MUNI ECON

WORKING PAPER

n. 2018-01
ISSN 2571-130X

Broadband Internet and Social Capital

Andrea Geraci / European Commission JRC
Mattia Nardotto / KU Leuven
Tommaso Reggiani / Masaryk University
Fabio Sabatini / Sapienza University of Rome

Broadband Internet and Social Capital

Abstract

We study how the diffusion of broadband Internet affects social capital using two data sets from the UK. Our empirical strategy exploits the fact that broadband access has long depended on customers' position in the voice telecommunication infrastructure that was designed in the 1930s. The actual speed of an Internet connection, in fact, rapidly decays with the distance of the dwelling from the specific node of the network serving its area. Merging unique information about the topology of the voice network with geocoded longitudinal data about individual social capital, we show that access to broadband Internet caused a significant decline in forms of offline interaction and civic engagement. Overall, our results suggest that broadband penetration substantially crowded out several aspects of social capital.

Masaryk University
Faculty of Economics and Administration

Authors:
Andrea Geraci / European Commission JRC
Mattia Nardotto / KU Leuven
Tommaso Reggiani / Masaryk University
Fabio Sabatini / Sapienza University of Rome

Contact: tommaso.reggiani@econ.muni.cz

Creation date: 2018-12
Revision date: 2018-12

Keywords: ICT, broadband infrastructure, networks, Internet, social capital, civic capital
JEL classification: C91, D9, D91, Z1

Citation:
Geraci, A., Nardotto, M., Reggiani, T.,Sabatini, F. 2018. *Broadband Internet and Social Capital.* MUNI ECON Working Paper n. 2018-01. Brno: Masaryk University.

ISSN 2571-130X

Broadband Internet and Social Capital

Andrea Geraci[*], Mattia Nardotto[†], Tommaso Reggiani[‡], Fabio Sabatini[§]

October 18, 2018

Abstract

We study how the diffusion of broadband Internet affected social capital in the UK. Our empirical strategy exploits a technological feature of the telecommunication infrastructure that generated substantial variation in Internet access conditions between households. Merging information on the topology of the Internet broadband network with geo-coded longitudinal data about individual social capital, taken from the British Household Panel Survey, we show that access to broadband Internet caused a significant decline in multiple forms of offline interaction and on civic engagement. Overall, our results suggest that the introduction of the Internet crowded out several aspects of social capital.

Keywords: ICT, broadband infrastructure, networks, Internet, social capital, civic capital.
JEL Classification: C91, D9, D91, Z1.

[*]European Commission, Joint Research Centre (JRC); University of Oxford, INET. andrea.geraci@spi.ox.ac

[†]KU Leuven, Department of Management Strategy & Innovation; CEPR; CESifo. mattia.nardotto@kuleuven.be

[‡]Masaryk University, Department of Public Economics; IZA. tommaso.reggiani@econ.muni.cz

[§]Sapienza University of Rome, Department of Economics and Law. fabio.sabatini@uniroma1.it

1 Introduction

Social capital has been credited with playing a role in many desirable outcomes such as access to credit and loan repayment (Karlan, 2005; Feigenberg et al., 2013), financial development (Guiso et al., 2004), innovation (Knack and Keefer, 1997), mitigation of agency problems in organizations (Costa and Kahn, 2003a), political accountability (Nannicini et al., 2013), and economic growth (Algan and Cahuc, 2010; Guiso et al., 2016), just to name a few. In his best seller *Bowling Alone*, Putnam (2000) documented that a decline in measures of social capital–such as participation in formal organizations, informal social connectedness, and interpersonal trust–began in the United States in the 1960s and 1970s, with a sharp acceleration in the 1990s. This study prompted many subsequent empirical tests that mostly supported Putnam's "decline of community life thesis" (Paxton, 1999). Costa and Kahn (2003b), for example, found a decline in indicators of volunteering, membership of organizations and entertainment with friends in the United States since 1952. Li et al. (2003) recorded similar patterns for the UK starting from 1972.

In *Bowling Alone*, three explanations were put forward for the decline in social capital: a) the reduction in the time available for social interaction—related to the rise in labor flexibility and to the expansion in commuting time; b) the rise in mobility of workers and students; c) progress in information and communications technology (ICT). Putnam (2000) argued that television and other forms of domestic entertainment such as video games and video players displaced relational activities in individuals' leisure time. This argument is consistent with empirical evidence of a negative role of television exposure in social relations (Bruni and Stanca, 2008), civic engagement (Olken, 2009), and voter turnout (Gentzkow, 2006). As television, a unidirectional mass medium, was found to significantly affect aspects of social capital, it stands to reason that the Internet, which provides on-demand content and allows for interactive communication, might induce an even more powerful substitution effect.

Given the pervasiveness of the Internet and the importance of social capital in economic outcomes, the effect of broadband penetration should be put under scrutiny by economic research. Studying the relationship between high-speed Internet and social capital, however, poses several methodological problems. The available longitudinal surveys contain limited information regarding Internet access and use. We lack longitudinal data about the time interviewees spend using the Internet and their online activities. In addition, the use of survey data entails endogenous sample selection and treatment assignment. As a result, it is difficult to establish causality. The purchase of a fast Internet connection and aspects of social capital such as interpersonal interactions and civic engagement may be co-determined by unobservable personality traits. Reverse causality is also at stake, as more socially active individuals may have a stronger propensity for using the Internet as a tool to preserve and extend their offline relationships. As a result, the existing evidence on the role of the Internet in the accumulation of social capital is limited and mostly anecdotal.

This paper studies the effect of the introduction of high-speed Internet on social capital using two data sets from the UK. To address endogeneity concerns, we exploit exogenous discontinuities in the quality of Internet access. During the time period considered in this paper, access to fast Internet in the UK was mostly based on the digital subscriber line (DSL) infrastructure. DSL technology allows the high-speed transmission of data over the old copper telephone network. However, the existence of a voice network is a necessary but not a sufficient condition for the availability of broadband. The actual speed of a domestic connection rapidly decays with the distance of a final user's telephone line from the node of the network serving the area, also called local exchange (hereafter LE). Our empirical analysis exploits the fact that, while at the time the network was designed in the 1930s the length of the copper wire connecting houses to the LE did not affect the quality of voice communications, the introduction of DSL technology in the 1990s unpredictably turned distance from the LE into a key determinant of Internet access and quality. Proximity to the relative node of the network thus resulted in access to fast Internet, while more distant dwellings were de facto excluded from accessing the broadband.[1] This identification strategy is similar to those developed in recent studies that exploit distance from the LE (or between the LE and higher nodes of the network) to identify the causal effect of broadband Internet on political participation (Falck et al., 2014; Campante et al., 2017), electoral results (Miner, 2015), health (Amaral-Garcia et al., 2017), and fertility (Billari et al., 2017).

Merging unique information about the topology of the voice network provided by Ofcom - including the geolocation of LEs and of the city blocks served by each of them - with geocoded individual survey data from the British Household Panel (BHPS) over the period 1997-2009, we are able to assess how broadband access affected several dimensions of social capital, such as participation in voluntary organizations, political participation, the frequency of voluntary work, and certain types of cultural consumption that are usually enjoyed in company such as cinema attendance.

First, we use our detailed map of the topology of the network to calculate the distance of the LE serving each Lower Layer Super Output Area (LSOA) from the centroid of the area. LSOAs are the second-narrowest geographical areas in the UK census, comprising on average 650 households and 1,500 inhabitants. In densely populated metropolitan areas they correspond to portions of city blocks. We then match this information with the geographic coordinates of the households surveyed in the BHPS. Since the availability

[1] Ofcom (2011).

of fast Internet was strongly affected, for technological reasons, by the physical distance between the LE and the premises, we are able to employ an intention-to-treat approach to assess the effect of fast Internet on social capital.

We find that after the advent of the broadband in the area, several indicators of civic engagement and offline interaction started to decrease with proximity to the node of the network, suggesting that the exposure to fast Internet displaced social capital. Placebo tests support the causal interpretation of our results. The panel structure of the dataset allows us to confirm that distance from the LE is not associated with changes in individual social capital before the penetration of the broadband.

Our paper bridges three strands of literature. The first broadly includes empirical research on the sources of social capital. Most studies in this field investigate the persistent role of exogenous variations that took place decades or centuries ago, such as inherited culture (Algan and Cahuc, 2010), long-gone formal institutions (Becker et al., 2014), a community's past history of independence (Guiso et al., 2016), and slave trade (Nunn and Wantchekon, 2011). We add to this field by investigating how progress in ICT can induce a much more rapid, though presumably persistent, change in the stock of social capital. Our paper is particularly related to contributions assessing the response of social capital to other contingent stimuli such as conflict (Guriev and Melnikov, 2016), exposure to television (Bruni and Stanca, 2008), teaching practices (Algan et al., 2013), unemployment (Algan et al., 2017), and regulation (Aghion et al., 2010).

The second strand encompasses sociological and economic studies that analyze how social engagement may be substituted by private activities (such as videogames) as new technology-intensive devices become more accessible. Several sociologists suggest that Internet use may displace forms of social capital in individuals' leisure time (Kraut et al., 1998; DiMaggio et al., 2001; Wellman and Hampton, 2001). Antoci et al. (2011) developed a dynamic model to analyze how technological progress can lead individuals to replace relational goods with material consumption. This substitution process may trigger a chain of reactions leading society into a "social poverty trap" (Antoci et al., 2015). We add to this field by offering an empirical test of the possible displacement effect caused by progress in ICT.

The third strand studies the effect of domestic broadband access or penetration on political participation (Czernich, 2012; Falck et al., 2014; Campante et al., 2017), electoral results (Miner, 2015; Gavazza et al., 2018), economic growth (Czernich et al., 2011), social capital (Bauernschuster et al., 2014), fertility (Billari et al., 2017), sex crime (Bhuller et al., 2013; Nolte, 2017), health (Amaral-Garcia et al., 2017), and well-being (Castellacci and Tveito, 2018). Recent studies also focus on the role of the Internet 2.0, highlighting the potential of social media to support collective action and political mobilization in young democracies or authoritarian regimes (Enikopolov et al., 2016;

Enikopolov et al., 2018), but also to exacerbating polarization (Müller and Schwartz, 2018a, a; 2018b, b), foster the spread of misinformation (Del Vicario et al., 2016), and biasing electoral results (Allcott and Gentzkow, 2017) in older democracies. In the paper that is closer in spirit to ours, Bauernschuster et al. (2014) exploited a quasi-experiment created by a technology choice of the state-owner provider, which unintentionally hindered broadband penetration in some areas, to identify the effect of fast Internet on social capital in East Germany. We differentiate from this study in several respects. Our identification strategy, though similar to that in Bauernschuster et al. (2014), exploits unique information about the distance between customers' dwellings and the nodes of the voice network. We use an intention-to-treat approach to test whether changes in the social capital of households occurred after the penetration of the broadband in relation to users' position in the topology of the network resulting in the actual access to fast Internet. The analysis was conducted in the UK over a period of 10 years. Finally, we assess the effect of broadband Internet on a wider range of indicators encompassing both the structural and the cognitive dimensions of social capital.

The remainder of this paper is organized as follows. Section 2 briefly reviews the literature on the effect of Internet-mediated communication on social capital. Section 3 describes the diffusion of broadband Internet in the UK. Section 4 describes the data. Section 5 presents our our empirical analysis of the effect of broadband Internet on social capital. Section 6 discusses how the topology of the network affected the Internet take up Section 7 concludes.

2 Social capital and the Internet

Social capital is generally referred to as all features of social life – networks, norms, civic engagement and trust – that enable individuals to act together more effectively to pursue shared objectives (Putnam, 1995). The literature has provided so many definitions of social capital that clarifying the dimensions of the concept has long been a research priority. Uphoff (1999) proposed a distinction between structural and cognitive dimensions: structural social capital refers to individuals' behaviors and consists of social participation and civic engagement (e.g. meetings with friends and membership in organizations). Cognitive social capital derives from individuals' perceptions resulting in trust, values and beliefs that promote pro-social behavior.

Putnam's (2000) concern about the detrimental role of technology related to the structural dimension of social capital. In *Bowling Alone*, the author borrowed two main arguments from the sociological literature to explain how ICT development could crowd out face-to-face interaction. First, the more time people use the Internet for leisure, the more time is detracted from social activities like communicating with friends, neighbors and family members (DiMaggio et al., 2001; Nie et al., 2002; Gershuny, 2003; Wellman and Hampton, 2001). The second argument relies on the concept of "community without propinquity" (Webber, 1963) and on the earlier theories of the Chicago School of Sociology. In a famous paper, Wirth (1938) claimed that any increase in the heterogeneity of the urban environment would provoke the cooling-off of "intimate personal acquaintanceship" and would result in the "segmentation of human relations" into those that were "largely anonymous, superficial, and transitory" (Wirth, 1938, p. 1). This line of reasoning can be easily applied to the Internet, which has the potential to fragment local communities into new virtual realities of shared interest that may negate the necessity of face-to-face encounters (see for example Antoci et al., 2011 and Conrads and Reggiani, 2017).

Empirical tests of the crowding out hypothesis have mostly been conducted in the fields of sociology and psychology and mainly focus on the structural dimension of social capital. In one of the earliest studies, Kraut et al. (1998) observed 69 individuals from 93 households in Pittsburgh for two years, concluding that increased Internet use was associated with a decline in interactions with family members within the household, a reduced social circle, and a rise in loneliness and depression. Nie and Erbring (2000) used U.S. cross-sectional data to show that Internet users reported spending less time with family and friends than non-users. Stepanikova et al. (2010) used panel time-diary data collected in a group of U.S. residents in 2004 and 2005 to examine whether loneliness and life satisfaction were associated with time spent on various Internet activities. Cross-sectional models revealed that time spent using the Internet was positively related to loneliness. However, the relationship was not robust to time fixed effects, suggesting that cross-sectional results could be driven by endogeneity issues such as omitted variables bias and reverse causality.

The concern for reverse causality is supported by studies finding that lonely people tend to use the Internet more. Drawing on data from a field study with 89 participants, Hamburger and Ben-Artzi (2003) found that lonely people spend more time using the Internet than non-lonely people. Analyzing responses from a survey of 277 undergraduate Internet users, Morahan-Martin and Schumacher (2003) suggested that lonely individuals may be drawn online because of the increased potential for companionship and as a way to mitigate negative moods associated with loneliness.

This literature mostly refers to the first stage of the Internet penetration that took place before the advent of social networking sites (SNS). More recent studies specifically focusing on the role of social media such as Facebook support the hypothesis that online interaction may instead help preserve social ties against time and space constraints. SNS have been found to allow the crystallization of weak or latent ties which might otherwise remain ephemeral (Ellison et al., 2007), boost teenagers' self-esteem by encouraging them to relate to their peers (Steinfield et al., 2008), and promote interest in politics and public affairs in general (Gil de Zúñiga et al., 2012).

Overall, this literature points out two opposing trends. While Internet access per se has been found to displace offline activities, social networking sites seem to have the potential to facilitate interaction and coordination among agents. These results are not as conflicting as they may seem. The first wave of Internet use, in fact, mainly consisted of asynchronous interaction through emails and forums and of the consumption of on-demand contents such as news sites and blogs. As the time devoted to web surfing necessarily had to be detracted from other activities such as face-to-face interaction, early sociological studies explained the negative correlation between Internet use and social participation as a result of a trade-off in the use of time. The web 2.0, on the other hand, is characterized by synchronicity, interactivity and the use social networks via mobile devices instead of desktop computers (Aghaei et al., 2012). These characteristics allow users to exploit the Internet to preserve existing relationships, develop new ties and in some cases promote collective actions, thereby making online and offline interaction more complements than substitutes.

Other work has assessed how the use of social media correlates with the cognitive dimension of social capital. Results are conflicting, with earlier studies finding a positive relationship in samples of US college students (e.g. Ellison et al., 2007; Valenzuela et al., 2009) and more recent studies finding a negative correlation in bigger and representative samples (e.g. Sabatini and Sarracino, 2017).

The findings of the sociological and communication literature, however, remain inconclusive due to sample bias, limited observations and the lack of longitudinal data. Economic studies added important insights to this literature by reaching more robust conclusions about the relationship between broadband access and social engagement. The longitudinal study of Bauernschuster et al. (2014) did not find evidence that broadband access displaced offline relationships in post-reunification Germany. Falck et al. (2014) and Gavazza et al. (2018), by contrast, provided evidence that fast Internet crowded out political participation in Germany and the UK. Campante et al. (2017) found that the initial spreading of Internet access indeed displaced political and civic engagement in Italy. In a second moment, however, the use of online networks triggered new forms of disintermediated involvement in public affairs that, according to the authors, was conducive to the later rise in the populist movement.

We add to this field by testing the crowding out hypothesis based on longitudinal data collected in a representative sample of the British population, using an identification strategy that has proved promising for studying the causal effect of broadband penetration, and testing the effect of broadband Internet on a wider range of indicators also including the cognitive dimension of social capital. The United Kingdom is an interesting case study in that it has an old and large telephone network, which was designed in the 1930s and irregularly shaped access to fast Internet in the second half of the 2000s. In addition, the unbundling experience caused a very rapid broadband penetration in a particularly short period of time, as it will be explained in detail in Section 3.

3 The broadband infrastructure in the UK

Internet access in the UK between the end of the 1990s and the first decade of the 2000s mainly relied on an infrastructure built several decades earlier: the telephone network. This network has been designed and rolled-out in the 1930s by the former state monopolist British Telecom (BT), which was formed as a branch of the UK's General Post Office. The network is made up of nodes (i.e. the local exchanges LEs), which are connected to each other to ensure global connectivity, each serving all premises located in the their respective catchment areas.

The voice network, which was designed for the transmission of the analog signal of voice communication, could be used to transmit digital signals, and thus enable all forms of digital communication, among which Internet access. The main challenge in doing so is given by the material of telephone lines, which were traditionally made of copper. A digital signal transmitted on a copper wire suffers substantial decay with the distance traveled, which made the length of the copper section of the network a crucial variable determining local Internet access conditions.

In the 1990s, the copper wires of the network provided low speed connection to the Internet via dial-up (i.e. a modem connecting to a service provider by dialing a telephone number). Around 1995 the introduction of the Digital Subscriber Line technologies (DSL) and later of the Asymmetric Digital Subscriber Line (ADSL), which use a wider range of frequencies over the copper line, made it possible to provide Internet access at a low cost through the voice network. Although the achievable connection speed by the first versions of ADSL was very limited (and did not qualify as broadband), technological improvements allowed reaching a speed of 2Mbit/s (which qualifies as broadband) at the beginning of the 2000s'. The maximum download speed that could be reliably provided to users grew rapidly during the first decade of the 2000s, reaching 24Mbit/s in 2008. The technological possibility to reach a high connection speed did not however imply that all Internet users could immediately enjoy such fast access. The adoption of state of the art DSL technologies required continuous upgrades of the network and faced a fundamental local limitation: the so-called *last mile*. As explained, the digital signal suffers strong decay when it is transmitted on a copper wire, with its strength declining more then proportionally with the distance traveled. Because of that, BT replaced all connections between LEs with fiber optic wires, as they account for most of distance traveled in the communication between the final user and the content provider/ISP but did not replace all connections between the local exchanges and the premises.[2] This allowed to reach good Internet speed at a relatively low investment cost, but generated local differences in the quality of access between households that depended on the length of their *last mile*, i.e., on the distance between their house and the respective LE. Having been installed in 1930s for different purposes than the transmission of the digital signal, the LEs have not been located in order to minimize the average decay. The LEs' catchment areas are irregularly shaped and LEs are often not located in their center. Thus, local access conditions can vary substantially in relatively small areas. In a 2011 report, Ofcom, the UK's communications regulator says: "A characteristic of ADSL broadband is that performance degrades due to signal loss over the length of the telephone line. This means that the speeds available to different customers vary significantly, with those with shorter line lengths (i.e. who live closer to the exchange) typically able to achieve higher speeds than those with longer line lengths. [...] We found that the average download speed received for *up to* 20 Mbit/s or 24 Mbit/s ADSL packages was 6.6 Mbit/s, and 37% of customers had average speeds of 4 Mbit/s or less" (Ofcom, 2011, p. 7).

Broadband Internet penetration in the UK grew slowly between the end of the 1990s and early 2000s (Deshpande, 2014). This was mainly due to two factors. First, the Internet speed that a private user could obtain was relatively low, due to the early stage of development of the DSL technology. Second, the institutional setting was not favoring private investments in the sector. The breakthrough in broadband penetration occurred in 2005, following the implementation of the so-called "local loop unbundling" (LLU) required by the European Union's policy on competition in the telecommunications sector, and introduced in the UK between 2003 and 2004. LLU is the process whereby the incumbent makes its local voice network available to other companies, and it has been the cornerstone of the open access legislation in European countries. Entrants are allowed to put their equipment inside BT's exchanges, in order to supply customers with an upgrade of their individual voice lines to DSL services (Nardotto et al., 2015). The number of Internet service providers grew rapidly, together with the market share of LLU operators which went from only 2.2% at the end of 2005 to almost 40% at the end of 2009. The process substantially boosted the broadband penetration in the UK, as shown in Figure 1, which reports the evolution of broadband penetration between 2003 and 2011. In the 5 years from 1999 which can be considered the starting year of

[2] The case of fiber until the LE is called *fiber to the cabinet* (FTTC) while the case of fiber to the premise is *called fiber to the home* (FTTH). The latter enables faster connections but it requires also to replace all lines between the LE and the premises and is thus much more costly than the former, and almost exclusively done, at least for the years that we consider in this paper, for large companies or institutions which had dedicated high bandwidth fiber connections.

broadband, to 2004 Internet penetration went from 0 to 18%, while in the following 6 years it almost reached the threshold of 80%.

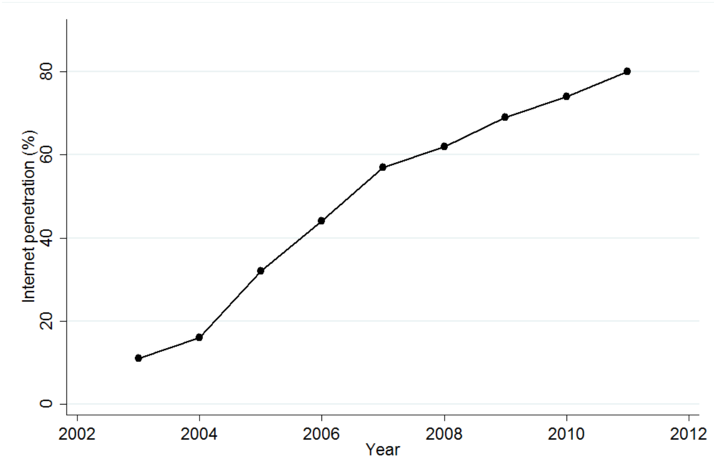

Figure 1: Broadband penetration between 2003 and 2011 (source: Eurostat).

DSL was not the only option to access the Internet in the years that we consider, although it was the most popular choice. Until 2010, approximately 80 percent of broadband accesses in the UK was through DSL, thereby transforming the old telephone network into the main determinant of broadband penetration, and the remaining 20 percent of broadband accesses used the cable network, while less than 0.1 percent relied on fiber and mobile operators.[3]

A crucial element in our identification strategy is the length of the *last mile*. As explained, despite the breakthrough in broadband penetration, not every household connected to the voice network was able to access fast Internet with DSL technology. Because of this technological limitation, the advent of DSL unpredictably turned distance from the LE into a key determinant of broadband penetration, thereby creating an exogenous source of variation in access to fast Internet.

4 Data and empirical strategy

In this section, we first present the data and we then detail our identification strategy. In a nutshell, the empirical analysis exploits individual differences in the actual quality of Internet access to identify the effect of broadband penetration on social capital. For this purpose, we combine two sources of data: [I] a dataset with detailed geographical

[3]The cable network, originally deployed to offer cable-TV, could also be upgraded to supply Internet access. The cable company, Virgin Media, made this conversion in parallel to the DSL market and saw its market share declining from 29% in 2005 to 22% in 2010, mainly due to the increased quality of DSL connections over time (see Nardotto et al., 2015 for more details).

information on the topology of the telephone network provided by Ofcom, the UK Office of Communications, which we match with [II] geocoded individual data from the British Household Panel Survey (BHPS) over the period 1997-2009. The resulting dataset is a 13 years panel including information on the distance of each BHPS respondent from the relative node of the telephone network.

British Household Panel Survey

The BHPS is a panel survey started in 1991 to address a variety of research topics based on a representative sample of the British population (Taylor et al., 2010) including more than 5,000 households, approximately totaling 10,000 individual interviews. It is household based, and every adult in the household is interviewed. The BHPS was originally designed as an indefinite life panel but has now ended. There have been 18 waves of annual interviewing, with the 18th and last wave completed in 2008.

In order to match BHPS data with the map of the telephone network provided by Ofcom, we employ the BHPS Special License[4] version "Lower Layer Super Output Areas" (LSOA). This upgraded license provides spatial LSOA references[5] that are crucial for matching the two datasets.

Social capital

Our social capital indicators comprise both the structural and the cognitive dimensions of the concept as defined by Uphoff (1999). To measure structural social capital we employ three sets of indicators. The first set captures the frequency of specific forms of cultural consumption that are usually enjoyed in company during leisure time, such as watching movies at the cinema and attending concerts and theatre shows, on a scale ranging from "never", "once a year or less", "several times a year", "at least once a month" to "at least once a week". We transform responses into a dichotomic variable taking value 0 if the attendance is less than once a month and 1 if at least once a month.

The second set includes aspects of social connectedness such as the frequency with which respondents meet friends and talk to neighbors on a scale ranging from "never", "less than once a month", "once or twice a month", "once or twice a week", to "most days". We recoded responses into a dichotomic variable equal to 0 if the frequency is less than once or twice a week and 1 otherwise.

[4]University of Essex, Institute for Social and Economic Research. (2014). British Household Panel Survey, Waves 1-18, 1991-2009: Special License Access, Lower Layer Super Output Areas and Scottish Data Zones. [data collection]. 3rd Edition. UK Data Service. SN: 6136, `http://doi.org/10.5255/UKDA-SN-6136-2`. Application: project number 107760.

[5]LSOAs are the second-narrowest geographical areas in the UK census, comprising on average 650 households and 1,500 inhabitants. In densely populated metropolitan areas they correspond to portions of city blocks.

The third set captures political and civic engagement through dummies revealing whether respondents are members of political parties, trade unions, professional associations, environmental groups, and other organizations. The BHPS reports information on membership and active participation in the form of "yes/no" answers. In our empirical analysis we consider a respondent as participating in an organization if she is either a member of it or she declares to participate in its activities. [6]

We consider 6 types of organization, which we partition into two groups based on our elaboration of the literature about the "Olson-Putnam controversy"[7]: Olson-type organizations and Putnam-type organizations. While the former include political parties, trade unions and professional associations, the latter includes environmental associations, voluntary service groups and scout/guides organizations.

Our indicator of cognitive social capital concerns trust towards unknown others, or "social trust", as measured through responses to the question: "Generally speaking, would you say that most people can be trusted, or that you can't be too careful in dealing with people?" as developed by Rosenberg (1956), possible answers being "depends", "can't be too careful ", or "most people can be trusted". We transform responses into a binary variable that takes value 1 if the answer is that most people can be trusted and 0 otherwise.

In addition to the social capital indicators, we also utilize the information on the socio-demographic characteristics of respondents, including age, income, employment status, type of occupation, and characteristics of the household, the dwelling, and the housing contract, all of which are collected as part of the BHPS.

Broadband infrastructure

Information on the broadband infrastructure consists of a detailed map of the topology of the telephone network provided by Ofcom and previously used in Nardotto et al. (2015) and Ahlfeldt et al. (2017). The data report the geographic coordinates of each LE and all the 7-digits post codes served by the node of the network[8]. Using this information, we are able to reconstruct the exact catchment area of each LE, and thus compute the (linear) distance between each household and the respective LE.

[6]Notice that it is not always the case that a member also declares that she participates in the organization's activities. On the other hand, those who declare that they participate in an organization's activities are not necessarily members.

[7]In addition to the seminal works of Olson (1971) and Putnam et al. (1993), see for example Knack and Keefer (1997) and, for a review of the literature, Degli Antoni and Grimalda (2016).

[8]There are approximately 1.7 million active post codes in the UK. On average, a post code covers an area with a radius of 50 meters, but it is often smaller (i.e., a building) in urban areas.

4.1 Empirical strategy

To identify the causal effect of broadband Internet on social capital we exploit individual differences in the actual speed of the connection determined by the variation in the distance between respondents' dwellings and the respective LEs, as explained in Section 3. We estimate an *intention-to-treat* effect assuming that the penetration of the broadband resulted in the actual access to fast Internet depending on the distance from the LE. This approach was used because of the lack of reliable individual-level survey data about the actual access to fast Internet, and because BHPS data on Internet access is available only for a limited number of waves and do not distinguish between fast and slow connections (see Section 6 for further details and for an empirical analysis of how the topology of the network affected the Internet take-up).

Using information on the broadband infrastructure allows us to exploit the panel dimension of the data, as the time span is long enough to observe the sampled individuals before and after the introduction of broadband Internet. The panel dimension of the data proves useful in two respects. First, it allows us to control for unobserved characteristics that might be correlated both with Internet access and with our measures of social capital. Second, it allows us to perform a falsification test by assessing whether distance from the LE is associated with changes in social capital before the penetration of the broadband, which further strengthens a causal interpretation of results.

We divide the BHPS waves into three periods as reported in Table 1 where we mark the waves in which the indicators employed in the analysis were collected. We then classify the waves in three periods according to the status of broadband Internet diffusion. The *Pre-Internet I* period collects waves between 1997 and 2000, referring to years in which broadband access was very rare among British households. Years between 2001 and 2004 are in the *Pre-Internet II* period. Just as in the previous period, broadband access was at most very limited (overall broadband penetration in 2004 was lower than 20% and mainly confined to the richer parts of large cities). Thus, we consider *Pre-Internet II* as our pre-treatment condition in the main empirical analysis, and later as our post-placebo in the falsification test[9].

Finally, the years between 2005 and 2008, when the rapid diffusion of broadband Internet took place, are in the *Post-Internet* period. Summarizing, in our main analysis we employ the two most recent periods: the *Pre-Internet II* period represents the pre-treatment condition and the *Post-Internet* period is the post-treatment.

In the falsification test, on the other hand we employ the two periods preceding

[9]The fact that some household could have broadband access already in this period might bias our results towards zero, and thus our estimates should be interpreted as lower bounds of the true effect. Instead, in the case of the falsification test it generates the opposite bias, with can lead to an overestimate of the true effect and, importantly of false positives.

the diffusion of broadband Internet: the *Pre-Internet I* period serves as pre-placebo condition while *Pre-Internet II* now functions as the post-placebo.

Table 1: Treatment periods, waves in the BHPS, and questions on social capital.

Years:	1997-2000				2001-2004				2005-2008			
Period:	***Pre-Internet I***				***Pre-Internet II***				***Post-Internet***			
					MAIN							
	PLACEBO											
Wave in the BHPS:	7	8	9	10	11	12	13	14	15	16	17	18
Leisure activities		✓		✓		✓		✓		✓		✓
Organizations	✓		✓		✓		✓		✓		✓	
Meeting/Talking	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Trusting		✓		✓			✓		✓		✓	✓

Notes: The table reports the division of years into *Pre-Internet I* (from 1997 to2000), *Pre-Internet II* (from 2001 to 2004), and *Post-Internet* (from 2005 to 2008). The table also reports the availability of the different questions in the different waves of the BHPS. *Leisure activities* are the two questions about going to the cinema and going to concerts or theaters. *Organizations* are the questions on being member or an active participant of social organizations. *Meeting/Talking* are the questions on the frequency of meeting friends and talking to neighbors. *Trusting* is the question on the level of trust of other people.

As a result of this partition, and of the heterogeneous availability of the information underlying each of the selected indicators of social capital, the empirical analysis is based on different sub-samples of the full BHPS. The sample selection process leading to each final sub-sample can be described as follows. After selecting the waves of the survey in which the information is available for the selected indicator, separately for MAIN and PLACEBO regressions, all observations containing missing values for any of the considered covariates are excluded.

Individuals are finally kept in the final sub-sample if i) they are observed in at least one wave of both the relevant PRE and POST period; ii) they do not change LSOA across the considered waves. Importantly, the latter condition avoids the potential bias due to neighborhood sorting on the basis of time-varying unobservable characteristics which may also affect social capital.

Table 9, in the Appendix, shows the progressive steps of the sample selection process, and their impact on the sample size, separately for each set of indicators and for main and placebo regressions. The final sub-samples are on average 50%-60% the size of the full starting samples containing only the waves of the survey in which information is collected for the relevant set of indicators. Importantly, most of these drops in size are due to the exclusion of individuals who change their address across waves.

Given that our outcomes are binary variables we estimate linear probability models for the effect of the distance from the LE, determining the quality of Internet access (lower distance $\longrightarrow$ faster Internet access $\longrightarrow$ higher exposure to the treatment), on our measures of social capital. Our regression model is reported in (1):

$$y_{it} = \gamma Distance_i \times \text{POST}_t + \beta X_{it} + Wave_t + \eta_i + \varepsilon_{it} \quad (1)$$

where y_{it} is the outcome of interest for person i at year t. $Distance_i \times \text{POST}_t$ is the (reversed) treatment intensity for individual i in year t. This variable is the product of $Distance_i$, which is the distance in kilometers between the individual's house and the LE, and POST_t, a binary variable set to 0 if year t is in the *Pre-Internet II* period, and 1 if year t is in the *Post-Internet* period. X_{it} is a set of observed time-varying characteristics: income, household type (categorized), employment status, type of occupation, age and housing tenure. η_i is the individual's fixed effect, which enables us to control for time-invariant unobserved characteristics. ε_{it} is the error term.

Controlling for individual fixed effects is crucial for the causal interpretation of our estimates, as it accounts for the fact that unobserved (and pre-existent) individual characteristics might be systematically associated with the propensity for Internet use. As a result, our design allows us to isolate the effect of more intense Internet exposure on social capital. In Section 6, we will provide evidence that being located farther away from the LE is associated both with a lower propensity for having a broadband connection at home and with less time spent online.

4.2 Summary statistics

Table 2 reports the descriptive statistics of the dependent and control variables. To compute the summary statistics we consider each individual/wave observation that we use in our empirical analysis. Since the panel is not perfectly balanced, this results in different sample sizes, depending on the waves considered (see Section 4.1 for more detail).

Panel A of Table 2 reports the summary statistics of the indicators employed as dependent variables. In our sample, which is representative of the UK's population, 12% of people regularly go to the cinema, and 5% attend concerts and theatre shows. A large majority declares talking regularly with neighbors and meeting friends, while approximately 40% believe that most people can be trusted. Less than 30% of the population is a member or participates in the organizations that we consider, with Olson-type organizations attracting more participation (22%) than Putnam-type ones (9%).

Panel B of Table 2 reports summary statistics of the socio-demographic information collected in the BHPS that we employ in our empirical analysis.[10] On average, the BHPS

[10]Notice that these variables are a subset of the socio-demographic information collected by the BHPS. We do not employ all possible variables, but we focus on key demographics (related to age,

Table 2: Descriptive statistics.

Panel A: Dependent Variables	Mean	St.Dev.	Min	Max	Obs
Cinema attendance	0.12	0.33	0.00	1.00	35697
Theatre and concerts attendance	0.05	0.21	0.00	1.00	35698
Any organization	0.28	0.45	0.00	1.00	35656
Olson organizations	0.22	0.42	0.00	1.00	35656
- Political party	0.02	0.15	0.00	1.00	35656
- Trade union	0.15	0.36	0.00	1.00	35656
- Professional organizations	0.08	0.27	0.00	1.00	35656
Putnam organizations	0.09	0.29	0.00	1.00	35656
- Environmental organizations	0.03	0.17	0.00	1.00	35656
- Voluntary organizations	0.05	0.21	0.00	1.00	35656
- Scout organizations	0.02	0.14	0.00	1.00	35656
Talking to neighbors	0.80	0.40	0.00	1.00	70194
Meetings with friends	0.87	0.34	0.00	1.00	70189
Most people can be trusted	0.40	0.49	0.00	1.00	28528
Panel B: Demographic characteristics					
Age	48.62	18.11	15.00	101.00	84946
Log of real household income	10.22	0.75	-0.55	14.14	84950
Household type:					
- Single non elderly	0.06	0.23	0.00	1.00	84950
- Single elderly	0.09	0.28	0.00	1.00	84950
- Couple: no children	0.30	0.46	0.00	1.00	84950
- Couple: dependent children	0.30	0.46	0.00	1.00	84950
- Couple: non dependent children	0.13	0.34	0.00	1.00	84950
- Lone parent: dependent children	0.05	0.21	0.00	1.00	84950
- Lone parent: non dependent children	0.04	0.20	0.00	1.00	84950
- 2+ unrelated adults	0.01	0.09	0.00	1.00	84950
- Other	0.02	0.13	0.00	1.00	84950
Employment status:					
- Employed or self-employed	0.55	0.50	0.00	1.00	84950
- Unemployed	0.03	0.17	0.00	1.00	84950
- Inactive	0.42	0.49	0.00	1.00	84950
Type of occupation:					
- Higher managerial and professional occupations	0.06	0.24	0.00	1.00	84950
- Lower managerial and professional occupations	0.15	0.36	0.00	1.00	84950
- Intermediate occupations (clerical, sales, service)	0.08	0.28	0.00	1.00	84950
- Small employers and own account workers	0.06	0.23	0.00	1.00	84950
- Lower supervisory and technical occupations	0.05	0.23	0.00	1.00	84950
- Semi-routine occupations	0.11	0.31	0.00	1.00	84950
- Routine occupations	0.07	0.26	0.00	1.00	84950
- Unemployed/Inactive	0.41	0.49	0.00	1.00	84950
Housing tenure:					
- Owned outright	0.34	0.47	0.00	1.00	84950
- Owned with mortgage	0.45	0.50	0.00	1.00	84950
- Rented privately	0.05	0.22	0.00	1.00	84950
- Rented - housing assoc. or local authority	0.16	0.36	0.00	1.00	84950
Distance house-LE (km)	2.70	2.11	0.01	24.33	84950

Notes: Panel A reports the variables that measure social capital. Panel B reports the socio-demographic variables employed in the empirical analysis. In both Panel A and Panel B, the number of observations depends on the BHPS waves considered (see Section 4.1). In particular, Panel B reports the summary statistics of the socio-demographic variables taking each individual/wave (only once) that enters any of the regression models estimated in Section 5.

respondent is approximately 50 years old and earns an annual real income of £27,174. The median individual is employed or self employed and almost 60% of households consist of two partners, with or without children. Most households own their dwelling or have a mortgage while 20% rent their habitation privately, or through a housing association or benefiting from housing assigned by the local government. Finally, the average household is located 2.7 kilometers from the LE providing Internet access, with a significant variation, the standard deviation being equal to 2.12 kilometers.

5 Results

In this section we present the results of the estimations of model (1). We start by analyzing how the quality of Internet access (decreasing/increasing in the distance from/proximity to the LE) affects two forms of cultural consumption that are usually enjoyed in company. We then present results regarding participation in associations. Finally, we show how access to fast Internet relates to trust and some forms of offline interaction such as the frequency with which respondents meet friends and talk to neighbors.

5.1 Fast Internet and cultural consumption

As discussed in section 4, the BHPS does not report either a precise measure of the time spent in leisure activities, or detailed information on the composition of leisure time. We thus focus on two forms of cultural consumption that usually entail social interaction: watching movies at the cinema, and attending any kind of concert or theater show.

Results are illustrated in Table 3, where columns (1) and (2) report the estimation results for going with the cinema, and columns (3) and (4) for going to concerts or to theaters. In each pair of regressions we report the results on the main sample (i.e., *Pre-Internet II* and *Post-Internet*) and on the placebo sample (i.e., *Pre-Internet I* and *Pre-Internet II*).

Results suggest that the faster Internet access associated to a shorter distance from the LE lowers the time spent on cultural activities. The size of the effect is economically relevant. The magnitude of the coefficient implies that one standard deviation reduction (increase) in the distance from the LE (equal to 2.12 km), causes a reduction (increase) in the likelihood of going to the cinema of 4.95 percent.

The relationship between broadband access and concerts or theater attendance is not statistically significant. The falsification test conducted by assessing how the interaction

household composition, income etc) because in the econometric analysis we employ individual's fixed effects, and because the panel dimension is relatively short (at most 6 years).

Table 3: Effect of fast Internet on leisure activities.

Dep. Variables:	Cinema attendance		Theatre and concerts attendance	
	Main	Placebo	Main	Placebo
	(1)	(2)	(3)	(4)
Distance × Post	0.28**	-0.17	0.09	-0.13
	(0.12)	(0.13)	(0.09)	(0.10)
Controls	✓	✓	✓	✓
Time FEs	✓	✓	✓	✓
Individual FEs	✓	✓	✓	✓
Observations	35695	35859	35696	35864
R^2	0.01	0.01	0.00	0.00
Num. PIDs	9670	10397	9670	10397

between the distance from the LE and the post-placebo relates to our dependent variables supports a causal interpretation of the results.

5.2 Fast Internet and civic engagement

We now study the effect of broadband access on civic engagement, measured as participation in voluntary organizations. Since its introduction in the pioneering work of Putnam et al. (1993), membership in organizations is commonly considered as one of the most significant and reliable indicators of social capital, since it captures individuals' interest in public affairs and their propensity for contributing to the public good (see for example Knack and Keefer, 1997; Guiso et al., 2004; 2016). We define participation as either being a member or actively participating in an organization's activities. Tables 4, 5 and 6 report estimation results. In Table 4 we partition organizations into two main types following the social capital literature (e.g. Knack and Keefer, 1997). Columns (1)-(2) report results when the outcome variable is participation in any type of organization, while columns (3)-(4) and columns (5)-(6) respectively refer to participation in Olson- and Putnam-type organizations. The paired regressions follow the usual order: columns (1), (3) and (5) report the results on the main sample, whereas columns (2), (4) and (6) report the results on the placebo sample.

Similar to what was found in the previous section, access to fast Internet (shorter distance from the LE) significantly and strongly reduces civic engagement. When we consider all the organizations without distinction, the estimated effect - column (1) - implies that a reduction (increase) of 1 standard deviation in the distance from the LE, resulting in a higher connection speed, causes a reduction (increase) in the likelihood of participation of 3.6 percent.

Table 4: Effect of fast Internet on participation in social organizations.

Dep. Variables:	Any organization		Olson organizations		Putnam organizations	
	MAIN (1)	PLACEBO (2)	MAIN (3)	PLACEBO (4)	MAIN (5)	PLACEBO (6)
Distance × Post	0.48***	-0.09	0.42***	-0.08	0.29***	0.01
	(0.14)	(0.18)	(0.13)	(0.16)	(0.10)	(0.14)
Controls	✓	✓	✓	✓	✓	✓
Time FEs	✓	✓	✓	✓	✓	✓
Individual FEs	✓	✓	✓	✓	✓	✓
Observations	35654	30192	35654	30192	35654	30192
R^2	0.01	0.01	0.02	0.02	0.00	0.00
Num. PIDs	9616	9068	9616	9068	9616	9068

In Columns (3) to (6) we report results for Olson- and Putnam-type organizations separately. In both cases, the estimated coefficients are positive and highly statistically significant, suggesting that participation decreases with the speed of the connection (shorter distance from the LE). In the case of Olson-type organizations, the estimates imply that a one-standard deviation increase in the distance from the LE, resulting in a slower connection, increases the likelihood of participation by 4 percent. For Putnam-type organizations the estimated effect is larger and amounting to 6.8 percent.

Finally, we notice that while the estimated coefficients in the main samples are all statistically significant and display a consistent pattern, the coefficients estimated on the placebo sample – reported in columns (2), (4), and (6) – are much smaller in size, do not show any consistent pattern and are never statistically significant, thus supporting a causal interpretation of results.

In Tables 5 and 6 we report disaggregated results for Olson and Putnam organizations. Table 5 focuses on 3 distinct types of Olson-organizations: political parties, trade unions, and professional organizations. Table 6 focuses on 3 types of Putnam-organizations: environmental, voluntary service, and scout organizations. In both tables, we follow the usual order, reporting the estimates on the main sample in the odd columns and the estimates on the placebo sample in the even columns.

Results reported in Table 5 show a sizable and statistically significant effect of access to broadband Internet on participation in political parties and trade unions. The estimated coefficients imply that a reduction (increase) of 1 standard deviation in the distance from the LE, resulting in a faster (slower) connection, causes a reduction (increase) of the likelihood of participation of 12.7 percent and 4.8 percent respectively.

On the other hand, access to fast Internet does not affect participation in professional organizations, which is generally aimed at the pursuit of particular interests and redistributive goals, and mostly takes place in the context of individuals' professional

Table 5: Effect of fast Internet on participation in Olson organizations.

Dep. Variables:	Political parties		Trade unions		Professional organizations	
	MAIN (1)	PLACEBO (2)	MAIN (3)	PLACEBO (4)	MAIN (5)	PLACEBO (6)
Distance × Post	0.12**	0.03	0.34***	-0.05	-0.07	0.16
	(0.05)	(0.06)	(0.11)	(0.13)	(0.09)	(0.11)
Controls	✓	✓	✓	✓	✓	✓
Time FEs	✓	✓	✓	✓	✓	✓
Individual FEs	✓	✓	✓	✓	✓	✓
Observations	35654	30192	35654	30192	35654	30192
R^2	0.00	0.00	0.02	0.02	0.00	0.01
Num. PIDs	9616	9068	9616	9068	9616	9068

life, instead of during their leisure time.

Regarding Putnam organizations, Table 6 reports a strong and highly statistically significant effect in the case of scout/guides organizations. The estimated coefficient implies that a reduction (increase) of 1 standard deviation in the distance from the LE, resulting in a faster (slower) access to the Internet, causes a reduction (increase) of the likelihood of participation in this type of organizations equal to 13.8 percent.

Table 6: Effect of fast Internet on participation in Putnam organizations.

Dep. Variables:	Environmental organizations		Voluntary service organizations		Scout organizations	
	MAIN (1)	PLACEBO (2)	MAIN (3)	PLACEBO (4)	MAIN (5)	PLACEBO (6)
Distance × Post	0.09	0.04	0.14*	0.05	0.13***	-0.05
	(0.06)	(0.08)	(0.08)	(0.11)	(0.05)	(0.07)
Controls	✓	✓	✓	✓	✓	✓
Time FEs	✓	✓	✓	✓	✓	✓
Individual FEs	✓	✓	✓	✓	✓	✓
Observations	35654	30192	35654	30192	35654	30192
R^2	0.00	0.00	0.00	0.00	0.00	0.00
Num. PIDs	9616	9068	9616	9068	9616	9068

We also find a sizable effect, corresponding to a reduction (increase) in participation equal to 6 percent for voluntary service organizations, although in this case the coefficient is significant only at the 10% level.

We do not find a strong effect of broadband access on participation in environmental organizations. However, it is worth noting that, in the case of Putnam organizations, all coefficients estimated using the main sample are oriented in the expected direction (while this is not the case for the coefficients estimated using the placebo sample), thus indicating a general tendency towards a decrease in participation with faster Internet access.

Summarizing, we find that better Internet access has a sizable impact on the engagement in voluntary organizations. This finding holds both for Olson- and Putnam-type organizations, with some heterogeneity within these two groups. The estimation results obtained using the placebo sample support a causal interpretation of the effect.

5.3 Fast Internet, social interaction and trust

We conclude our analysis by reporting the estimates of our empirical model (1) when the outcomes of interest are related to the frequency of specific forms of social interaction and the level of trust. (Table 7).

The frequency of meetings with friends, the habit of talking with neighbors and social trust seem to be unaffected by broadband Internet, suggesting that the displacement effect does not take place in these cases. The null result regarding the frequency of meetings may stem from the opposing effects that the literature has attributed to Internet use in the development of offline relationships. While several authors have highlighted the risk that ICTs may crowd out interaction with friends and relatives (e.g. Putnam, 2000; Nie et al., 2002; Gershuny, 2003), more recent studies suggest that access to fast Internet may also be a tool for preserving and developing existing relationships despite time and distance constraints, thank to the interactivity of social networking sites (SNS) (Ellison et al., 2007; Bauernschuster et al., 2014; Antoci et al., 2015).

Table 7: Effect of fast Internet on social interactions and trust.

Dep. Variables:	Talking to neighbors		Meetings with friends		Trusting people	
	MAIN (1)	PLACEBO (2)	MAIN (3)	PLACEBO (4)	MAIN (5)	PLACEBO (6)
Distance × Post	0.01	-0.04	-0.09	0.10	-0.36	-0.10
	(0.11)	(0.13)	(0.10)	(0.13)	(0.24)	(0.28)
Controls	✓	✓	✓	✓	✓	✓
Time FEs	✓	✓	✓	✓	✓	✓
Individual FEs	✓	✓	✓	✓	✓	✓
Observations	70190	59571	70185	59570	28525	19827
R^2	0.00	0.01	0.00	0.00	0.03	0.01
Num. PIDs	9800	9631	9799	9632	7863	7740

Chats with neighbors, on the other hand, generally occur occasionally and incidentally, for example when leaving or coming back home. They thus seem to be less or not at all vulnerable to the displacement effect possibly caused by Internet use.

Social trust is a cognitive phenomenon depending on individuals' values and perceptions, unrelated to time constraints and less sensitive to the risk of crowding out. Some studies suggested that Internet use may be detrimental to trust to the extent to which it entails engagement in interactions with strangers on SNS, due to the phenomenon of online incivility recently spreading on platforms such as Facebook and Twitter (Antoci et al., 2016; Sabatini and Sarracino, 2017). Our data, however, refers to an earlier period in which social media just started flourishing and online incivility was a much rarer phenomenon (Rost et al., 2016).

6 Effect of distance on Internet take-up

The empirical analysis carried out in sections 4 and 5 relies on the fact that, in the years we consider, the distance between the geographical location of the households and the respective LE was crucial in affecting the actual quality of broadband Internet access. The use of technological factors as a source of exogenous variation in Internet access conditions is supported by 1) technical reports produced by the industry and the regulator, which emphasize the role of distance as a crucial determinant of connection speed; (Ofcom, 2010; Ofcom, 2011; Ofcom, 2012; Ofcom, 2013); and 2) other studies that also make use of factors affecting the quality of Internet access (such as the distance of the dwellings from the LE) to identify the effect of broadband penetration on a range of hypothetical outcomes. (see, for instance, Amaral-Garcia et al., 2017; Falck et al., 2014).

Most of those studies took the effect of distance between the premises and the LEs on the Internet take up for granted, although, due to the lack of suitable data, they were not able to test it empirically (e.g. Ahlfeldt et al., 2017; Falck et al., 2014). In this section we use self-reported information on individual Internet access collected in the BHPS to provide evidence that distance from the LE actually affected the access to broadband Internet in the UK.

For this purpose, we use a question asked in some waves of the BHPS on broadband Internet access. Respondents were asked whether they had a fixed-line broadband connection at home at the time of the interview and, in the affirmative case, how much time they spent online on average per day. On one hand, answers to these questions are worth examining because they can provide evidence on the effect of distance on take up. On the other hand, they have certain limitations, which is why we do not exploit this information in the main empirical analysis. The first limitation is that this variable is likely to be subject to measurement error. Most users hardly knew whether a connection could be defined as broadband and what the broadband speed/technology actually was, with some of them answering affirmatively when they actually had a slow

DSL connection (such as an ISDN) or an only in theory broadband connection that actually suffered from substantial decay due to the distance from the LE.[11] In addition, respondents might give a positive answer even when the connection was not at home (which is crucial for instance in the allocation of leisure time) but for example at the workplace.

The second limitation is due to the waves in which this information was collected and the sample of households that were interviewed, which is not perfectly consistent with the other samples employed in the rest of the empirical analysis. Although these limitations prevented us from using information on individual broadband access in a TSLS strategy, it is worth investigating the link between distance and Internet access, keeping in mind that the following results are not fully conclusive.

The empirical model we employ, reported in equation (2), is similar to (1) that has been employed in previous sections.

$$Internet_{it} = \gamma Distance_i + \beta X_{it} + Wave_t + \eta_i + \varepsilon_{it} \quad (2)$$

Here, the outcome $Internet_{it}$ is in one case the presence of a broadband connection at home, and in the other case the time spent online; $Distance_i$ is the distance between the household and the respective LE, and, as in previous models, X_{it} is a set of time-varying controls including income, household type (categorized), employment status, type of occupation, age and tenure; η_i is the individual's random effect; and ε_{it} is the error term.

The main difference with respect to model (1) is that we cannot employ a fixed-effect estimator, due to the fact that our main variable of interest, the distance between the home and the LE, is constant over time and because the question is asked only in the last waves of the BHPS, all belonging to the *Post-Internet* period. Hence, we employ a random-effect estimator (with controls) when the dependent variable is the presence of broadband connection at home, and OLS estimator (with controls) when the dependent variable is the time spent online.

A clear negative relationship between the distance and broadband access emerges

[11] In our period of analysis, broadband packages were typically advertised referring to their *theoretical* maximum speed while information about the actual or average speed was omitted by providers. As a result, consumers largely ignored the fact that the actual speed depended by the distance from LEs. According to Ofcom reports focusing on consumer protection issues, this has been a source of major confusion for UK Internet users (Ofcom, 2006; Ofcom, 2009). The remarkable 60% gap between advertised and actual speed registered in the UK was far above the EU average of 40% (EuropeanCommission, 2012). Still in 2016, an Ofcom research found that even "business consumers –particularly small or medium sized enterprises– are confused about how the *actual* speed of their broadband service compared to the *headline* maximum speed used in advertising" (Ofcom, 2016; HouseCommons, 2017). For these reasons, consumer self-reported survey data on Internet connections are considered not completely reliable (most likely upward biased) and therefore only weakly informative (OECD, 2008).

from the data, and it holds both for the presence of a broadband connection at home (the extensive margin), and for the time spent online (the intensive margin). This negative relationship can be appreciated in Figure 2, that results from the estimation of our model, and a straightforward application of the Frisch-Waugh-Lowell theorem (see, for instance Davidson et al. 2004), that enables us to partial-out the role of socio-demographics when we examine the relation between take up and distance. We split the set of regressors into two groups: the geographical distance between the households and the respective LEs, and the socio-demographic control variables. We report on the y-axis the residuals of model 2 where we employ as independent variables only the socio-demographic control variables (i.e., we exclude the *Distance*), and on the x-axis the residuals of a regression of *Distance* on the socio-demographic control variables. Residuals are grouped in 100 bins for which we take the average value.

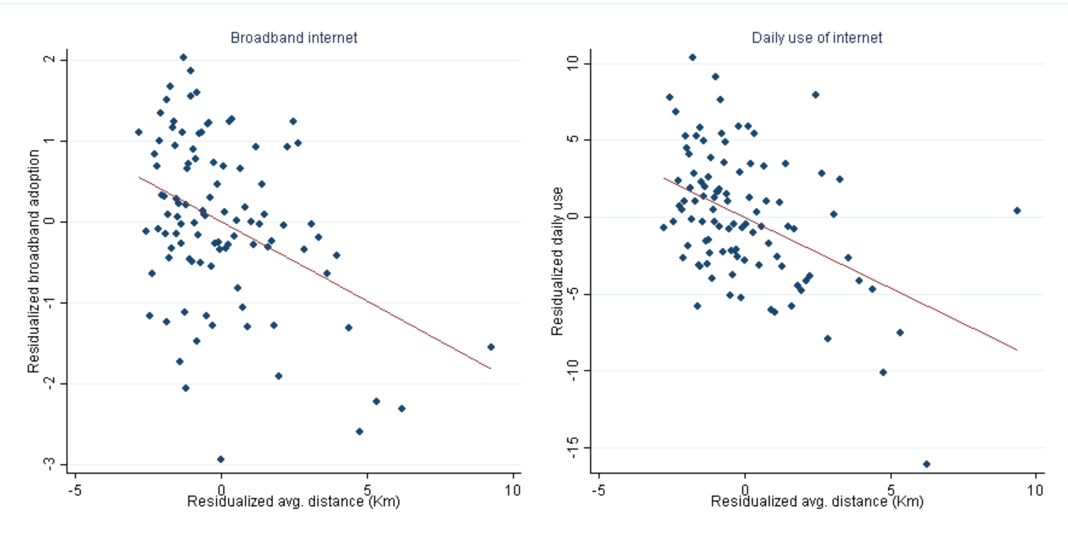

Figure 2: Internet access and distance between the house and the LE. Both panels report on the x-axis the residuals of a regression of the distance between the house and the respective LE on the socio-demographic control variables. The y-axis of the left panel reports the residual of a regression for the presence of broadband at home on the socio-demographic control variables. The y-axis of the rigth panel reports the residual of a regression for the time spent online on the socio-demographic control variables.

As explained, Figure 2 is strictly related to the main model in equation (2), whose estimates are reported in Table 8. Column (1) of the table shows the estimated effect of distance between the house and the respective LE on the adoption of a broadband connection. The coefficient, as expected, is negative and statically significant, thus indicating that distance has an influence on Internet access and the *extensive margin*. Furthermore, column (2) of the table reports the estimated effect of distance on the time spent online, again showing a strong, negative impact of distance on the access, which in this case is a measure of the *intensive margin*. Thus, we can conclude that the distance,

Table 8: Effect of distance from the LE on fast Internet take up.

Dep. Variables:	Broadband internet (1)	Daily use of internet (2)
Distance	-0.89***	-0.90***
	(0.23)	(0.22)
Controls	✓	✓
Time FEs	✓	no
Individual REs	✓	no
Observations	36081	13066
R^2	0.30	0.18
Num. PIDs	14064	13066

by affecting the quality and the reliability of the connection, the running costs for the Internet providers, and in turn possibly the availability (as pointed out in Falck et al., 2014, given the status of the technology, Internet quality could be so low beyond 4.2 kilometers that broadband connections until 2008 could simply be not available), was a crucial element of the fast Internet take up up and of the time that users spent online.

7 Conclusions

In this paper we studied how the penetration of broadband Internet affected social capital in the UK. Matching unique information on the topology of the old voice communication infrastructure with geocoded survey data on individual behaviors, we were able to exploit discontinuities in the speed of Internet connection to test whether the availability of fast Internet displaced offline activities such as civic engagement, political participation, and other forms of face-to-face interaction. Our results paint a complex picture. As in Bauernschuster et al. (2014), we do not find evidence that broadband access displaced offline relationships such as meetings with friends. On the other hand, the empirical analysis in this paper shows that fast Internet crowded out forms of cultural consumption that are usually enjoyed in company such as watching movies at the cinema and attending concerts and theatre shows. In addition, broadband penetration significantly displaced civic engagement and political participation, i.e. time consuming activities that usually take place during leisure time, are not pursued in order to reach particularistic goals, and generally relate to a non self-interested involvement in public affairs. Associational activities have been often mentioned as forms of bridging social capital creating positive societal and economic externalities (Putnam et al., 1993; 1995), which has recently started to decline in many OECD countries (e.g. Putnam, 2000; Costa and Kahn, 2003b). In this respect, our study offers a possible interpretation of the "decline in community life-thesis" (Paxton, 1999) supporting Putnam's early intuitions on the detrimental role of technological progress in social cohesion. The picture provided by our findings is also consistent with the patterns of declining engagement in public affairs previously sketched by those Internet studies in economics that analyzed how the first stage of broadband penetration affected political participation before the advent of social media (Falck et al., 2014; Campante et al., 2017; Gavazza et al., 2018).

The developing role of fast Internet use, however, certainly calls for further investigation, as new forms of SNS-mediated civic and political participation spread after the period covered by our data. A more recent wave of Internet studies suggests that social media may also support collective action and political mobilization, especially in young democracies and authoritarian regimes, thereby providing a potentially positive contribution to the strengthening of political participation (Enikopolov et al., 2016; Enikopolov et al., 2018). Other studies, on the other hand, highlight how the increasing importance of social media in the public discourse entails new systemic risks connected to the propagation of misinformation (Del Vicario et al., 2016), the extreme polarization of the political debate (Müller and Schwartz, 2018a) and the spreading of online incivility (Antoci et al., 2018) Future research should deal with these conflicting effects, also in light of the prominent role that a limited number of platforms, such as Facebook and Twitter, assumed in biasing electoral results (Allcott and Gentzkow, 2017).

References

Aghaei, S., Nematbakhsh, M. A., and Farsani, H. K. (2012). Evolution of the world wide web: From web 1.0 to web 4.0. *International Journal of Web & Semantic Technology*, 3(1):1.

Aghion, P., Algan, Y., Cahuc, P., and Shleifer, A. (2010). Regulation and distrust. *Quarterly Journal of Economics*, 125(3):1015–1049.

Ahlfeldt, G., Koutroumpis, P., and Valletti, T. (2017). Speed 2.0: Evaluating access to universal digital highways. *Journal of the European Economic Association*, 15(3):586–625.

Algan, Y. and Cahuc, P. (2010). Inherited trust and growth. *American Economic Review*, 100(5):2060–92.

Algan, Y., Cahuc, P., and Shleifer, A. (2013). Teaching practices and social capital. *American Economic Journal: Applied*, 5(3):189–210.

Algan, Y., Guriev, S., Papaioannu, E., and Passari, E. (2017). The european trust crisis and the rise of populism. *Brookings Papers on Economic Activity*, BPEA Conference Drafts, September 7–8, 2017.

Allcott, H. and Gentzkow, M. (2017). Social media and fake news in the 2016 election. *Journal of Economic Perspectives*, 31(2):211–236.

Amaral-Garcia, S., Nardotto, M., Propper, C., and Valletti, T. (2017). Internet and health choices: Evidence from the uk. DIW Berlin, mimeo.

Antoci, A., Bonelli, L., Paglieri, F., Reggiani, T., and Sabatini, F. (2018). Civility and trust in social media. *IZA Discussion Paper - No. 11290.*

Antoci, A., Delfino, A., Paglieri, F., Panebianco, F., and Sabatini, F. (2016). Civility vs. incivility in online social interactions: An evolutionary approach. *PLoS ONE*, 11(11):e0164286.

Antoci, A., Sabatini, F., and Sodini, M. (2011). The solaria syndrome: Social capital in a growing hyper-technological economy. *Journal of Economic Behavior and Organization*, 81(3):802–814.

Antoci, A., Sabatini, F., and Sodini, M. (2015). Online and offline social participation and social poverty traps. *Journal of Mathematical Sociology*, 39(4):229–256.

Bauernschuster, S., Falck, O., and Woessmann, L. (2014). Surfing alone? the internet and social capital: Evidence from an unforeseeable technological mistake. *Journal of Public Economics*, 117:73–89.

Becker, S. O., Boeckh, K., Hainz, C., and Woessmann, L. (2014). The empire is dead, long live the empire! long-run persistence of trust and corruption in the bureaucracy. *The Economic Journal*, 126:40–74.

Bhuller, M., Havnes, T., Leuven, E., and Mogstad, M. (2013). Broadband internet: an information superhighway to sex crime? *Review of Economic Studies*, 4(1):1237–1266.

Billari, F., Giuntella, O., and Stella, L. (2017). Does broadband internet affect fertility? IZA Discussion Paper 10935.

Bruni, L. and Stanca, L. (2008). Watching alone: Relational goods, television and happiness. *Journal of Economic Behavior and Organization*, 65(3-4):506–528.

Campante, F., Durante, R., and Sobbrio, F. (2017). Politics 2.0.: The multifaceted effect of broadband internet on political participation. *Journal of the European Economic Association*, page forthcoming.

Castellacci, F. and Tveito, V. (2018). Internet use and well-being: A survey and a theoretical framework. *Research Policy*, 47(1):308–325.

Conrads, J. and Reggiani, T. (2017). The effect of communication channels on promise-making and promise-keeping: experimental evidence. *Journal of Economic Interaction and Coordination*, 12(3):595–611.

Costa, D. and Kahn, M. E. (2003a). Cowards and heroes: group loyalty in the american civil war. *Quarterly Journal of Economics*, 118(2):519–548.

Costa, D. and Kahn, M. E. (2003b). Understanding the american decline in social capital, 1952-1998. *Kyklos*, 56(1):17–46.

Czernich, N. (2012). Broadband internet and political participation: Evidence for Germany. *Kyklos*, 65(1):31–52.

Czernich, N., Falck, O., Kretschmer, T., and Voessmann, L. (2011). Broadband infrastructure and economic growth. *The Economic Journal*, 121(552):505–532.

Davidson, R., MacKinnon, J. G., et al. (2004). *Econometric theory and methods*, volume 5. Oxford University Press New York.

Degli Antoni, G. and Grimalda, G. (2016). Groups and trust: Experimental evidence on the olson and putnam hypotheses. *Journal of Behavioral and Experimental Economics*, 61:38–54.

Del Vicario, M., Bessi, A., Zollo, F., Petroni, F., Scala, A., Caldarelli, G., Stanley, H. E., and Quattrociocchi, W. (2016). The spreading of misinformation online. *Proceedings of the National Academy of Science of the United States of America*, 113(3):554–559.

Deshpande, A. (2014). *An examination of the evolution of broadband technologies in the UK*. PhD thesis, The Open University.

DiMaggio, P., Hargittai, E., Russel Neumann, W., and Robinson, J. P. (2001). Social implications of the internet. *Annual Review of Sociology*, 27:307–336.

Ellison, N. B., Steinfield, C., and Lampe, C. (2007). The benefits of facebook "friends:" social capital and college students' use of online social network sites. *Journal of Computer-Mediated Communication*, 12:1143–1168.

Enikopolov, R., Makarin, A., and Petrova, M. (2016). Social media and protest participation: Evidence from russia. *CEPR Discussion Papers*, (11254).

Enikopolov, R., Petrova, M., and Sonin, K. (2018). Social media and corruption. *American Economic Journal: Applied*, 10(1):150–174.

EuropeanCommission (2012). Quality of broadband services in the eu. Technical report, European Commission.

Falck, O., Gold, R., and Heblich, S. (2014). E-lections: Voting behavior and the internet. *American Economic Review*, 104(7):2238–65.

Feigenberg, B., Field, E., and Pande, R. (2013). The economic returns to social interaction: Experimental evidence from microfinance. *Review of Economic Studies*, 80(4):1459–1483.

Gavazza, A., Nardotto, M., and Valletti, T. (2018). Internet and politics: Evidence from uk local elections and local government policies. *Review of Economic Studies*, forthcoming.

Gentzkow, M. (2006). Television and voter turnout. *Quarterly Journal of Economics*, 121(3):921–972.

Gershuny, J. (2003). Web-use and net-nerds: A neo-functionalist analysis of the impact of information technology in the home. *Social Forces*, 82(1):141–168.

Gil de Zúñiga, H., Jung, N., and Valenzuela, S. (2012). Social media use for news and individuals' social capital, civic engagement and political participation. *Journal of Computer-Mediated Communication*, 17:319–336.

Guiso, L., Sapienza, P., and Zingales, L. (2004). The role of social capital in financial development. *American Economic Review*, 94(3):526–576.

Guiso, L., Sapienza, P., and Zingales, L. (2016). Long-term persistence. *Journal of the European Economic Association*, 14(6):1401–1436.

Guriev, S. and Melnikov, N. (2016). War, inflation, and social capital. *American Economic Review*, 106(5):230–235.

Hamburger, Y. A. and Ben-Artzi, E. (2003). Loneliness and internet use. *Computers in Human Behavior*, 19:71–80.

HouseCommons (2017). Broadband speeds and advertising. Technical report, House Commons - CDP 2017/0072.

Karlan, D. (2005). Using experimental economics to measure social capital and predict financial decisions. *American Economic Review*, 95(5):1688–1699.

Knack, S. and Keefer, P. (1997). Does social capital have an economic payoff? *Quarterly Journal of Economics*, 112(4):1251–1288.

Kraut, R., Patterson, M., Lundmark, V., Kiesler, S., Mukophadhyay, T., and Scherlis, W. (1998). Internet paradox: A social technology that reduces social involvement and psychological well-being? *American Psychologist*, 53:1011–1031.

Li, Y., Savage, M., and Pickles, A. (2003). Social capital and social exclusion in england and wales (1972-1999). *British Journal of Sociology*, 54(4):497–526.

Miner, L. (2015). The unintended consequences of internet diffusion: Evidence from malaysia. *Journal of Public Economics*, 132:66–78.

Morahan-Martin, J. and Schumacher, P. (2003). Loneliness and social uses of the internet. *Computers in Human Behavior*, 19:659–671.

Müller, K. and Schwartz, C. (2018a). Fanning the flames of hate: Social media and hate crime. Available at SSRN: https://ssrn.com/abstract=3082972 or http://dx.doi.org/10.2139/ssrn.3082972.

Müller, K. and Schwartz, C. (2018b). Making america hate again? twitter and hate crime under trump. Available at SSRN: https://ssrn.com/abstract=3149103 or http://dx.doi.org/10.2139/ssrn.3149103.

Nannicini, T., Stella, A., Tabellini, G., and Troiano, U. (2013). Social capital and political accountability. *American Economic Journal: Economic Policy*, 5(2):222–250.

Nardotto, M., Valletti, T., and Verboven, F. (2015). Unbundling the incumbent: evidence from uk broadband. *Journal of the European Economic Association*, 13(2):330–362.

Nie, N. H. and Erbring, L. (2000). Internet and society, a preliminary report. Technical report, Stanford Institute for the Quantitative Study of Society, Stanford, CA.

Nie, N. H., Sunshine Hillygus, D., and Erbring, L. (2002). Internet use, interpersonal relations and sociability: A time diary study. In Wellman, B. and Haythornthwaite, C., editors, *The Internet in everyday life*, pages 215–243. Blackwell, Oxford.

Nolte, A. (2017). The internet effects on sex crime and murder–evidence from the broadband internet expansion in germany. Technical report.

Nunn, N. and Wantchekon, L. (2011). The slave trade and the origins of mistrust in africa. *American Economic Review*, 101(7):3221–52.

OECD (2008). Broadband growth and policies in oecd countries. Technical report, OECD.

Ofcom (2006). Wireless last mile - final report. Technical report, Ofcom.

Ofcom (2009). Uk broadband speeds 2009: Consumers experience of fixed-line broadband performance. Technical report, Ofcom.

Ofcom (2010). Uk broadband speeds 2010: The performance of fixed-line broadband delivered to uk residential consumers. Technical report, Ofcom, London, UK.

Ofcom (2011). Uk fixed-line broadband performance 2011: The performance of fixed-line broadband delivered to uk residential consumers. Technical report, Ofcom, London, UK.

Ofcom (2012). Infrastructure report: 2012 update. Technical report, Ofcom, London, UK.

Ofcom (2013). Uk fixed-line broadband performance 2013: The performance of fixed-line broadband provided to uk residential consumers. Technical report, Ofcom, London, UK.

Ofcom (2016). Clarity for businesses baffled by broadband speeds. Technical report, Ofcom.

Olken, B. A. (2009). Do television and radio destroy social capital? evidence from indonesian villages. *American Economic Journal: Applied*, 1(4):1–33.

Olson, M. (1971). *The Logic of Collective Action*. Harvard University Press, Cambridge, MA.

Paxton, P. (1999). Is social capital declining in the united states? a multiple indicator assessment. *American Journal of Sociology*, 105(1):88–127.

Putnam, R. D. (1995). Bowling alone: America's declining social capital. *Journal of Democracy*, 6(1):65–78.

Putnam, R. D. (2000). *Bowling Alone: The Collapse and Revival of American Community*. Simon & Schuster, New York.

Putnam, R. D., Leonardi, R., and Nanetti, R. Y. (1993). *Making Democracy Work: Civic Traditions in Modern Italy*. Princeton University Press.

Rosenberg, M. (1956). Misanthropy and political ideology. *American Sociological Review*, 21:690–695.

Rost, K., Stahel, L., and Frey, B. (2016). Digital social norm enforcement: Online firestorms in social media. *PLoS ONE*, 11(6):e0155923.

Sabatini, F. and Sarracino, F. (2017). Online networks and subjective well-being. *Kyklos*, 70(3):456–480.

Steinfield, C., Ellison, N. B., and Lampe, C. (2008). Social capital, self-esteem, and use of online social network sites: A longitudinal analysis. *Journal of Applied Developmental Psychology*, 29:434–445.

Stepanikova, I., Nie, N. H., and He, X. (2010). Time on the internet, loneliness and life satisfaction: Evidence from panel time-diary data. *Computers in Human Behavior*, 26:329–338.

Taylor, M. F., Brice, J., Buck, N., and Prentice-Lane, E. (2010). British household panel survey: User manual. Technical report.

Uphoff, N. (1999). *Understanding social capital: Learning from the analysis and experience of participation*. The World Bank, Washington, DC.

Valenzuela, S., Park, N., and Kee, K. F. (2009). Is there social capital in a social network site?: Facebook use and college students' life satisfaction, trust, and participation. *Journal of Computer-Mediated Communication*, 14(4):875–901.

Webber, M. M. (1963). *Order in diversity: Community without propinquity.* Johns Hopkins Press, Baltimore.

Wellman, B. and Hampton, K. (2001). Long distance community in the network society: Contact and support beyond netville. *American Behavioral Scientist*, 45(3):477–496.

Wirth, L. (1938). Urbanism as a way of life. *American Journal of Sociology*, 44:3–24.

Appendix

Table 9: Sample selection steps.

	Leisure activities		Organizations		Meeting-Talking		Trusting	
	MAIN	PLACEBO	MAIN	PLACEBO	MAIN	PLACEBO	MAIN	PLACEBO
1 - Starting samples containing the relevant waves only								
PIDs	20310	22251	22601	23241	23760	24648	19318	20933
Obs.	60748	61777	63889	59825	124637	116944	59631	41329
2 - Ecluding observations with missing values for any covariate								
PIDs	19207	21313	21489	22396	22612	23766	17684	17370
Obs.	55952	57455	59155	56500	115133	110067	51099	36072
3 - Excluding PIDs not oberved at least once in both PRE and POST period								
PIDs	12884	13720	13050	12538	13845	13825	10208	10266
Obs.	47513	47773	48209	42240	98608	86971	37161	26642
4 - Excluding individuals who change LSOA across the considered waves								
PIDs	9670	10397	9616	9068	9800	9631	7863	7740
Obs.	35697	35860	35656	30193	70194	59572	28528	19827

Notes: The table reports the number of PIDs and observations left out after each step of the sample selection process. Figures are reported separately for each set of social capital indicators, and for MAIN and PLACEBO regressions

MUNI Econ Working Paper Series (since 2018)

2018-01 Geraci, A., Nardotto, M., Reggiani, T.,Sabatini, F. 2018. *Broadband Internet and Social Capital*. MUNI ECON Working Paper n. 2018-01. Brno: Masaryk University.

ISSN electronic edition 2571-130X

MUNI ECON Working Paper Series is indexed in RePEc:

https://ideas.repec.org/s/mub/wpaper.html