the most active traders to become even more active). We also show that established investors tilt their portfolios towards equity funds, thereby obtaining more diversified portfolios and higher Sharpe ratios. Overall, our findings suggest that access to fast internet spurs a democratization of finance: Stock market participation increases, and established investors make better portfolio decisions.

To better understand the channels through which broadband internet use affects stock market participation, we exploit a nationally representative survey which provides details on households' internet activities. The survey provides some evidence of a direct link between internet use and stock market participation, for example the fraction of respondents

[3]For example, the 2007 annual report of DNB, the largest bank in Norway, is a PDF file of about 4 MB. With a 56 kbs dialup, the download takes about 10 minutes, versus 30 seconds with a 1 Mbps DSL broadband connection.

purchasing stocks or financial services online more than quadruples during the reform period. In Section VII, we discuss the survey results in more detail.

Our paper connects to the existing literature in several ways. The household finance literature emphasizes the need to understand the drivers of stock market participation rates (e.g., Campbell (2006); Guiso and Sodini (2013); Lusardi and Mitchell (2014)). The starting point of the literature is that too few individuals invest in equity markets relative to the predictions of the CCAPM and other asset allocation models — the so-called "participation puzzle" (e.g., Grinblatt et al. (2011); Guiso and Sodini (2013); Campbell (2016)). The literature has suggested several factors that affect stock market participation, such as personal wealth (Brunnermeier and Nagel (2008); Calvet et al. (2009); Briggs et al. (2015); Fagereng et al. (2018)), educational attainment (Cole et al. (2014)), computer ownership (Bogan (2008)), and financial literacy (Lusardi and Mitchell (2014); Lusardi et al. (2017)). We contribute to this literature by analyzing the effects of an exogenous reduction in the fixed costs of equity market participation due to faster internet access, and, in line with theoretical predictions, show that equity market participation increases with access to broadband internet.[4]

For established investors, our findings contrast sharply with prior literature, particularly Barber and Odean (2002) and Choi et al. (2002), who document negative welfare effects of the introduction of online trading platforms.[5] We do not find adverse effects

[4]Our results line up with a conjecture from the survey article Guiso and Sodini (2013): "Additionally, the increase in stock market participation that has taken place over the past two decades is also consistent with a decline in participation costs. The availability of financial information on the Internet, and the expansion of the mutual fund industry have effectively made access to the equity market cheaper." (p., 1454).

[5]Using the staggered introduction of the EDGAR system in the 1990s as a shock to information acquisition technology, recent work by Gao and Huang (2019) shows that trades by individual investors, especially those with internet access, became more informative about future stock returns. Although this finding qualifies the Barber and Odean (2002) findings in an important way, it does not appear to

of broadband use for established investors — the average stock trading activity by these investors does not increase with broadband, and they tilt their portfolios from stocks to equity funds. The explanation behind these differences in findings appears to be simple: While the adopters of online trading platforms in the 1990s were mostly young males, the introduction of broadband in the 2000s brought a much broader group of adopters, who, at least on average, had a more prudent response to the new technology.

Policy makers around the world, including in the United States, debate whether to use public funding to expand broadband internet coverage into new regions.[6] This debate has focused on the benefits of fast and reliable internet access for education and health (e.g., LaRose et al. (2011), Bauerly et al. (2019)), democratic participation (e.g., Campante et al. (2017)), economic growth (e.g., Czernich et al. (2011)), wage and employment growth (e.g.,Forman et al. (2012)), productivity for firms (e.g., Akerman et al. (2015)), and possible costs including increased sexual crime (e.g., Bhuller et al. (2013)), reduced psychological well-being (e.g., Kraut et al. (1998)), and internet addiction (e.g., Ko et al. (2012)). Our evidence suggest that broadband has an important additional benefit: Increasing the equity market participation of households.

The paper proceeds as follows. Section II describes the broadband reform, and Section III presents the data. Section IV introduces the empirical methodology, and Section V presents the main results on stock market participation. Section VI presents results for established investors. Section VII discusses mechanisms, and Section VIII concludes.

overturn their main conclusions.

[6]For example, in the 2020 U.S. Presidental election, president-elect Joe Biden's policy plan includes universal broadband. The American Recovery and Reinvestment Act (ARRA) of 2009 allocated USD 7.2 billion to expand broadband internet access (LaRose et al. (2011)).

II. The Reform

We wish to estimate the causal effect of broadband internet use on stock market participation. As a source of exogenous variation in internet use, we exploit a program rolled out by the Norwegian government in the 2000s that aimed at ensuring broadband internet coverage at a reasonable price throughout the country.

The transmission of broadband signals through fiber-optic cables requires the installation of local access points. During the 2000s, such access points were progressively rolled out in Norway, which generated spatial and temporal variation in broadband coverage. The staged nature of the roll-out of broadband was in part a result of limited public funding, but also in part because Norway is a geographically large and sparsely populated country. Panel A of Figure 1 plots the mean municipality-level broadband coverage rate, and its distribution, at the start of each year between 2000 and 2010. Before 2002, most municipalities had 0 percent coverage, but over time the distribution widened, with several municipalities achieving coverage rates above 80 percent already by 2006. By 2010, the mean coverage rate was about 99 percent.

The expansion of broadband coverage facilitated increased broadband internet use. Panel B of Figure 1 plots the mean municipality-level broadband user rate, and its distribution, at the start of each year between 2000 and 2010. The figure shows that broadband user rates increased significantly over time, with most of the increase taking place after 2002. The mean broadband user rate increased from practically 0 percent in 2002 to almost 60 percent in 2010. The figure suggests a substantial increase in broadband internet use following the expansion of broadband coverage.

Our empirical analysis uses the spatial and temporal variation in broadband coverage across municipalities generated by the broadband reform in an IV setup: We use broadband coverage rates (Panel A, Figure 1) as an instrument for broadband user rates (Panel B, Figure 1). In Section IV, we present evidence that the timing of the broad-

band expansion was uncorrelated with both levels and pre-existing trends in stock market participation, which is key to the validity of the IV setup.

III. Data

Our analysis uses several data sets from Norway, which we link via unique identifiers for individuals and municipalities. The coverage and reliability of Norwegian data are rated as exceptional in international quality assessments (Atkinson et al. (1995)). Døskeland and Hvide (2011) provide a general description of Norway and the Oslo Stock Exchange (OSE). In terms of representativeness, as shown by Døskeland and Hvide (2011), individual investors in Norway are similar to individual investors in other Scandinavian countries and somewhat less wealthy than those surveyed by the Survey of Consumer Finance in the United States. Also, apart from a substantial government ownership fraction in the most valuable listed companies, the OSE is representative of a large number of small and middle-sized stock exchanges in industrialized countries.

A. Transaction-level data

To characterize individuals' stock market participation, we collect a record of all common stock trades made on the OSE by Norwegian residents between 1993 and 2010 from the Norwegian Central Securities Depository (NCSD), as well as a record of all trades made by Norwegian residents in all the equity funds and exhange traded funds covered by the NCSD. For each transaction made by an individual investor, the data contain the anonymized ID of the individual, the date of transaction, the ticker of the security, and the number of shares purchased or sold. We use the transactions data together with a record of initial holdings (at the end of 1993) to construct end-of-year holdings in stocks and equity funds for each individual. Moreover, from the OSE, we obtain daily ticker prices and other company information such as market capitalization and company ID

number. Where needed, we supplement this information with data from *Borsprosjektet* at the Norwegian School of Economics (similar to CRSP). All fund prices in the data are expressed in terms of net asset values — that is, net of fund management fees.

While the stock transactions data are exhaustive for trades on the OSE, the fund transactions data from the NCSD only cover about 25 percent of all Norwegian fund customer relationships. For this reason, we supplement the NCSD fund data with data obtained directly from DNB, the main equity fund provider in Norway among those not recording transactions through the NCSD.[7] The DNB data cover another 50 percent of all Norwegian fund customer relationships (see Internet Appendix Section B for details on these data). We cannot merge the NCSD and DNB data because the investor ID codes are not aligned across data sources. In the main analysis, we focus on the stock and fund data obtained from the NCSD. In robustness tests, we show that the main results are similar when using the DNB rather than the NCSD fund data.

B. Internet data

The internet data contain a complete record of the fraction of households that are covered by or subscribe to broadband internet in every municipality over the period 2000–2010. The data on broadband *coverage* come from the Norwegian Ministry of Government Administration. The ministry monitors the coverage of broadband internet, and the suppliers of broadband access to end users are required to file annual reports about their coverage rates to the Norwegian Telecommunications Authority. The coverage rates are based on information on the area signal range of the local access points and detailed information on the place of residence of households. In computing the coverage rates, it is taken into account that multiple suppliers may provide broadband access to households living in the same area, so that double counting is avoided.

[7] DNB was until 2003 known as Den Norske Bank ("The Norwegian Bank").

For the years 2000 and 2001, the data on broadband *subscriptions* come from Telenor, the state-owned enterprise that was the sole provider of broadband internet in Norway in this period. For the remaining period, 2002–2010, the data on broadband subscriptions come from the quarterly Internet Survey performed by Statistics Norway, surveying all suppliers of broadband access to end users. The Internet Survey contains information on the aggregate number of households with broadband subscriptions in each municipality.

C. Socio-demographic data

The socio-demographic data come from administrative registers provided by Statistics Norway and cover all Norwegian residents in the period 1993–2010. The registers contain individual demographic information (such as sex, age, marital status, number of children), socio-economic data (such as years of education, income, employment status), and geographic identifiers for municipality of residence. The information on educational attainment is based on annual reports from Norwegian educational establishments, whereas the income data and employment data are collected from tax records and other administrative registers.

D. Summary statistics

Although most of the data sources provide information at the individual level, the broadband internet data, our main source of exogenous variation, only provide information at the municipality-year level. For this reason, we analyze the effects of broadband internet on stock market participation rates at the municipality level.

The first panel of Table I displays the mean of stock market participation across municipalities, with standard deviations in parentheses. We measure stock market participation by the fraction of individuals in a municipality holding any stocks or equity funds at the end of a calendar year, labeled "Holds Any". Stock market participation is

increasing over time, with Holds Any increasing from about 13 percent in 2000 to 18 percent in 2010. The table also shows the fraction holding individual stocks ("Holds Stocks") and the fraction holding equity funds ("Holds Funds"). The increase in Holds Any over the period from 2000 to 2010 is driven primarily by Holds Funds, which increases from 8.6 to 13.9 percent over the period 2000–2010

The second panel of Table I shows means and standard deviations of broadband internet coverage and user rates. Over the period 2000–2010, the mean broadband user and coverage rates are 27.7 and 61.2 percent, respectively. In 2000, Norway had no broadband coverage (or use). In 2008, mean coverage reached 97.5 percent, increasing further to 99.6 percent in 2010, whereas the mean user rate reached 54 percent in 2008 and 62 percent in 2010. The largest standard deviation in coverage rates across municipalities is observed around 2004, whereas broadband user rates vary the most across municipalities during the final four years of the broadband roll-out period.

Finally, the third panel of Table I shows socio-demographic variables. The mean educational attainment is 11.6 years, and the after-tax household income is NOK 503,000, or approximately $40,000. The mean unemployment rate is negligible, at just 1%. Both educational attainment and household incomes are slightly increasing over time, while unemployment rates are stable at a low level throughout the period 2000–2010.

IV. Methodology

The goal of our paper is to estimate the causal effect of broadband internet use on individuals' stock market participation. The empirical identification strategy exploits exogenous variation in broadband internet use generated by the gradual expansion of broadband coverage in Norway over the period 2001–2010. In the following, we outline our empirical strategy and explain how it may uncover causal effects.

As a starting point, consider the following cross-sectional regression:

$$y_{kt} = \alpha + \psi i_{kt} + \epsilon_{kt}, \tag{1}$$

where y_{kt} is the stock market participation rate for municipality k in year t; $i_{k,t}$ is the household broadband subscription rate in the same year; and ψ captures the effect of broadband use on stock market participation. This "naive" regression is unlikely to capture the causal effect of broadband use on stock market participation because municipalities with high and low i_{kt}'s may differ in their stock market participation for other reasons than their i_{kt}. We can expand equation (1) with municipality fixed effects, α_k, and thus control for level differences in y_{kt} between high- and low-i_{kt} municipalities. Moreover, as both stock market participation and i_{kt} are increasing over time (see Table I), nationwide trends in stock market participation may mistakenly be attributed to the estimated effect of broadband, ψ. We therefore further expand equation (1) with calendar year fixed effects, τ_t, and obtain the modified regression

$$y_{kt} = \omega i_{kt} + \alpha_k + \tau_t + \varepsilon_{kt}, \tag{2}$$

where the coefficient ω, due to the inclusion of α_k and τ_t, measures the within-municipality change in y_{kt} following an increase in broadband use, net of nationwide trends in y_{kt} that are unrelated to broadband use. However, despite the addition of fixed effects, an OLS estimate of ω in (2) is likely to suffer from two types of bias: simultaneity bias, as y_{kt} and i_{kt} may be jointly determined; and omitted variables bias, as i_{kt} may be correlated with omitted determinants of y_{kt} not captured by the fixed effects, α_k and τ_t.

To address these concerns, an ideal experiment would randomize broadband use, i_{kt}, across households. But randomizing broadband use is not feasible: We cannot in practice force households to adopt a new technology. One can, however, think of an experiment

which randomizes broadband *coverage* at the municipality level. The randomization would solve the issue of simultaneity and break the correlation between coverage rates and unobserved determinants of stock market participation. The goal of our identification strategy is to mimic this hypothetical experiment. Our source of exogenous variation in broadband use (conditional on year and municipality fixed effects) comes from the gradual expansion of broadband infrastructure over the period 2001–2010.

More specifically, our main analysis is based on two-stage least-squares (2SLS) estimation of ω with (2) as the "second stage" and a "first stage" equation specified as

$$i_{kt} = \phi z_{kt-1} + \gamma_k + \theta_t + \nu_{kt}, \tag{3}$$

where z_{kt-1} is the fraction of households in a municipality that was covered by broadband infrastructure in the previous year.[8] By estimating equations (2) and (3) jointly by 2SLS, we obtain an estimate of ω, the effect of broadband internet use on stock market participation, that leverages exogenous variation in broadband coverage as an instrument for broadband use. To give a causal interpretation, the IV model requires two key assumptions, the first of which is instrument exogeneity.[9]

Because the IV model (2)–(3) includes municipality and year fixed effects, the exogeneity assumption is that the instrument z_{kt-1} is as good as randomly assigned, conditional

[8]Specifically, we assume that it takes one year from broadband becoming available in a municipality to households actually installing broadband in their homes. In Internet Appendix Section E, we estimate equation (3) separately using z_{kt}, z_{kt-1}, and z_{kt-2}, respectively, as the explanatory variables, and find that households indeed take about one year to adopt broadband.

[9]A third assumption of the IV model is instrument monotonicity, that is, that increased access to broadband internet makes it weakly more likely that a household adopts and uses broadband internet (Imbens and Angrist (1994)). Recent finance papers that estimate similar IV models as us include Chang et al. (2015), Ben-David et al. (2018), and Farre-Mensa et al. (2020). Bhuller et al. (2013) use an identical IV specification as (2)–(3) in their study of the effects of broadband internet use on sex crimes.

on the fixed effects. The validity of this conditional independence assumption can be evaluated by comparing levels and trends in outcomes and characteristics, measured prior to the expansion of broadband, for municipalities receiving broadband coverage early and late, respectively. To this end, we estimate the following regression specification separately for each calendar year of the broadband roll-out:

$$\Delta z_{kt} = \alpha + [m_{k,2000}]'\beta + \kappa_{kt}, \tag{4}$$

where $\Delta z_{kt} = z_{kt} - z_{k,t-1}$, and $m_{k,2000}$ is a vector that includes a wide range of municipality characteristics, such as levels and trends in stock market participation, average years of educational attainment, unemployment rate, share of population residing in a densely populated locality, and households' after-tax incomes, all measured in the pre-reform year 2000. The purpose of estimating equation (4) is to assess whether municipalities with different coverage shocks were similar in terms of their baseline characteristics and outcomes before the shocks.[10]

Figure 2 plots the estimated coefficients from the vector β for every year, with associated 95% confidence intervals.[11] Importantly, we find no correlation between changes in the instrument and baseline levels (Panel A) and trends (Panel T) in stock market participation, or between changes in the instrument and other key determinants of stock market participation, such as household income and education. This supports the validity of the

[10] This is the same diagnostic test as the one used by Bhuller et al. (2013) and Akerman et al. (2015). Besides minor differences in sample periods, all three diagnostics tests lead to the same conclusions. By fixing the calendar year and focusing on within-municipality changes in the broadband coverage rate, this diagnostic test mimics the identifying variation used in the IV (fixed effects) model (2)–(3).

[11] In practice, we estimate all the calendar year-specific effects in Figure 2 in a single regression model by pooling data from the period 2000–2010 and interacting all the terms in equation (4), including the constant term α, with year fixed effects. This procedure provides identical coefficients as when estimating equation (4) year-by-year, but allows us to cluster the standard errors at the municipality level.

IV model. We do find, however, that the timing of the broadband roll-out is correlated with baseline urbanization: More densely populated areas received coverage earlier than less densely populated areas. A potential concern is that our estimates might be biased due to differential underlying trends in stock market participation between high- and low-coverage municipalities, with the underlying trends being driven by urbanization or some unobserved characteristic common to urban municipalities. In Section V, we report results with and without a large set of time-varying controls, including urbanization, and find that the estimates barely move. We also show robustness to allowing for differential time trends across municipalities by including municipality-specific trends. Overall, the evidence supports the validity of the IV model in (2)–(3).

The other key assumption underlying the IV model — the exclusion restriction — is that the instrument z_{kt-1} affects stock market participation *only* through the broadband adoption of households, and not through any other channels such as the broadband adoption of firms. In Section VII, we present survey evidence supporting this assumption. In addition, we estimate the "reduced form" effects of broadband coverage on stock market participation from the following regression specification:

$$y_{kt} = \delta z_{kt-1} + \alpha_k + \tau_t + \varepsilon_{kt}, \tag{5}$$

where δ captures the effect of broadband coverage on stock market participation. Importantly, as the reduced form model makes no assumptions about the nature of broadband adoption, the parameter δ has a causal interpretation even if the exclusion restriction does not hold. In what follows, we report estimates of the effect of broadband coverage on stock market participation (δ from the reduced form model), the effect of broadband coverage on broadband internet use (ϕ from the first stage model), and the effect of broadband internet use on stock market participation (ω from the IV model).

V. Stock Market Participation

A. *Main results*

Table II reports IV estimates of ω from equation (2) along with estimates of the reduced form and first stage coefficients δ and ϕ. The IV estimate reported in the first column shows that when the broadband user rate increases by 100 percentage points, the stock market participation rate increases by about 7 percentage points, which is about 53 percent of the pre-reform mean stock market participation rate. The effect is highly statistically significant. The estimated first stage coefficient, i.e., the estimate of ϕ from equation (3), equals 0.11, which implies that a 100 percentage points increase in broadband coverage induces an additional 11 percent of the population to adopt broadband internet within the next year. The first stage relationship is strong, with an F-statistic around 200, which means that weak instrument bias is not a concern in this setting.

In columns (2) and (3) of Table II, we decompose the overall effect on stock market participation into separate effects on stock and fund holding rates. We find that a 100 percentage point increase in the broadband internet user rate gives an increase in the fund holding rate by about 7.6 percentage points. In contrast, we find no statistically or economically significant effect of broadband use on stock holding rates. Thus, the large effect of broadband use on stock market participation appears to be operating primarily through an increase in the fund holding rate of individual investors.

We challenge the validity of the empirical strategy in two ways. First, we include in the IV model (2)–(3) a wide range of time-varying municipality controls to see whether the main results are driven by changes in municipality characteristics other than broadband coverage, such as urbanization, household income, or educational attainment. Although slightly smaller upon the inclusion of controls, the estimated effects remain positive and highly statistically significant. Second, we interact the municipality fixed effects with

a linear time trend and include these interactions in the IV model. Thus, we allow the broadband roll-out to be correlated with different underlying time trends in stock market participation across municipalities. Again, we find significant effects of broadband internet use on stock market participation, suggesting that the main results are not driven by differential pre-existing trends in stock market participation.

A potential concern relates to the coverage of the NCSD data with respect to fund holdings. While providing nearly exhaustive coverage of individuals' stock trades, the NCSD fund trade data is less exhaustive, covering trades by about 25 percent of all fund customer relationships in Norway (see Section III for details). Most notably, the NCSD data do not cover the fund trades made by clients at DNB, the largest bank in Norway, which accounts for about 50 percent of all fund customer relationships. In Panel B of Table II, we estimate the IV model from equations (2)–(3) using fund trading rates from the DNB data as the outcome. Similar to the main results, we find that the effect of broadband use on fund holding rates as measured in the DNB data is positive and statistically significant. Hence, the main results are not specific to the fund customer relationships covered by the NCSD data, but seem to apply more broadly.

As outlined in Section IV, the IV estimates in Table II can only be interpreted as the causal effect of individuals' broadband internet use on stock market participation under the assumption that increased broadband coverage affects stock market participation only through the broadband adoption of individuals, as specified by the first stage relationship (3). The reduced form model in equation (5), in contrast, makes no such assumptions about broadband adoption and provides causal effects even if broadband adoption does not conform with with the first stage relationship (3). Panel A of Table II reports estimates of δ from equation (5), showing that a 100 percentage point increase in broadband coverage causes a 0.78 percentage point increase in stock market participation. Like the IV effect, the reduced form effect is highly statistically significant.

B. *Effect heterogeneity*

Following Imbens and Angrist (1994), we interpret the main IV estimates in Table II as the effect of broadband internet use on stock market participation for the part of the population that is induced to use broadband internet as a direct result of the broadband reform.[12] It is possible that the complier group consists mostly of young males, as in Barber and Odean (2002) and Choi et al. (2002), and that the large IV estimates in Table II result from a strong response among this subgroup.

To estimate the effects of broadband use for different subgroups, we use data from a yearly nationally representative survey on broadband user rates. The survey includes details on broadband internet use, as well as individual characteristics such as age, sex, and educational attainment (see Internet Appendix Section C for details) for more than 1,000 individuals each year in the period 2001–2010. Using this survey, we first reconstruct the user rate i_{kt} from (3) separately for subgroups by age, sex, and educational attainment. For each of the subgroups, we are able to calculate i_{kt} for around 40 percent of the 4,220 municipality-year observations in the full sample. Then, we estimate the IV effect ω from equation (2) separately for each of the subgroups, using all municipality-years with non-missing i_{kt}'s. The results are presented in Panel A of Table III. The effects appear to be quite universal across sociodemographic groups: Relative to pre-reform stock market participation rates, the effect of a 100 percentage point increase in broadband use on stock market participation is slightly larger for males (39 percent) than for females (29 percent), for younger (59 percent) than for older (34 percent) individuals, and for less (30 percent) than for more educated (27 percent) individuals.

The IV effects in Panel A of Table III are estimated based on the subset of municipality-year observations for which the survey in Internet Appendix Section C allows

[12]This estimator is often refered to as a local average treatment effect, or LATE; see Imbens and Angrist (1994).

us to calculate subgroup-specific broadband user rates. To assess whether the results are robust to changes in the estimation sample, we also estimate subgroup-specific reduced form effects (which does not require subgroup-specific user rates) of broadband coverage on stock market participation, using the full sample of municipality-year observations. The results, which are presented in Panel B of Table III, show that the full-sample reduced form estimates broadly line up with the restricted-sample reduced form estimates in Panel A, supporting the conclusion that broadband internet has a broad positive effect on stock market participation across socioeconomic groups.

Overall, broadband internet appears to have had a positive impact on the stock market participation across socioeconomic groups, suggesting that the introduction of broadband internet led to a "democratization of finance".

VI. Effects for Established Investors

Motivated by Barber and Odean (2002) and Choi et al. (2002), who find negative welfare effects from the adoption of online trading among established (already active) investors in the 1990s, predominately due to relatively quick adoption by young males who started trading excessively, we now analyze the effect of broadband internet on established investors. On the one hand, access to broadband internet reduces the cost of acquiring information about individual companies, which may increase investors' belief that they can beat the market by being relatively better informed and thus lead to increased trading activity and decreased diversification. Faster internet also decreases the time cost of trading, an effect that could be important for the most active traders. On the other hand, increased broadband access might improve trader welfare if a broader group of investors than young males adopts the internet, or if the internet is used to collect information on how to diversify or form better portfolios.

We do not observe broadband user rates broken down by past trading activity. In

principle, we could construct IV estimates by assuming that established investors have the same broadband user rates as the population as a whole — that is, recycle the first-stage relationship from Table II — but this approach is unappealing, as established investors likely adopt broadband earlier than the population average. To assess the effect of broadband on the trading activity of established investors, we therefore estimate the reduced form effects given by δ in equation (5). As explained in Section IV, the parameter δ has a causal interpretation and can be estimated without broadband user data.

The estimated effect of broadband coverage on the trading activity of established investors is presented in Table IV. The results reported in columns (1)–(4) show a positive and statistically significant effect of broadband coverage on fund buying among established investors, and no statistically significant effect of broadband on fund selling, stock buying, or stock selling. Taken together, these results imply that broadband coverage should lead to an increase for established traders in the portfolio share of stock funds as opposed to individual stocks. This is confirmed in column (5) of Table IV.

Next, we analyze the effects of broadband coverage on various measures of trader welfare adopted from Calvet et al. (2007).[13] The estimates reported in columns (6)–(8) of Table IV show that increased broadband coverage causes an increase in investors' Sharpe ratios (column (6)) and leads to more diversified portfolios (column (7)) in the sense that it reduces the portfolios' idiosyncratic risk share (column (8)). To give a sense of the economic magnitudes of these effects, the mean pre-reform Sharpe-ratio in our sample

[13]Individual investors' Sharpe ratios are calculated based on excess returns relative to the Norwegian Central Bank's overnight deposit rate. Following Calvet et al. (2007), the relative Sharpe ratio loss (RSRL) captures diversification losses by comparing the individual investors' Sharpe ratio to the Sharpe ratio of an appropriate benchmark index, in our setting chosen to be the OBX index in Oslo (see equations (7)-(8) in Calvet et al. (2007)). Finally, the portfolio's idiosyncratic risk share is the share of portfolio variance that can be attributed to idiosyncratic risk, as opposed to systematic risk, and is calculated following equations (1)-(3) in Calvet et al. (2007).

is about 11 percent. A 100 percentage point increase in broadband coverage increases the Sharpe ratio by about 0.06 percentage points the year after, or approximately 0.5 percent of the pre-reform mean. If we assume a first-stage coefficient of 0.15 for the group of established investors — that is, slightly larger than the 0.11 first stage coefficient for the average person in Table II — these reduced form effects would imply IV estimates of about 0.47 percentage points, or 4.3 percent of the pre-reform mean.

While columns (3) and (4) of Table IV show that the average established investor does not increase his stock trading activity following increased broadband access, it could be that the most active ones do, as in Barber and Odean (2002) and Choi et al. (2002). To assess this possibility, we first group all investors into 20 (nationwide) ventiles based on their stock trading activity in the previous year. Then, we calculate the average number of trades within a given ventile-municipality-year. Finally, we re-estimate the reduced form effect δ from (2) twenty times, each time using a different ventile's average number of stock trades as the outcome.[14] Intuitively, this approach involves comparing stock trading activity between established investors that (i) currently experience different broadband coverage shocks but (ii) in the previous year belonged to the same trading activity ventile, conditional on calendar year and municipality fixed effects.

Panel A of Figure 3 presents the estimates of δ for each of the ventiles. Across the trading activity distribution, there are uniformly weak effects of broadband coverage on current stock trading. The exception is at the top: For the top 10 percent of the past trading activity distribution, we find positive effects of broadband coverage on stock trading. However, the effect is statistically significant (p-value $= 0.051$) only for the 19th ventile. To assess the robustness of this result, in Panel B of Figure 3 we re-estimate the ventile-specific δ's using the log of the mean number of stock trades as the outcome, and

[14] In practice, all of the ventile-specific effects are estimated in the same regression model by pooling all the ventile-municipality-year observations and interacting all the terms in equation (2) with ventile fixed effects.

find that the effects of broadband on the trading activity of the most active investors are no longer economically or statistically significant. We conclude that there may be an increase in stock trading activity among a small subset of the established investors.

Overall, we find positive effects of increased access to broadband internet among established investors: They increase their equity fund portfolio shares and their Sharpe ratios and do not increase their stock trading activity. These findings contrast quite sharply with Barber and Odean (2002) and Choi et al. (2002), who find that the adoption of online trading platforms induced individual investors — young males in particular — to trade excessively, thereby increasing their trading costs and reducing welfare.

VII. Mechanisms

While exogeneity of the instrument z_{kt-1} is sufficient for a causal interpretation of the reduced form effects reported in Tables II–III, the IV estimates reported in the same tables can only be interpreted as causal effects of individuals' broadband use on stock market participation under the additional assumption that increased broadband coverage affects stock market participation through the broadband adoption of individuals, and not in any other way. Here we discuss this assumption in more detail.

A. Alternative channels

One possibility is that the estimated effect of broadband coverage on stock market participation results from broadband adoption at the firm level rather than at the household level. Broadband adoption at the firm level could lead to increased productivity and wages of the firms' workers and increase stock market participation through an income or wealth effect.[15] Using the same methodology as in Sections V–VI, we assess whether

[15] Akerman et al. (2015) find that firm-level adoption of broadband internet increases the productivity of high-skill workers and decreases the productivity of low-skill workers, but they do not report the total

broadband coverage affects labor income reported to the tax authorities. The results reported in Internet Appendix Section F suggest that broadband internet does not have a significant impact on labor incomes. Thus, it seems unlikely that the observed effect of broadband coverage on stock market participation is driven by income effects.

Alternatively, through a combination of firm- and household-level broadband adoption, increased broadband coverage could allow skilled workers to work from home, creating more time for leisure activities such as getting acquainted with stock market opportunities. This mechanism is likely to be more prevalent for high-skill than low-skill workers if, for example, low-skill workers do physical tasks that require on-site presence, whereas high-skill workers can perform their jobs remotely. However, at least relative to pre-reform stock market participation rates, our results are stronger for individuals with low education (Table III) which makes this mechanism unlikely to explain our results.

B. Survey evidence on households' internet activities

A nationally representative survey from Norway on internet usage allows us to provide evidence on the link between households' internet adoption and their stock market participation. The survey is administered by Statistics Norway and each year has more than 1,000 respondents that give detailed information about whether or not they have access to the internet and for what purposes they use the internet.[16] The survey covers each year over the period 2003–2010, which allows us to study how households used the internet before, during, and after the broadband reform.

One survey question is of particular relevance: Whether respondents have used the

effect.

[16]In the percentages reported below, we include all the respondents to the survey, also those that report not having internet access. Note also that the survey used in the current subsection is distinct from the one used in Section VI. Internet Appendix Sections C and D provide more details on each of the surveys.

internet to purchase stocks and/or financial services. Panel A of Figure 4 plots the fraction of respondents with affirmative answer to this question before (2003) and after (2010) the broadband reform.[17] In the pre-reform period, a very small percentage of the respondents (less than 2 percent) used the internet to purchase stocks or other financial services. After the reform, more than six times as many (about 12 percent) respondents reported that they use the internet to purchase stocks or other financial services. The relative increase in the online purchasing of stocks or financial services is considerably larger than for the use of online banking, also shown in Panel A of Figure 4, which was fairly common (about 49 percent) even before the broadband reform. Hence, in percentage terms there was a strong increase in the usage of the internet to purchase stocks and/or financial services, even compared to other personal finance activities.

To explore whether the increase in the online purchasing of stocks or financial services is related to the broadband reform, in Panel B of Figure 4, we plot the fraction of respondents that have purchased stocks or financial services online against broadband coverage in the previous year. The analysis is at the regional level (there are 7 regions) as the survey contains information about respondents' region of residence, but not their municipality of residence.[18] The figure shows a strong positive association between broadband coverage and the tendency to purchase stocks or financial services online; the correlation between online stock/financial purchasing and broadband coverage is about 0.8, statistically significant at the 1 percent level, and a linear regression of online stock/financial purchasing on broadband coverage yields a slope of 0.11, also significant at the 1 percent level.[19] These results suggest that the observed increase in online purchasing of stocks or

[17] In 2003, the first year of the survey, the average municipality-level broadband internet coverage was about 20%, as shown in Figure 1. In 2010, the average broadband coverage was about 99.9%.

[18] In Panel B of Figure 4, there are 7 geographical regions $\times$ 8 survey waves $= 64$ observations. We do not have sufficient statistical power to estimate the IV model (2)–(3) at the regional level.

[19] As additional evidence, in Panel D of Figure 4, we plot for males, females, and three age groups the change from pre-reform to post-reform in the online purchasing of stocks or financial services against the

financial services may be related to the broadband reform.

Why would faster internet access lead to increased stock market participation rates? As suggested by the theoretical literature, entering the stock market involves fixed costs such as becoming aware of stock market opportunities (Guiso and Jappelli (2005)) and acquiring financial competence (e.g., Lusardi and Mitchell (2014); Lusardi et al. (2017)). It is plausible that faster internet would facilitate these activities and thus increase stock market participation rates. However, the internet also facilitates leisure activities such as social networking or watching movies, which could reduce the time spent on information acquisition and learning. While the survey does not ask respondents whether they have used the internet to learn about personal finance, it broadly supports that the internet increasingly was used for information acquisition and learning during the sample period. For example, information acquisition about health — which, like personal finance, is important for long-term outcomes — increased from 29 percent in the pre-reform period to 45 percent in the post-reform period, as shown in Panel A of Figure 4. Post-reform, about 54 percent of the respondents answered that they have "Consulted the internet with the purpose of learning", but this question was not asked pre-reform. Panel A also shows the pre-post change for other forms of online information acquisition and learning. The variable "Other info. acq." is the fraction of respondents that confirms having used the internet to acquire information about goods and services, the labor market, travel and accommodation, or have taken an online course.[20] This variable increases from 67 percent

subgroup-specific reduced form effect of broadband coverage on stock market participation from Table III. The figure shows that the subgroups with the largest causal effects of broadband coverage on stock market participation are also the ones with the largest before-after changes in online purchasing of stocks or financial services.

[20]The fraction of respondents with affirmative answers to each of these questions before and after the broadband reform were: travel (40%, 60%), labor market (16%, 20%), education (5%, 5%), goods/services (62%, 79%).

in the pre-reform period to 84 percent post-reform. Taken together, this evidence supports a broad trend towards increased internet-based information acquisition and learning in the broadband reform period.

VIII. Conclusion

The internet has greatly improved the opportunities for individual investors to gather information and easily connect to stock markets. This paper combines plausibly exogenous variation in broadband internet use with detailed register data to study the effects of broadband internet use on stock market participation and trading behavior. We find that broadband use leads to increased stock market participation, and to improved portfolio allocation for established investors. We do not find adverse effects of broadband use; for example, access to faster internet does not lead to excessive stock trading among established investors. Overall, the introduction of broadband internet seems to induce individual investors to make portfolio decisions that are more in line with the advice from portfolio theory, spurring a democratization of finance.

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IX. Tables

Table I. Summary Statistics

This table shows means of equity market participation rates, broadband internet use and coverage rates, and municipality characteristics over the time period 2000–2010. The data are at the municipality-year level. Internet Appendix Section A provides details on variable construction and also presents summary statistics for additional control variables. Standard deviations are presented in parentheses.

	Overall	2000	2002	2004	2006	2008	2010
Equity market participation:							
Holds any (%)	16.02	13.13	14.72	14.19	16.18	18.00	18.03
	(5.87)	(5.23)	(5.33)	(5.22)	(5.75)	(6.18)	(5.84)
Holds fund (%)	11.81	8.65	10.08	9.95	12.20	13.99	13.93
	(6.17)	(5.38)	(5.54)	(5.47)	(6.06)	(6.51)	(6.13)
Holds stock (%)	6.40	6.33	6.94	6.31	6.12	6.27	6.38
	(2.51)	(2.54)	(2.63)	(2.49)	(2.40)	(2.45)	(2.40)
Internet use and coverage:							
User rate (%)	27.69	0.00	0.08	6.10	31.93	53.97	61.87
	(25.83)	(0.00)	(0.60)	(6.98)	(11.86)	(10.37)	(10.06)
Coverage rate (%)	61.22	0.00	10.90	39.17	85.92	97.51	99.60
	(41.51)	(0.00)	(22.68)	(30.04)	(12.18)	(4.73)	(1.09)
Control variables:							
Unemployment rate (%)	1.45	1.34	1.56	1.99	1.50	0.82	1.21
	(0.80)	(0.69)	(0.78)	(0.83)	(0.76)	(0.50)	(0.57)
Educational attainment	11.61	11.27	11.39	11.52	11.64	11.78	11.84
	(0.46)	(0.42)	(0.42)	(0.42)	(0.42)	(0.43)	(0.43)
After-tax household income	503.14	483.10	489.62	484.43	514.31	521.88	514.83
	(42.99)	(41.70)	(38.97)	(36.12)	(39.50)	(41.73)	(40.50)
N	4220	422	422	422	422	422	422

Table II. Equity Market Participation

Panel A shows estimates of ω and ϕ from the IV model (2)–(3) as well as δ from the reduced form model (5). The outcomes are the equity market participation rate (Holds Any), the stock holding rate (Holds Stocks), and the fund holding rate (Holds Funds), all measured using data from the NCSD. Panel B shows estimates from three robustness tests. The first column shows estimates from IV and reduced form models which include controls for time-varying municipality characteristics. The second column shows estimates from IV and reduced form models which include controls for time-varying municipality characteristics as well as municipality-specific linear time trends. The third column shows estimates from the baseline IV and reduced form models using Holds Funds as measured in the DNB data as the outcome. All regressions are based on 422 municipalities $\times$ 10 years $= 4,220$ observations. Standard errors are clustered at the municipality level and presented in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	Panel A. Main Results			Panel B. Robustness		
	Holds Any	Holds Stocks	Holds Funds	Holds Any	Holds Any	Holds Funds
IV Estimate	0.0698***	-0.0062	0.0764***	0.0486***	0.0287***	0.0248**
	(0.0169)	(0.0075)	(0.0173)	(0.0152)	(0.0077)	(0.0099)
Reduced Form	0.0078***	-0.0007	0.0085***	0.0057***	0.0034***	0.0028**
	(0.0018)	(0.0008)	(0.0018)	(0.0018)	(0.0010)	(0.0011)
First Stage	0.1116***	0.1116***	0.1116***	0.1168***	0.1185***	0.1116***
	(0.0079)	(0.0079)	(0.0079)	(0.0077)	(0.0047)	(0.0079)
Controls	No	No	No	Yes	Yes	No
Muni. trends	No	No	No	No	Yes	No
DNB data	No	No	No	No	No	Yes
N	4220	4220	4220	4220	4220	4220

Table III. Trader Heterogeneity

Panel A presents subgroup-specific estimates of ω and ϕ from the IV model (2)–(3) as well as δ from the reduced form model (5). Equity market participation rates for subgroups by age, sex, and educational attainment are calculated using data from the NCSD. Broadband user rates for each of the subgroups are calculated using the survey described in Internet Appendix Section C. In Panel A, the estimation sample includes the subset of municipality-year observations for which we observe both equity market participation and subgroup-specific broadband user rates. Panel B presents subgroup-specific estimates of δ from the reduced form model (5). In Panel B, the estimation sample includes all 4,220 municipality-year observations in the main sample. In both panels, the pre-reform equity market participation rate is measured in 2000. Standard errors are clustered at the municipality level and presented in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	Panel A. IV, RF, FS Using Survey Data							
	Age bins:			Gender:		Education:		
	16-34	35-54	>54	Male	Female	Low	Medium	High
IV Estimate	0.0597***	0.0630**	0.0581**	0.0610***	0.0267**	0.0169**	0.0807**	0.0643
	(0.0215)	(0.0287)	(0.0276)	(0.0224)	(0.0110)	(0.0075)	(0.0382)	(0.0627)
Reduced Form	0.0134***	0.0130***	0.0122***	0.0125***	0.0061***	0.0056**	0.0124***	0.0062
	(0.0037)	(0.0048)	(0.0032)	(0.0031)	(0.0021)	(0.0024)	(0.0037)	(0.0041)
First Stage	0.2247***	0.2063***	0.2101***	0.2046***	0.2282***	0.3300***	0.1542***	0.0957
	(0.0589)	(0.0606)	(0.0776)	(0.0509)	(0.0574)	(0.0699)	(0.0579)	(0.0714)
N	1731	1926	1209	2144	1987	1491	1975	1421
Pre-reform mean	0.1005	0.1858	0.1706	0.1544	0.0905	0.0561	0.1853	0.2377
	Panel B. RF Using Full Sample							
	Age bins:			Gender:		Education:		
	16-34	35-54	>54	Male	Female	Low	Medium	High
Reduced Form	0.0116***	0.0144***	0.0041**	0.0091***	0.0064***	0.0061***	0.0122***	0.0060**
	(0.0030)	(0.0033)	(0.0019)	(0.0021)	(0.0016)	(0.0015)	(0.0028)	(0.0026)
N	4220	4220	4220	4220	4220	4220	4220	4220
Pre-reform mean	0.1005	0.1858	0.1706	0.1544	0.0905	0.0561	0.1853	0.2377

Table IV. Effects for Established Investors

This table presents estimates of δ from the reduced form model (5). In the first four columns, the outcomes are the fraction of established investors — that is, investors with positive stock or fund holdings in the previous calendar year — that buy or sell equity funds and stocks in a given municipality-year. In the fifth column, the outcome is the average share of established investors' portfolios that is invested in stocks as opposed to equity funds. In the final three columns, the outcomes are average portfolio Sharpe ratios (SRatio), relative Sharpe ratio losses (RSRL), and idiosyncratic risk shares (IdioShare), calculated following Calvet et al. (2007). Regressions are based on 422 municipalities $\times$ 10 years $=$ $4,220$ observations. We are unable to compute SRatio, IdioShare, and RSRL for a small share of the municipality-years. Standard errors are clustered at the municipality level and presented in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	Funds		Stocks		Portfolio			
	Buy	Sell	Buy	Sell	Stock Share	SRatio	IdioShare	RSRL
Reduced Form	0.0068*	0.0004	-0.0013	-0.0030	-0.0202***	0.0006**	-0.0010***	-0.0014**
	(0.0040)	(0.0005)	(0.0026)	(0.0028)	(0.0061)	(0.0003)	(0.0004)	(0.0006)
N	4220	4220	4220	4220	4220	4105	4105	4105

X. Figures

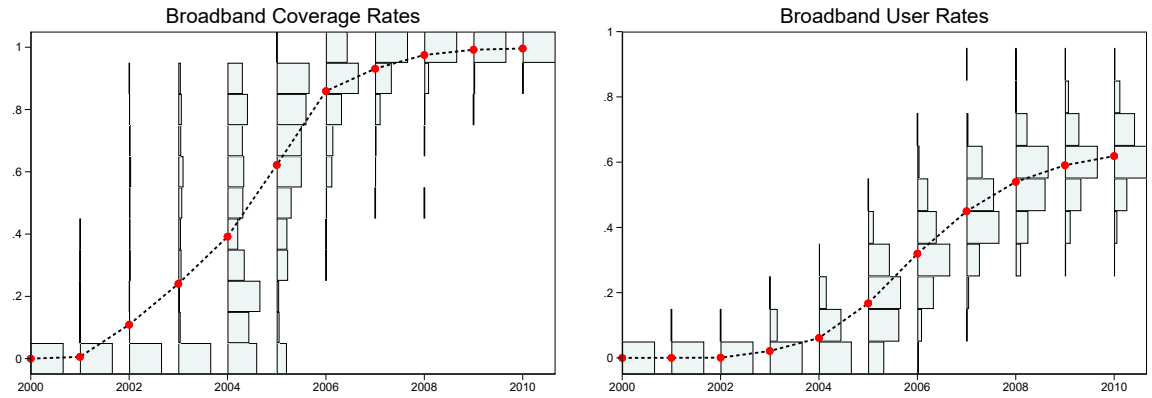


Figure 1. Broadband coverage and user rates, 2000–2010. This figure shows the overall mean and distribution of broadband coverage rates (left panel) and user rates (right panel) across municipalities for each year during the period 2000–2010.

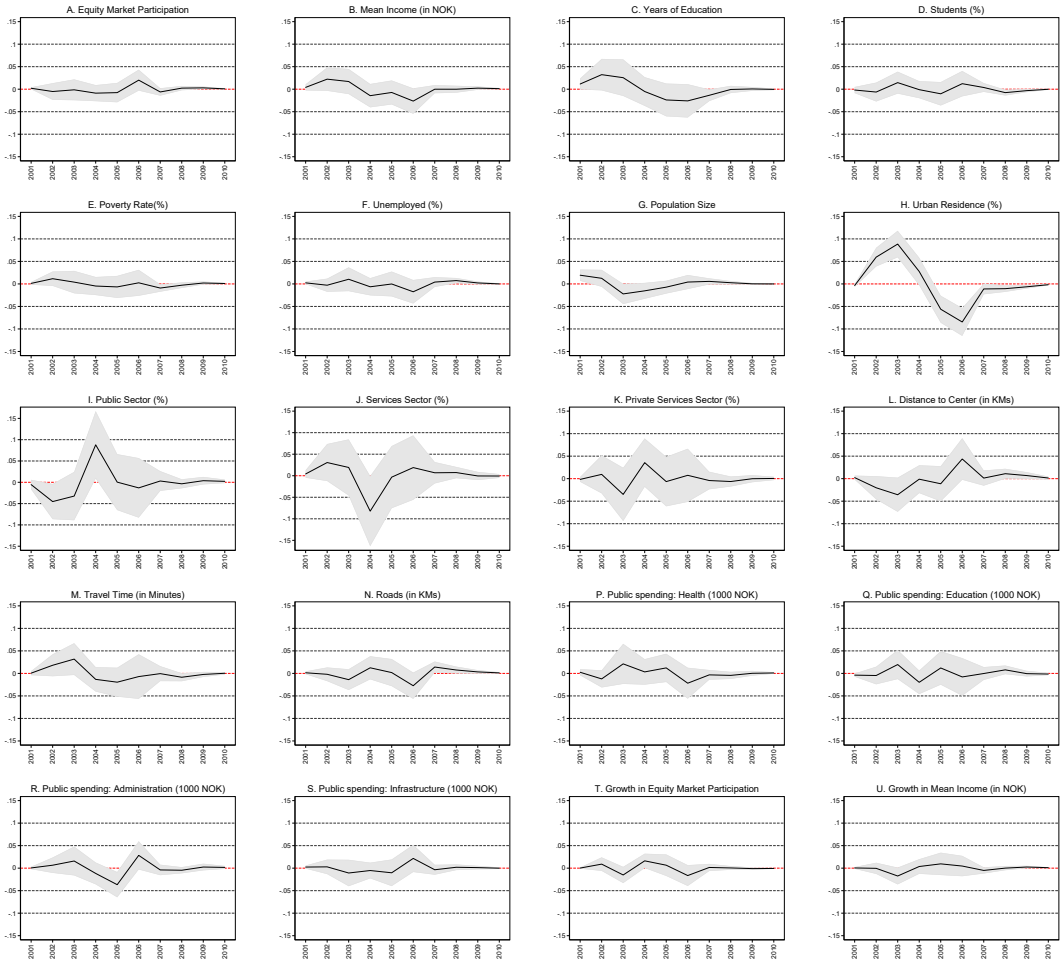


Figure 2. Timing of broadband roll-out and baseline covariates. This figure shows calendar year-specific estimates of β (along with the associated 95 percent confidence intervals) from equation (4), a regression of the change in municipality-level broadband coverage rates, Δz_{kt}, on baseline municipality characteristics, as measured in the pre-reform year 2000. For comparability across panels, all baseline municipality characteristics have been scaled by their respective standard deviation. Internet Appendix Section A provides an overview of the variable definitions.

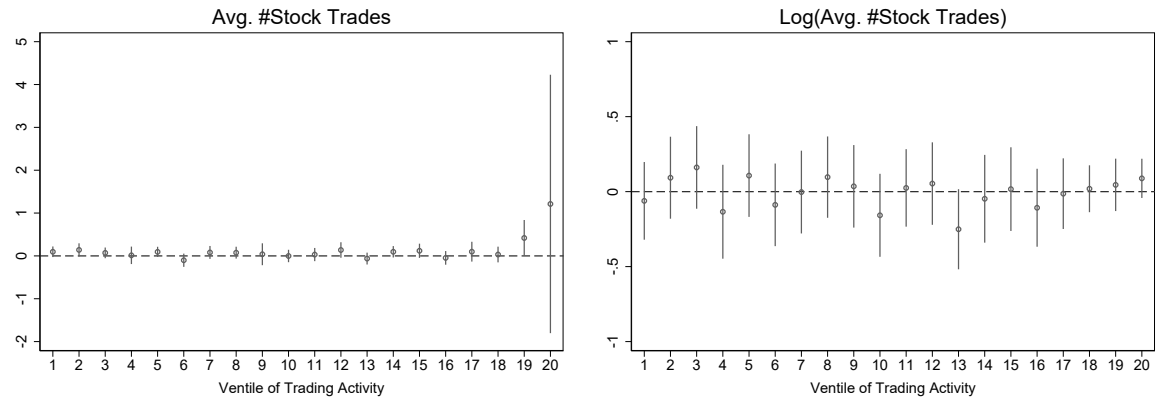
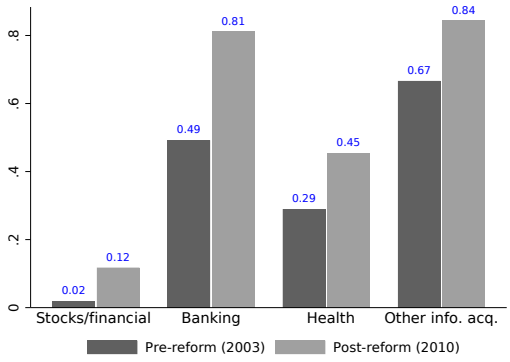
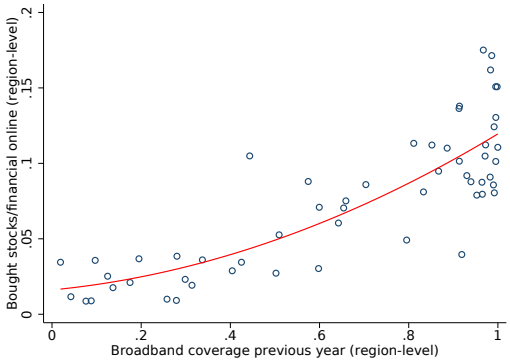


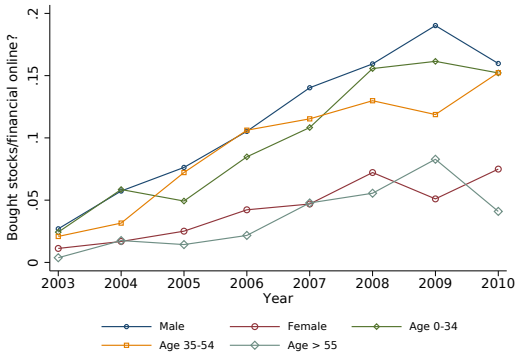
Figure 3. Effects on stock trading, by past trading activity. This figure shows reduced form effects of broadband coverage on the trading activity of established investors, along with the associated 95 percent confidence intervals. For each year, we first rank each established investor into 20 ventiles based on the number of trades in the previous year (individuals without stock or fund holdings in the previous calendar year are excluded from the sample). We then calculate the mean number of stock trades (the outcome in Panel A) and the log of the mean number of stock trades (the outcome in Panel B) within each ventile-municipality-year observation. Finally, we estimate the reduced form coefficient δ from equation (2) 20 times, each time using a different ventile's mean number of stock trades or log mean number of stock trades as the outcome variable.



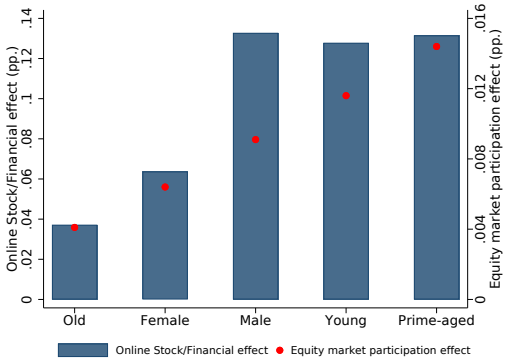
Panel A. Internet activities



Panel B. Online stock/financial over time



Panel C. Online stock/financial over time



Panel D. Effects in survey and register data

Figure 4. Survey evidence. This figure presents summary statistics from a yearly survey on how individuals interact with the internet. Internet Appendix Section D provides more details on the survey. For the years 2003 (first survey wave) and 2010 (post-reform), Panel A presents the fraction of respondents answering "Yes" to whether they have recently used the internet for the purposes of purchasing stocks or financial services, online banking, searching for information about health, or for other forms of information acquisition and learning ("Other info. acq."). "Other info. acq." equals one if the respondent has recently searched the internet for information about goods, services, health, travel and accommodation, the labor market, or have taken an online course (in any subject). For all years 2003–2010, Panel B plots the fraction of respondents in a given geographical region that report having purchased stocks or financial services online against the previous year's broadband coverage in the respondent's region. There are 7 geographical regions $\times$ 8 years $=$ 64 observations in Panel B. For all years 2003–2010, and separately by sex and age, Panel C plots the fraction of respondents that report having purchased stocks or financial services online. Finally, Panel D shows the absolute change from 2003 to 2010 in the fraction of respondents that report having purchased stocks or financial services online (from Panel C) as well as the subgroup-specific reduced form effect δ of broadband coverage on equity market participation rates (from Table II), both separately by sex and age.

Internet Appendix for "Broadband Internet and the Stock Market Investments of Individual Investors"

Hans K. Hvide, Tom G. Meling, Magne Mogstad, and Ola Vestad

This document provides supplementary material for the article "Broadband Internet and the Stock Market Investments of Individual Investors".

A. Data and variable construction

In this appendix, we provide additional details on both outcome and control variables used in Table II of the main text. In the top panel of Table IA.I, we define the stock market participation, and internet use and coverage rates variables. In the bottom two panels, we define the control variables used in Panel B of Table II. In Table IA.II, we present summary statistics for a selection of municipality-level control variables.

Table IA.I. Variable Definitions

Variable	Description
Equity market variables	
Holds Any	Fraction of households residing in a given municipality at the end of year t, who hold stocks or equity funds. Growth in Holds Any, considered in Figure 2 of the main text, is defined as the change in Holds Any from 1999 to 2000.
Holds Funds	Fraction of households residing in a given municipality at the end of year t, who hold equity funds.
Holds Stocks	Fraction of households residing in a given municipality at the end of year t, who hold stocks.
Internet variables	
User rate t	Fraction of households residing in a given municipality at the beginning of year t, who are subscribing to broadband internet (with access speed at or above 256 kilobits per second).
Coverage rate t	Fraction of households residing in a given municipality at the beginning of year t, who can have access to broadband internet (with access speed at or above 256 kilobits per second).
Covariates of equity market participation and portfolio selection	
Demographic factors	
Urbanization	Percentage share of the population in a given municipality residing in a densely populated locality at the beginning of year t.
Immigrants	Percentage shares of the immigrant and non-western immigrant populations residing in a given municipality belonging to the age-groups 16–21, 22–24, 25–34, 35–44, 45–54, 55–66, and 67 or above at the beginning of year t.
Females	Percentage shares of the female population residing in a given municipality belonging to the age-groups 16–21, 22–24, 25–34, 35–44, 45–54, 55–66, and 67 or above at the beginning of year t.
Age groups	Percentage shares of the population residing in a given municipality belonging to the age-groups 16–21, 22–24, 25–34, 35–44, 45–54, 55–66, and 67 or above at the beginning of year t.
Students	Percentage share of the population aged 16 and above residing in a given municipality that is registered as students at the beginning of October each year t.
Divorced	Percentage share of the population aged 16 and above residing in a given municipality that is registered as divorced or separated at beginning of year t.
College or university	Dummy variable set equal to one if there is a registered college or university located in the municipality in year t.
Socioeconomic factors	
Income	Average after-tax disposable income earned during year t by individuals aged 16–59 years residing in a given municipality. Growth in Income, considered in Figure 2 of the main text, is defined as the proportional change in Income from 1999 to 2000.
Poverty	Percentage share of population having income during year t below half of the median equivalent after-tax income in a given municipality, when the equivalent income is calculated using the OECD equivalence scale.
Unemployment	Percentage share of the population aged 16–59 residing in a given municipality that is registered as fully unemployed at beginning of year t.
Welfare dependency	Percentage share of the population aged 16–59 residing in a given municipality that is registered as recipients of social economic assistance at beginning of year t.
Education	Average years of schooling in the age-group 16–59 residing in a given municipality at the beginning of year t.
Covariates of broadband	
Industry composition	
Services	Percentage share of the population aged 16–59 employed in the services sector at the beginning of year t.
Services, private	Percentage share of the population aged 16–59 employed in the private services sector at the beginning of year t.
Public sector	Percentage share of the population aged 16–59 employed in the public sector at the beginning of year t.
Public services provision	
Total spending	Per capita spending on municipal public services in year t (in NOK).
Administration	Per capita spending on municipal administration in year t (in NOK).
Education	Per capita spending on municipal schools and other educational institutions in year t (in NOK).
Health services	Per capita spending on municipal health care services in year t (in NOK).
Supply factors	
Travel time	Average travel time in minutes to municipal center at the beginning of year t.
Distance	Distance in kilometers to municipal sub-center at the beginning of year t.
Road networks	Distance in kilometers covered by municipal roads at the beginning of year t.
Infrastructure	Per capita spending on municipal infrastructural maintenance (incl. roads, pipes and tunnels) in year t (in NOK).

Table IA.II. Summary Statistics

This table shows summary statistics on time-varying municipality characteristics over the time period 2000–2010. The variables are defined in Table IA.I. We restrict attention to the municipality characteristics considered in Figure 2 of the main text. Standard deviations are presented in parentheses.

	Overall	2000	2002	2004	2006	2008	2010
Students (%)	0.11	0.12	0.12	0.11	0.11	0.11	0.10
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)
Poverty Rate (%)	0.05	0.06	0.05	0.05	0.05	0.04	0.05
	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Population Size (000's)	10.46	10.07	10.18	10.30	10.45	10.67	10.94
	(31.64)	(29.77)	(30.12)	(30.69)	(31.58)	(32.76)	(34.17)
Urban Residence (%)	0.50	0.48	0.49	0.49	0.49	0.50	0.50
	(0.28)	(0.27)	(0.27)	(0.28)	(0.28)	(0.28)	(0.28)
Public Sector (%)	0.27	0.26	0.27	0.26	0.26	0.27	0.29
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Services Sector (%)	0.31	0.29	0.30	0.30	0.30	0.31	0.33
	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)	(0.05)	(0.04)
Private Services Sector (%)	0.08	0.07	0.07	0.07	0.07	0.08	0.08
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)
Distance to Center (in KMs)	0.82	0.87	0.85	0.82	0.82	0.80	0.80
	(0.73)	(0.75)	(0.73)	(0.70)	(0.71)	(0.74)	(0.75)
Travel Time (in Minutes)	0.16	0.20	0.15	0.15	0.16	0.15	0.15
	(0.12)	(0.16)	(0.12)	(0.12)	(0.12)	(0.11)	(0.11)
Roads (in KMs)	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
N	4220	422	422	422	422	422	422

B. Fund data from DNB

In the main text, we use stock and fund transactions data from the Norwegian Central Securities Depository (NCSD) to calculate holding rates at the municipality-year level. While the stock transactions data from the NCSD are exhaustive for trades on the Oslo Stock Exchange, the fund transactions data from the NCSD only cover about 25% of all Norwegian fund customer relationships. For this reason, we supplement the NCSD fund data with data obtained directly from DNB, the largest Norwegian bank and the main equity fund provider among the institutions that do not record their transactions through the NCSD. Here, we provide details on the fund transactions data from DNB.

B.1. About the DNB data

The fund transactions data from DNB cover all individuals who traded equity funds through DNB at least once in the period from 2000 to 2010 and contain detailed information on all transactions in funds traded through DNB in the same period, with unique identifiers for both the individual traders and the funds. The data contain more than 14 million transactions by 941,068 unique individuals. For each transaction, we observe the price, the date of the transaction, and the type of transaction (buy/sell). For each of the 130 funds, we observe the type of fund (equity fund, bond fund, or mixed fund) and its risk classification (seven categories). In addition to the fund and transaction level information, we also observe each trader's municipality of residence, age (in bins), and sex.

B.2. Summary statistics

Table IA.III presents summary statistics from the DNB funds data, after aggregating the data from the transaction level to the investor-year level. We restrict attention to

investor-years with at least one fund trade. In a given year, there are between 150,000 and 270,000 unique investors with at least one fund trade. Around half of the investors are male. Most investors are old (60+) or prime-aged (40–60) and, in a typical year, less than 20% are young (20–40). Both the age and the sex compositions are fairly stable across years. The yearly trade value (not inflation-adjusted) varies between NOK 38,000 and 83,000, or about $4,750–10,375, spread out across an average of 4 to 7 transactions. Trading activity measured in the number of transactions is highest in the years leading up to the financial crisis in 2007; the lowest recorded mean number of trades, at 3.89, is in 2008, down from a high of 7.43 in 2007.

Table IA.III. Overview of DNB Data

This table shows summary statistics from the DNB funds data. The underlying data are at the investor-year level and, for the purposes of this table, we only keep investor-years with at least one fund trade. The four leftmost columns show the fractions of DNB investors in a given year that are male, young (20–40), prime-aged (40–60), or old (60+). (The DNB data only provide investors' ages in ten-year bins.) The next three columns show investors' mean yearly trading value and their yearly number of trades, as well as the total number of unique investors with at least one trade in a given year.

	Male	Young	Prime	Old	Value	#Trades	#Investors
2000	0.49	0.11	0.31	0.57	38716.39	4.89	151011
2001	0.47	0.14	0.34	0.51	39789.83	5.75	230486
2002	0.47	0.14	0.32	0.53	36718.87	6.13	241325
2003	0.46	0.15	0.33	0.50	42521.45	6.32	207490
2004	0.48	0.15	0.33	0.50	41195.17	6.18	240924
2005	0.48	0.15	0.32	0.50	89251.92	6.58	268749
2006	0.48	0.17	0.32	0.44	79326.59	7.40	271193
2007	0.48	0.18	0.32	0.43	64342.67	7.43	286876
2008	0.49	0.18	0.32	0.43	83791.17	3.89	206612
2009	0.50	0.20	0.34	0.37	51840.49	4.47	140551
2010	0.50	0.20	0.34	0.37	57128.68	4.44	150973

C. Media Use Survey: Broadband use

In the main text, we use an instrumental variable model to explore the effects of broadband internet use on equity market participation and find that broadband use increases equity market participation. In additional analyses, we use data from the Media Use Survey to estimate heterogeneous effects for subgroups by age, sex, and education. Here, we provide additional details on the Media Use Survey.

C.1. About the Media Use Survey

Since 1991, Statistics Norway has conducted annual surveys on individuals' access to and consumption of media. The surveys are cross-sectional, with representative samples of about 2,000-3,000 individuals drawn from the population aged 9-79. Respondents are interviewed about a wide array of topics related to their access to and consumption of media, including questions on whether the individual had access to dial-up or broadband internet. We received anonymized extracts from these survey data sets for the years 2000–2010, with information on the respondents' age, sex, educational attainment, and municipality of residence. Following Bhuller et al. (2013), we exclude respondents that report not having a PC installed in their home and thus focus on broadband adoption among individuals that actually have the means to adopt broadband. We also exclude individuals that are younger than 16 in the survey year.

C.2. Summary statistics

Table IA.IV provides summary statistics from the Media Use Survey. After excluding respondents that do not have access to a computer, we are left with between 1,150 and 1,500 respondents each year between 2000 and 2010. In a typical year, 50 percent of the respondents are male. Across all respondents, 35-40 percent are young (16–34 years),

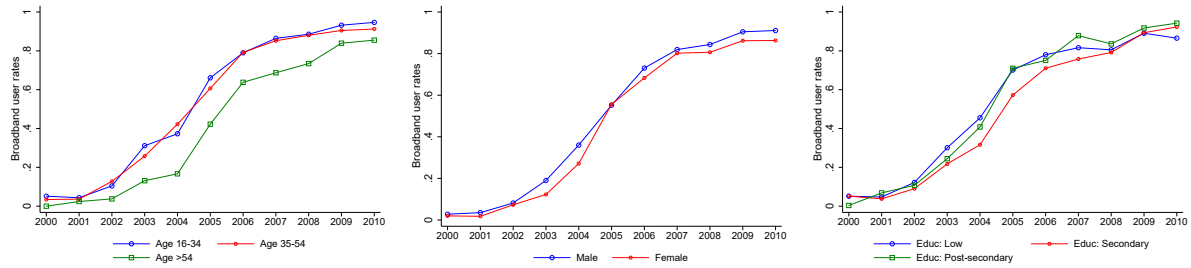
40 percent prime-aged (35–54 years), and 20-25 percent are old (> 55 years). About 25 percent of the respondents are low-educated (≤10 years), 35 are high-educated (>13 years), and the remaining 40% have completed between 11 and 13 years of education (medium-educated). Over time, the average respondent becomes slightly older while the sex and education compositions remain fairly stable.

Figure IA.1 summarizes broadband user rates by age, sex, and education. Over the broadband reform period 2000–2010, broadband user rates increase sharply across all subgroups. Older individuals seem to adopt broadband internet at a somewhat slower pace than younger individuals.

Table IA.IV. Overview of Media Use Survey

This table shows summary statistics from the Media Use Survey. The first seven columns show the fractions of respondents in a given year that are male, young, prime-aged, old, or have low, medium, or high education. The rightmost column reports the number of respondents in a given survey wave.

	Male	Young	Prime	Old	Low Educ	Med Educ	High Educ	N
2000	0.524	0.416	0.457	0.127	0.275	0.357	0.368	1173
2001	0.520	0.405	0.457	0.139	0.259	0.404	0.338	1191
2002	0.520	0.415	0.424	0.161	0.257	0.415	0.328	1236
2003	0.520	0.410	0.423	0.167	0.250	0.419	0.331	1211
2004	0.515	0.422	0.407	0.171	0.221	0.431	0.348	1240
2005	0.506	0.408	0.409	0.183	0.237	0.405	0.358	1327
2006	0.527	0.384	0.411	0.205	0.252	0.388	0.360	1371
2007	0.510	0.368	0.408	0.224	0.208	0.442	0.350	1362
2008	0.501	0.333	0.437	0.230	0.212	0.425	0.363	1395
2009	0.523	0.355	0.399	0.246	0.221	0.398	0.381	1437
2010	0.508	0.341	0.394	0.265	0.185	0.429	0.386	1481



Panel A. Age Panel B. Sex Panel C. Education

Figure IA.1. Subgroup-specific broadband user rates. This figure presents evidence on subgroup heterogeneity in broadband internet user rates over the sample period 2000–2010. Subgroup-specific user rates are calculated using the Media Use Survey described in Internet Appendix Section C. Panel A plots broadband user rates for three age bins. Panel B plots broadband user rates separately for males and females. Panel C plots broadband user rates for three education groups.

D. ICT Usage Survey: Internet Activities

In the main text, we show that broadband internet use increases individuals' equity market participation. To inform this finding, we use data from the ICT Usage Survey, which provides details about how households interacted with the internet during the broadband reform period, 2000–2010. Here, we provide more details on the ICT Usage Survey.

D.1. About the ICT Usage Survey

Since 2003, Statistics Norway has conducted annual surveys on individuals' access to and use of information and communications technology (ICT). The surveys are cross-sectional, with representative samples of more than 1,000 individuals drawn from the population aged 16-79. Respondents are interviewed about a wide array of topics related to their access to and use of ICT, including questions on whether the individual has used internet and broadband for particular purposes such as online banking and stock trading. We received anonymized extracts from the ICT Usage Survey data sets for the years 2003 to 2010, with information on the respondents' age, sex, and educational attainment.

D.2. Summary statistics

Table IA.V provides summary statistics from the ICT Survey. There are between 1,150 and 1,250 responses each year between 2003 and 2010. In a typical year, 50% of the respondents are male. Across all respondents, about 30-35% are young (16–34 years), 40% are prime-aged (35–54 years), and 25% are old (> 55 years). Over time, the respondents become slightly older on average while the fraction of males stays fairly stable across the full period 2003–2010.

Table IA.V. Overview of ICT Usage Survey

This table shows summary statistics from the ICT Usage Survey. The first four columns show the fractions of respondents in a given year that are male, young (16–34), prime-aged (35–54 years), and old (>54 years). The rightmost column gives the number of respondents in a given year.

	Male	Young	Prime	Old	N
2000	0.488	0.372	0.394	0.219	1216
2003	0.488	0.372	0.394	0.219	1216
2004	0.499	0.345	0.400	0.240	1188
2005	0.497	0.359	0.396	0.235	1188
2006	0.525	0.336	0.378	0.270	1195
2007	0.507	0.298	0.394	0.294	1210
2008	0.493	0.298	0.412	0.273	1120
2009	0.494	0.277	0.413	0.291	1161
2010	0.500	0.272	0.414	0.289	1014

D.3. Survey questions: Online stock/financial purchases

In Figure 4 of the main text, we summarize a variable Stock/financial$_{it}$ to gauge the extent to which respondents to the ICT Usage Survey used the internet to purchase stocks and/or financial services before, during, and after the Norwegian broadband reform period. Here, we detail how Stock/financial$_{it}$ is constructed. For respondent i in survey wave t, Stock/financial$_{it}$ equals one if for the question *"What types of goods or services did you buy or order over the Internet for private use in the last 12 months? Tick all that apply."* the box

– Share purchases, insurance policies and other financial services,

is ticked. Stock/financial$_{it}$ equals zero for respondents that do not tick this box. In Figure 4 of the main text, we summarize the mean of Stock/financial$_{it}$ for each survey wave over the period 2003–2010. The exact wording of the question above is taken from the 2010 survey wave. Note that the wording is slightly different in the 2003 survey wave compared to the later waves, 2004–2010. In 2003, respondents are asked whether they have *ever* purchased stocks or financial services online while in the 2004–2010 waves, respondents are asked whether they have done so in the past 12 months. As a result, in

Figure 4 of the main text, we are likely to underestimate the increase in Stock/financial$_{it}$ from before (2003) to after (2010) the broadband reform.

D.4. Survey questions: Online information acquisition and learning

In Figure 4 of the main text, we also summarize three variables Health$_{it}$, OnlineBanking$_{it}$ and OtherInfoAcq$_{it}$ to gauge the extent to which, respectively, respondents to the ICT Usage Survey used the internet to search for information about health, for online banking, or to engage in other forms of online information acquisition and learning before, during, and after the Norwegian broadband reform. Here, we detail how these three variables are constructed. For respondent i in survey wave t, we focus on the question *"For which of the following activities did you use the Internet in the last 3 months for private purpose? Tick all that apply."* and check whether any of the following boxes are ticked (our variable names are in parentheses):

- Finding information about goods or services (Goods/Services$_{it}$).
- Using services related to travel and accommodation (Travel$_{it}$).
- Looking for a job or sending a job application (JobMarket$_{it}$).
- Doing an online course in any subject (Education$_{it}$).
- Internet banking.
- Seeking health-related information (e.g., injury, disease, nutrition, improving health, etc).

Constructing our variables, we set Health$_{it}$ equal to one if the final box is ticked, and zero otherwise, OnlineBanking$_{it}$ is set equal to one if the second to last box is ticked, and zero otherwise, and finally, OtherInfoAcq$_{it}$ is set equal to one if any of the first four boxes

are ticked, and zero otherwise. In Panel A, Figure 4 of the main text, we summarize the means of Health_{it}, $\text{OnlineBanking}_{it}$ and OtherInfoAcq_{it} before (2003) and after (2010) the broadband reform. Note that the exact wording of the questions above comes from the 2010 survey wave. The 2003 survey asked three separate questions about online education: whether the respondents have taken i) formal education online, ii) continuing education online, or iii) other courses online related to job opportunities. In 2003, we set Education_{it} equal to one if the subject answers "Yes" to either of these questions. In 2010, we set Education_{it} equal to one if the respondents answers "Yes" to to "Doing an online course in any subject." The results in Panel A, Figure 4 of the main text are robust to omitting Education_{it} from the definition of OtherInfoAcq_{it}.[21]

[21]The fraction of respondents with $\text{Education}_{it} = 1$ in 2003 and 2010 are 5% and 5%, respectively. For the remaining questions not individually summarized in Figure 4, the corresponding pre-post figures are: $\text{Goods/Services}_{it}$ (62%, 79%), Travel_{it} (40%, 60%), JobMarket_{it} (16%, 20%).

E. First Stage: Timing

In equation (3) of the main text, we propose a first stage relationship between broadband coverage and broadband use that assumes that households adopt broadband one year after receiving broadband coverage. Here, we provide additional empirical evidence on the dynamics of broadband adoption in private homes. We present separate first stage estimates using the contemporaneous, once-lagged, and twice-lagged coverage rate, respectively, as the explanatory variable. We also provide estimates from a first stage regression where all three coverage lags are included simultaneously. The results suggest that households start adopting broadband around a year after receiving coverage.

Table IA.VI. First Stages

This table reports estimates of ϕ from the first stage regression (3) in the main text, using the contemporaneous (z_{kt}), once-lagged (z_{kt-1}), and twice-lagged (z_{kt-2}) broadband coverage, respectively, as the explanatory variable. All regressions are based on the same 422 municipalities $\times$ 10 years $= 4,220$ observations as in the main text. Standard errors are clustered at the municipality level and presented in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	Outcomes			
	Use	Use	Use	Use
Current coverage	0.0181**			-0.0137
	(0.0088)			(0.0088)
Lagged coverage		0.1116***		0.0685***
		(0.0079)		(0.0059)
Twice-lagged coverage			0.1380***	0.1065***
			(0.0083)	(0.0077)
N	4220	4220	4220	4220

F. Income Effects

In the main text, we find that broadband internet use leads to increased equity market participation. Access to broadband internet might increase households' disposable incomes, which could be driving the observed increase in equity market participation. For example, Akerman et al. (2015) find that the Norwegian broadband reform increased the productivity of high-skilled workers. In Table IA.VII, we re-estimate the baseline IV and reduced form models using measures of household income, debt, and bank deposits as the outcomes. We find that broadband has no statistically or economically significant effect on household income, debt, or bank deposits. Overall, it seems unlikely that the main results are driven by increases in household incomes.

Table IA.VII. Income Effects

This table shows estimates of ω and ϕ from the IV model (2)–(3) in the main text as well as δ from the reduced form model (5). The outcomes are household income, debt, and bank deposits. All of the outcomes are first averaged across households at the municipality-level before being transformed with the natural logarithm. All regressions are based on the same 422 municipalities $\times$ 10 years $= 4,220$ observations as in the main text. Standard errors are clustered at the municipality level and presented in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	Outcomes		
	Log(Income)	Log(Debt)	Log(Deposits)
IV Estimate	0.0088	0.0475	-0.0991
	(0.0469)	(0.1045)	(0.1123)
Reduced Form	0.0010	0.0053	-0.0111
	(0.0052)	(0.0117)	(0.0126)
First Stage	0.1116***	0.1116***	0.1116***
	(0.0079)	(0.0079)	(0.0079)
N	4220	4220	4220