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Broadband Internet and the Stock Market Investments of Individual Investors

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ABSTRACT

We study the effects of broadband internet use on the investment decisions 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 tilt their portfolios toward funds, thereby obtaining more diversified portfolios and higher Sharpe ratios, and do not increase their trading activity in stocks. Overall, access to high-speed internet spurs a "democratization of finance," with individuals making investment decisions that are more in line with the advice from portfolio theory.

DOES INTERNET USE SPUR A "democratization of finance" (Shiller (2007)), meaning improved portfolio choices by households, or does it amplify behavioral biases? Pioneering studies by Barber and Odean (2002) and Choi, Laibson, and Metrick (2002) suggest the latter: In the 1990s, individuals who adopted online stock trading platforms increased their trading activity and trading costs without any apparent increase in risk-adjusted returns. More recently, social media usage appears, at best, to have mixed effects on the quality of financial decisions (e.g., Allen et al. (2022), Barber et al. (2022), Hirshleifer, Peng, and Wang (2023)).

We study the effects of the rollout of high-speed broadband internet on the stock market participation and portfolio choices of individual investors in Norway in the 2000s. In addition to the rollout, Norway offers extraordinary

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data opportunities through detailed common stock and equity fund trading records for the entire population, which allows us to estimate the effects of internet use not only within subgroups of investors but also within the broader population. We find that the increased internet use induced by the broadband rollout leads to a substantial increase in stock market participation and to increased diversification, Sharpe ratios, and portfolio efficiency (as defined by Calvet, Campbell, and Sodini (2007)) among existing investors.

Standard asset allocation theory suggests that all individuals should participate in the stock market, provided their background risks are not too positively correlated with stock returns. 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 (Barber and Odean (2001)), and acquiring financial competence (Lusardi and Mitchell (2014), Lusardi, Michaud, and Mitchell (2017)). On the one hand, it is plausible that faster internet would reduce the cost of these activities and thus increase stock market participation rates. On the other hand, faster internet also reduces the cost of leisure-related activities, such as social networking or watching movies, which could crowd out individuals' focus on personal finance. For example, Brown et al. (2020) document that stock market trading activity increases on days with Blackberry outages, consistent with internet use being an attention-diverting activity.

To study the effects of broadband use on portfolio choices, we employ several data sets. Data from the Norwegian Central Securities Depository (NCSD) provide a record of common stock and fund transactions made by all Norwegian individual investors between 2000 and 2010. Each transaction can be linked to register data on investor sociodemographics, including age and gender, income, education, and municipality of residence, allowing us to compare those who experience an expansion of broadband and those who do not. Household balance sheet data allow us to construct measures of wealth and returns to wealth. In secondary analyses, we use data from two nationally representative surveys on internet use to analyze potential channels underlying the main results.

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 resulting spatial and temporal variation in broadband coverage across municipalities in an instrumental variables (IV) setup: We instrument the share of households with a broadband subscription in a given year with the share of households that are covered by broadband infrastructure.[1]

We find that broadband internet use leads to increased stock market participation driven by an increase in the share of the population investing in equity funds; we find no effect of internet use on the share of the population holding

[1] Existing works that use the Norwegian broadband data, and a very similar empirical methodology, include Bhuller et al. (2013) on the effects of broadband use on sex crime, Akerman, Gaarder, and Mogstad (2015) on the effects of broadband on worker productivity, Bhuller, Kostøl, and Vigtel (2020) on the effects of broadband on labor market matching, and Akerman, Leuven, and Mogstad (2022) on the effects of broadband on bilateral trade.

common stocks. The effects are economically significant: For every 10 percentage point increase in broadband use, the stock market participation rate increases by 0.7 percentage points, that is, about 5.3% of the prereform mean. The effects of broadband internet are larger for the least wealthy individuals when measured relative to prereform participation rates. Broadband also has a slightly larger effect for less-educated individuals than for those with the most education. These findings suggest that internet use spurs a democratization of finance: Stock market participation increases, particularly among the socioeconomic groups with the lowest participation rates to begin with.

Our second main question is whether broadband internet affects the trading behavior and portfolio efficiency of individuals who are already stock market 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 well informed and thus lead to increased trading activity and possibly decreased diversification.[2] On the other hand, broadband may provide easier access to information about sound portfolio allocation principles and thus lead to improved choices. We find that existing investors on average do not increase their stock trading activity following the introduction of broadband, though there is a slight tendency for the most active traders to become even more active. Moreover, existing investors tilt their portfolios toward equity funds, thereby obtaining more diversified portfolios and higher Sharpe ratios, and portfolio efficiency, as defined by Calvet, Campbell, and Sodini (2007), increases.

To better understand the channels through which internet use leads to increased equity market participation without excessive stock trading, we use a nationally representative survey that provides details on households' internet activities. The survey provides evidence of a direct link between internet use and stock market participation: For example, the fraction of respondents using the internet to purchase stocks or financial services more than quadruples over the reform period. The survey responses also show a broad trend toward increased use of the internet for information acquisition and learning. In addition, data on firms' internet activities and marketing expenses allow us to document important supply-side responses to increased internet access. In Section VI.C, we present evidence consistent with firms responding to increased internet use among households by supplying the households with more information—through new web pages, new online sales platforms, and increased marketing. These supply-side effects may further reduce the cost for households of online information acquisition.

If the introduction of broadband internet eases access to information and improves individuals' financial skills, it could also have effects on aspects of financial decision making other than equity market participation. In auxiliary analyses, we use household balance sheet data to analyze broader financial outcomes. We find that broadband internet use increases participation in

[2] 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 dial-up, the download takes about 10 minutes, versus 30 seconds with a 1 Mbps DSL broadband connection.

bonds and bond funds and in unlisted stocks. We also find that broadband use increases households' financial wealth and their return on financial wealth, though only the latter effect is statistically significant. These results corroborate the message from the main analyses: Broadband internet appears to have a beneficial impact on financial decision making.

Our paper is primarily related to a literature on how internet use affects the portfolio choices of individual investors (e.g., Barber and Odean (2002), Choi, Laibson, and Metrick (2002), Barber et al. (2022), Allen et al. (2022), Hirshleifer, Peng, and Wang (2023)). For example, Barber and Odean (2002) and Barber et al. (2022) find evidence of excessive stock trading among adopters of online trading platforms, and Allen et al. (2022) document herding and speculation among users of Twitter, Stocktwits, and Reddit's "wallstreetbets" stock forum. In contrast, we document positive effects of internet use on the stock market participation and portfolio efficiency of individual investors. We believe our results differ from those of the existing literature for relatively straightforward reasons. The existing literature documents detrimental effects of the use of internet platforms that aim to make trading easier or more fun and for this reason likely attract investors with speculative motives. Access to broadband internet, by contrast, eases all internet activities, not just online trading, and affects a broad group of people. While we find some evidence of increased trading activity among the very most active individual investors following the introduction of broadband internet, which is consistent with the existing literature, our survey evidence suggests a much clearer trend toward using the internet for information acquisition and learning over the broadband reform period.

Our paper also relates and contributes to a literature in household finance (see Campbell (2006), Guiso and Sodini (2013), Gomes, Haliassos, and Ramadorai (2021) for surveys) that tries to understand why, relative to the predictions of the CCAPM and other asset allocation models, too few individuals invest in equity markets—the "participation puzzle" (e.g., Grinblatt, Keloharju, and Linnainmaa (2011), Guiso and Sodini (2013), Campbell (2016)). The literature has suggested several factors that affect stock market participation, including personal wealth (Brunnermeier and Nagel (2008), Calvet, Campbell, and Sodini (2009), Briggs et al. (2021), Fagereng, Mogstad, and Rønning (2021)), educational attainment (Cole, Paulson, and Shastry (2014)), computer ownership (Bogan (2008)), and financial literacy (Lusardi and Mitchell (2014), Lusardi, Michaud, and Mitchell (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, document that participation increases with access to high-speed broadband internet. [3] We also document positive effects of broadband internet on participation rates in other assets, including bonds and bond funds and unlisted stocks.

[3] Our results line up with a conjecture from the survey article of 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).

Finally, our paper speaks to ongoing policy debates on the government expansion or funding of broadband infrastructure (see Internet Appendix[4] Section I for an overview of recent policy changes, as well as international comparisons of broadband coverage and usage).[5] The introduction of broadband internet constitutes a major policy shift that was enacted in Norway in the 2000s. We shed light on this policy's effects, and the central finding of our paper is that access to and use of high-speed internet leads to a democratization of finance: Stock market participation increases, and existing investors increase their portfolio efficiency.[6]

The paper proceeds as follows. Section I describes the broadband reform. Section II presents the data. Section III introduces the empirical methodology, and Section IV presents the main results on stock market participation. Section V presents results for existing investors. Section VI discusses mechanisms, and Section VII concludes. The Internet Appendix provides additional documentation and analysis.

I. The Reform

We seek to estimate the causal effects of broadband internet use on stock market participation and other financial outcomes. 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 coverage at a reasonable price throughout the country.

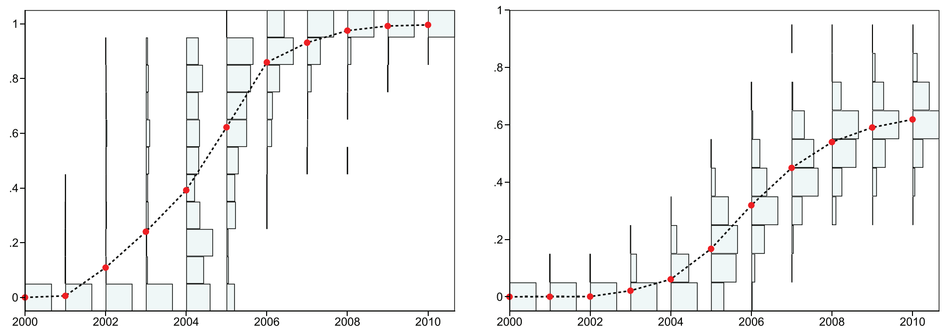
The transmission of broadband signals through fiber-optic cables requires the installation of local access points. During the 2000s, such access points were progressively rolled out in Norway, which generates spatial and temporal variation in broadband coverage. The broadband expansion occurred in stages partly because there was limited public funding, and partly 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.[7] Before 2002, most municipalities have no broadband coverage, but over time the distribution widens, with several municipalities reaching coverage rates of 80% by 2006. By 2010,

[4] The Internet Appendix may be found in the online version of this article.

[5] For example, in May 2022, following up on campaign trail promises, the Biden administration committed to reducing the cost of high-speed internet for low-income families (White House (2022)).

[6] The prior literature focuses on the effects of internet on education and health (LaRose et al. (2011), Bauerly et al. (2019)), democratic participation (Campante, Durante, and Sobbrio (2017)), economic growth (Czernich et al. (2011)), wage and employment growth (Forman, Goldfarb, and Greenstein (2012)), productivity for firms (Akerman, Gaarder, and Mogstad (2015)), and possible costs including increased sexual crime (Bhuller et al. (2013)), reduced psychological well-being (Kraut et al. (1998)), and internet addiction (Ko et al. (2012)).

[7] We note that fiber-optic (fixed line) broadband is distinct from mobile broadband technology. All our measures of broadband coverage and use are based on fiber-optic broadband coverage and use. See Section II for more details about the broadband coverage and use data.



Panel A. Broadband coverage rates

Panel B. Broadband user rates

Figure 1. Broadband coverage and user rates, 2000 to 2010. This figure shows the overall mean and distribution of broadband coverage rates (Panel A) and user rates (Panel B) across municipalities for each year during the period 2000 to 2010. The overall means are shown as solid circles, and the distributions are displayed as histograms with 11 equidistant bins. (Color figure can be viewed at wileyonlinelibrary.com)

nearly all municipalities have complete coverage for the entire population.[8] Section III presents evidence that the timing of the broadband expansion is uncorrelated with prereform trends in stock market participation, which is key to the validity of our IV strategy.

Panel B of Figure 1 plots the mean broadband user rate and its distribution at the start of each year between 2000 and 2010. The figure shows a strong increase in broadband user rates that appears to lag coverage rates by about one year. In Internet Appendix Table IA.XIV, we regress broadband user rates on contemporaneous and lagged coverage rates, and find that households start adopting broadband one year after receiving coverage. Our IV strategy outlined in Section III incorporates this feature of the data: We use the prior year's coverage rate (z_{kt-1}) as our instrument for the current user rate (i_{kt}), as specified in the "first stage" relationship in equation (3). Internet Appendix Figure IA.6 provides a graphical illustration of the first-stage relationship.

II. Data

Our analysis uses several administrative register data sets from Norway. The register data encompass the entire population of individuals and firms in Norway, and they can be linked via unique identifiers. The coverage and reliability of Norwegian register data are rated as exceptional in international quality assessments (Atkinson, Rainwater, and Smeeding (1995)). Døskeland and Hvide (2011) provide a general description of Norway and the Oslo Stock

[8] As all the municipalities reach universal broadband coverage within a relatively short time span, the Norwegian reform cannot be used to study the long-term effects of broadband.

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.[9] Also, apart from a substantial government ownership share 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 data on all common stock trades made on the OSE by Norwegian residents between 1993 and 2010 from the NCSD, as well as data on all trades made by Norwegian residents in all equity funds and exchange traded funds covered by the NCSD. For each transaction made by an individual investor, the data contain the anonymized identifier of the individual, the date of the 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 *Bø rsprosjektet* 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 cover only about 25% 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.[10] The DNB data cover another 50% of all Norwegian fund customer relationships (see Internet Appendix Section III for details on these data). We cannot merge the NCSD and DNB data because the investor identifiers 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 we use the DNB data rather than the NCSD fund data.

[9] Using data from SimilarWeb in April 2022, we find that Norwegians and Americans overlap on about 50% of each country's most-visited websites; Reddit, the subject of several recent papers on American individual investors (e.g., Allen et al. (2022)), is the 14$^{\text{th}}$ most-visited site in Norway. Popular Norwegian stock forums during the broadband reform period, such as HegnarOnline, appear similar in both content and activity to their American counterparts, such as Reddit's "wallstreetbets."

[10] Until 2003, DNB was known as Den Norske Bank ("The Norwegian Bank").

B. Internet Data

The internet data set contains a complete record of the share of households that are covered by or subscribe to broadband internet in every municipality over the period 2000 to 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 to end users are required to file annual reports about their coverage rates to the Norwegian Telecommunications Authority. The broadband coverage rates are based on information on the area signal range of the local access points and detailed information on households' place of residence. To avoid double-counting, the computation of coverage rates takes into account the possibility that multiple suppliers provide broadband coverage to households living in the same area.

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 to 2010, the data on broadband subscriptions come from the quarterly Internet Survey performed by Statistics Norway, which surveys all suppliers of broadband access to end users. The Internet Survey contains information on the total number of households with broadband subscriptions in each municipality.

C. Other Data

The sociodemographic data come from administrative registers provided by Statistics Norway and cover all Norwegian residents in the period 1993 to 2010. The registers contain individual demographic information, such as sex, age, and marital status, socioeconomic data, such as years of education, income, and wealth, and geographic identifiers for municipality of residence. The information on educational attainment is based on annual reports from Norwegian educational establishments, and the income and wealth data are collected from tax records and other registers. The data sources are the same as the ones used by Eika, Mogstad, and Vestad (2020) to study household consumption, income, and wealth.

The firm-level data come from yearly accounting statements submitted by all incorporated firms to the tax authorities in the period 2001 to 2010. The data include detailed information from firms' income statements and balance sheets: The income statements cover more than 80 unique income or expense items, while the balance sheets cover more than 90 types of assets or liabilities. Using unique firm identifiers, we merge the income statement and balance sheet data with information on the industry and geographic location of each firm from the Central Register of Establishments and Enterprises.

In addition to the register data described above, our analyses use several survey data sets. The survey data sets are described in the main text and appendices.

D. Summary Statistics

Although most of the data sources provide information at the individual level, the broadband coverage data, the source of exogenous variation, provide information only 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 part of Table I displays the mean of stock market participation at the municipality level, with standard deviations in parentheses.[11] 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 increases over time, with *Holds Any* increasing from about 13% in 2000 to 18% in 2010. The table also shows the fraction of the population 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% over the period 2000 to 2010.

The second part of Table I shows means and standard deviations of broadband coverage and broadband user rates. Over the period 2000 to 2010, the mean broadband user and coverage rates are 27.7% and 61.2%, respectively. In 2000, Norway had zero broadband coverage and use. In 2008, mean coverage reached 97.5%, increasing further to 99.6% in 2010, whereas the mean user rate reached 54% in 2008 and 62% in 2010. The largest standard deviation in broadband coverage rates across municipalities is observed around 2004, whereas user rates vary the most across municipalities during the final four years of the broadband rollout period.

Finally, the third part of Table I shows sociodemographic 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 2000 to 2010 period. Internet Appendix Table IA.IV summarizes additional municipality characteristics.

III. Methodology

The chief goal of our paper is to estimate the causal effect of broadband internet use on individuals' stock market participation and other outcomes. Our IV strategy exploits exogenous variation in broadband internet use generated by the gradual expansion of broadband coverage between 2001 and 2010. To make the identifying assumptions of the IV model as transparent as possible, we start out in Section III.A with the reduced form of the IV model, which

[11] As in our main analyses, the unit of analysis in Table I is municipality-year. In other words, the descriptive statistics in Table I are reported for the average municipality, not the average person.

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 to 2010. The data are at the municipality-year level. Internet Appendix Section II provides details on variable construction and 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)
Education (in years)	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)
Household income (000's)	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)
Students (%)	11.09	11.55	11.58	11.29	11.20	10.57	10.43
	(1.59)	(1.72)	(1.69)	(1.58)	(1.53)	(1.41)	(1.37)
Poverty rate (%)	4.97	5.68	4.93	5.31	5.05	4.49	4.61
	(1.39)	(1.59)	(1.29)	(1.41)	(1.33)	(1.26)	(1.26)
Urban residence (%)	49.50	47.87	49.19	49.22	49.40	50.26	50.26
	(27.68)	(27.49)	(27.37)	(27.89)	(27.89)	(27.76)	(27.76)
Public sector (%)	27.01	25.77	26.92	26.47	25.95	26.53	29.22
	(5.23)	(5.41)	(5.18)	(4.99)	(4.79)	(5.11)	(5.37)
Services sector (%)	30.85	28.63	30.17	29.98	29.98	31.26	33.47
	(4.79)	(5.33)	(4.78)	(4.63)	(4.44)	(4.54)	(4.38)
Private services sector (%)	7.59	7.01	7.18	7.16	7.45	8.19	8.29
	(3.40)	(3.41)	(3.45)	(3.30)	(3.34)	(3.60)	(3.19)
Distance to center (in kms)	8.19	8.66	8.47	8.20	8.24	8.00	8.00
	(7.25)	(7.46)	(7.32)	(7.03)	(7.15)	(7.39)	(7.47)
Travel time (in hours)	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	4,220	422	422	422	422	422	422

regresses stock market participation and other outcomes directly on the instrument, before explaining the IV model in Section III.B.

A. Reduced Form and the Exogeneity Assumption

The reduced form of our IV model is specified as follows:

$$y_{kt} = \delta z_{kt-1} + \mu_k + \chi_t + \varepsilon_{kt}, \tag{1}$$

where y_{kt} is the stock market participation rate (or some other outcome) for municipality k in year t, z_{kt-1} is the prior year's broadband coverage rate, the instrument, and μ_k and χ_t are municipality and year fixed effects. The parameter δ captures the effect of broadband coverage on the stock market participation rate. This effect is relevant for policymakers who contemplate increasing their broadband coverage, z_{kt-1}.

Identifying assumption: The reduced-form coefficient δ can be given a causal interpretation if z_{kt-1}, our instrument, is exogenous—that is, as good as randomly assigned—conditional on municipality and year fixed effects. Controlling for municipality and year fixed effects implies comparing changes in outcomes within municipalities while eliminating common changes over time. Thus, exogeneity can be interpreted as a common trends assumption: In the absence of broadband coverage expansions, municipalities with early and late expansions would, on average, have followed the same trend in outcomes.

Assessing the assumption: The validity of this exogeneity assumption can be evaluated by comparing prereform trends in outcomes and characteristics for municipalities with early and late broadband coverage expansions. The test can be bolstered by also comparing prereform levels of outcomes and characteristics: While the municipality fixed effects in (1) would account for any time-invariant differences between treated and control municipalities, one might argue that common trends are more likely if the municipalities with early and late expansion were similar in levels. To examine this, we estimate the following regression separately for each year of the broadband expansion, from 2001 to 2010:

$$\Delta z_{kt} = \alpha + [m_{k,2000}]'\beta + \kappa_{kt}, \tag{2}$$

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 trends and levels in stock market participation, average years of educational attainment, unemployment and urbanization rates, and household incomes, all measured in the prereform year 2000.[12] The goal is to assess whether or not municipalities with different broadband

[12] We estimate (2) by pooling data from the 2000 to 2010 period and interacting all the terms in equation (2) with year fixed effects. This procedure provides identical coefficients as estimating equation (2) year by year, but it allows us to cluster the standard errors at the municipality level.

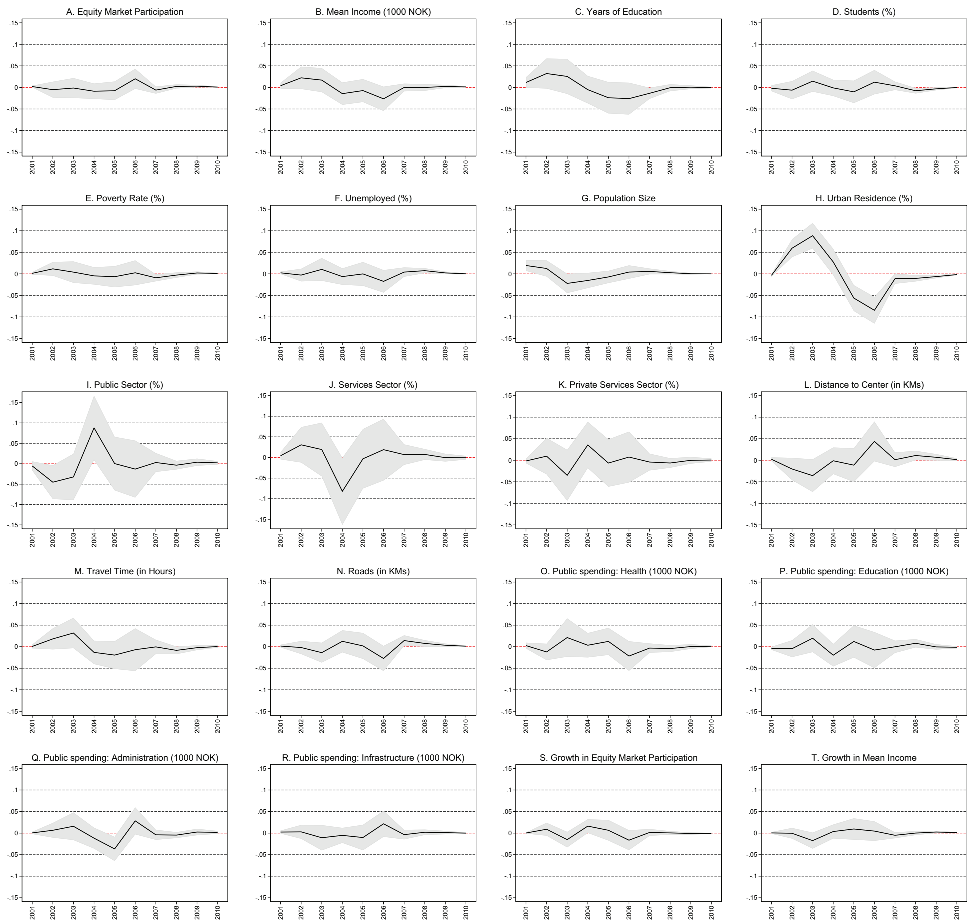


Figure 2. Timing of broadband rollout and baseline covariates. This figure shows calendar year-specific estimates of β (along with the associated 95% confidence intervals) from equation (2), a regression of the change in municipality-level broadband coverage rates, Δz_{kt}, on baseline municipality characteristics, as measured in the prereform year 2000. For comparability across panels, all baseline municipality characteristics have been scaled by their respective standard deviations. Internet Appendix Section II provides an overview of the variable definitions. (Color figure can be viewed at wileyonlinelibrary.com)

coverage expansions looked similar in trends and levels of their outcomes and characteristics before the expansions.[13]

Figure 2 plots the estimated yearly β coefficients, with associated 95% confidence intervals. Importantly, we do not find evidence of any significant relationship between changes in the instrument and prereform levels (Panel A) or trends (Panel S) in stock market participation, or between changes in the instrument and other key determinants of stock market participation, such as

[13] This is the same diagnostic test as the one used by Bhuller et al. (2013) and Akerman, Gaarder, and Mogstad (2015).

household income and education, supporting the exogeneity assumption. We do find, however, that the timing of the broadband coverage expansion is correlated with prereform urbanization: More densely populated areas received coverage earlier than less densely populated areas, as evident from Panel H of Figure 2. A potential concern is therefore that our estimates might be biased due to differential underlying trends in stock market participation between urban and rural municipalities. We deal with this concern in several ways. First, in Figure IA.7 and Table IA.XIX, we show that urban and rural municipalities followed very similar trends in stock market participation in the years 1994 to 2000 prior to the broadband coverage expansion. Second, in Table IA.XX, we obtain almost identical results when we estimate the baseline IV model separately for urban and rural municipalities, which allows for differential time trends between urban and rural municipalities. Finally, in Section IV, we report results with and without a large set of time-varying controls, including urbanization, and find that the estimates barely move. Overall, the evidence supports the (conditional) exogeneity of z_{kt-1}.

Another potential threat to instrument exogeneity is that the timing of the broadband coverage expansion may coincide with other reforms or developments in the financial sector that impact stock market participation. In Internet Appendix Section XV, we address three such concerns: (i) a pension reform in 2006 that affected private- but not public-sector workers, (ii) financial sector growth over the broadband expansion period, and (iii) expansions in the availability of online banking and trading solutions over the same time period. We find no evidence of any significant relationship between these financial sector developments and the timing of the broadband coverage expansion.

B. IV Model and the Exclusion Restriction

Our IV model has the following first- and second-stage equations:

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

$$y_{kt} = \omega i_{kt} + \alpha_k + \tau_t + \epsilon_{kt}, \tag{4}$$

where i_{kt} is the broadband user rate and α_k and τ_t (and γ_k and θ_t in equation (3)) are municipality and time fixed effects, respectively. The IV parameter ω is given by the ratio of the reduced-form coefficient to the first-stage coefficient, that is, $\omega = \frac{\delta}{\phi}$, and measures the effect of broadband internet use on stock market participation.

Identifying assumptions: A causal interpretation of the parameter ω in (4) requires that the instrument z_{kt-1} is exogenous, as defined in Section III.A. We also have to assume that z_{kt-1} is *excludable* from the second stage (4).[14] This

[14] A third assumption of the IV model, which seems plausible in our setting, is monotonicity, namely, that increased access to broadband makes it weakly more likely that a household adopts broadband (Imbens and Angrist (1994)). A fourth assumption is instrument relevance, that

amounts to assuming that lagged broadband coverage affects stock market participation only through its impact on current household broadband use, and not directly in any other way.

Assessing the assumptions: Section III.A provides evidence supporting the exogeneity assumption. The exclusion restriction may still be violated if, for example, the installation of broadband has a direct impact on local real estate prices, which in turn impacts stock market participation, or, more subtly, if z_{kt-1} impacts labor productivity and incomes (and, in turn, stock market participation) through broadband adoption at the firm level. Section VI.A addresses these and other threats to the exclusion restriction. We also note that the instrument affecting some correlate of stock market participation, such as the extent of online information acquisition and learning, through its impact on i_{kt}, does *not* violate the exclusion restriction of the IV model. Instead, such effects should be interpreted as mechanisms that help explain the effects of broadband use on stock market participation. Sections VI.B and VI.C discuss possible mechanisms.

While we are primarily interested in the effects of broadband internet use on stock market participation and other outcomes—that is, ω from the IV model in equation (4)—we also report estimates of the reduced-form effect of broadband coverage on stock market participation (δ from equation (1)) and the first-stage effect of broadband coverage on broadband internet use (ϕ from equation (3)).

IV. Stock Market Participation

In Sections IV.A and IV.B, we present our main results concerning the effect of broadband internet use on stock market participation. In Section IV.C, we present additional results concerning the effects of broadband use on a broader set of financial outcomes.

A. Main Results

Column (1) of Table II shows estimates from the IV model (3)–(4) and the reduced-form model (1) using the stock market participation rate as the outcome. The estimated first stage coefficient equals 0.11, which means that a 100 percentage point increase in broadband coverage induces an additional 11% of the population to adopt broadband internet within the next year. The first stage relationship is strong, with an F-statistic around 200; weak instrument bias is not a concern. The reduced form is also highly significant, with a coefficient of 0.0078. Taken together, the first-stage and reduced-form coefficients imply an IV estimate of 0.0698, which means that for every 10 percentage point increase in the broadband user rate (the user rate's standard deviation is 10.06 in 2010; see Table I), the stock market participation rate

ϕ in equation (3) is nonzero. As shown in Section IV, we have a strong first stage. Recent works that estimate similar IV models include Ben-David, Franzoni, and Moussawi (2018), Farre-Mensa, Hegde, and Ljungqvist (2020), and Meling (2021). Bhuller et al. (2013) use an IV model identical to (3)–(4) to study the effects of broadband use on sex crimes.

Table II

Equity Market Participation

Panel A shows estimates of ω and ϕ from the IV model (3)–(4) as well as δ from the reduced-form model (1). The outcome variables 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 of Panel B shows estimates from IV and reduced-form models that include controls for time-varying municipality characteristics. See Internet Appendix Table IA.III for details about the control variables. The second column of Panel B shows estimates from IV and reduced-form models that include controls for time-varying municipality characteristics as well as municipality-specific linear time trends. The third column of Panel B shows estimates from the baseline IV and reduced-form models using *Holds Funds* as measured in the DNB data as the outcome variable. 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)	(0.0105)	(0.0099)
Reduced form	0.0078***	−0.0007	0.0085***	0.0057***	0.0034**	0.0028**
	(0.0018)	(0.0008)	(0.0018)	(0.0018)	(0.0013)	(0.0011)
First stage	0.1116***	0.1116***	0.1116***	0.1168***	0.1185***	0.1116***
	(0.0079)	(0.0079)	(0.0079)	(0.0077)	(0.0077)	(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	4,220	4,220	4,220	4,220	4,220	4,220
Prereform mean	0.1313	0.0865	0.0633	0.1313	0.1313	0.0893

increases by 0.698 percentage points, or approximately 5.3% of the prereform mean stock market participation rate. The effect is highly statistically significant.[15]

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 for every 10 percentage point increase in the broadband user rate, the fund holding rate increases by about 0.76 percentage points. In contrast, we find no statistically or economically significant effect of broadband use on stock holding rates. Given that the first-stage coefficients in columns (2) and (3) are unchanged compared to those in column (1) of Table II, the reduced-form coefficients paint the exact same picture. That is, the large effect of broadband

[15] The estimates in Table II are based on a balanced panel of municipality-year level observations, which means that the estimated effects pertain to the average municipality. One might also be interested in the effects for the average Norwegian, which can be obtained by weighting the municipality-year observations by their population counts. Doing so, we find an IV estimate of 0.17. Excluding the four largest cities from the estimation sample reduces the population-weighted IV estimate to 0.12, which suggests that our IV results are stronger in the most populous municipalities.

use and coverage 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 main ways. First, we include in the IV model (3)–(4) 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 control variables, the estimated effects are contained within the 95% confidence interval of the baseline estimates and remain positive and highly statistically significant.[16] 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 expansion to be correlated with differential underlying time trends in stock market participation across municipalities. Again, we find significant effects of broadband use on stock market participation, suggesting that the main results are not driven by differential underlying trends in stock market participation.

While a common robustness test in the literature, the inclusion in column (5) of Table II of municipality-specific time trends is somewhat contentious. The issue is that the municipality-specific trend not only may eliminate possible bias due to different underlying trends across municipalities—but it also may control away parts of the treatment effect. This is simply because the linear time trends in the outcome may be driven in part by the actual treatment effect. Indeed, the IV estimate in column (5) of Table II (0.0287) is outside the 95% confidence interval of the baseline IV estimate in column (1) (0.0698). In Internet Appendix Section XII, we follow Bhuller et al. (2013) in estimating municipality-specific trends using only data covering years *prior* to the expansion of broadband internet. For each municipality k, we first obtain a trend estimate, $\hat{\upsilon}_k$. We then extrapolate preexpansion time trends into our IV specification by including $\hat{\upsilon}_k t$ as a covariate in both the first- and the second-stage equations, which will take into account any variation in our instrument that reflects preexisting trends in the outcome. The results presented in Internet Appendix Section XII show that accounting for pretrends in this way has very little impact on our estimates. In particular, we obtain an IV estimate of 0.0704, which is very similar to the baseline IV estimate of 0.0698.

A potential concern relates to the coverage of the NCSD data with respect to fund holdings. While NCSD provides nearly exhaustive coverage of individuals' stock trades, its fund trade data are less exhaustive, covering trades by about 25% of all fund customer relationships in Norway (see Section II for details). Most notably, the NCSD data do not cover the fund trades made by

[16] Column (4) of Table II controls for a comprehensive list of municipality characteristics, all measured with little error using register data (see Internet Appendix Section II for details). One might still be concerned that unobserved control variables would, upon inclusion, drive the estimated effect in column (4) to zero. Following the approach in Oster (2019), we find that the results are robust to selection on unobservables, in the sense that selection on unobservables must be more than proportional to selection on observables for the bias-adjusted effects to be zero or switch signs.

clients at DNB, the largest bank in Norway, which accounts for about 50% of all fund customer relationships. In the final column of Panel B of Table II, we estimate the IV model using fund trading rates from the DNB data as the outcome. Similar to the main results, the findings show that the effect of broadband use on fund holding rates as measured in the DNB data is positive and statistically significant.[17] Hence, the main results are not specific to the fund customer relationships covered by the NCSD data but seem to apply more broadly.

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.[18] It is possible that the large IV estimates in Table II result from a strong response among a particular subgroup, such as young males. We now estimate the effects of broadband use for subgroups by age, sex, and educational attainment.

To estimate the effects of broadband use for 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 IV for details) for more than 1,000 individuals each year in the 2001 to 2010 period. 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% of the 4,220 municipality-year observations in the full sample. Then, we estimate the IV effect ω from equation (4) separately for each of the subgroups, using all municipality-years with nonmissing i_{kt} values. The results are presented in Panel A of Table III. The estimates are positive across sociodemographic groups with some heterogeneity: Relative to prereform 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%) than for females (29%), and larger for younger (59%) than for older (34%) individuals. The effects are reasonably similar across education groups (30%, 43%, and 27% for low, medium, and high education groups, respectively).

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

[17] We note that the DNB and NCSD databases cover different individuals, which means that coefficient estimates from the two samples are not directly comparable. Unlike the NCSD data, the DNB data do not include detailed sociodemographic characteristics, which means that we cannot credibly use covariate balancing (matching) techniques to construct comparable estimation samples.

[18] This is often referred to as a local average treatment effect, or LATE (see Imbens and Angrist (1994)).

Table III

Trader Heterogeneity

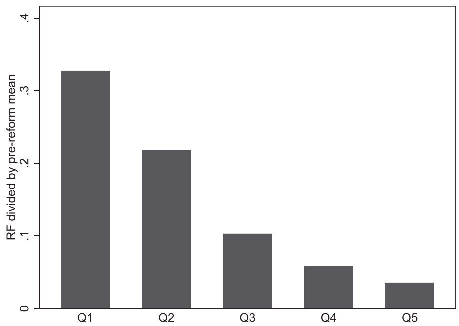
Panel A presents subgroup-specific estimates of ω and ϕ from the IV model (3)–(4) as well as δ from the reduced-form model (1). Equity market participation rates for subgroups by age, gender, and educational attainment are calculated using data from the NCSD. Broadband user rates for each of the subgroups are calculated using the survey described in Internet Appendix Section IV. 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 (1). In Panel B, the estimation sample includes all 4,220 municipality-year observations in the main sample. In both panels, the prereform 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

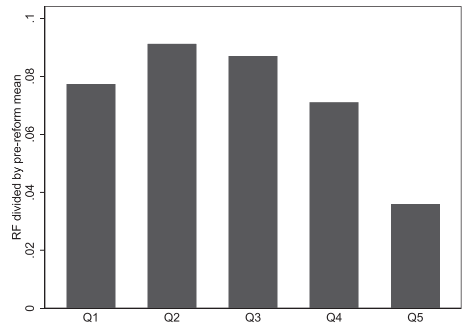
	Age Bins:			Gender:		Education:		
	16–34	35–54	>54	Male	Female	Low	Medium	High
IV estimate	0.0597***	0.0630**	0.0581**	0.0610***	0.0267**	0.0169**	0.0807**	0.0643
	(0.0215)	(0.0287)	(0.0276)	(0.0224)	(0.0110)	(0.0075)	(0.0382)	(0.0627)
Reduced form	0.0134***	0.0130***	0.0122***	0.0125***	0.0061***	0.0056**	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	1,731	1,926	1,209	2,144	1,987	1,491	1,975	1,421
Prereform mean	0.1005	0.1858	0.1706	0.1544	0.0905	0.0561	0.1853	0.2377

Panel B: RF Using Full Data

	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	4,220	4,220	4,220	4,220	4,220	4,220	4,220	4,220
Prereform mean	0.1005	0.1858	0.1706	0.1544	0.0905	0.0561	0.1853	0.2377



Panel A. Effects by wealth



Panel B. Effects by income

Figure 3. Effects on stock market participation, by wealth and income. This figure shows reduced-form effects of broadband coverage on equity market participation rates. For each year, we first rank individuals into quintiles based on their wealth (Panel A) or income (Panel B) in the previous year. Individuals in Q1 have the lowest wealth or income; individuals in Q5 have the highest. We then calculate the equity market participation rate within each quintile. Finally, we estimate the reduced-form coefficient δ from equation (4) for each quintile, using the respective quintile's equity market participation rate as the outcome variable. The quintile-specific estimates of δ are scaled by the quintile's prereform stock market participation rate. Internet Appendix Tables IA.XV and IA.XVI present the unscaled regression coefficients along with the corresponding confidence intervals.

reduced-form effects (which does not require subgroup-specific broadband user rates) of broadband coverage on stock market participation, using the full sample of municipality-year observations. The results, reported 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 positive effect on stock market participation across socioeconomic groups.[19]

We are also interested in how the effect of broadband internet on stock market participation varies with individuals' wealth and income. We do not observe broadband user rates broken down by wealth or income. For this reason, in Figure 3, we present (full-sample) reduced-form estimates of the effect of broadband coverage on stock market participation separately for subgroups by wealth (Panel A) and income (Panel B). Across all wealth and income levels, we find that broadband coverage has a positive and statistically significant effect on stock market participation. Relative to prereform participation rates, the effects are largest for low-wealth and low-income individuals.

Overall, the introduction of broadband internet appears to have a positive impact on stock market participation rates across socioeconomic groups—and a relatively stronger impact for younger, less-educated, lower-income, lower-wealth individuals, who have the lowest stock market participation rates (and

[19] The reduced-form effect heterogeneity in Panel B of Table III is also broadly similar to the effect heterogeneity documented for the IV model in Panel A. In particular, in both the reduced form and the IV model we find stronger effects of broadband for younger and less-educated individuals.

likely the lowest financial literacy) to begin with—suggesting that broadband spurs a democratization of finance.

C. Broader Financial Outcomes

Sections IV.A and IV.B focus on the effects of broadband internet use on stock market participation as measured using NCSD data on ownership of common stock and equity funds. We now estimate the effects of broadband internet on a broader set of financial outcomes. To this end, we supplement the NCSD data with administrative tax records that give end-of-year household balance sheets for the population of Norwegian residents, including information about various asset holdings, insurance policies, and pension plans. Internet Appendix Section VII provides more detail on the balance sheet data.

In Table IA.IX, we find that broadband internet use increases individuals' participation in bonds and bond funds as well as in unlisted stocks.[20] By contrast, we do not find evidence of any significant relationship between broadband use and the take-up of life insurance or private pension plans, which suggests that the financial effect of broadband use is centered primarily on direct investment decisions. While we do not have sufficient precision to detect a statistically significant impact of broadband use on households' wealth, the results reported in Table IA.X show that broadband use increases households' historical returns on financial wealth.

These results corroborate the message from the main analyses: Broadband use appears to positively impact portfolio allocation and outcomes for individual investors.

V. Effects for Existing Investors

We now analyze the effect of broadband internet on existing investors. On the one hand, access to high-speed 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. Broadband internet also decreases the time cost of trading, an effect that could be important for the most active traders. On the other hand, increased access to broadband internet might improve financial decision making 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. To assess the effect of broadband on the trading activity of existing

[20] The bond funds category includes regular bond funds plus money market funds (registered and not registered in a securities register). The bond category includes those registered in a securities register. The unlisted stocks category includes stocks that are not registered in a securities register (typically ownership shares). It is slightly puzzling that we find no effects of broadband on listed stocks but positive effects on unlisted stocks. One potential explanation is that unlisted stocks are more informationally opaque than listed stocks, so the value of online information acquisition is higher.

Table IV
Effects for Existing Investors

This table presents estimates of δ from the reduced-form model (1). In the first four columns of Panel A, the outcomes are the fractions of existing investors– that is, investors with positive stock or fund holdings in the previous calendar year—that buy or sell equity funds or stocks in a given municipality-year. In the fifth column of Panel A, the outcome is the average fraction of existing investors' portfolios that is invested in stocks as opposed to equity funds. In Panel B, the outcomes are the return loss (*RLoss*), risky asset weight (*RWeight*), standard deviation of risky assets (*SD*), relative Sharpe ratio loss (*RSRL*), Sharpe ratio (*SRatio*), and idiosyncratic risk share (*IdioShare*) of existing investors' portfolios, calculated following Calvet, Campbell, and Sodini (2007). 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: Trading Activity

	Funds		Stocks		
	Buy	Sell	Buy	Sell	Stock Share
Reduced form	0.0371***	−0.0042	0.0045	0.0011	−0.0308***
	(0.0082)	(0.0053)	(0.0040)	(0.0033)	(0.0089)
N	4,220	4,220	4,220	4,220	4,220
Prereform mean	0.2298	0.0777	0.1377	0.0848	0.4781

Panel B: Portfolio Efficiency

	RLoss	RWeight	*SD*	RSRL	SRatio	IdioShare
Reduced form	−0.0034***	−0.0187***	−0.0419	−0.0057***	0.0025***	−0.0031**
	(0.0008)	(0.0038)	(0.0284)	(0.0021)	(0.0009)	(0.0015)
N	4,220	4,220	4,220	4,220	4,220	4,220
Prereform mean	0.0376	0.3230	0.3373	0.6604	0.1488	0.8637

investors, we therefore estimate the reduced-form effects given by δ in equation (1). As explained in Section III, 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 existing investors is presented in Table IV. The results reported in the first four columns of Panel A show a positive and statistically significant effect of broadband on fund buying among existing investors, and no significant effect of broadband on fund selling, stock buying, or stock selling.[21] Taken together, these results imply that broadband coverage should lead to an increase for existing investors in the portfolio share of funds, that is, the amount invested in funds divided by the combined amount invested in funds and individual stocks. This is confirmed in the fifth column of Panel A in Table IV.

In Panel B of Table IV, we analyze the effects of broadband coverage on measures of portfolio efficiency adopted from Calvet, Campbell, and

[21] In Internet Appendix Section XIII, we also find no evidence of any significant effect of broadband coverage on stock portfolio turnover, an alternative measure of stock trading activity.

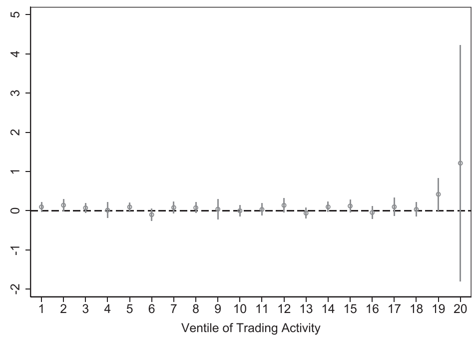
Sodini (2007).[22] We first consider the return loss, that is, the average return individuals lose by choosing their actual portfolio rather than a position combining the benchmark portfolio with cash to achieve the same risk level (see equation (10) in Calvet, Campbell, and Sodini (2007)).[23] In the first column of Panel B, we find a negative and statistically significant effect of broadband coverage on the return loss. The estimates in the next three columns of Panel B are based on the decomposition of the return loss in equation (11) of Calvet, Campbell, and Sodini (2007). We find that broadband coverage decreases all three components of the return loss—the portfolio weight in risky assets, the standard deviation of the risky assets chosen by the individual, and the relative Sharpe ratio loss, with the effects on the risky asset share and the relative Sharpe ratio loss being statistically significant.[24] In the final two columns of Panel B, we report estimates of the effects of broadband coverage on two other measures of portfolio risk, the Sharpe ratio and the portfolio idiosyncratic risk share. The portfolio 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) to (3) in Calvet, Campbell, and Sodini (2007). We find that broadband coverage increases the Sharpe ratio and decreases the idiosyncratic risk share. Overall, the estimates reported in Panel B of Table IV show that increased access to broadband internet leads to more diversified portfolios and improved outcomes for existing investors. To give a sense of the economic magnitudes of the effects, the mean prereform Sharpe ratio in our sample is about 15%. As column (5) of Panel B shows, a 100 percentage point increase in broadband coverage increases the Sharpe ratio by about 0.25 percentage points the year after, or about 1.6% of the prereform mean. If we assume a first-stage coefficient of 0.15 for the group of existing investors—slightly larger than the 0.11 first-stage coefficient for the average person in Table II—these reduced-form effects would imply an IV estimate of approximately 0.016. In other words, a 100 percentage point increase in the broadband user rate increases the Sharpe ratio by 1.6 percentage points, or about 10.6% of the prereform mean.

While columns (3) and (4) of Panel A in Table IV show that the average existing investor does not increase his stock trading activity following increased access to broadband, it could be that the most active ones do, as documented by Barber and Odean (2002) and Choi, Laibson, and Metrick (2002) in the context of individual investors' adoption of online trading platforms. To assess this

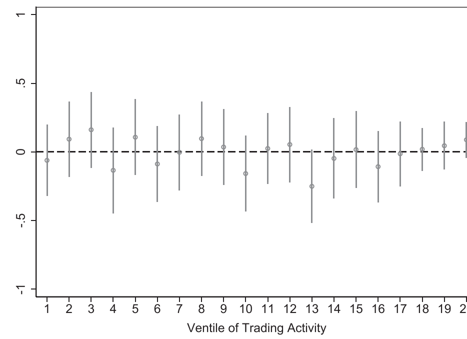
[22] A related question is whether the introduction of broadband has an impact on the trading performance of existing investors, as measured by alphas. Unfortunately, there are too few municipalities in Norway to give power to abnormal returns estimations at the municipality-year level using standard tools from the asset pricing literature.

[23] The mean return loss across individual-years is about 0.31%. The distribution of return losses is comparable to the distribution reported by Calvet, Campbell, and Sodini (2007), with a slightly fatter right tail.

[24] The relative Sharpe ratio loss captures diversification losses by comparing individuals' Sharpe ratios to the Sharpe ratio of the Morgan Stanley Capital International All Country World Index (MSCI ACWI) (see equations (7) and (8) in Calvet, Campbell, and Sodini (2007)). Individuals' Sharpe ratios are calculated based on excess returns relative to the Norwegian Central Bank's overnight deposit rate.



Panel A. Avg. #stock trades



Panel B. Log(Avg. #stock trades)

Figure 4. Effects on stock trading, by past trading activity. This figure shows reduced-form effects of broadband coverage on the trading activity of existing investors, along with the associated 95% confidence intervals. For each year, we first rank existing investors 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 (4) 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.

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 reestimate the effect δ from equation (4) 20 times, each time using a different ventile's average number of stock trades as the outcome. Intuitively, this approach involves comparing stock trading activity between existing investors that (i) currently experience different broadband coverage shocks but (ii) in the previous year belonged to the same trading activity ventile, conditional on municipality and year fixed effects.

Panel A of Figure 4 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 very top: For the top 10% of the past trading activity distribution, we find positive effects of broadband coverage on stock trading. The estimated coefficient for the top ventile is large but statistically insignificant. For the 19$^{\text{th}}$ ventile, the effect is borderline statistically significant (p-value $= 0.051$). To assess the robustness of this result, in Panel B of Figure 4 we reestimate the ventile-specific δ's using the log of the mean number of stock trades as the outcome and 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 the most active existing investors.

Overall, we find positive effects of increased access to broadband internet among existing investors: They increase their equity fund portfolio shares and their Sharpe ratios. We do not find evidence of increased stock trading activity among existing investors, except possibly at the very top of the trading activity distribution.

VI. Mechanisms

While exogeneity of the instrument, z_{kt-1}, is sufficient for a causal interpretation of the reduced-form effects reported in Tables II and III, the IV estimates reported in the same tables can only be interpreted as causal effects of households' broadband use on stock market participation under the exclusion restriction that increased broadband coverage affects stock market participation only through the broadband adoption of households, and not directly in any other way. Section VI.A addresses threats to the exclusion restriction; Sections VI.B and VI.C discuss potential mechanisms, that is, effects on stock market participation that do operate through households' broadband use.

A. Threats to the Exclusion Restriction

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 effect.[25] Using the same methodology as in Sections IV and V, we assess whether broadband coverage affects labor income reported to the tax authorities. The results reported in Internet Appendix Section XVII suggest that broadband 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. We also note that column (4) of Table II shows that our results are robust to controlling for a comprehensive list of time-varying municipality characteristics, including household incomes.

Another possibility is that 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- than low-skill workers if, for example, low-skill workers do physical tasks that require on-site presence while high-skill workers can perform their jobs remotely. But at least relative to prereform participation rates, our results are equally strong for individuals with low education (Table III), which means that this mechanism is unlikely to explain our results.

A third possibility is that the installation of broadband internet, an amenity, could have a direct causal impact on local real estate prices and thus increase stock market participation through a loosening of household budget

[25] Akerman, Gaarder, and Mogstad (2015) find that firm-level broadband adoption increases the productivity of high-skill workers and decreases the productivity of low-skill workers, but they do not report the total effect.

constraints. To address this concern, we follow the methodology of Eika, Mogstad, and Vestad (2020) and construct measures of each household's real estate wealth using data on transactions in real estate, information on the characteristics of each property, and detailed housing price indices. Using the same methodology as in Sections IV and V, we then assess whether broadband coverage impacts household real estate wealth. The results reported in Internet Appendix Section VII.B show that broadband coverage does not have a significant impact on household real estate wealth, so this mechanism is also unlikely to explain our results.

A final and perhaps subtler possibility is that the instrument, lagged broadband coverage, z_{kt-1}, affects stock market participation not only through current household broadband use, i_{kt}, but also through its impact on lagged use, i_{kt-1}. This would violate the exclusion restriction of the IV model (3)–(4), which imposes that lagged broadband coverage affects stock market participation only through current use. In Internet Appendix Section XVI, we expand the IV model to allow for dynamics in both the first- and second-stage equations. The results from the expanded model show that controlling for lagged broadband use has little impact on the estimates, and hence support the exclusion restriction of the IV model.

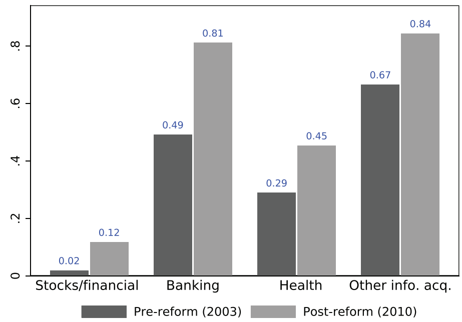
B. Household Internet Activities

We now explore channels through which household broadband adoption may increase stock market participation. A nationally representative survey on household internet activities allows us to provide evidence on the link between households' internet adoption and their stock market participation. The survey is administered by Statistics Norway. Each year, more than 1,000 respondents give detailed information about whether or not they have access to the internet and how they use it.[26] The survey covers each year over the 2003 to 2010 period, which allows us to study how households used the internet throughout the broadband reform period.

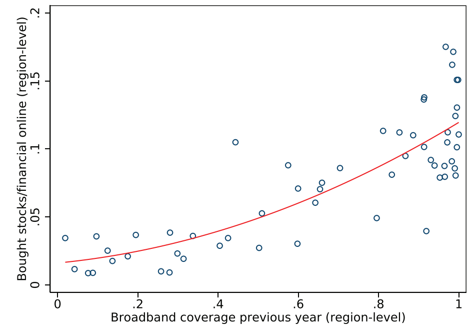
Online trading. One survey question is of particular relevance: whether respondents have used the internet to purchase stocks and/or financial services. Panel A of Figure 5 plots the share of respondents with affirmative answers to this question before (2003) and after (2010) the broadband reform.[27] In the prereform period, a very small percentage of the respondents (less than 2%) used the internet to purchase stocks or other financial services. After the reform, more than six times as many (12%) respondents reported that they used the internet to purchase stocks or other financial services. The relative

[26] In the percentages reported below, we include in the estimation sample all the respondents to the survey, even the respondents who report not having internet access. Note also that the survey used in the current subsection is distinct from the one used in Section V. Internet Appendix Sections IV and V provide more details on each of the surveys.

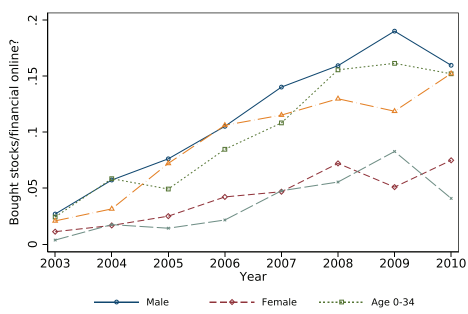
[27] In 2003, the first year of the survey, the average municipality-level broadband internet coverage was about 20%, as shown in Figure 1, Panel A. In 2010, the average broadband coverage was about 99.9%.



Panel A. Internet activities



Panel B. Online stock/financial over coverage



Panel C. Online stock/financial over time

Panel D. Effects in survey and register data

Figure 5. Survey evidence. This figure presents summary statistics from a yearly survey on how individuals interact with the internet. Internet Appendix Section V provides more details on the survey. For the years 2003 (first survey wave) and 2010 (postreform), Panel A presents the share 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, or the labor market, or has taken an online course (in any subject). For all years 2003 to 2010, Panel B plots the share of respondents in a given geographical region who 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 to 2010, and separately by sex and age, Panel C plots the share of respondents who report having purchased stocks or financial services online. Finally, Panel D shows the absolute change from 2003 to 2010 in the share of respondents who 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 III). (Color figure can be viewed at wileyonlinelibrary.com)

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 5, which was fairly common (at 49%) even before the broadband reform. Hence, in percentage terms there was a strong increase in the use of the internet to purchase stocks and/or financial services, even compared to other personal finance activities.[28]

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 5, we plot the share of respondents who have purchased stocks or financial services online against broadband coverage in the previous year. The analysis is at the regional level (there are seven regions) as the survey contains information about respondents' region of residence, but not their municipality of residence.[29] 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% level, and a linear regression of online stock/financial purchasing on broadband coverage yields a slope of 0.11, also statistically significant at the 1% level.[30] These results suggest that the observed increase in online purchasing of stocks or financial services may be related to the broadband reform.

Online information acquisition. Why would access to faster internet lead to increased stock market participation and other beneficial outcomes? 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 (Lusardi and Mitchell (2014), Lusardi, Michaud, and Mitchell (2017)). It is plausible that faster internet facilitates these activities and thus increases stock market participation. 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 whether respondents have used the internet to learn about personal finance, it broadly supports the notion that the internet was increasingly 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% in the prereform period to 45% postreform, as shown in Panel A of Figure 5.

[28] As shown in Internet Appendix Section XV.C, the major banks in Norway introduced online banking services in the 1990s, before the broadband reform. While smaller in relative terms than the increase in the online purchasing of stocks or financial services, the share of survey respondents reporting that they used the internet for banking increased materially, from 46% to 81%, from before to after the broadband reform. In Internet Appendix Section VIII, we find that bank customers reduced their frequency of physical bank visits in favor of online banking over the same period.

[29] In Panel B of Figure 5, there are 7 geographical regions $\times$ 8 survey waves = 64 observations. We do not have sufficient statistical power to estimate the IV model (3)–(4) at the regional level.

[30] As additional evidence, in Panel D of Figure 5, we plot for the two genders and three age groups the change from pre- to postreform in the online purchasing of stocks or financial services against the 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 on stock market participation are also the ones with the largest before-after changes in online purchasing of stocks or financial services.

Postreform, about 54% of the respondents answered that they have "Consulted the internet with the purpose of learning," but this question was not asked prereform. Panel A also shows the prepost change for other forms of online information acquisition and learning. The variable "*Other info. acq.*" is the share of respondents who have used the internet to acquire information about goods and services, the labor market, or travel and accommodation, or have taken an online course.[31] This variable increases from 67% prereform to 84% postreform. Taken together, this evidence supports a broad trend toward increased internet-based information acquisition and learning during the broadband reform period.

The before-after changes in online information acquisition documented in Figure 5 may be driven not by the broadband reform but rather by secular trends in how households interact with the internet. In Internet Appendix Section XVIII, we use data from a different survey about household media use, which includes information about respondents' municipality of residence. This allows us to estimate the baseline IV model (3)–(4) using proxies for information acquisition as the outcomes. While the survey in Internet Appendix Section XVIII is not as detailed as the one studied in Figure 5, we can construct two measures of online information acquisition at the municipality-year level: the shares of respondents who have used the internet to "Check facts" or "Read the news." The results in Internet Appendix Section XVIII show that broadband internet increases the time individuals spend acquiring information online by reading the news and checking facts, though only the former effect is statistically significant.

Other effects of household internet use. In addition to increasing online information acquisition, the introduction of broadband is likely to impact a wide range of other household activities. For example, using the same survey as in Figure 5, we find that the shares of respondents who have used the internet to purchase food/take-out or to gamble also increased over the broadband reform period, from 0% and 1% to 3% and 6%, respectively (see Statistics Norway (2022) for summary statistics for other internet activities). Existing papers also show that increased internet use may have a wide range of adverse effects, such as increased sexual crime (Bhuller et al. (2013)), reduced psychological well-being (Kraut et al. (1998)), and internet addiction (Ko et al. (2012)); as well as benefits in terms of improved education and health (LaRose et al. (2011), Bauerly et al. (2019)) and democratic participation (Campante, Durante, and Sobbrio (2017)). To the extent that these activities impact stock market participation, we cannot exclude the possibility that reform-induced changes to these activities may in part shape the observed effects of broadband use on stock market participation. We note that column (4) of Table II shows that our main results are robust to controlling for a comprehensive list of time-varying municipality characteristics, including measures of education,

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

income, health, public sector spending, industry compositions, and welfare dependency, which does not support that reform-induced changes to these variables are driving our main results.

C. Firm Responses to Household Internet Use

Section VI.B presents evidence consistent with households increasing their online information acquisition and learning from before to after the introduction of broadband internet. One would expect firms to ramp up their online presence and marketing in response and thus further reduce the costs for households of online information acquisition and learning. We assess this hypothesis by using two data sources.

First, we use data from a nationally representative survey of *firms'* ICT usage. The survey is administered by Statistics Norway and each year has about 3,000 firms that give detailed information about whether they have access to internet and how the firm uses the internet. Compliance is exceptionally high, at around 95%, due to heavy fines for noncompliance. The survey covers the years 2001 to 2010, which allows us to study how firms used the internet before, during, and after the broadband reform. In Figure IA.4, we find that firms increase their online presence—by adding online sales platforms and web pages—from before to after the broadband reform. Internet Appendix Section VI provides additional detail and analysis.

Second, we use detailed tax returns data for the population of Norwegian firms (as explained in more detail in Internet Appendix Section XIX), which allow us to measure firms' marketing-related costs. Using the same methodology as in Sections IV and V, we assess whether broadband impacts firms' marketing expenses (the data do not allow us to distinguish whether these costs are from online or other forms of marketing). In Table IA.XXVII, we find that the introduction of broadband leads to a significant increase in firms' spending on marketing as a share of total costs, consistent with firms ramping up their marketing in response to increased broadband use by households.

We are also interested in how financial institutions changed their online information provision in response to increased internet use by households. The survey in Internet Appendix Section VI has insufficient coverage of financial firms. The tax returns data in Internet Appendix Section XIX cover all firms, including financial ones, but financial firms in Norway are mostly clustered in the largest cities, which leaves little variation to estimate the IV model. However, two pieces of anecdotal evidence suggest important responses also among financial firms. First, in 2005 DNB, the largest bank and fund provider in Norway, launched a comprehensive Save Smart marketing campaign specifically for its fund products, motivated by "intensifying competition for customer savings"; the bank citing "trading via the Internet and other electronic channels" as a source of intensified competition in the savings market (DNB, 2005, pp. 10 and 68). According to DNB, the campaign was "very well received by the market." Second, in Internet Appendix Section IX, we find that major financial institutions in Norway significantly expanded their offerings of fund products over the broadband reform period. Taken together, the evidence suggests that financial institutions increasingly pushed their fund products in response to increased internet use by their customers.[32]

The results above and in Section VI.B suggest that shifts in both household demand and firm supply of online information may be important to understand why broadband internet use increases stock market participation. Further supporting an information channel, we find that the effects of broadband on stock market participation are relatively stronger for individuals with lower income and wealth, that is, the individuals who likely have the least information and financial literacy to begin with.

VII. Conclusion

The internet has greatly improved the opportunities for individual investors to gather information and easily connect to financial 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, to improved portfolio allocation for existing investors, and to increased participation in bonds, bond funds, and unlisted stocks. We do not find adverse effects of internet use; for example, access to high-speed internet does not lead to excessive stock trading among existing investors, except possibly for the very most active investors. Overall, the introduction of broadband internet seems to spur a democratization of finance, with households making investment decisions that are more in line with the advice from portfolio theory.

Why would high-speed internet lead to increased participation rates and improved portfolio efficiency? As suggested by the theoretical literature, entering financial markets involves fixed costs such as becoming aware of stock market opportunities and acquiring financial competence, and it is plausible that high-speed internet would facilitate these activities and thus reduce fixed costs. Survey evidence broadly supports this interpretation: Over the broadband expansion period, we observe a broad trend toward increased internet-based information acquisition and learning. Heterogeneity analyses also point toward an information acquisition channel: Compared to prereform stock market participation rates, the effects of broadband on stock market participation are stronger for younger, lower-income, and lower-wealth individuals, who have the lowest stock market participation rates and likely the lowest financial literacy to begin with.

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[32] To further explore the idea that financial institutions respond to increased household internet use by increasingly pushing fund products through online channels, we wrote a script to scrape information from Norwegian financial institutions' web pages using Wayback Machine, a web service that provides snapshots of historical web pages. Unfortunately, the coverage of the Wayback Machine proved too thin to allow us to perform any reliable quantitative analysis.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Appendix S1: Internet Appendix.
Replication Code.