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Solopreneurs in the Digital Economy

Has broadband diffusion implied increased self-employment entry and higher income dispersion among self-employed in incorporated firms in Sweden?

Anna-Mi Fredriksson (22736)

Abstract. This thesis empirically investigates the impact of broadband diffusion on self-employment entry and income dispersion of self-employed in incorporated firms. I use firm-level data of self-employed in incorporated firms in Sweden between 2007 and 2012 matched with broadband data for the share of population with fiber-connected broadband access at the municipal level. I use panel estimation with fixed effects for municipality, sector and year. First, the results suggest that full broadband diffusion of at least 90% of the population with access to fiber-connected broadband is negatively associated with the share of population entering into self-employment in incorporated firms. Second, the results suggest that full broadband diffusion is positively associated with the income dispersion of self-employed in incorporated firms. Moreover, the magnitude and significance of these relationships vary between the service sector, the ICT sector, and the economy as a whole. Overall, the results contribute to a better understanding of labor market changes induced by digitalization.

Keywords: Digitalization, structural change, self-employment, broadband

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Supervisor:	Mark Sanctuary
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Discussant:	James Finucane
Examiner:	Martina Björkman Nyqvist

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1 Introduction

> "By changing the way work is done, electronic networks may lead to a new kind of economy centered on the individual. […] The fundamental unit of such an economy is not the corporation but the individual. Tasks aren't assigned and controlled through a stable chain of management but rather are carried out autonomously by independent contractors. These electronically connected freelancers - e-lancers - join together into fluid and temporary networks to produce and sell goods and services. When the job is done - after a day, a month, a year - the network dissolves, and its members become independent agents again, circulating through the economy, seeking the next assignment."
> – Malone and Laubacher (1998)

The objective of this paper is to empirically investigate the relationship between broadband diffusion, self-employment entry, and income dispersion of self-employed. This topic is of high policy relevance to understand ongoing changes in the labor market induced by digitalization.

Broadband diffusion is a measure of digitalization (i.e. Hagsten 2016, Kolko 2012), and is defined as the share of population with access to fiber-connected broadband Internet. Broadband has enabled faster download speed of data, thereby improved the information management of firms and individuals, as well as enabled automation and robotization of production chains (Brynjolfsson and McAfee 2014). Moreover, broadband has improved the connectivity among remote individuals by enabling access to global markets (Audretsch et al. 2014).

A self-employed individual is the smallest unit of entrepreneurship and is also known as a freelancer, an independent contractor, or an own-account firm (Bögenhold and Klinglmair 2016, Earle and Sakova 2000). The impact of broadband diffusion on self-employment entry intends to capture entrepreneurial activity enabled by technology, whereas income dispersion of self-employed aims to capture the impact on income polarization.

Structural changes of digitalization are expected to impact labor markets as job tasks are increasingly automated and computerized. In particular, routine tasks within transportation, administration, and production are projected to have a high probability of automation within the next ten to twenty years (Frey and Osborne 2013). Similarly, Brynjolfsson and McAfee (2015) argue that advanced new technologies will soon replace a number of occupations, such as professional drivers, accountants and laboratory technicians.

Recent studies estimate that around 9% of jobs in OECD countries are at risk of automation and that automation potential falls with education, thereby low educated individuals face a higher risk (Arntz et al. 2016).

A study of the Swedish business sector finds that digitalization may act as both a complement and a substitute to different occupations and thus may impact labor demand as well as increase productivity differences between various individuals in society (Heyman et al. 2016). For example, a higher probability of automation in an occupation has implied a worse employment development in terms of the occupation's share of total employment.

Meanwhile, jobs that are lost due to digitalization and robotization may to some extent be replaced by self-employed individuals in the Sharing Economy (Felländer et al. 2015). Self-employed constitute an increasing part of labor markets globally (Falco and Haywood 2016).

In the U.S., freelancers made up 35% of the total labor force in 2016 (Pofeldt 2016), while platform companies such as Upwork, Uber, and Airbnb have made it easier to find freelance work (Edelman Intelligence 2016).

In Sweden, around 10% of all employed people are self-employed in either unincorporated firm (F-skatt) or incorporated firm (AB) (Bögenhold and Klinglmair 2016, Andersson and Wadensjö 2013). Self-employment in incorporated firms officially counts as permanent employment (Försäkringskassan 2017), whereas self-employment in unincorporated firms counts as a temporary employment contract. The trend is moving towards more temporary employment, and today one out of four working individuals has a temporary employment such as a time limited contract or self-employment in an unincorporated firm (Wingborg 2016).

As the market for self-employment is growing, business opportunities arise for companies that provide platform services to these micro firms (Jakobsson 2017). This type of platform-based labor market, where demand and supply matching takes place through a digital platform, could create new jobs and increase aggregate economic efficiency through resource allocation to more valued activities (Blix 2017).

Although the rise of this gig-economy generates more entrepreneurial activity, the development also implies shifting more economic risk onto workers (Friedman 2014) as they are excluded from employment-bound social insurance programs and collective wage bargaining (Blix 2017). Whether this shift to on-demand labor will result in concentrated wealth, rising inequalities, and job polarization will be up to policy responses, and for example Blix (2015) argues that policy should reduce the discrepancy between employees and self-employed.

Labor market changes spurred by digitalization can be understood through theories of economic structural change. The Internet has been identified as a general purpose technology (Falck and Schüller 2016, Clarke et al. 2015, Jovanovic and Rousseau 2005) diffusing the economy with disruptive innovation throughout industry, labor markets, and consumer behavior. Compared to previous technological shifts such as electrification, digitalization is expected to have a particularly strong effect on labor markets (Brynjolfsson and McAfee 2011).

Previous empirical work on digitalization and labor markets focused on broadband diffusion and its impact on employment (Ivus and Boland 2015, Czernich 2014), entrepreneurship (Alderete 2014, Audretsch et al. 2014), labor productivity (Bertschek and Niebel 2016, Hagsten 2016), and economic growth (Arvin 2014, Kolko 2012).

Moreover, recent literature on the skill-complementarity of broadband Internet finds that broadband complements high-skilled workers, while low-skilled workers that perform routine tasks are to a higher extent replaced by broadband technology (Akerman et al. 2015).

To my knowledge, there is no empirical study to date that investigates the impact of broadband availability on entry or income dispersion of self-employed. Given the rise of on-demand labor and concerns regarding income polarization, there is a need for empirical evidence on these relationships to better understand technologically driven labor market shifts and foresee necessary policy changes.

In order to explore these relationships, the study focuses on the national broadband expansion in Sweden during the 2000s. Several government support schemes were implemented to ensure high quality Internet access to all citizens. Specifically, I study the availability of fiber-connected broadband in Swedish municipalities between 2007 and 2012.

In terms of self-employment, I limit the scope to include only self-employed in incorporated firms (AB), as opposed to unincorporated firms (F-skatt). This is mainly due to data access limitations. I use data from PAR, Bisnode, on all Swedish incorporated firms between 2007 and 2012. Consequences of this scope will be discussed in the literature review, section 3.2.

Against this background, the research questions to be answered in this thesis are as follows.

1. Has broadband diffusion implied an increase in self-employment entry of incorporated firms in Sweden?

2. Has broadband diffusion implied higher income dispersion among self-employed individuals in incorporated firms in Sweden?

Furthermore, do these effects differ between the service and manufacturing sectors and is there a more significant impact on sectors within Information and Communication Technology (ICT)?

For the first research question, the results indicate a negative relationship between full broadband diffusion and self-employment entry, where full broadband diffusion is defined as above 90% of the population with access to fiber broadband. Second, full broadband diffusion is positively associated with income dispersion of self-employed. However, these results do not hold for lower measures of broadband diffusion.

Thus, the main contribution of this thesis is to provide empirical evidence on the relationship between broadband diffusion on 1) self-employment entry, and 2) income dispersion of self-employed in incorporated firms in Sweden. Moreover, the paper provides a conceptual framework for understanding these relationships.

In terms of structure, Section 2 provides a background to the national broadband expansion in Sweden as well as a description of regulatory changes that may have affected self-employment during the time period. Section 3 defines main concepts and summarizes previous empirical findings. Section 4 develops a framework to describe the main mechanisms, and Section 5 provides descriptions of the econometric model and data. Section 6 includes analysis and summary of results. In section 7, interpretations of the results are discussed as well as limitations, internal and external validity, and implications for future research. Section 8 concludes the thesis by providing a summary of the main results.

2 Background

To provide a background for the analysis, this section first presents an overview of the Swedish national broadband policies during the time period studied, 2007-2012. Second, the development of self-employment in Sweden is summarized together with relevant regulatory changes that have affected self-employment over this period.

2.1 Swedish broadband policies and programs

National broadband strategy

In the 1990s, the Swedish government implemented its first broadband policies to ensure access to ICT infrastructure of high service speed for all geographic regions (Näringsdepartementet 2009). This infrastructure specifically referred to fiber-connected broadband as opposed to previously available dial-up or DSL copper technology.

A financial support program was established in 2001 to facilitate broadband development in rural areas with low commercial prospects. Between 2001 and 2007, 7,6 BSEK from government funds, regional growth funds, EU funds, municipalities, and service providers was invested in electronic infrastructure (Bredbandsforum 2012).

In 2009, the national broadband strategy "Bredbandsstrategin" established targets for the share of households and firms with access to high speed Internet. According to these targets, 40% of all households and firms should have access to broadband of at least 100Mbit/s in 2015, and 90% should have access to 100Mbit/s in 2020. This service speed requires coverage of fiber-based connection (Näringsdepartementet 2009).

The aim of the national broadband support has been to improve market conditions for private actors to invest in broadband infrastructure. Broadband infrastructure in Sweden is both publically and privately owned. In 2009, the State owned between 15% and 20% of fiber infrastructure (Näringsdepartementet 2009). Municipalities have invested in local fiber networks since the 1990s and in 2012, 200 out of 290 municipalities owned local fiber infrastructure (Bredbandsforum 2012).

The market for broadband service provision is privately operated, and the responsibility of the government is to ensure competition between private market actors.

Regional development programs

ICT development was a priority area in the National Strategy for Regional Competitiveness, Entrepreneurship and Employment 2007-2013 (Näringsdepartementet 2007). Several support schemes were established to improve access to fiber broadband in remote and rural areas.

The main schemes between 2007 and 2013 were Landsbygdsprogrammet, Strukturfonderna, and Kanalisationsstödet, combined with public co-financing through PTS and regional growth funds. Total investment in broadband through these programs between 2007 and 2013 was 2,416 MSEK including public co-financing (PTS 2014).

Table 1: Broadband infrastructure support programs in Sweden 2007-2013 (PTS 2014, SKL 2012*)*

Support program	Time period	Used amount	Funding	Decision	Receiver
Landsbygdsprogrammet	2007-2013	1,625 BSEK	Government	Länsstyrelsen	Rural projects
Strukturfonderna	2007-2013	685,7 MSEK	EU	Tillväxtverket	Regional projects
Kanalisationsstöd	2008-2013	151,2 MSEK	Government	Government	Rural projects
Total	2007-2013	2,416 MSEK			Rural and regional

Landsbygdsprogrammet (Regional Development Program)

Financial support for broadband expansion in rural Sweden was given through the Regional Development Program. During 2007-2013, the county administrative boards distributed 1,625 BSEK in project funding, including PTS co-financing, to planning and construction of local broadband projects in rural areas (PTS 2014).

Strukturfonderna

As part of the long-term goal to strengthen Europe's competitiveness, one of the most important programs was the regional structure funds program. Between 2007-2013, 1 BSEK was available for broadband projects in Sweden, of which 685,7 MSEK were used (PTS 2014). These funds were available for large regional projects, and the program was managed by Swedish Agency for Economic and Regional Growth (SKL 2012).

Kanalisationsstöd

In 2008, the scheme "Kanalisationsstöd" was implemented to ensure that broadband infrastructure was built in rural areas where market incentives were too low for private actors to invest. The government managed this program that enabled municipalities, private companies, associations and individuals to apply for funds to build pipes for fiber-based ICT infrastructure.

Public co-financing

For both the Landsbygdsprogram and Kanalisationsstöd, EU required a national public actor to partly finance all projects. Therefore in 2010, the public authority Post- och Telestyrelsen (PTS) was given the mission to co-finance the broadband expansion in rural areas with regards to these two programs. For the structure funds, Tillväxtverket has managed co-financing through regional growth funds, "Regionala utvecklingsmedel".

Impact evaluation of programs

By the end of 2013, 97.000 households in Sweden had broadband access, which largely exceeded the initial target of 30.000 households. A recent evaluation shows that this outcome was mostly a result of the regional development programs (Jordbruksverket 2016).

Conclusively, the above described national strategies and support schemes made Sweden an early adopter of comprehensive broadband penetration and have contributed to placing Sweden at the forefront of ICT development (SOU 2015).

2.2 Self-employment in Sweden

In Sweden, the self-employment rate has remained low at around 10% compared to the EU-28 average of 14% in 2013 (Bögenhold and Klinglmair 2016). The legal form of self-employment in Sweden is two-fold: unincorporated firm (enskild firma, handelsbolag, kommanditbolag) and incorporated firm (aktiebolag) (Andersson and Wadensjö 2013).

Self-employed in incorporated firms officially count as permanent employees (Försäkringskassan 2017). However, neither self-employed in unincorporated or incorporated firms are connected to collective wage bargaining, unemployment benefits, or social insurance that correspond to a wage employee. The distinction between the two forms is important as the determinants of self-employment entry differ (Andersson and Wadensjö 2013).

Self-employment entry

The unincorporated form of self-employment is most common and is often combined with wage employment (FA-skatt). The number of unincorporated firms in Sweden has increased from 700.000 in 2005 to nearly 900.000 in 2016 (Wingborg 2016). To start an unincorporated firm, no equity capital is required but an individual can simply register the firm at Bolagsverket.

An incorporated firm requires an initial capital investment and it also has limited liability so business owners have no personal responsibility to the firm's financial health. Both the corporate tax rate and capital gains tax rate is lower for incorporated firms than for wage employment or self-employment in unincorporated firms.

The number of active incorporated firms in Sweden with 0-1 employees has increased from around 120.000 in 2007 to over 160.000 in 2012. This corresponds to an increase of 37% over the time period.

Notably, the annual growth rate in the number of incorporated firms with 0-1 employees dropped significantly during the financial crisis 2009-2010. The entry activity increased again in 2011, which may partly be a consequence of a policy change to lower the capital requirements as discussed below.

Figure 1: Annual increase in number of incorporated firms, 0-1 employees (PAR data)

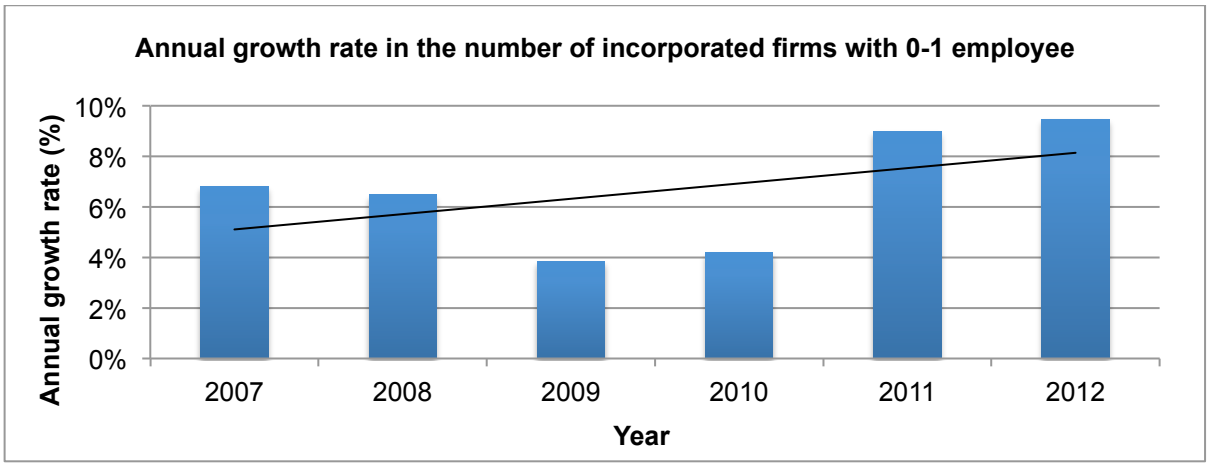
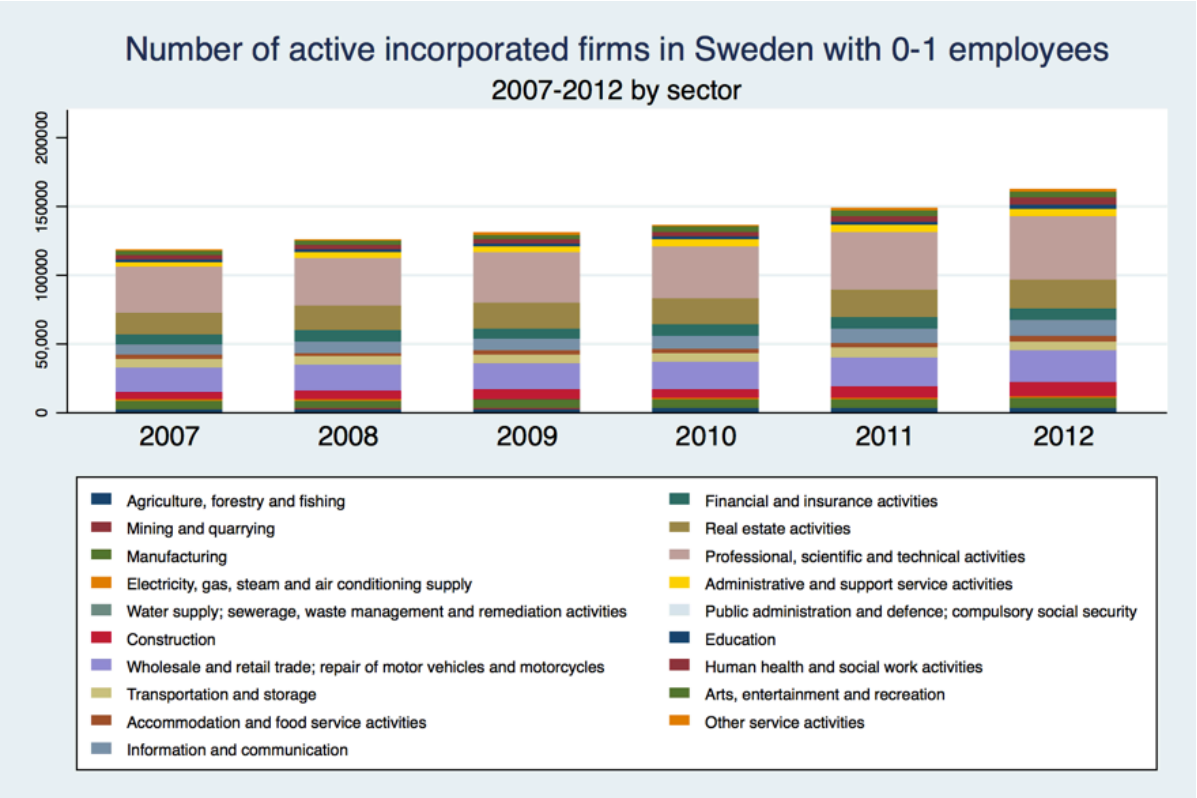


Figure 2: Number of own-account incorporated firms by sector (PAR data)



Between 2007 and 2012, the largest sectors of active incorporated firms with 0-1 employees were in professional, scientific and technical activities, wholesale and retail trade, and real estate activities. The largest increase in the number of incorporated own-account firms over this period were in health and social work (87%), other service activities (85%), construction (83%), information and communication (50%), education (49%), and entertainment (44%). Note however that some of those sectors increased from very small numbers.

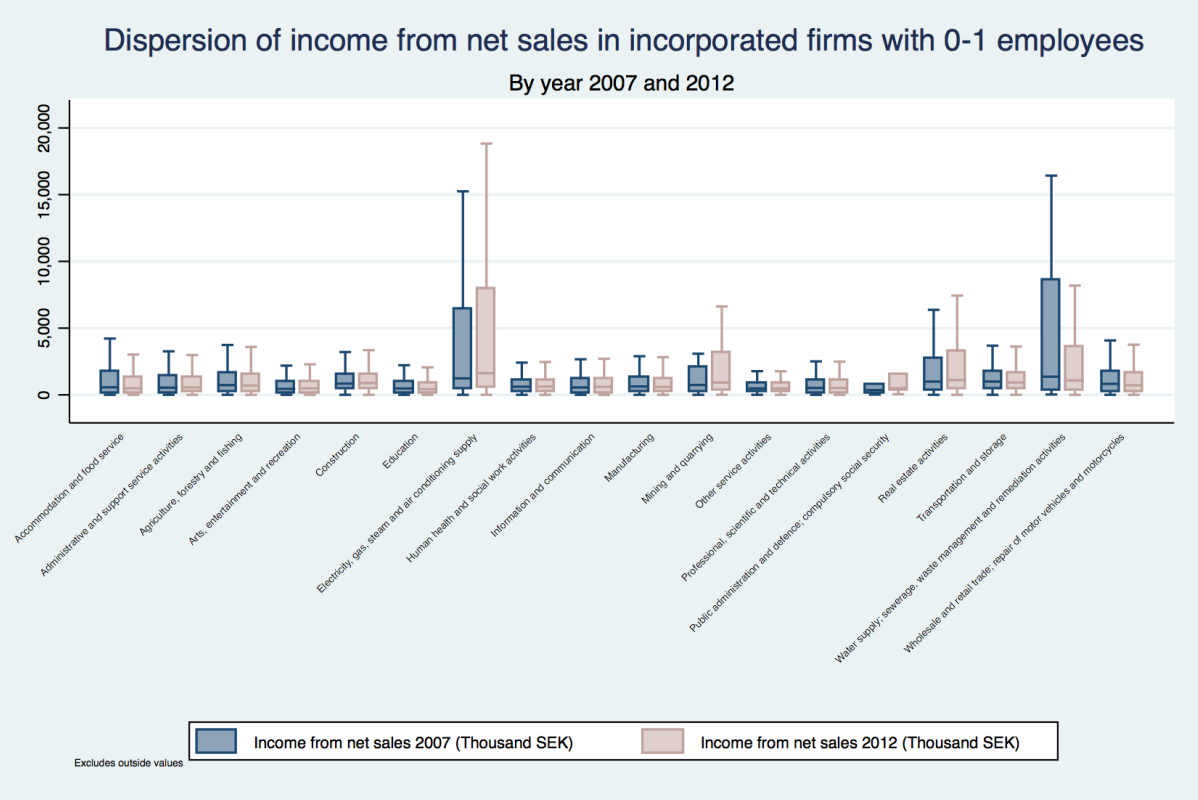
Income dispersion among self-employed

The income dispersion is large within the group of unincorporated self-employed in Sweden, especially within sectors such as media, culture, IT, and consulting (Wingborg 2016). For example, a competitive self-employed computer programmer can earn more than a wage employee and is thereby able to compensate for the lack of employment-based social insurance. Meanwhile, a less competitive self-employed within journalism may not be able to afford private alternatives.

Moreover, Wingborg (2016) also finds indications that the income dispersion among self-employed in Sweden has increased due to a combination of globalization and digitalization. Today, companies search for talent on global markets where the price spread is larger than on the Swedish labor market alone. In particular, the number of contracts and transfers in digital form where fixed fees are offered for pre-specified orders on a global labor market have increased dramatically.

The spread of income from net sales in incorporated own-account firms by sector, SNI2007 at the one digit level are plotted below. The first and last years of observation are compared, 2007 and 2012. The graph suggests an increase in the spread for activities within electricity supply and water supply, mining and quarrying as well as real estate activities. Although, in other sectors such as accommodation and food services or water supply activities, the spread rather seems to decrease.

Figure 3: Spread of income from net sales by sector in 2007 and 2012 (PAR data)



Important policy changes affecting self-employment

New legal form of temporary employment

First, in 2008 a change in employment form to temporary employment, "visstidsanställning", enabled more flexible work contracts which has contributed to an increase in the number of project based employees (Wingborg 2016). Since then, self-employed in unincorporated firms can be employed through self-employment companies such as Frilans Finans that administrate the employment contracts and give access to social security while taking a percentage of the generated income. However, since this study focuses on incorporated firms this effect is unlikely to be significant in the data.

Lower capital requirement

Second, in 2011 the capital requirement to start an incorporated firm was lowered from 100.000 SEK to 50.000 SEK (Bolagsverket 2011). As financial constraint may act as an entry barrier for solopreneurs, this change most likely influenced individuals' decisions to enter self-employment relative to wage employment.

Lower tax rate

Third, a change in corporate tax rate was implemented in accounting year starting 2013-01-01, from 26,3% to 22%. As the income tax rate is substantially higher than the corporate tax rate, this relatively lower corporate tax rate most likely impacted the number of individuals entering into self-employment in incorporated firms. The change was implemented after the time period studied in this paper and thus would not directly affect the analysis. However, they could be an anticipation effect as people may have started a company in 2012 knowing that the tax rate would be lower the coming year. Thus, the analysis should control for this by excluding 2012 as an additional robustness check.

3 Current State of Knowledge

3.1 Definitions of main concepts

Broadband diffusion

Broadband diffusion is used in the literature to describe the share of a population of firms or households with access to broadband Internet. Other terms in use are broadband penetration, ICT technology diffusion, and Internet access.

Broadband diffusion is not equivalent to broadband adoption, which is another frequently used measure. Broadband adoption usually refers to survey data on the share of firms, employees or households who use broadband services available to them. In this paper, I chose to follow the definition of broadband diffusion as the share of population in a municipality with access to fiber connected broadband Internet. This is a common definition in the research literature and it is also compatible with both the firm-level data used in this paper as well as the Swedish broadband data available from PTS.

Self-employed in incorporated firm

Self-employment is used in the research literature for individuals that work as independent contractors without a long-term employer-employee contract. The concept of being self-employed may also broadly be referred to as a freelancer, solopreneur, own-account firm, micro-enterprise, contingency workforce, homeworker, teleworker, portfolio worker, or temporary worker. Related terms used in the context of digitalization are e-lance, crowdsourcing and independent professionals in the gig-economy.

I chose to follow the definition provided by Andersson and Wadensjö (2013) for the Swedish context, where self-employed can be divided into four categories: (i) self-employed running an incorporated firm with employees, (ii) self-employed in incorporated firm without employees, (iii) self-employed in unincorporated firm with employees, and (iv) self-employed in unincorporated firm without employees. I focus on category (i) and (ii), self-employed in incorporated firms with and without employees, which together constitutes around 32% of all self-employed. This scope is mainly due to data access limitations for individual-level data. In order to study other groups of self-employed, information at the individual level is required which I discuss in section 7 as a further extension to this paper.

3.2 Literature review

The impact of broadband diffusion on self-employment entry and income spread

Regarding the impact of broadband availability on startup entry and earnings of self-employed in incorporated firms, there is to my knowledge no empirical study to date that analyses these relationships directly. However, closely related is empirical work by Kolko (2012) who finds that expanding broadband availability in the US between 1999 and 2006 did not change the prevalence of telecommuting or other home-based work. Meanwhile, Lee and Lin (2011) find that developments in personal ICT have created opportunities for turning Internet-based hobbies into self-employed occupations, although the study mainly focuses on how the lack of a physical work place impacts the work identity of self-employed.

In terms of non-academic literature, recent evaluation of the Swedish regional development programs (Jordbruksverket 2016) finds that the local broadband development has improved conditions for local businesses as people can work locally or from home. The evaluation also finds indications that people who spend leisure time in rural areas now consider spending more time there as they can work from a distance. Furthermore, Wingborg (2016) finds indications that a combination of digitalization and globalization has led to higher income dispersion among self-employed in Sweden, as companies search for talent on global markets with larger income spread and more contracts are managed entirely online.

The impact of broadband diffusion on related outcomes

Indirectly related to the research question, previous studies have focused on the impact of broadband diffusion or broadband adoption on outcomes such as entrepreneurial startup activity, employment level, wage growth, labor productivity and relative demand for high-skilled labor. The most relevant findings are presented below.

Broadband diffusion and entrepreneurship

A positive and significant influence of ICT development on explanatory factors of entrepreneurship has been found for 59 countries (Alderete 2014). Additionally, certain types of infrastructure such as broadband, which facilitate connectivity and linkages among people, are found to be more conducive to entrepreneurial startup activity than are other infrastructure such as highways and railroads (Audretsch et al. 2014).

Broadband diffusion and employment

A negative relationship between DSL broadband Internet availability and unemployment rates were found in Germany (Czernich 2014). However, the results from OLS estimation are not robust to an instrumental variable where the instrument is based on impediments to the rollout of DSL networks that stem from the structure of the pre-existing voice-telephony network.

Broadband deployment in rural areas by Canadian firms in 1997–2011 were found to promote rural employment and wage growth in service industries but not in goods industries (Ivus and Boland 2015). To estimate the causal effect, the authors use the variation in elevation that explains the regional difference in broadband coverage as an instrument.

ICT development, labor productivity, and innovation

The labour productivity in German firms were found to significantly increase with the share of employees with mobile Internet access (Bertschek and Niebel 2016). The authors establish a causal relationship by using an instrumental variable, where the number of years an individual used a private smartphone is used as an instrument.

A significant and positive relationship was also found between ICT intensity, approximated as the proportion of broadband Internet enabled employees, and labour productivity in firms in 14 European countries (Hagsten 2016). Using pooled OLS estimations, the author finds that the relationship varies across countries and industries with manufacturing firms receiving 50% larger estimates than service firms.

There is also a positive correlation between the DSL broadband Internet expansion in Germany in 2001-2003 and the innovation activity of firms (Bertschek et al. 2013). However, using an instrumental variable based on information about the availability of DSL broadband at the postal code level, the authors find no evidence for a causal impact of broadband Internet on labor productivity.

Digitalization and productivity development in Sweden

In terms of digitalization and employment dynamics in Sweden, a recent study by Heyman et al. (2016) investigates how digitalization impacted the Swedish business sector during 1996–2013, where digitalization is measured as the average probability of automation of an occupation. The empirical analysis indicates that a higher probability of automation in an occupation has implied a worse employment development in terms of the occupation's share of total employment.

In terms of digitalization and income dispersion in Sweden, the same authors find that digitalization may act as both a complement and a substitute to different occupations and thus may impact labor demand as well as increase productivity differences between various individuals in society. It is emphasized that the right education and further education will be more important for employment and good wage development. The empirical analysis shows that digitalization primarily impacted firms that had a large proportion of less qualified workers. Specifically, an increase in the average probability of automation for employees in a firm is associated with increased productivity in firms that had less qualified workers, but to a lesser extent in firms that had a high proportion of employees with a university education.

Broadband adoption and firm performance

Doherty et al. (2016) find that the adoption of broadband technology drives both efficiencies and strategic development in Irish SMEs. Similarly, Grimes et al. (2012) find that broadband adoption boosts firm productivity by 7-10% and that these effects are consistent across both urban and rural locations as well as across both high and low knowledge intensive sectors. Moreover, Majumdar (2010) find a positive relationship between broadband deployment and the revenue growth of firms in the US telecommunications industry from 1988 to 2001.

In terms of endogenous broadband adoption, Colombo et al. (2013) find that the willingness of Italian SMEs to adopt broadband-based applications depend on intra-firm capabilities such as IT skills level of employees as well as extra-firm capabilities such as the ability to hire a young and skilled workforce in the local labor market.

Relative demand for high-skilled labor

A related literature is the skill-complementarity of broadband Internet. Falk and Biagi (2017) find that for manufacturing industries, skill intensity is significantly and positively related to the share of employees with Internet broadband access and mobile Internet access. For service industries however, only mobile Internet usage intensity is significantly and positively related to skill intensity, which is measured as the share of workers with a tertiary degree.

Akerman et al. (2015) find that broadband Internet improves labor market outcomes of skilled workers as they become more productive, but worsens the outcomes for unskilled workers in Norwegian firms. The findings suggests that broadband adoption by firms complements skilled workers in executing nonroutine abstract tasks, but rather substitutes for unskilled workers in

performing routine tasks. Furthermore, the authors suggest a model of endogenous technology adoption where firms' choices reflect principles of comparative advantage.

Urban-rural digital divide

Findings by Ivus and Boland (2015) indicate that broadband facilitates for service firms in rural areas to overcome geographical barriers that otherwise hinder rural growth. Moreover, Shore et al. (2011) study small businesses in the U.S. and find that competitiveness of firms in rural areas rely on the provision of the same basic resources and infrastructure as their larger urban counterparts. The authors also highlight the importance of education about technology in rural areas.

Other determinants of self-employment entry and income dispersion

Push and pull factors of self-employment entry

Determinants of self-employment are often discussed in terms of push and pull factors. In general, push factors displace individuals into self-employment as an occupation of last resort whereas pull factors rather attract individuals into self-employment. The most common push factor in the literature is unemployment whereas pull factors include access to capital, entrepreneurial knowledge and flexible work hours.

Evidence by Andersson and Wadensjö (2013) indicates that a pull effect drives entry into self-employment in incorporated firms in Sweden, while a push effect rather dominates for unincorporated firms. Specifically, the authors find that male wage earners who enter self-employment in incorporated firms in Sweden are mostly drawn from the high end of the income residual distribution relative to employed, whereas unincorporated firms are on the low end.

Business cycles

Business cycles affect self-employment through such push and full factors (Svaleryd 2013). In economic booms, more business opportunities arise to new firms and in downturns self-employment can be a way to avoid unemployment. Moreover, Svaleryd finds that individuals with high endowments of human capital are more likely to be pulled into self-employment while those with lower human capital endowments are more likely to be pushed into self-employment.

Location and agglomeration

Tavassoli and Jienwatcharamongkhol (2016) find that for a newly established entrepreneurial firm, location matters significantly. The authors investigate the role of Marshallian and Jacobian externalities on the survival of newly established and self-employed Swedish firms in the Knowledge-Intensive Business Service sector 1997-2012.

Relative earnings of self-employment vs. wage-employment

According to the literature on relative earnings, an individual will choose self-employment instead of wage-employment if the utility from being self-employed exceeds that of being wage-employed.

In a study of Swedish self-employed, Hammarstedt (2009) finds that the predicted differential between self-employment and wage-employment earnings plays an important role for the self-employment decision and that an increase in this earnings differential will lead to a higher self-employment rate and to an increase in total employment.

One issue with this approach is the extensive prevalence of hybrid self-employed - individuals who hold a wage employment and are self-employed on the side. Thus, the individual choice between employment and self-employment may not be as binary as previously assumed in the literature (Bögenhold and Klinglmair 2016).

Individual characteristics

Entry into self-employment may also be determined by individual characteristics such as age, sex, and ethnicity. For example, self-employment in Sweden is more common among men than women (Andersson and Wadensjö 2013). Also, self-employment entry is more common among unemployed than among wage earners. Furthermore, non-Western immigrants are overrepresented among self-employed compared to Swedish natives (Ohlsson et al. 2012).

Education and professional experience

Recent theory suggests that generalists are more likely than specialists to become self-employed, which has been found to be the case in careers of scientists and engineers, mostly for male, incorporated, and nonacademic entrepreneurial self-employment (Hsieh 2016). Moreover, Tåg et al. (2016) establish a negative correlation between the hierarchical structure of a firm and the likelihood of business creation among its former employees in Sweden. The authors suggest that employees in less hierarchical organizations have broader skills.

Prior wealth level

The transition between wage-employment and self-employment is also affected by the wealth of the individual. In a study of self-employed in the Netherlands, Li et al. (2016) find that an average reduction of net future pension wealth by 16.000 euros reduces the transition rate into self-employment by 38%.

In a famous study, Lindh and Ohlsson (1996) find that the probability of being self-employed increases when people receive windfall gains in the form of lottery winnings and inheritances. These findings support the hypothesis that liquidity constraints are binding on the decision to become and stay self-employed.

Risk appetite

Risk aversion on the decision to become self-employed is a much-discussed topic in the entrepreneurial literature. Caliendo et al. (2009) show that individuals with lower risk aversion are more likely to become self-employed, but that this is true only for people coming out of regular employment. For individuals coming out of unemployment or inactivity, risk attitudes do not seem to play a role in the decision process. Moreover, Ekelund et al. (2005) find that risk aversion has a significant negative effect on self-employment status.

4 Conceptual framework

This section presents a conceptual view of the relationship between broadband diffusion and 1) self-employment entry, 2) self-employment income dispersion. As there is no previous empirical work on the direct relationship between broadband diffusion and the self-employment outcomes of interest, I use a combination of mechanisms in order to hypothesize the expected outcome of the analysis.

4.1 Broadband diffusion impact on self-employment entry

Skill-complementarity of broadband as a pull factor into self-employment

Based on the literature review, the impact of broadband diffusion on self-employment entry can be thought of as the following combination of mechanisms:

> *1. Broadband technology complements high-skilled workers who benefit from productivity gains and substitutes less skilled workers who to a higher extent perform routine tasks that can be replaced by digital technology.*

This argument builds on Autor et al. (2003) in that ICT substitutes for workers in performing routine tasks, more amenable to automation, and complements workers in executing problem-solving, complex communication, and information-intensive tasks often called "non-routine abstract tasks".

> *2. High-skilled and ICT-skilled individuals are more quick to adopt broadband than other individuals because their complementary factors to broadband are abundant, such as computers and ICT-intensive skills.*

That is, when broadband Internet becomes available it is more quickly adopted in firms in which complementary factors are abundant, including computers and skilled workers (Akerman et al. 2015). Thus, the adoption of broadband by firms and individuals is endogenous.

> *3. Broadband availability increases the demand for high-skilled and ICT-intensive skilled individuals who, at the same time, become more productive due to broadband and earn even higher wages.*

Broadband diffusion then implies an increased demand for those skills that complement broadband technology and enable firms to increase their productivity. These workers can earn higher wages, partly because less labor in general is needed to perform the same tasks as before ICT technology, and partly because of the increased demand for their specific ICT-intensive skillset.

> *4. Lagging supply of educating ICT-intensive skills results in labor supply shortage, which increases the wage levels for these skills further.*

Lagging supply of educating such complementary ICT-intensive skills results in labor supply shortage. For example, there was a shortage of computer programmers in Sweden already in 2006 and the demand was projected to rise (Statistics Sweden 2006). Increased demand combined with labor shortage results in even higher wage levels for those skills.

5. The cost of outsourcing labor tasks by large firms fall with broadband technology, as search costs and other transaction costs decrease.

That is, broadband adoption by large firms imply falling transaction costs for outsourcing services to self-employed individuals. For example, cheaper and more reliable ICT-enabled communication has decreased the cost of coordinating complex activities over long distances both within and between companies (Ek 2014). From a large firm's perspective, this means that the transaction cost associated with outsourcing services have fallen. This is supported by Wingborg (2016) who states that the number of online job contracts and transfers where fixed fees are offered for pre-specified orders have increased dramatically.

6. Broadband increases connectivity and enables access to global markets by individuals and remote market actors.

Broadband diffusion increases connectivity, which positively impacts entrepreneurship and enables access to global markets for remote independent actors. Broadband facilitate connectivity and linkages among people, and is found to be conducive to entrepreneurial startup activity (Audretsch et al. 2014). Thus, the global markets for labor, goods, services, and finance that were previously not accessible to individuals in remote areas are becoming available. Broadband Internet then facilitates for service firms in rural areas to overcome geographic barriers that otherwise hinder rural growth (Ivus and Boland 2015).

7. Online work platforms lower search costs for individuals to find freelance work opportunities outside of the large organization.

From the employee's perspective, platforms such as Upwork and Linkedin have lowered the search cost for work opportunities outside the organization and enabled individuals to combine wage employment with self-employment. This implies a lower relative cost of being self-employed vs. wage employed compared to before broadband.

8. Higher expected earnings from self-employment relative to wage employment for high-skilled and ICT-skilled individuals implies a pull effect into self-employment.

A high demand for ICT-intensive skills implies that expected earnings from being self-employed and working for several clients on a project basis may exceed actual earnings from wage employment. This income differential implies a pull effect into self-employment as expected earnings of self-employment exceed expected earnings of wage employment.

Last, workers with abundant complementary factors to broadband technology end up at the high end of the income residual distribution of expected earnings from self-employment compared to wage employment. Thus, these individuals are more likely to start an incorporated firm and enter self-employment (Andersson and Wadensjö 2013).

Additionally, positive spillover effects and network externalities of broadband Internet (Briglauer 2014, Majumdar et al. 2010, SOU2015) imply that higher broadband diffusion further increases the benefit of using technologies both for firms and for individual self-employed.

4.2 Broadband diffusion impact on income dispersion

Increased productivity differences between individuals in society

The impact of broadband diffusion on self-employment income dispersion also relates to the literature on skill-complementarity of broadband Internet as well as job polarization.

> *1. Broadband technology complements high-skilled workers who benefit from productivity gains and substitutes less skilled workers who to a higher extent perform routine tasks that can be replaced by digital technology.*

This statement is, as mentioned above for Hypothesis 1, an argument that builds on for example Autor et al. (2003).

> *2. Productivity differences increase between individuals in society as on the one hand already productive individuals become even more productive but on the other hand less productive individuals become even less productive.*

Heyman et al. (2016) find that digitalization appears to reinforce the transmission of certain skills and talents, which means that differences in productivity between various individuals in society can be expected to increase. The value of the right education and further education will thereby become increasingly important for the opportunity to be employed and for good wage development.

> *3. Self-employment entry in general is highest in the tails of both educational attainment and income distribution.*

Many previous studies found a u-shaped relationship where self-employment entry is highest in the tails of both the educational and income distribution (i.e. Blanchflower 2000). This u-shaped relationship may still prevail even though Andersson and Wadensjö (2013) find that self-employed in incorporated firms are to a higher extent drawn from the top end of these distributions.

> *4. Increased productivity differences between self-employed individuals imply larger income differences and thus higher income dispersion.*

As a result, there would be a positive relationship between broadband diffusion and income dispersion of self-employed in incorporated firms.

Finally, the expected outcome may be amplified by network externalities and positive spillovers. When companies adopt broadband and ICT and transform their supply chains, they prompt other companies to change too, either because they are part of the chain, or because they copy an innovative leader. By its nature, ICT also creates positive network externalities whereby the benefits that accrue from using technologies increase as broadband diffusion increases (Briglauer 2014, Majumdar et al. 2010, SOU2015).

5 Method and Data

The following section specifies the econometric model used to test the relationship between broadband diffusion and the self-employment related outcomes of interest. The section concludes with a description of the data set and main variables.

5.1 Econometric model for panel estimation

To test the relationship between broadband diffusion, self-employment entry and income dispersion of self-employed in incorporated firms, the basic OLS regression model of interest is:

$$\text{Self employment entry}_{mt} = \beta_0 + \beta_1 \text{Broadband diffusion}_{mt} + X_{mt} + u_{mt} \quad (1)$$

$$\text{Income dispersion}_{mt} = \beta_0 + \beta_1 \text{Broadband diffusion}_{mt} + X_{mt} + u_{mt} \quad (2)$$

where m is each municipality in Sweden and the dependent variable is (1) the number of individuals entering self-employment as a share of the working population in each municipality and (2) the average income dispersion of self-employed in a given municipality.

This basic regression is estimated as a pooled OLS using the time period 2007-2012. A vector of additional controls, X, is added at the municipal level including population growth, share of population with higher education, and employment rate.

There may however be unobserved factors in this basic model specification that are correlated with the dependent variable, such as time specific and sector specific factors, which implies that the error term will be correlated with the dependent variable and cause biased estimators. Therefore, using panel estimation with fixed effects, the regression model of interest is then:

$$\text{Self employment entry}_{mst} = \theta_m + \propto_s + \gamma_1 \text{Broadband diffusion}_{mt} + \delta_t + X_{mt} + \varepsilon_{mst} \quad (3)$$

$$\text{Income dispersion}_{mst} = \theta_m + \propto_s + \gamma_1 \text{Broadband diffusion}_{mt} + \delta_t + X_{mt} + \varepsilon_{mst} \quad (4)$$

where municipality, m, and sector, s, fixed effects are used to control for unobserved time-invariant characteristics that are unique to each municipality and sector. Year dummies are used to control for aggregate trends that are unrelated to the causal relationship between broadband and self-employment related outcomes, such as economic cycles and nation wide regulatory changes. I also allow for different time trends between municipal-sector observations. A vector of additional controls, X, is added to control for municipal specific factors that vary over time.

The dependent variable of interest is (3) the number of individuals entering self-employment as a share of the working population and (4) the average income dispersion of self-employed in a given municipality, sector, and year.

The independent variable, broadband diffusion, is defined as the share of population with access to fiber-connected broadband in a given municipality and year. Furthermore, this variable is tested using one-year and two-year lags as well as binary measures of broadband diffusion above a certain threshold share of the population, such as 0.3, 0.5, 0.7, 0.8 and 0.9.

The model is estimated for the total sample, and then for a separate subsample of firms in the service sector. Furthermore, a separate regression is estimated for ICT and ICT-service sectors as defined by Eurostat, in order to gain further insight into the sector specific relationship at a more detailed level.

Hypothesis 1 - Broadband diffusion and self-employment entry

In equation 3, the expected outcome is that the association between broadband diffusion and self-employment entry is positive, which follows from the reasoning in section 4.1. First, in a municipality with full broadband diffusion, the productivity of high skilled and ICT-intensive skilled individuals increases. These productivity gains combined with a surge in demand for these skills imply higher wages. Remote individuals gain access to global markets and the transaction cost of outsourcing services to self-employed fall. The possibility to work on a freelance or consultancy basis, for several companies simultaneously, implies higher expected earnings from self-employment relative to wage employment. This leads to a pull effect into self-employment in incorporated firms for high skilled and ICT-intensive skilled individuals.

Hypothesis 2 – Broadband diffusion and income dispersion

In equation 4, the expected outcome is that the impact of broadband diffusion on the income dispersion of self-employed is positive. In a municipality with full broadband diffusion, the productivity difference between individuals increases due to the skill-complementarity of broadband Internet, and thus income dispersion also increases.

Relationships as correlation rather than causation

The relationships analyzed should be seen as correlations rather than causation, as there may be other factors determining whether a municipality invested in broadband or not. Hence, the variation in broadband diffusion is not exogenous.

Hypothesis 1 aims to test whether broadband diffusion has implied a higher entry rate of self-employed in incorporated firms. However, it is plausible that municipalities with more entrepreneurs initially had a higher demand for broadband, which makes the municipality more likely to invest in fiber infrastructure. Thus, estimating this relationship using a panel regression and controlling for municipality fixed effects would not remove the risk of a counter causal effect.

One way to handle this issue is to use an instrumental variable to isolate the exogenous variation in the explanatory variable. Akerman et al. (2015) use broadband availability as an instrument for broadband adoption in firms to explain labor productivity. Other instruments are based on impediments to broadband rollout caused by the structure of the pre-existing voice-telephony network (Czernich 2014) and the variation in elevation that explains the regional difference in broadband coverage (Ivus and Boland 2015). In the absence of such appropriate instrument, an alternative approach is to use propensity score matching or cell matching, which is discussed further in section 7.

5.2 Data and main variables

Data description

Firm level data

I use data on the total population of incorporated firms in Sweden provided by PAR. The data contains financial information, number of employees, registration date of the firm, related SNI2007 industry code, and registered location by municipality.

The sample selection criteria is that the firm had 0-1 employees over the fiscal year used in the data. The time period selected is fiscal years 2007-2012, as these years can be matched with the broadband data. Moreover, I only select active firms to mainly capture those individuals that are self-employed in the incorporated firm for a living. I also allow for entry and exit of firms over the time period studied.

Broadband data

I use broadband data collected by government agency PTS on the share of fiber connected properties at the municipal level between 2007 and 2012. The data is part of the PTS Bredbandskartläggning: 2007-2012.

Specifically, the measurement used is the share of population in a municipality that is located in or within 354 meters of a broadband connected property. The measure 354 meters is the length of a diagonal with sides' length of 250 meters, which is the smallest geographic unit of analysis available from the PTS broadband mapping.

According to PTS, the measurement is used to show how large share of the population lives near a fiber broadband connection. In the PTS data collection, all providers, suppliers and owners of broadband infrastructure in Sweden were obliged to provide data on broadband availability in their respective geographical area.

Thus, compared to previous studies that use individual survey data to construct a measurement of broadband access, the PTS data is a more accurate measure with less measurement error.

Municipal data

I complement the dataset with municipal data regarding population size, population growth, share of population 15-64 years old, employment rate, tax base, number of inbound commuters, and number of individuals with higher education. This data is obtained through Statistikatlas managed by Statistics Sweden. The dataset includes 289 out of 290 municipalities in Sweden.

Industry codes and ICT sector

I also use industry codes SNI2007 and NACE2 to combine the dataset with the Eurostat definition of ICT sector and ICT service sector. One problem that arises is that there are several SNI-codes registered per firm. I chose to use the most recent SNI-code registered for each firm. Moreover, I have tried using the first registered code and the most frequently registered SNI-code per firm with similar results.

Variable description

Dependent variables

For hypothesis 1, the outcome variable of interest is startup rate or self-employment entry. The variable is defined as the number of started incorporated firms with 0-1 employees in a municipality and year divided by the total population in a municipality in that given year.

$$Self\ employment\ entry_{mst} = \frac{Number\ of\ started\ own\ account\ firms_{mst}}{Working\ population_{mt}}$$

For hypothesis 2, the dependent variable is income dispersion, which is defined as the standard deviation of the nominal net income of self-employed in incorporated firms in a municipality and sector in a given year.

$$Income\ dispersion_{mst} = Standard\ deviation\ (Net\ income\ of\ self employed)_{mst}$$

Another alternative measure used for income dispersion is the ratio of the top and bottom quartiles of the nominal income distribution in the sample:

$$Income\ dispersion_{mst} = \frac{Top\ quartile\ of\ income\ distribution_{mst}}{Bottom\ quartile\ of\ income\ distribution_{mst}}$$

Both of the measurements for income dispersion use nominal income rather than real income. Due to the low inflation rate in Sweden over the time period, the results would not be significantly impacted using real income.

Independent variable

The independent variable is broadband diffusion, which is defined as the share of population in or within 345 meters of a fiber-connected property, by municipality and year. I also construct a binary treatment variable for the broadband availability being below or above a certain threshold. In this case, different levels of broadband diffusion are defined as reaching a share of 0.3, 0.5, 0.7, 0.8 or 0.9 of the population.

Based on previous research, I define 0.9 share of the population as full broadband diffusion. As showed in the table below, the distribution of municipalities' share of population with fiber access has shifted from right skewed with mean around 0.2 in 2007 to more normally distributed around a mean of 0.5 in 2012.

Figure 4: Distribution of fiber broadband diffusion over time

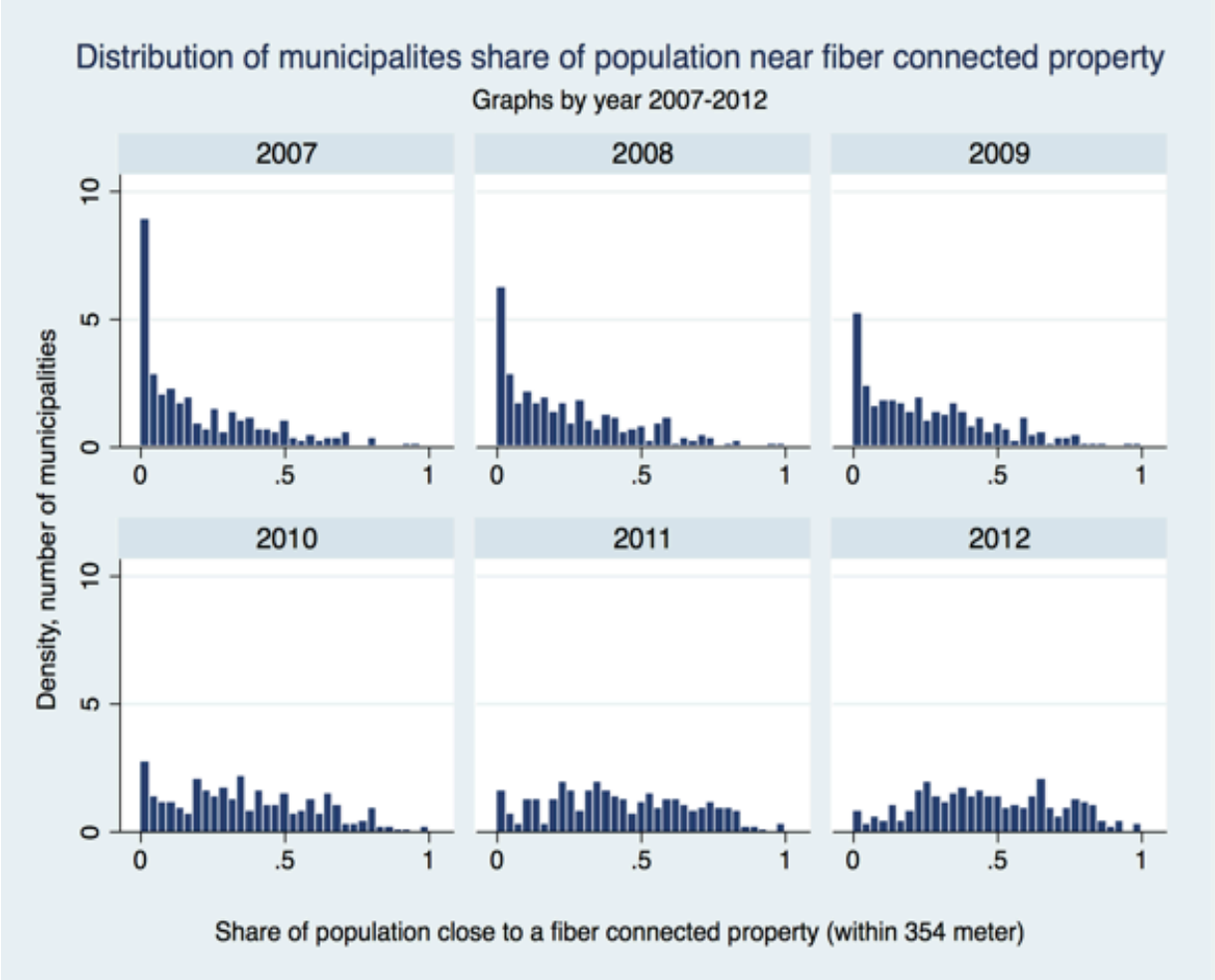
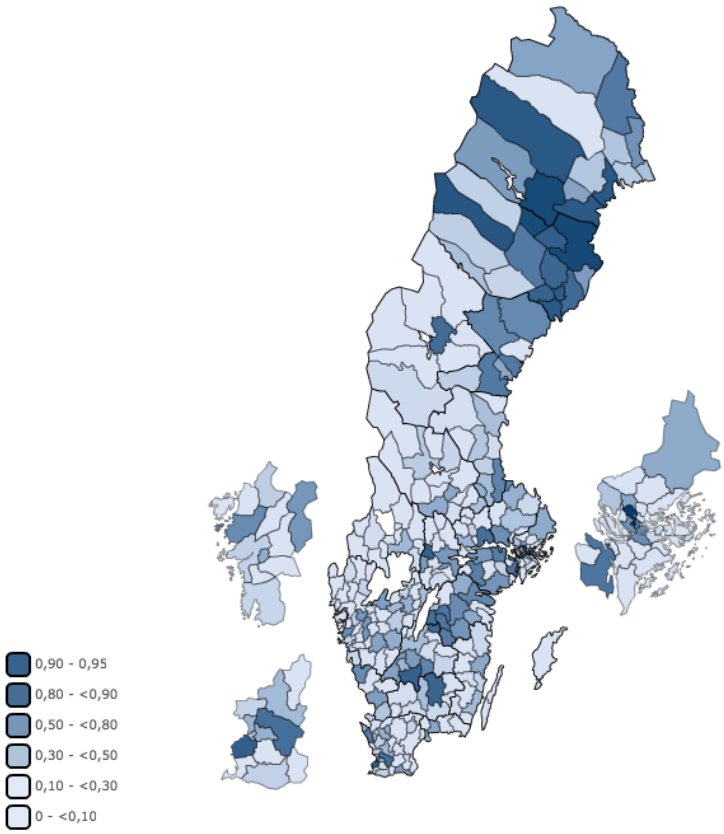
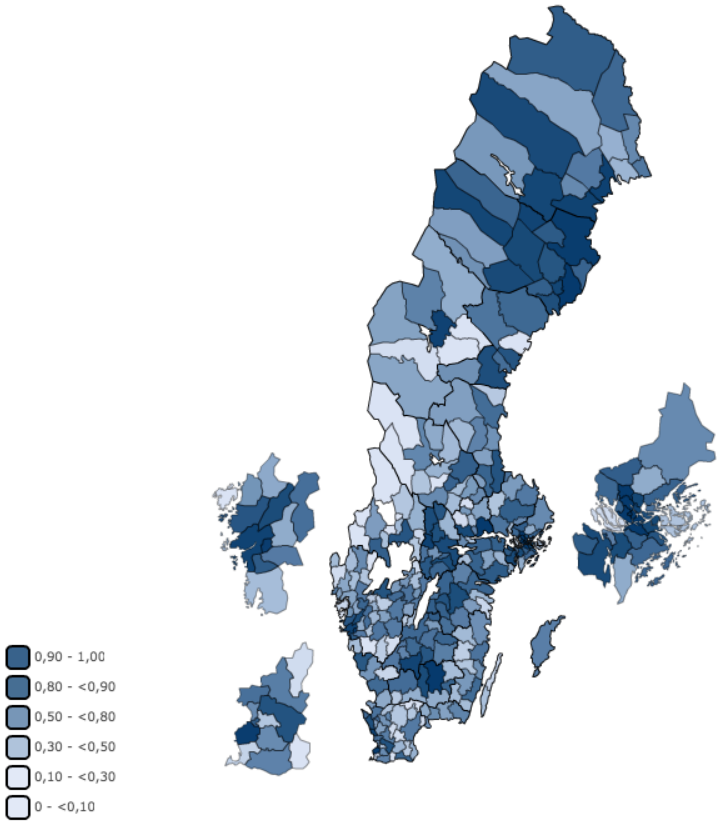


Table 2: Share of population near a fiber connected property, 2007-2012 (PTS 2016)

Year	Obs	Mean	Std dev	Min	Max
2007	289	.2021179	.2122357	0	.945751
2008	289	.2369487	.2172396	0	.995467
2009	289	.2634522	.2220067	0	.996987
2010	289	.3630255	.238595	0	.9985335
2011	289	.4250509	.2416885	0	.99854
2012	289	.4686348	.2358	0	.9990624

Figure 5: Fiber broadband diffusion in Swedish municipalities in 2007, top, and 2012, bottom. (PTS data, created using Statistikatlas)





Summary of descriptive statistics

Table 3: Aggregate firm-level data at the municipal level

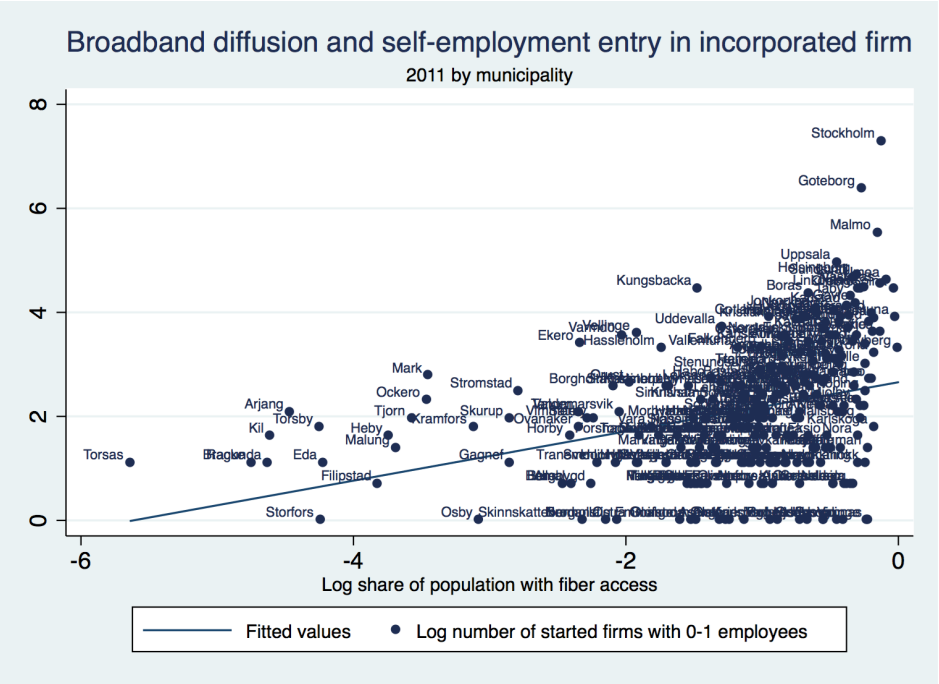
Variable	Description	Obs	Mean	Std. Dev.	Min	Max
Dependent var.						
ENTRY_SH	Number of self-employed in incorporated firm started as share of population	1740	.002	.002	0	.019
LN_ ENTRY_SH	Natural log of ENTRY_SH	1428	-6.130	.862	-9.042	-3.989
SD_INC	Average standard deviation of self-employed income from net sales	1740	10620.83	22027.29	562.449	327136.4
LN_ SD_INC	Natural log of SD_INC	1740	8.558	1.056	6.332	12.698
INC_RATIO	Ratio of the top and bottom income quartile of self-employed	1740	88.457	113.814	16.406	1928.874
LN_IN_RATIO	Natural log of INC_RATIO	1740	4.222	.624	2.798	7.565
Independent var.						
FIBER	Share of population within 345 meters of a fiber connected property	1734	.327	.248	0	.999
LN_FIBER	Natural log of FIBER	1653	-1.546	1.297	-9.309	-.001
FIBER_50	Dummy variable of FIBER (1=at least 0,5; 0=less that 0,5 access)	1740	.257	.437	0	1
FIBER_70	Dummy variable of FIBER (1=at least 0,7; 0=less that 0,7 access)	1740	.098	.297	0	1
FIBER_80	Dummy variable of FIBER (1=at least 0,8; 0=less that 0,8 access)	1740	.016	.126	0	1
FIBER_90	Dummy variable of FIBER (1=at least 0,9; 0=less that 0,9 access)	1740	.043	.203	0	1
Municipality var.						
POP_SIZE	Size of population in a municipality	1740	32318.55	64225.23	2421	881235
WORK_AGE	Share of population 15-64 years old	1740	62.695	2.384	55.2	71.31
POP_GROWTH	Population growth	1740	.11	.955	-3.000	4.554
EMPL_RATE	Employment rate	1740	78.177	4.037	60	88
COM_INB	Number of inbound commuters	1740	27.577	13.634	3.4	87.2
TAX_BASE	Average tax income per citizen (SEK)	1740	156621.6	20531.93	120280	318288
HIGH_EDU	Share of population with higher education	1740	16.418	7.050	7.45	55.25
MED_INC	Median income	1740	223.544	22.532	178.7	328

6 Analysis

Hypothesis 1: Broadband diffusion impact on self-employment entry

First, plotting the natural logarithm of broadband diffusion against the number of started incorporated firms with 0-1 employees by municipality, visual inspection suggests a positive correlation. Also, a non-linear relationship is displayed which motivates including a squared term in the regression. Second, the relationship is plotted for the number of started firms as a share of the population in a municipality, which better captures entrepreneurial activity. Still a positive relationship is displayed, although the correlation is weaker.

Figure 6: Scatter plot of correlations, cross-section of data in 2011.



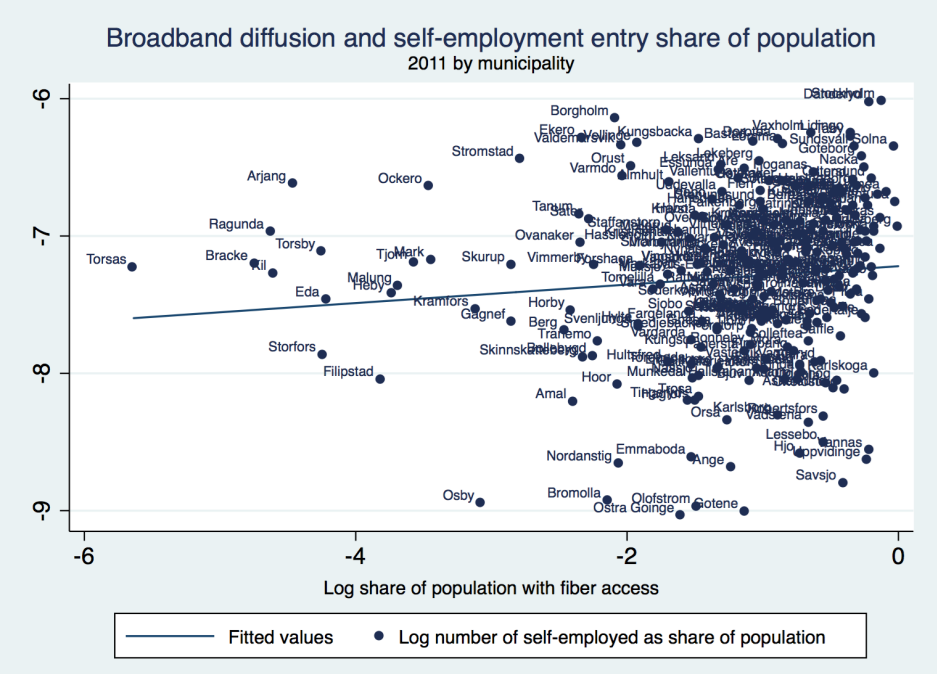


Table 4: Regression results for hypothesis 1, broadband diffusion and entry of self-employed in incorporated firms.

Fiber broadband diffusion and self-employment entry, all sectors.
Dependent variable: log of self-employment entry share of population (LN_ENTRY_SH)

	(1)	(2)	(3)	(4)	(5)
Measure of fiber diffusion	Log fiber access	50% fiber access	70% fiber access	80% fiber access	90% fiber access
Fiber diffusion	0.031***	-0.005	-0.014	-0.074***	-0.112**
	(0.010)	(0.018)	(0.021)	(0.028)	(0.047)
Controls	Yes	Yes	Yes	Yes	Yes
Municipal F.E.	Yes	Yes	Yes	Yes	Yes
Sector F.E.	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes
Observations	21,724	21,724	21,724	21,724	21,724
R-squared	0.398	0.398	0.398	0.399	0.399
Number of F.E. entities	8,020	8,020	8,020	8,020	8,020

Standard errors in parentheses clustered at municipal level.

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

Note: All regressions controls for employment rate, share of population with higher education, and population growth. Column (1) to (5) control for municipal, sector, and year fixed effects. The number of observations displayed is the number of unique municipal-sector-year observations. Regressions with all sectors use the 2-digit level of SNI2007 industry code as basis for grouping municipality-sector observations. Regressions with sub-samples service use 2-digit level, and ICT sectors use 4-digit level of SNI2007 industry code in order to capture variation between sectors at a more detailed level.

Table 5: Regression results for hypothesis 1, 90% broadband diffusion and entry of self-employed in incorporated firms.

90% fiber diffusion and self-employment entry

Dependent variable: log of self-employment entry share of population (LN_ENTRY_SH)

	(1)	(2)	(3)	(4)	(5)
Sub-sample	All sectors	All sectors	Service	ICT sector	ICT service
90% fiber diffusion	-0.463**	-0.112**	0.827**	-0.226*	-0.216*
	(0.192)	(0.047)	(0.354)	(0.127)	(0.125)
Controls	Yes	Yes	Yes	Yes	Yes
Pooled OLS	Yes				
Municipal F.E.		Yes	Yes	Yes	Yes
Sector F.E.		Yes	Yes	Yes	Yes
Year F.E.		Yes	Yes	Yes	Yes
Observations	1,642	21,724	1,409	1,671	1,672
R-squared	0.086	0.399	0.312	0.390	0.388
Number of F.E. entities		8,020	789	682	683

Standard errors in parentheses clustered at municipal level.

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

Note: All regressions controls for employment rate, share of population with higher education, and population growth. Column (2) to (5) control for municipal, sector, and year fixed effects. For these regression, the number of observations displayed is the number of unique municipal-sector-year observations. Regressions with all sectors use the 2-digit level of SNI2007 industry code as basis for grouping municipality-sector observations. Regressions with sub-samples service use 2-digit level, and ICT sectors use 4-digit level of SNI2007 industry code in order to capture variation between sectors at a more detailed level.

Estimating hypothesis 1 as the impact of broadband diffusion on self-employment entry, the main results are presented in table 4 and 5. As opposed to my hypothesis, the results indicate that there is a negative relationship between full broadband diffusion and entry into self-employment in incorporated firms, where full broadband diffusion is defined as at least 90% of the population with fiber-connected broadband access (Table 5). All regressions control for population growth, employment rate and education level, which are all positively associated with self-employment entry.

In Table 4, column (1) displays the results using the natural logarithm of broadband diffusion which displays a positive relationship where a 1% increase in broadband access is associated with a 3.1% increase in the number of individuals entering self-employment as a share of the working population. The relationship is significant at 1% level and the model has an R-squared around 0.4 so around 40% of the variation in the data is explained by the model.

In column (2) and (3), analyzing thresholds of 50% and 70% of the population with broadband access reveals no significant results. However, when moving towards full broadband diffusion of 80% or 90% in columns (4) and (5) the relationship turns negative. A municipality where 90% of the population had fiber access was associated with a 11% lower share of the working population entering into self-employment compared to municipalities where less than 90% of the population had broadband access. This result is significant at 5% level.

Table 5 displays the results using full broadband diffusion as the independent variable. Column (1) displays the pooled OLS regression where the results indicate that being in a municipality where 90% of the population had access to fiber-connected broadband implied that a 46% smaller share of the population entered self-employment in an incorporated firm compared to municipalities where the broadband diffusion was below 90%. The results are significant at 5% level.

In column (2), controlling for municipal, sector and year fixed effects, full broadband diffusion implies a 11% lower share of the working population entering into self-employment in incorporated firms, holding all other factors constant. This result is significant at 5% level.

In column (3), a sub-sample of firms in the service sector is regressed. Here, full broadband diffusion implies a 83% larger share of the working population entering into self-employment in incorporated firms. This indicates that the relationship varies in direction between the service sector and the rest of the economy.

In columns (4) and (5), the sample is restricted to ICT and ICT-service firms. The coefficients are negative and significant at 10% level when controlling for municipal and sector fixed effects. In both cases, full broadband diffusion implies around 20% lower share of the population entering self-employment in incorporated firms.

Additionally, for the lower thresholds of broadband diffusion, the results are not consistent across model specifications (see Appendix table A3-A6). The results are only significant for the total sample regression when testing for 80% broadband diffusion.

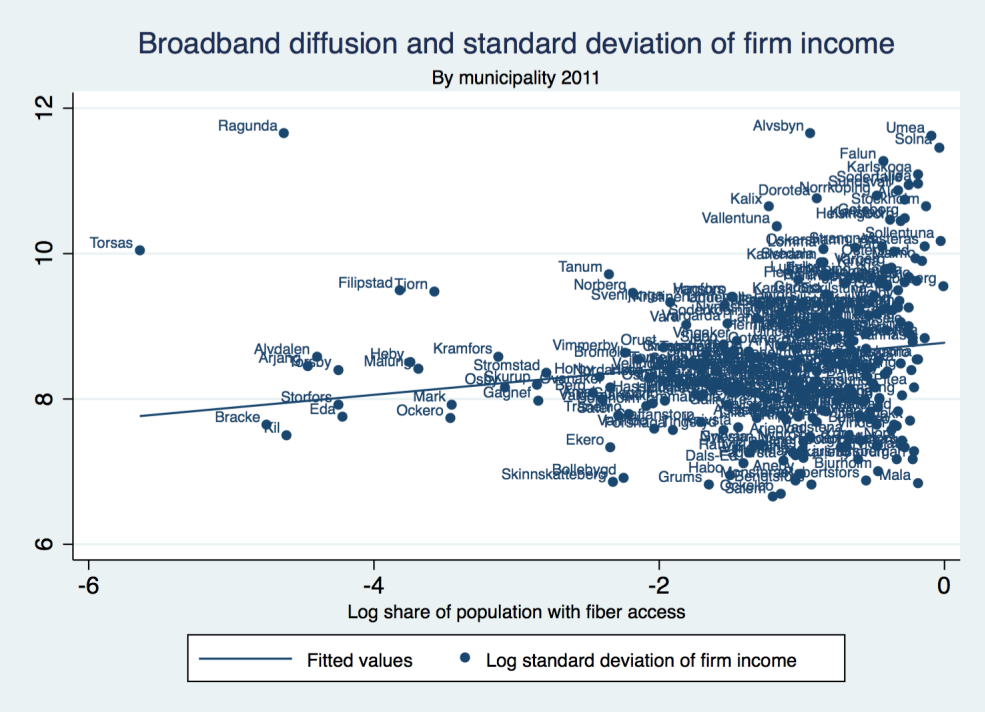
The regressions were also tested allowing for different time trends across municipal-sector observations, however, the results were not significant. Moreover, an additional robustness check excluded the last year of observation, 2012, to control for a possible anticipation effect caused by a lowered corporate tax rate in 2013. The results are robust to this test.

Hypothesis 2: Broadband diffusion impact on income dispersion

First, plotting a cross section of the natural logarithm of broadband diffusion against the standard deviation of nominal firm income, visual inspection displays a positive correlation. Specifically, the correlation is 0.16 in the pooled sample of all municipality-year observations.

Second, the alternative measure of income dispersion is the relative nominal income of the top quartile with the bottom quartile, displayed in the second graph. Here, the correlation is still slightly positive.

Figure 7: Scatter plot of correlations, cross-section of data in 2011.



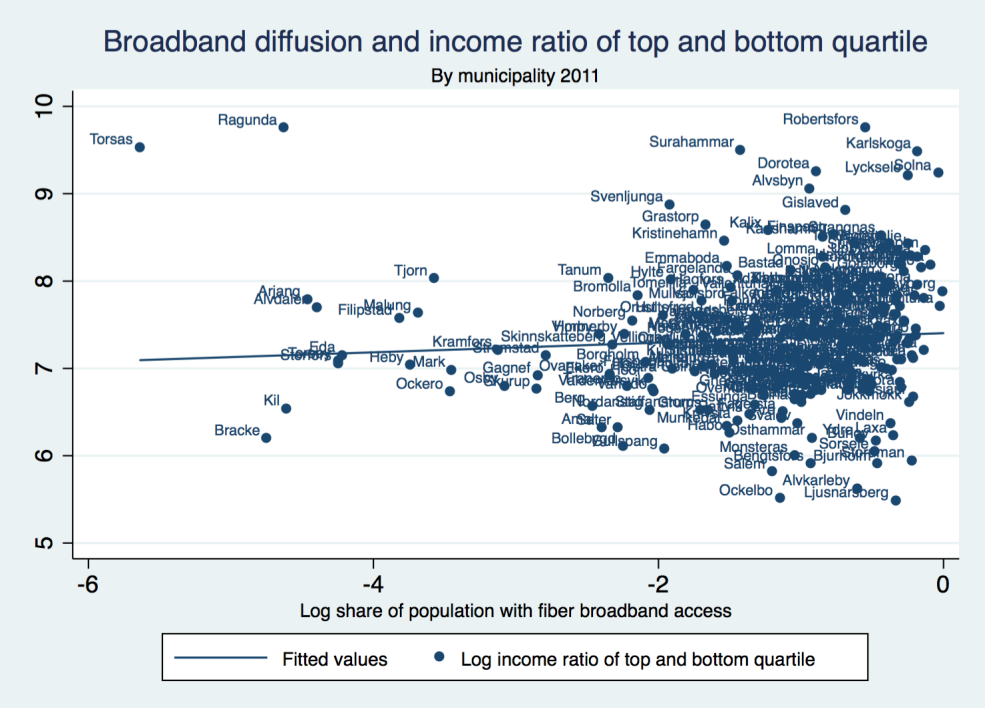


Table 6: Regression results for hypothesis 2, broadband diffusion and income dispersion of self-employed in incorporated firms.

Fiber broadband diffusion and income spread, all sectors.

Dependent variable: log of standard deviation of firm income (LN_SD_INC)

	(1)	(2)	(3)	(4)	(5)
Measure of fiber diffusion	Log fiber access	50% fiber access	70% fiber access	80% fiber access	90% fiber access
Fiber diffusion	0.013	-0.043*	-0.071**	-0.029	0.174**
	(0.009)	(0.022)	(0.028)	(0.040)	(0.079)
Controls	Yes	Yes	Yes	Yes	Yes
Municipal F.E.	Yes	Yes	Yes	Yes	Yes
Sector F.E.	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes
Observations	21,100	21,100	21,100	21,100	21,100
R-squared	0.000	0.001	0.001	0.000	0.001
Number of F.E. entities	3,984	3,984	3,984	3,984	3,984

Standard errors in parentheses clustered at municipal level.

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

Note: All regressions controls for employment rate, share of population with higher education, and population growth. Column (1) to (5) control for municipal, sector, and year fixed effects. The number of observations displayed is the number of unique municipal-sector-year observations. Regressions with all sectors use the 2-digit level of SNI2007 industry code as basis for grouping municipality-sector observations. Regressions with sub-samples service use 2-digit level, and ICT sectors use 4-digit level of SNI2007 industry code in order to capture variation between sectors at a more detailed level.

Table 7: Regression results for hypothesis 2, 90% broadband diffusion and income dispersion of self-employed in incorporated firms.

90% fiber broadband diffusion and income dispersion
Dependent variable: Log of standard deviation of firm income (LN_SD_INC)

	(1)	(2)	(3)	(4)	(5)
Sub-sample	All sectors	All sectors	Service	ICT sector	ICT service
90% fiber diffusion	0.383**	0.174**	0.272**	0.589***	0.750***
	(0.194)	(0.079)	(0.111)	(0.167)	(0.175)
Controls	Yes	Yes	Yes	Yes	Yes
Pooled OLS	Yes				
Municipality F.E.		Yes	Yes	Yes	Yes
Sector F.E.		Yes	Yes	Yes	Yes
Year F.E.		Yes	Yes	Yes	Yes
Observations	1,740	21,100	10,406	2,628	2,499
R-squared	0.122	0.001	0.002	0.010	0.013
Number of F.E. entities		3,984	1,917	580	541

Standard errors in parentheses clustered at municipal level.
*** p<0.01, ** p<0.05, * p<0.1

Note: All regressions controls for employment rate, share of population with higher education, and population growth. Column (2) to (5) control for municipal, sector, and year fixed effects. For these regression, the number of observations displayed is the number of unique municipal-sector-year observations. Regressions with all sectors use the 2-digit level of SNI2007 industry code as basis for grouping municipality-sector observations. Regressions with sub-samples service use 2-digit level, and ICT sectors use 4-digit level of SNI2007 industry code in order to capture variation between sectors at a more detailed level.

Estimating the effect of broadband diffusion on self-employment income dispersion, the main results are presented in Tables 6 and 7. In line with the hypothesis, the results indicate a positive relationship between full broadband diffusion and income dispersion of self-employed in incorporated firms, where full broadband diffusion is defined as at least 90% of the population with fiber-connected broadband access. All regressions controls for population growth, education level, and employment levels.

In Table 6 column (1), analyzing the complete sample using the natural logarithm of broadband diffusion does not display any significant result. In columns (2) and (3), the same regression for 50% and 70% fiber diffusion displays a negative relationship. In a municipality where above 70% of the population had access to fiber-connected broadband, the standard deviation of income was 7% smaller compared to municipalities where less than 70% of the population had fiber access. The results are not significant for 80% broadband diffusion. Column (5) displays that 90% broadband diffusion implies a 17% larger standard deviation of income, which is significant at 5%.

Table 7 further presents the results for full broadband diffusion. In column (1), analyzing the entire sample using a pooled OLS regression indicates that a municipality with 90% broadband diffusion has 40% larger standard deviation of income compared to municipalities with less than 90% broadband diffusion. The results are significant at 5% level.

Column (2) to (5) controls for municipal, sector and year fixed effects. In column (2), the impact of full broadband diffusion is a 17% higher standard deviation of income for self-employed in incorporated firms compared to municipalities with less than full broadband diffusion, holding all other factors constant. The results are significant at 5% level. However, the R-squared is 0.01 so only 1% of the variation in the data is explained by the model.

In column (4), a sub-sample of firms in the service sector is regressed. Again, full broadband diffusion implies a 27% higher standard deviation of income for self-employed in incorporated firms compared to municipalities with less than full broadband diffusion. The results for service firms are significant at 5% level. Thus, the relationship between full broadband diffusion and income dispersion is higher for service firms than in the total sample of firms.

In column (4) and (5), restricting the sample to ICT firms, similar results are found. The coefficient is positive and significant at 1% level when controlling for municipal, sector, and year fixed effects. Full broadband diffusion implies a 59% higher standard deviation of income in the ICT-sector and in the ICT-service sector it implies 75% higher standard deviation of income for self-employed in incorporated firms compared to municipalities with less than full broadband diffusion. However, the explanatory power of the model is low with R-squared around 0.01.

Furthermore, the alternative measure for income dispersion was tested as the ratio between the top and bottom income quartile of self-employed (Table A11 in Appendix). The results were similar to the ones described above. Controlling for municipal, sector, and year fixed effects, a municipality with full broadband diffusion has 15% higher ratio of top and bottom income quartile compared to municipalities with less than full broadband diffusion. In the subsample of service sector, the corresponding relationship is 33% higher and for the ICT sector the impact is around 50% higher ratio. Again however, the power is limited with R-squared ranging between a few percentages only.

The results for 70% and 80% broadband diffusion as well as the natural logarithm of broadband diffusion are presented in Appendix, Tables A8-A10. The above regressions were also tested allowing for different time trends across municipal-sector observations. However, the results were not significant.

Last, alternative measures for income dispersion were tested such as the standard deviation of the profit of firms. However, this measure did not display significant results. One issue with profit as a measure of income is that many self-employed report zero profit. Therefore, income from net sales of the firm seems to be a more suitable measure for this analysis.

7 Discussion

Hypothesis 1 - Interpretation of results on self-employment entry

In hypothesis 1, the relationship between broadband diffusion and the share of the working population entering self-employment in incorporated firms seems to depend on the extent of broadband diffusion. The relationship displayed is positive when using the natural logarithm of broadband diffusion. However, the coefficients turn negative when approaching 80% or 90% broadband diffusion.

In addition, the results seem to depend on the sector analyzed. Service sector firms display a positive relationship whereas the economy as a whole is negatively associated with full broadband diffusion. The results also indicate a more negative relationship between full broadband diffusion and self-employment entry for ICT firms than for the overall economy.

There are several reasons why these results are plausible. First, one explanation is that broadband diffusion spurred broadband adoption of large companies that became more productive and demanded more high-skilled workers as well as ICT-intensive skills. As these individuals were highly demanded by large firms at high wage levels, they had less incentive to enter self-employment. This explanation relates to Akerman et al. (2015) and can be exemplified with computer programmers and web developers that were highly demanded in the job market at the time.

Second, it could be that broadband technology had a positive impact on employment rates in general, as found by Czernich (2014). Thus, when more jobs became available there were fewer incentives to be self-employed. This explanation is supported by the results in hypothesis 1, as controlling for employment rate in the pooled OLS regression displays a positive and significant relationship between employment rate and full broadband diffusion.

Moreover, positive spillovers and network externalities may explain why the results hold for municipalities with full broadband diffusion and not for lower thresholds or the continuous variable of broadband access. When individuals adopt broadband and digitalize value-creating processes, they prompt other individuals to do the same, either because they are interlinked, or because they copy more productive and innovative market leaders. Examples of this are the phenomena of self-employed bloggers and "YouTubers" that arose during this time period, which I aimed to capture in the data. Although, these phenomena may be at such small scale that they are outweighed by the counter effect of productive firms demanding more high performing labor which diminishes the pull effect of high-performing individuals entering self-employment in incorporated firms. This is particularly relevant since the study focuses on the

incorporated type of self-employment, which mainly attracts high-performing individuals in the high end of the income distribution (Andersson and Wadensjö 2013).

Meanwhile, some issues arise regarding the results that should be discussed. First, one issue may be counter causality. Is it possible that municipalities with lower initial entrepreneurial activity in the form of self-employment were more likely to invest in broadband? The government support programs enabled municipalities without commercial prospects to provide fiber-connected broadband Internet access to all citizens. Thus, it could be the case that municipalities with less entrepreneurial activity initially invested more in broadband infrastructure when they received government support. However, the measurement of full broadband diffusion is not likely to be subject to counter causality. The subsample of municipalities with full broadband diffusion consists of 4.3% of municipality-year observations and these municipalities were probably more digitally mature, as a large share of the population had broadband for a longer period of time than in other municipalities.

Second, another concern is the model fit as year fixed effects explain most of the variation in the data. This can be seen when comparing R-squared with and without controlling for year fixed effects. The time period studied, 2007-2012, covers the recession years of the financial crisis, which impacted exports of Swedish companies and therefore employment levels. However, Svaleryd (2013) finds that in downturns of the business cycle self-employment can be a way to avoid unemployment, which suggests that self-employment rates would increase rather than decrease over the recession years. Contrarily, the results suggest that each year had a negative impact on self-employment rate compared to the first year of analysis, holding all other factors constant. At the same time, Svaleryd studies the unincorporated type of self-employment that to a higher extent attracts individuals in the low end of the income distribution who are pushed into self-employment. Therefore, these opposite results for self-employed in incorporated firms may not contradict previous findings.

Third, the magnitude of the coefficients seem large. For the ICT sector, around 20% lower share of the population started incorporated firms in municipalities with full broadband diffusion compared to 11% lower share in all sectors. The magnitude of these coefficients raises concerns whether other unobserved factors than broadband diffusion that are not captured in the model may partly explain the results. However, the share of the working population entering self-employment is only 0.2% on average as displayed in Table 3, so a decrease by 11% is not as high in magnitude it seems.

Moreover, for lower thresholds of broadband diffusion, the results do not hold when controlling for year fixed effects. Only the natural logarithm of the broadband diffusion variable displays a positive and significant coefficient for the total sample, which is in line with the initial hypothesis.

Conclusively, there are several reasons for why the empirical results are not in line with the expected outcome, and subsequently, a number of concerns arise. At the same time, some of the estimated coefficients are in fact significant and consistent across model specifications, and I argue that the analysis does reveal meaningful results. Referring to the conceptual framework in section 4.1, it could be that the time period studied is too short to reach the final point 8, where higher expected earnings from self-employment relative to wage employment implies a pull effect to self-employment entry in incorporated firms. Perhaps the time period 2007-2012

is too short and too early to fully capture the effect of broadband diffusion on labor market changes. Much as happened since 2012, such as a steady increase in the business service sector with professional consultants entering own-account firms, as well as a similar increase in web development and computer programming. Moreover, Uber, for example, had not yet had its breakthrough in Sweden, neither had Airbnb, food delivery services like Foodora and Uber Eats, nor freelance personal service platforms like Task Runner.

It could also be a case of time lag, that the effect of broadband diffusion may not be seen on a large scale until several years after the fiber infrastructure was constructed. Therefore, adding more year observations would be an interesting further step to this study.

Hypothesis 2 - Interpretation of results on self-employment income dispersion

In hypothesis 2, the empirical results confirm that full broadband diffusion implies higher income dispersion among self-employed in incorporated firms in Sweden. The results are consistent across model specifications and robust to alternative measurements. Again, there are several explanations that make these results plausible.

First, one explanation is the skill-complementarity of broadband Internet in line with the conceptual framework in section 4.2. High-skilled and ICT-intensive skilled individuals can become more productive and earn even higher wages as the demand for their skills increase. Meanwhile, routine tasks performed by less skilled individuals are to a higher extent replaced by broadband technology and thus, these individuals lose in terms of productivity. As productivity differences increase between individuals in society, income differences also increase, which implies higher income dispersion.

Second, another explanation is that broadband Internet enables individuals in remote areas to access global markets. This, in turn, implies increased competition so that highly competitive individuals can magnify their income by selling to global markets, whereas less competitive individuals will find it harder to compete. Again, this would result in higher income dispersion.

Moreover, according to the results, the impact of broadband diffusion on income dispersion is stronger and more significant for self-employed in the service sector and ICT sectors than for the total sample. This is counterintuitive to what is suggested by Akerman et al. (2015), where high-skilled and ICT-intensive skilled individuals overall benefit from productivity increases more than low-skilled individuals. One explanation could be that there are large differences in skill quality among individuals in ICT sectors so high performing individuals gain and low performing individuals lose in terms of productivity. Another plausible explanation is related to the discussion in hypothesis 1, where full broadband diffusion led to more employment opportunities. Hence, I believe that connecting firm level and individual level data would be interesting for future research, especially since recent literature highlights the increase in a hybrid form of self-employment combined with wage-employment.

Additionally, there are some concerns related to the analysis of hypothesis 2 that should be addressed. First, the low power of the model means that it does not explain more than a few percent of the variation in the data. As suggested above, a better model would need to connect firm level data with individual level information about educational attainment, age, tenure, and other characteristics that determine self-employment outcomes, as described in section 3.2.

Second, it is difficult to interpret the estimated coefficients in hypothesis 2, especially when using the measure standard deviation of income as a dependent variable. A slightly better measure is the ratio of top and bottom income quartile, presented in Appendix Table A11. This is easier to interpret, as for example a municipality with full broadband diffusion had a 15% higher ratio of top and bottom income quartiles. Again, these coefficients seem large and one should be careful when drawing conclusions. In general, these relationships should be interpreted as correlations rather than causation, as discussed in 5.1.

To conclude, the relationship between full broadband diffusion and income dispersion is positive and significance level varies between 5% and 1% across sub-samples. In line with theory and previous research, the empirical analysis shows that full diffusion of broadband technology is associated with an increase in income dispersion for self-employed in incorporated firms. These results motivate a more detailed analysis of how policy can help individuals gain from the productivity increases of digitalization. In a globalized labor market, where ICT-intensive skills become more important for productivity, the right education and skillset to remain competitive becomes much more important than ever before.

Internal validity of results

First, the internal validity of the results is strong due to the high quality of the data. The sample includes the entire population of active self-employed in incorporated firms in Sweden over the time period studied. Also, the broadband data is of high quality and contains low risk of measurement error, as the data was collected by government agency PTS and service providers were obliged to comply with data provision. Thus, compared to previous studies that use survey data to construct measurements for broadband adoption and indices for entrepreneurship, this paper analyzes higher quality data. This strengthens its relevance and contribution to the research literature.

Second, in terms of inference I have highlighted that the results should be interpreted as correlations rather than causation. This is mainly due to the non-exogenous nature of broadband diffusion, as factors outside the model determine whether a municipality invests in broadband infrastructure or not. A better identification strategy would be a method based on propensity score matching or cell matching to compare municipalities that were equally likely to invest in broadband over the time period.

Third, another question is why the results do not hold for other measures of broadband access than full broadband diffusion? The most compelling reason for this relates to network externalities and positive spillovers. The more people with access to broadband, the more people can learn from each other in terms of digital processes for value creation and practices to increase productivity. Moreover, another explanation could relate to digital maturity as those municipalities with full broadband diffusion between 2007 and 2012 most probably had broadband access earlier than other municipalities.

Despite these concerns, I argue that the high quality of the broadband data as well as the large sample of the total population of firms, make the internal validity of the results stronger than many previous studies. This paper is therefore an important addition to the research literature as it contributes to a better understanding of the relationship between broadband diffusion and self-employment. The topic has entailed a research gap and is of high relevance to the current policy discussion on labor market changes, both in Sweden and globally.

External validity of results

In terms of generalizing the results to all types of self-employment, one limitation is that this study only includes self-employed in incorporated firms with no employees, which accounts for 32% of all self-employed in Sweden (Andersson and Wadensjö 2013). Also, this group of self-employed is likely drawn for the higher end of the education and income distribution. Thus, I cannot say anything about self-employed in unincorporated firms, which would be an even more relevant analysis. Self-employed in unincorporated firms are found to be drawn from the lower end of the education and income distribution in general, and they would mainly be driven into self-employment entry by push factors such as unemployment. This group accounts for the largest share of self-employed, and may be affected more negatively by digitalization, as they would to a higher extent be on the losing side of increased income dispersion.

In terms of generalizing the results to other countries, the relationships between broadband diffusion and self-employment entry and income dispersion are likely to be context dependent. For example, the definition of self-employment as well as related institutions are specific for each national labor market. Also, the extent to which governments have supported construction of broadband infrastructure to areas without commercial potential varies between countries. Thus, the results found in this paper may best be generalized to Sweden and countries with similar labor market institutions and ICT infrastructure policies.

Results in a wider policy context

In Sweden, the national broadband strategy was revised in December 2016, and current targets are that 95% of all households and firms should have access to 100Mbit/s in 2020, and 98% should have access to 1Gbit/s in 2025 (Näringsdepartementet 2016). Thus, the measure of full broadband diffusion is a relevant indicator of what is to come for all Swedish municipalities within a near future. This development of ICT infrastructure is vital for Sweden to remain competitive and ensure high productivity levels.

Although, as showed in this thesis, with ICT development comes other structural changes that must be addressed, as firms and individuals may start organizing themselves in new ways. It will then be up to policy responses to ensure that productivity gains do not concentrate to small parts of the economy but rather come to benefit as many as possible. Due to the skill-complementarity of broadband Internet, those with complementary skills to broadband are more likely to benefit from these productivity gains, whereas those with skills that are to a higher extent substituted by broadband will lose in terms of productivity, and thereby income. In order to mitigate increased inequality, it will be essential to ensure life-long education where obsolete skills are upgraded to skills in-demand, as well as to enable more people to enter ICT-intensive entrepreneurship.

In a wider economic context, the results in this thesis should be interpreted through a time of an expanding service economy, more knowledge-intensive production, and a subsequent decrease in the manufacturing industry in the Western world. As projected by many researchers, large shares of jobs may be automated within the coming decades and it is important to focus policy efforts on sources of job creation that are enabled by new technology. One such source is self-employment as individuals are able to create their own jobs in the so called gig-economy. As discussed, broadband enables remote individuals to access global markets while platform companies like Linkedin and Uber have lowered the transaction costs

of outsourcing services to short term contractors. Eventually, broadband diffusion may enable individuals to transform their creative ideas into economic value outside the structure of the organization, as envisioned by Malone and Laubacher (1998) in the beginning of this paper.

Subsequently, self-employment is a type of entrepreneurial and job creating activity that can be enabled by new technology. I aimed to capture this effect in hypothesis 1, but was not able to prove it in the results. However, I am convinced that a more detailed analysis using individual level data and focusing on jobs within for example computer programming, web development, and software publishing would be able to find a positive effect of broadband diffusion on self-employment entry as well as entrepreneurial activity in general.

Future research

Finally, based on the research conducted in this paper I believe the most interesting extensions is to focus on unincorporated firms, combine individual level with firm level data, look at smaller geographical units, study a longer time period, as well as using a propensity score matching method to achieve better identification. Each is described in more detail below.

First, I believe the most interesting extension is to look at the relationship between broadband diffusion outcomes of self-employed in unincorporated firms. Compared to incorporated firms, these individuals are more concentrated in the low end of the income distribution and are more likely to be pushed into self-employment. They also constitute a larger share of the working population and are more widespread in many sectors of the economy.

Second, access to individual level data would enable to observe educational attainment, tenure, and other individual characteristics that determine self-employment entry and income. Also, combining individual and firm level data would make it possible to capture whether individuals enter self-employment from previous employment or from unemployment. This in turn, is likely to impact their performance as self-employed.

Third, it is possible to analyse smaller geographic units as broadband data is available on 250x250 meters grid from PTS. Thus, a more detailed analysis is possible at the geographic and individual unit level to connect broadband access to various outcomes of interest.

Forth, a study of a longer and more recent time period would be interesting. In 2007-2012, services like Uber, Airbnb, Linkedin, Task Runner, Frilans Finans or Foodora had not achieved market penetration in Sweden. Since then however, the development of self-employment has been accelerating through these platforms. Therefore, more recent data should be investigated.

Fifth, a study of broadband diffusion and entrepreneurship in general would be interesting where all firms regardless of size would be included. This relates to the tech revolution and startup companies, and thus, builds on a different research literature.

Sixth, in order to improve the internal validity of the results, I would suggest using a method based on propensity score matching or cell matching. This would mitigate the risk of counter causality and make a stronger argument by comparing treatment and outcome between municipalities that were equally likely to invest in broadband technology.

Finally, to investigate external validity of these results, several countries could be studied in a cross-country comparison of broadband diffusion and labor market changes.

8 Conclusion

To summarize, this thesis empirically investigates the relationship between broadband diffusion and 1) self-employment entry, 2) income dispersion of self-employed in incorporated firms in Sweden. The paper fills an important research gap, as there is no empirical study to date that investigates these relationships directly. Specifically, the subject is of high policy relevance due to the global increase in on-demand labor.

In order to analyze these relationships, I study self-employment in Sweden during the country's national broadband expansion. The dataset consists of firm level data of all self-employed in incorporated firms in Sweden between 2007 and 2012 matched with broadband data for the share of population with fiber-connected broadband access at the municipal level.

A conceptual framework is developed based on a literature review. The main mechanisms between broadband diffusion and the self-employment outcomes of interest are the skill-complementarity of broadband Internet (Akerman et al. 2015) combined with push and pull factors into self-employment (Andersson and Wadensjö 2013).

I use panel regression estimation controlling for municipal, sector, and year fixed effects. First, the results suggest that full broadband diffusion of at least 90% of the population with fiber-connected broadband access is negatively associated with the share of population entering into self-employment in incorporated firms. I discuss various reasons for this outcome.

Second, the results suggest that full broadband diffusion is positively associated with the income dispersion of self-employed in incorporated firms. Moreover, this relationship is stronger in the service sector and the ICT sector than in the economy as a whole. However, the results do not hold for lower thresholds of broadband diffusion.

Overall, the results contribute to a better understanding of labor market changes induced by digitalization. Future research should include individual level data and study the impact of broadband diffusion on self-employment in unincorporated firms over a longer and more recent time period.

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Appendix

Table A1: Variable description, aggregate firm-level data at the municipal level.

Variable	Description	Type	Source
Dependent variables			
ENTRY_SH	Number of incorporated firms with 0-1 employees started as a share of population in a municipality a given year	Fraction	PAR
LN_ENTRY_SH	Natural log of ENTRY_SHARE	Continuous	PAR
SD_INC	Average standard deviation of net income in incorporated firms with 0-1 employees in a municipality a given year	Continuous	PAR
LN_SD_ INC	Natural log of SD_ INCOME	Continuous	PAR
INCOME_RATIO	Ratio top and bottom quartiles of INCOME	Fraction	PAR
LN_INCOME_RATIO	Natural log of INCOME_RATIO	Continuous	PAR
Independent variables			
FIBER	Share of population within 345 meters of a fiber connected property in a municipality a given year	Fraction	PTS
LN_FIBER	Natural log of FIBER	Continuous	PTS
FIBER_50	Dummy variable of FIBER (1=at least 0,5 access; 0=less that 0,5 access)	Binary	PTS
FIBER_70	Dummy variable of FIBER (1=at least 0,7; 0=less that 0,7 access)	Binary	PTS
FIBER_80	Dummy variable of FIBER (1=at least 0,8; 0=less that 0,8 access)	Binary	PTS
FIBER_90	Dummy variable of FIBER (1=at least 0,9 access; 0=less that 0,9 access)	Binary	PTS
Municipality variables			
POP_SIZE	Size of population in a municipality	Continuous	Statistikatlas
WORK_AGE	Share of population 15-64 years old	Continuous	Statistikatlas
POP_GROWTH	Population growth	Continuous	Statistikatlas
EMPL_RATE	Employment rate	Continuous	Statistikatlas
COM_INB	Number of inbound commuters	Continuous	Statistikatlas
TAX_BASE	Average tax income per citizen (SEK)	Continuous	Statistikatlas
HIGH_EDU	Share of population with a higher education	Continuous	Statistikatlas
MED_INC	Median income	Continuous	Statistikatlas
Panel variables			
YEAR	Fiscal year registered in Swedish tax authority	Date	PAR
MUNICIPALITY	Municipality where the firm is registered	Non-numerical	PAR

Table A2: Variable description, firm level data before aggregating at the municipal level.

Variable	Description	Type	Source
ORGNR	Organization number of each incorporated firm	Discrete	PAR
REG_YEAR	Year the firm was officially registered	Date	PAR
FIS_YEAR	Fiscal year of financial data for each firm	Date	PAR
NUM_EMP	Number of employees in each firm	Discrete	PAR
SNI_5DIGIT	Industry code for each firm at the 5 digit level	Discrete	SCB
SNI_4DIGIT	Industry code for each firm at the 4 digit level	Discrete	SCB
SNI_3DIGIT	Industry code for each firm at the 3 digit level	Discrete	SCB
SNI_2DIGIT	Industry code for each firm at the 2 digit level	Discrete	SCB
SNI_1DIGIT	Industry code for each firm at the 1 digit level	Discrete	SCB
SERVICE	Sectors by SNI counted as service sectors	Discrete	SCB
ICT_TOTAL	Sectors by SNI counted as ICT sectors	Discrete	EUROSTAT
ICT_SERVICE	Sectors by SNI counted as ICT service sectors	Discrete	EUROSTAT

Table A3: H1) 90% broadband diffusion and self-employment entry in incorporated firms

90% fiber diffusion and self-employment entry

Dependent variable: log of self-employment entry share of population (LN_ENTRY_SH)

	(1)	(2)	(3)	(4)	(5)
Sub-sample	All sectors	All sectors	Service	ICT sector	ICT service
90% fiber diffusion	-0.463**	-0.112**	0.827**	-0.226*	-0.216*
	(0.192)	(0.047)	(0.354)	(0.127)	(0.125)
Controls	Yes	Yes	Yes	Yes	Yes
Pooled OLS	Yes				
Municipal F.E.		Yes	Yes	Yes	Yes
Sector F.E.		Yes	Yes	Yes	Yes
Year F.E.		Yes	Yes	Yes	Yes
Observations	1,642	21,724	1,409	1,671	1,672
R-squared	0.086	0.399	0.312	0.390	0.388
Number of F.E. entities		8,020	789	682	683

Standard errors in parentheses clustered at municipal level.

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

Note: All regressions controls for employment rate, share of population with higher education, and population growth. Column (2) to (5) control for municipal, sector, and year fixed effects. For these regression, the number of observations displayed is the number of unique municipal-sector-year observations. Regressions with all sectors use the 2-digit level of SNI2007 industry code as basis for grouping municipality-sector observations. Regressions with sub-samples service use 2-digit level, and ICT sectors use 4-digit level of SNI2007 industry code in order to capture variation between sectors at a more detailed level.

Table A4: H1) 80% broadband diffusion and self-employment entry in incorporated firms

80% fiber broadband diffusion and self-employment entry

Dependent variable: log of self-employment entry share of population (LN_ENTRY_SH)

	(1)	(2)	(3)	(4)
Sub-sample	All sectors	All sectors	Service	ICT sector
80% fiber diffusion	-0.505***	-0.074***	0.145	-0.137
	(0.110)	(0.028)	(0.131)	(0.084)
Controls	Yes	Yes	Yes	Yes
Pooled OLS	Yes			
Municipal F.E.		Yes	Yes	Yes
Sector F.E.		Yes	Yes	Yes
Year dummies		Yes	Yes	Yes
Observations	1,642	21,724	1,409	1,671
R-squared	0.094	0.399	0.307	0.390
Number of F.E. Entities		8,020	789	682

Standard errors in parentheses clustered at municipal level.

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

Note: All regressions controls for employment rate, share of population with higher education, and population growth. Columns (2) to (4) control for municipal, sector, and year fixed effects. The number of observations displayed is the number of unique municipal-sector-year observations. Regressions with all sectors use the 2-digit level of SNI2007 industry code as basis for grouping municipality-sector observations. Regressions with sub-samples service use 2-digit level, and ICT sectors use 4-digit level of SNI2007 industry code in order to capture variation between sectors at a more detailed level.

Table A5: H1) 70% broadband diffusion and self-employment entry in incorporated firms

70% fiber broadband diffusion and self-employment entry

Dependent variable: log of self-employment entry share of population (LN_ENTRY_SH)

	(1)	(1)	(2)	(3)
Sub-sample	All sectors	All sectors	Service	ICT sector
70% fiber diffusion	-0.398***	-0.014	-0.021	0.093
	(0.074)	(0.021)	(0.099)	(0.069)
Controls	Yes	Yes	Yes	Yes
Pooled OLS	Yes			
Municipal F.E.		Yes	Yes	Yes
Sector F.E.		Yes	Yes	Yes
Year dummies		Yes	Yes	Yes
Observations	1,642	21,724	1,409	1,671
R-squared	0.099	0.398	0.306	0.390
Number of F.E. Entities		8,020	789	682

Standard errors in parentheses clustered at municipal level.

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

Note: All regressions controls for employment rate, share of population with higher education, and population growth. All columns control for municipal, sector, and year fixed effects. The number of observations displayed is the number of unique municipal-sector-year observations. Regressions with all sectors use the 2-digit level of SNI2007 industry code as basis for grouping municipality-sector observations. Regressions with sub-samples service use 2-digit level, and ICT sectors use 4-digit level of SNI2007 industry code in order to capture variation between sectors at a more detailed level.

Table A6: H1) Log of broadband diffusion and self-employment entry in incorporated firms

Log fiber broadband diffusion and self-employment entry

Dependent variable: log of self-employment entry share of population (LN_ENTRY_SH)

	(1)	(2)	(3)	(4)
Sub-sample	All sectors	All sectors	Service	ICT sector
Log fiber diffusion	-0.156***	0.031***	-0.009	0.032
	(0.017)	(0.010)	(0.043)	(0.041)
Controls	Yes	Yes	Yes	Yes
Pooled OLS	Yes			
Municipal F.E.		Yes	Yes	Yes
Sector F.E.		Yes	Yes	Yes
Year F.E.		Yes	Yes	Yes
Observations	1,642	21,724	1,409	1,671
R-squared	0.130	0.398	0.306	0.389
Number of F.E. entities		8,020	789	682

Standard errors in parentheses clustered at municipal level.

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

Note: All regressions controls for employment rate, share of population with higher education, and population growth. Column (2) to (4) control for municipal, sector, and year fixed effects. For these regression, the number of observations displayed is the number of unique municipal-sector-year observations. Regressions with all sectors use the 2-digit level of SNI2007 industry code as basis for grouping municipality-sector observations. Regressions with sub-samples service use 2-digit level, and ICT sectors use 4-digit level of SNI2007 industry code in order to capture variation between sectors at a more detailed level.

Table A7: H2) 90% broadband diffusion and standard deviation of income of self-employed in incorporated firms

90% fiber broadband diffusion and income dispersion

Dependent variable: Log of standard deviation of firm income (LN_SD_INC)

	(1)	(2)	(3)	(4)	(5)
Sub-sample	All sectors	All sectors	Service	ICT sector	ICT service
90% fiber diffusion	0.383**	0.174**	0.272**	0.589***	0.750***
	(0.194)	(0.079)	(0.111)	(0.167)	(0.175)
Controls	Yes	Yes	Yes	Yes	Yes
Pooled OLS	Yes				
Municipality F.E.		Yes	Yes	Yes	Yes
Sector F.E.		Yes	Yes	Yes	Yes
Year F.E.		Yes	Yes	Yes	Yes
Observations	1,740	21,100	10,406	2,628	2,499
R-squared	0.122	0.001	0.002	0.010	0.013
Number of F.E. entities		3,984	1,917	580	541

Standard errors in parentheses clustered at municipal level.

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

Note: All regressions controls for employment rate, share of population with higher education, and population growth. Column (2) to (5) control for municipal, sector, and year fixed effects. For these regression, the number of observations displayed is the number of unique municipal-sector-year observations. Regressions with all sectors use the 2-digit level of SNI2007 industry code as basis for grouping municipality-sector observations. Regressions with sub-samples service use 2-digit level, and ICT sectors use 4-digit level of SNI2007 industry code in order to capture variation between sectors at a more detailed level.

Table A8: H2) 80% broadband diffusion and standard deviation of income of self-employed in incorporated firms

80% fiber broadband diffusion and income dispersion

Dependent variable: Log of standard deviation of firm income (LN_SD_INC)

	(1)	(2)	(3)	(4)	(5)
Sub-sample	All sectors	All sectors	Service	ICT sector	ICT service
80% fiber diffusion	0.151	-0.029	-0.063	0.026	0.046
	(0.122)	(0.040)	(0.055)	(0.101)	(0.106)
Controls	Yes	Yes	Yes	Yes	Yes
Pooled OLS	Yes				
Municipality F.E.		Yes	Yes	Yes	Yes
Sector F.E.		Yes	Yes	Yes	Yes
Year F.E.		Yes	Yes	Yes	Yes
Observations	1,740	21,100	10,406	2,628	2,499
R-squared	0.121	0.000	0.001	0.004	0.004
Number of F.E. entities		3,984	1,917	580	541

Standard errors in parentheses clustered at municipal level.

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

Note: All regressions controls for employment rate, share of population with higher education, and population growth. Columns (2) to (5) control for municipal, sector, and year fixed effects. The number of observations displayed is the number of unique municipal-sector-year observations. Regressions with all sectors use the 2-digit level of SNI2007 industry code as basis for grouping municipality-sector observations. Regressions with sub-samples service use 2-digit level, and ICT sectors use 4-digit level of SNI2007 industry code in order to capture variation between sectors at a more detailed level.

Table A9: H2) 70% broadband diffusion and standard deviation of income of self-employed in incorporated firms

70% fiber broadband diffusion and income dispersion

Dependent variable: Log of standard deviation of firm income (LN_SD_INC)

	(1)	(2)	(3)	(4)	(5)
Sub-sample	All sectors	All sectors	Service	ICT sector	ICT service
70% fiber diffusion	0.155*	-0.071**	-0.086**	-0.048	-0.049
	(0.084)	(0.028)	(0.039)	(0.083)	(0.085)
Controls	Yes	Yes	Yes	Yes	Yes
Pooled OLS	Yes				
Municipality F.E.		Yes	Yes	Yes	Yes
Sector F.E.		Yes	Yes	Yes	Yes
Year F.E.		Yes	Yes	Yes	Yes
Observations	1,740	21,100	10,406	2,628	2,499
R-squared	0.122	0.001	0.001	0.004	0.004
Number of F.E. entities		3,984	1,917	580	541

Standard errors in parentheses clustered at municipal level.

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

Note: All regressions controls for employment rate, share of population with higher education, and population growth. Columns (2) to (5) control for municipal, sector, and year fixed effects. The number of observations displayed is the number of unique municipal-sector-year observations. Regressions with all sectors use the 2-digit level of SNI2007 industry code as basis for grouping municipality-sector observations. Regressions with sub-samples service use 2-digit level, and ICT sectors use 4-digit level of SNI2007 industry code in order to capture variation between sectors at a more detailed level.

Table A10: H2) Log broadband diffusion and standard deviation of income of self-employed in incorporated firms

Log fiber broadband diffusion and income dispersion

Dependent variable: Log of standard deviation of firm income (LN_SD_INC)

	(1)	(2)	(3)	(4)	(5)
Sub-sample	All sectors	All sectors	Service	ICT sector	ICT service
Log fiber diffusion	0.070***	0.013	0.012	-0.074*	-0.085**
	(0.019)	(0.009)	(0.012)	(0.041)	(0.041)
Controls	Yes	Yes	Yes	Yes	Yes
Pooled OLS	Yes				
Municipality F.E.		Yes	Yes	Yes	Yes
Sector F.E.		Yes	Yes	Yes	Yes
Year F.E.		Yes	Yes	Yes	Yes
Observations	1,653	21,100	10,406	2,590	2,461
R-squared	0.136	0.000	0.001	0.005	0.006
Number of F.E. entities		3,984	1,917	578	539

Standard errors in parentheses clustered at municipal level.

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

Note: All regressions controls for employment rate, share of population with higher education, and population growth. Columns (2) to (5) control for municipal, sector, and year fixed effects. For these regression, the number of observations displayed is the number of unique municipal-sector-year observations. Regressions with all sectors use the 2-digit level of SNI2007 industry code as basis for grouping municipality-sector observations. Regressions with sub-samples service use 2-digit level, and ICT sectors use 4-digit level of SNI2007 industry code in order to capture variation between sectors at a more detailed level.

Table A11: H2) Log broadband diffusion and ratio of top and bottom income quartiles of self-employed in incorporated firms

90% fiber broadband diffusion and income dispersion

Dependent variable: Log ratio of top and bottom income quartiles (LN_INC_RATIO)

	(1)	(2)	(3)	(4)	(5)
Sub-sample	All sectors	All sectors	Service	ICT sector	ICT service
90% fiber diffusion	0.256**	0.148*	0.326***	0.504**	0.546***
	(0.117)	(0.080)	(0.111)	(0.199)	(0.209)
Controls	Yes	Yes	Yes	Yes	Yes
Pooled OLS	Yes				
Municipality F.E.		Yes	Yes	Yes	Yes
Sector F.E.		Yes	Yes	Yes	Yes
Year F.E.		Yes	Yes	Yes	Yes
Observations	1,740	13,876	7,788	1,029	997
R-squared	0.076	0.003	0.005	0.012	0.013
Number of F.E. entities		3,197	1,640	296	284

Standard errors in parentheses clustered at municipal level.

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

Note: All regressions controls for employment rate, share of population with higher education, and population growth. Columns (2) to (5) control for municipal, sector, and year fixed effects. For these regression, the number of observations displayed is the number of unique municipal-sector-year observations. Regressions with all sectors use the 2-digit level of SNI2007 industry code as basis for grouping municipality-sector observations. Regressions with sub-samples service use 2-digit level, and ICT sectors use 4-digit level of SNI2007 industry code in order to capture variation between sectors at a more detailed level.