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Broadband Internet and Social Capital*

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Abstract

We study the impact of broadband penetration on social capital in the UK. Our empirical strategy exploits a technological feature of the telecommunication infrastructure that generated substantial variation in the quality of Internet access across households. The speed of a domestic connection rapidly decays with the distance of a user's line from the network's node serving the area. Merging information on the topology of the network with geocoded longitudinal data about individual social capital from 1997 to 2017, we show that access to fast Internet caused a significant decline in civic and political engagement. Overall, our results suggest that broadband penetration crowded out several dimensions of social capital.

Keywords: ICT, broadband infrastructure, networks, Internet, social capital, civic capital.
JEL Classification: D91, L82, Z13.

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1 Introduction

Social capital plays a role in many desirable outcomes such as access to credit and loan repayment (Karlan, 2005), financial development (Guiso et al., 2004), innovation (Knack and Keefer, 1997), productivity (Bloom et al., 2012), mitigation of agency problems (Costa and Kahn, 2003), and economic growth (Algan and Cahuc, 2010). However, there are signals that some social capital dimensions are eroding. In his bestseller *Bowling Alone*, Putnam (2000) documented that a decline in civic engagement and trust began in the United States in the 1960s, with a sharp acceleration in the 1990s. The author suggested that domestic entertainment such as television, video players, and computer games displaced relational activities in individuals' leisure time. If television, a unidirectional mass medium, can crowd out face-to-face interaction, it stands to reason that broadband 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 economic outcomes of social capital, the effect of broadband penetration should be put under scrutiny by economic research. This paper uses panel data to compare the behavior of households before and after the diffusion of fast Internet. To address endogeneity concerns, we exploit the exogenous variation in the quality of the households' Internet connections due to the technical features of the access technology. In the UK, broadband penetration long relied on the digital subscriber line (DSL) infrastructure. This technology allows the high-speed transmission of data over the old copper telephone network. However, connection to the voice grid is a necessary but not sufficient condition for accessing fast Internet. The actual speed of a domestic connection rapidly decays with the distance of a final user's telephone line from the network's node serving the area, also called local exchange (hereafter LE). When 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. However, the introduction of the DSL technology unpredictably turned distance from the LE into a critical determinant of Internet access and quality in the 1990s. Proximity to the network's node serving the area thus resulted in actual broadband access, while higher distance prevented households from using fast Internet.[1] We exploit this feature of the telecommunication infrastructure by combining unique information about the topology of the voice network provided by Ofcom - including the geolocation of the LEs and the city blocks served by each of them - with geocoded individual survey data from the British Household Panel Survey (BHPS) over 1997-2008 and the UK Household Longitudinal Study (UKHLS) from 2009 to 2017.

First, we use our detailed map of the topology of the network to calculate the distance

[1] Ofcom (2011).

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 and the UKHLS. Since the physical distance between the LE and the premises long affected the connection's speed, we then employ an intention-to-treat approach to assess the impact of fast Internet on different social capital dimensions, such as participation in voluntary organizations, political engagement, social trust, and various forms of social interaction.

We find that, after broadband's take-up, civic and political engagement started to decline with proximity to the node of the network, suggesting that the use of fast Internet displaced social capital. The effect is sizable, as a one standard deviation reduction in the distance from the LE (equal to 1.8 kilometers), resulting in a higher connection speed, causes a statistically significant decrease in the likelihood of participation in civic organizations by 4.7 percent over the period 2005-2017.

Back of the envelope calculations based on the population's distribution across the distance from local exchanges suggest that proximity to the LE shifted the social participation of approximately 450,000 residents. The types of organizations that Putnam (1995) defined as supportive of collective action, such as volunteering associations, suffered the most from broadband penetration. We find that living one standard deviation closer to the LE caused a statistically significant reduction in the likelihood of participation in these organizations by 7.8 percent.

For organizations supporting redistributive goals such as political parties (Knack and Keefer, 1997), broadband availability caused a statistically significant reduction in the likelihood of participation by 5.1 percent.

By contrast, we find no significant impact of broadband penetration on cultural consumption and respondents' relationships with friends. Overall, our results suggest that broadband Internet displaced the time-consuming activities oriented to pursuing the common good that Putnam et al. (1993) referred to as "bridging social capital". However, the crowding-out effect spared the relationships between people who know each other well, generally referred to as "bonding social capital" (Putnam et al., 1993; Gittel and Vidal, 1998). 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 fast Internet's take-up.

The treatment effects do not change significantly across the two main stages of broadband penetration we address in the empirical analysis. This evidence suggests firstly that distance from the networks' nodes – and thus the quality of Internet connection – remained a relevant driver of fast Internet access and use in recent years, and secondly that, in different ways, broadband access continued to have a strong effect on social capital when new types of content appeared on the Internet landscape.

Our paper connects to three strands of literature. The first broadly includes empirical research on the sources of social capital. Several studies in this field investigated the role of historical experiences, such as slave trade (Nunn and Wantchekon, 2011), political independence (Guiso et al., 2016), and inherited culture (Algan and Cahuc, 2010). We add to this research by investigating how ICT progress can induce a more rapid, though persistent, change in the stock of social capital. We particularly relate to contributions assessing the response of civic engagement and trust to contingent stimuli such as conflict (Guriev and Melnikov, 2016), corruption (Barenjee, 2016), teaching practices (Algan et al., 2013), and regulation (Aghion et al., 2010).

The second strand of literature includes studies empirically testing the relationship between ICTs and political participation. Several authors assess the impact of Internet use by exploiting discontinuities in broadband access. Falck et al. (2014) and Gavazza et al. (2019) provide evidence that fast Internet crowded out voter turnout in Germany and the UK. Campante et al. (2018) consistently find that broadband availability displaced political engagement in Italy at the initial stages of Internet penetration. However, the advent of social media later triggered renewed interest in public affairs, encouraging disintermediated forms of political participation. Enikolopov et al. (2020) show that the penetration of VK, the most used Russian social networking site (SNS), supported the 2011 political protests in Russia. Engagement in SNSs is also associated with lower corruption in Russia (Enikolopov et al., 2018) and an increased ability of U.S. congress candidates to raise funds across their supporters (Petrova et al., 2017). On the negative side, social media have been found to support the spreading of political misinformation (Allcott and Gentzkow, 2017), increase polarization (Levy, 2021), erode social trust (Antoci et al., 2019), encourage hate crime against refugees in Germany (Müller and Schwartz, 2020a), and Muslim in the U.S. (Müller and Schwartz, 2020b), and undermine users' well-being (Allcott et al., 2020).[2]

Despite the growing knowledge on the political impact of fast Internet, there still is limited evidence on how broadband penetration affects social capital. The closest paper to ours is Bauernschuster et al. (2014), who exploit the incompatibility between the DSL technology and the glass fiber infrastructure installed in some areas of East Germany [3] to study the impact of Internet use on social capital over 1999-2009. The authors find that Internet use did not significantly affect social capital. Our finding that broadband

[2]For a review of the literature on the social and political impact of social media, see Zhuravskaya et al. (2020) and Campante et al. (2021).

[3]Glass fiber was deemed to improve the quality of voice communication, but later turned out to be incompatible with the DSL technology, thereby preventing cabled areas from accessing fast Internet.

penetration instead displaced some social capital dimensions in the UK allows us to catch another fragment of a larger and complex picture. As we document in Section 5, Germany displayed significantly higher social and civic engagement than the UK in the early 1990s. This difference in the level of participation reflects the different patterns of Internet use in the two countries. We show that, in the years of broadband's take-up, UK surfers used the Internet for commercial purposes, such as private entertainment and the purchase of goods and services, much more than German users. By contrast, Germans were more eager to use the Internet to engage in community affairs and keeping in touch with others. This descriptive evidence suggests that the baseline levels of social capital and the most popular online activities could help explain the differential impact of broadband penetration across countries. In Germany, citizens eager to be involved in community affairs took advantage of the increase in connection speed to exploit new tools for participation, resulting in strengthened civic engagement. In the UK, where bridging social capital was lower than in Germany and users mainly exploited the web for commercial purposes, fast Internet may have diverted users from time-consuming relational activities oriented to the common good.

More in general, our work connects to studies assessing the impact of broadband penetration on macroeconomic outcomes, such as employment (Hjort and Poulsen, 2019) and growth (Czernich et al. 2011), and human behaviors such as sex crime (Bhuller et al., 2013), sleep (Billari et al., 2018), self-image concerns (McDool et al., 2020), enrollment in colleges (Dettling et al., 2018), educational attainment (Faber et al., 2015), and demand for healthcare services (Amaral-Garcia et al., 2021).

The remainder of the paper proceeds as follows. Section 2 provides background about the broadband infrastructure in the UK. Section 3 presents the data and our empirical strategy. In Section 4, we present our empirical analysis of broadband Internet's effect on social capital. Section 5 discusses our results in light of the previous literature. Section 6 concludes.

2 The broadband infrastructure in the UK

Fast Internet access in the UK took its first steps at the end of the 1990s, relying on an infrastructure built several decades earlier: the telephone network. This network was designed and rolled out in the 1930s by the former state monopolist British Telecom (BT) to enable voice communication. The network consists of nodes, the Local Exchanges (LEs hereafter) connected to each other to ensure global connectivity, each serving all premises located in the respective catchment area. Internet service providers operating over this network have been by far the dominant supplier of broadband services until the first decade of the 2000s (the only competitor being the cable operator). However, providers exploiting the old voice networks also remained the primary source of broadband access in the second decade of the 2000s when mobile operators started to offer fast Internet services.

The voice network, which was designed to transmit the analog signal of voice communication, can also transmit digital signals, thus enabling all forms of digital communication and Internet access. The main limitation of the pre-existing network lies in its copper wires. A digital signal transmitted on a copper wire suffers from substantial decay with the distance traveled, making the length of the copper section of the network a crucial determinant of local Internet access conditions.

In the 1990s, the copper wires of the network provided a 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 first versions of ADSL could achieve very limited speed (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 increased rapidly during the first decade of the 2000s, reaching 24Mbit/s in 2008, and continued to increase during the second decade of the 2000s with the roll out of VDSL technologies, which enabled a theoretical maximum speed of 56Mbit/s. However, not every Internet user could immediately enjoy the maximum connection speed. DSL technologies required substantial network upgrades and faced a fundamental local limitation: the so-called *last mile*, i.e., the section of the network connecting premises with the LE serving the area. As the digital signal suffers from a substantial decay when transmitted over a copper wire, with its strength declining more than proportionally with the distance traveled, BT upgraded all the connections between the LEs, accounting for most of the distance between the final user and the content provider/ISP, with fiber optic wires. Still, the state monopolist did not replace the connections between the LEs and the premises, which continued to rely on the old copper infrastructure.[4] This choice allowed to reach a decent Internet speed at a relatively low investment cost but generated local differences in the quality of access between households depending on the length of their *last mile*. Having been installed in the 1930s for different purposes

[4]Connecting the LEs with premises through fiber cables (so-called *fiber to the home*, FTTH, connection) allows faster navigation speed as the signal never travels on copper, but requires to upgrade also the line between the LEs and the premise, resulting in a much higher cost (especially in the case of a large-scale roll-out). Until 2010, FTTH connections were deployed exclusively for large companies or institutions which had dedicated high-speed lines. After 2010, investments in FTTH remained very limited and confined to the center of the main cities.

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 characteristic implies 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).[5]

Broadband Internet penetrated slowly in the UK between the end of the 1990s and the early 2000s (Deshpande, 2014) for two primary reasons. First, the average navigation speed was relatively low due to the incomplete 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 after 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 to supply customers with an upgrade of their voice lines to DSL services (Nardotto et al., 2015). The number of Internet service providers increased 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 broadband penetration in the UK, as shown in Figure 1, which reports the evolution of broadband penetration between 2000 and 2018. In the five years from 1999, which can be considered the starting year of its take-up, to 2004 broadband penetration went from 0 to 18%, while in the following six years it almost reached the threshold of 80%. After that, with the market becoming almost saturated, broadband Internet penetration continued to grow slowly but constantly, passing the threshold of 90% in the second half of the 2010s.

DSL was not the only option to access fast Internet in our period of analysis, although it was the most popular choice. Until 2010, approximately 80 percent of broad-

[5]In line with the measurements by Ofcom, the data on the speed test used in Ahlfeldt et al. (2017), (see page 604), show the strong, nonlinear, decay in speed with distance. In particular, the first 2 kilometers reduce speed by approximately 50%. Therefore, adopting 2Mibt/s as the speed threshold for a broadband connection implies that beyond 2 kilometers to the LE, virtually all ADSL installed until 2008 would not qualify as broadband.

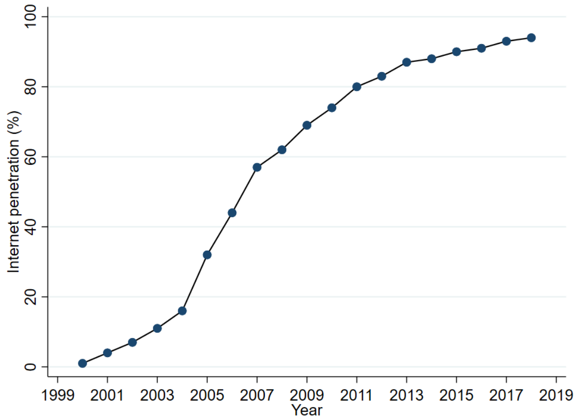

Figure 1: Broadband penetration between 2000 and 2018 (source: Eurostat).

band accesses in the UK relied on DSL, making the old telephone network the primary determinant of broadband penetration. The remaining 20 percent of broadband accesses used the cable network, while less than 0.1 percent relied on fiber and mobile operators.[6]

After 2010, mobile operators gained importance thanks to the development of 3G and then 4G technologies that could finally provide Internet access at a sufficient speed to be considered as broadband.[7] However, the fixed-line market remained dominated by DSL operators.[8]

In light of the evolution of the Internet market, it is natural to divide our period of analysis into three parts: i) A pre-Internet phase until 2004, characterized by limited take-up and low access speed; ii) A first post-Internet phase from 2005 until 2010 that saw the massive entry of ISPs and considerable improvements in Internet speed (resulting in significant take-up by final users); iii) A second post-Internet phase, after 2010, when

[6]The cable network, initially 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).

[7]Customers of mobile operators purchasing voice services could include data services in their mobile plans since the mid-2000s. However, mobile technologies lagged behind in terms of speed compared with fixed-line. A typical 2G connection (by far the most diffused type of mobile connection until the end of the 2000s) could offer a download speed of 0.1Mbit/s. Early versions of 3G, which started to gain market share at the end of the 2000s, despite being a significant improvement to the previous standard, barely passed the threshold of 1Mbit/s. Consistently with these technological limitations, the yearly reports by Ofcom (see, for instance, the 2010 Ofcom Report on the Communication Market available at: https://www.ofcom.org.uk/__data/assets/pdf_file/0010/20305/uk-telecoms.pdf) listed the poor connection quality, the data volume limitations, the network congestion in some moments of the day, and thus the overall value for money of the service, as the main reason for consumers' dissatisfaction with mobile Internet connections. It is only with the diffusion of later versions of 3G (in particular the HSPA+ that started to be deployed in 2011) that the mobile market finally took off, thanks to faster and more reliable connections, although limitations to data volumes persisted.

[8]The cable operator saw a slight decline in its market share in the fixed-line market but remained between 15 and 20 percent throughout the decade.

the market consolidated and broadband penetration peaked, but the length of the *last mile* remained an important determinant of the actual connection speed for domestic connections (Ofcom, 2017).

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 could access fast Internet with the DSL technology. Because of this technological limitation, the advent of DSL unpredictably turned distance from the LE into a critical determinant of broadband penetration, thereby creating an exogenous source of variation in access to fast Internet.

3 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 information on the topology of the telephone network provided by Ofcom (Office of Communications), the regulatory and competition authority for the telecommunications industries in the UK, which we match with [II] geocoded individual data from the British Household Panel Survey (BHPS) over the period 1997-2009 and the UK Household Longitudinal Study (UKHLS) over 2010-2017. The resulting dataset is a 20 years panel including information on each survey respondent's distance from the relative node of the telephone network.

Understanding Society and Harmonised BHPS

The British Household Panel Survey (BHPS) and the UK Household Longitudinal Study (UKHLS or Understanding Society) are two panel surveys containing detailed information on several aspects of UK households' life. The BHPS started in 1991 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 ended after 18 waves of annual interviewing, with the 18th and last wave completed in 2008. The UKHLS panel is a direct development of the BHPS. It started in 2009 and interviewed around 40,000 households, including approximately 8,000 of the initial BHPS households. Although the two surveys share many characteristics, BHPS being the predecessor of UKHLS, they also present several differences. In 2016, the Institute for Social and Economic Research started a project harmonizing the content of the two surveys to support their combined use.[9] In this paper, we make use of the last available update of the harmonised data file.[10] To match BHPS-UKHLS data with the map of the telephone network provided by Ofcom, we employ the Lower Layer Super Output Areas (LSOA) Special License version of the BHPS-UKHLS data that contains spatial LSOA references. Since former BHPS respondents were interviewed for the first time during the second wave of UKHLS (2010), our analysis covers the years 1991-2008 (waves 1-18) and 2010-2017 (waves 20-27). Importantly, we exclude from the analysis new UKHLS respondents who were not part of the BHPS sample.

Social capital

Social capital is generally referred to as all the features of social life, such as "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.

In measuring social capital, we follow Uphoff (1999) and consider both its structural and cognitive dimensions. We use three sets of measures of structural social capital. 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 dichotomous 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*. Again, we recode responses into a binary variable equal to 0 if the frequency is less than once or twice a week and 1 otherwise.

The third set captures political and civic engagement through dummies revealing

[9] For more information on the harmonization between the two surveys, see: http://repository.essex.ac.uk/21094/1/bhps-harmonised-user-guide.pdf

[10] University of Essex, Institute for Social and Economic Research. (2020). Understanding Society: Waves 1-10, 2009-2019 and Harmonized BHPS: Waves 1-18, 1991-2009: Special Licence Access, Census 2001 Lower Layer Super Output Areas. 12th Edition. UK Data Service. SN: 6670, http://doi.org/10.5255/UKDA-SN-6670-12

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 a member of it or declares to participate in its activities. [11]

We consider six types of organization, which we partition into two groups based on our elaboration of the literature about the "Olson-Putnam controversy"[12]: Olson-type organizations and Putnam-type organizations. Following Knack and Keefer (1997), we define participation in Olson-type organizations as either membership or active participation in political parties, trade unions, or professional associations. Though being different in scope and structure, these organizations serve similar purposes, as they represent "groups with redistributive goals" (Knack and Keefer, 1997, p. 1273). Thus, we include all of them into our indicator of Olson-type organizations. We also estimate the impact of fast Internet on political parties, trade unions, and professional associations separately in Section 5. Similarly, we define participation in Putnam-type organizations as either membership or active participation in environmental associations, voluntary service groups, or scout/guides groups. These organizations were credited by Putnam et al. (1993) with the ability to instill habits of cooperation, solidarity, and public-spiritedness in their members (Putnam et al., 1993, pp. 89-90). Knack and Keefer (1997) defined Putnam groups as those "least likely to act as distributional coalitions but which involve social interactions that can build trust and cooperative habits" (Knack and Keefer, 1997, p. 1273).

Our indicator of cognitive social capital captures trust towards unknown others, also called "social trust". We measure social trust 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?", developed by Rosenberg (1956), possible answers being: *depends*, *cannot be too careful*, or *most people can be trusted*. We transform responses into a binary variable that takes value 1 if the respondent believes that most people can be trusted and 0 otherwise.

We also draw from the BHPS and UKHLS information on respondents' socio-demographic characteristics, including age, income, employment status, type of occupation, the household's and the dwelling's features, and the housing contract.

[11]Notice that not every member actively engages in the organization's activities, and not all those reporting to take part in the activities are members. Thus, we include both behaviors to get a comprehensive measure of civic engagement.

[12]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).

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), Faber et al. (2015), and Ahlfeldt et al. (2017). The data report the geographic coordinates of each LE and all the 7-digits postcodes served by the node of the network.[13] Using this information, we can reconstruct the exact catchment area of each LE and, thus, compute the (linear) distance between each household's LSOA and the respective LE.[14]

3.1 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' LSOA and the LE serving their area of residence, as explained in Section 2. We estimate an *intention-to-treat* effect assuming that broadband penetration resulted in the household's access to fast Internet depending on the distance from the LE. This approach is driven by the lack of reliable individual-level survey data about the actual use of fast Internet. Information on Internet access is available only for a limited number of BHPS and UKHLS waves and does not distinguish between fast and slow connections (see Section 3.3 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 longitudinal structure of the data proves useful in two respects. First, it allows us to control for unobserved characteristics that might be correlated with both Internet access and our measures of social capital. Second, since the distance from the LE should not be associated with changes in social capital before the broadband penetration, we can perform a Difference-in-Differences exercise that further strengthens a causal interpretation of results.

In our main specification, we classify our panel waves into two distinct periods according to the stage of broadband Internet diffusion.[15] The *Pre-Broadband* period corresponds to the BHPS waves between 1991 and 2004 (waves 1–14), referring to years in which broadband access was minimal among British households (overall broadband

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

[14]Ideally, one would like to use the exact address of the household. However, the BHPS and Understanding Society report, even under restricted access, only the LSOA. Thus, we compute the distance between the (exact) coordinates of the LE and the geographical centroid of the LSOA.

[15]Figure A.4 in the Appendix reports the timeline of the data used in the empirical analysis and the division in periods.

penetration in 2004 was lower than 20% and mainly confined to the more affluent parts of large cities). The *Post-Broadband* period (labeled *Post* in equations and tables) covers the years from 2005 onward, witnessing broadband's take-up in the UK. In our setting, this period spans from 2005 to 2017, encompassing all the harmonized waves of the BHPS and UKHLS surveys in which our outcome variables were available (waves 15-27).

$$y_{it} = \gamma Distance_{it} \times Post_t + \beta X_{it} + MSOA_{it} \times t + Wave_t + \eta_i + \varepsilon_{it} \tag{1}$$

In our second specification, we unpack the *Post-Broadband* period into two different sub-periods: *Post-Broadband(1)* – labeled $Post(1)$ in equations and tables –, which ranges from 2005 to 2008 (covered by the BHPS waves 15–18), and captures the stage of rapid diffusion of broadband Internet in the UK; *Post-Broadband(2)* – labeled $Post(2)$ in equations and tables – which ranges from 2010 to 2017 (covered by the UKHLS harmonized waves 20–27). In these years, broadband coverage approximately reached 92 percent in England and between 85 and 89 percent in the rest of the UK, with distance remaining a significant determinant of fast Internet access (see Ofcom, 2017).[16] In Section 4.2, we exploit UKHLS data to document that the time spent in online activities such as gaming and surfing social media significantly decreases with distance in the $Post(2)$ period (see Table A.4 in the Appendix).

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):

$$\begin{aligned} y_{it} = &\gamma_1 Distance_{it} \times Post(1)_t + \gamma_2 Distance_{it} \times Post(2)_t + \beta X_{it} + \\ &+ MSOA_{it} \times t + Wave_t + \eta_i + \varepsilon_{it} \end{aligned} \tag{2}$$

In the above equation, y_{it} is the outcome of interest for person i in year t. $Distance_{it} \times$ $\textsc{Post}_t$ is the (reversed) treatment intensity for individual i in year t. This variable is the product of $Distance_{it}$, which is the average distance from the LE (expressed in kilometers) serving the LSOA where individual i lives in year t, and $\textsc{Post}_t$, a binary variable set to 1 if year t is in the *Post-Broadband* period, and 0 otherwise. X_{it} is a set of observed time-varying characteristics: age, log of real annual household income, indicators for (i) occupation type, (ii) occupational status, (iii) type of housing tenure, (iv) type of household, (v) education level. Since respondents might change address

[16] As mentioned in the data description, 2009 was a transition year for former BHPS respondents, who entered the new UKHLS sample only in the second wave of 2010.

between waves, the vector X_{it} also includes an indicator variable for change of address[17], and the variable $Distance_{it}$. We also include a set of monthly indicators for the month in which the interview took place. η_i is the individual's fixed effect, which allows us to control for time-invariant unobserved characteristics that might be systematically associated with the propensity for Internet use and social capital.[18]

As in standard Diff-in-Diffs, causal interpretation of parameter γ in equation (1) requires parallel trends in pre-treatment outcomes. In our setup, this requires differences in distance from the LE not being associated with differential trends in the considered outcome in the *Pre-Broadband* period, conditional on the considered individual characteristics, time, and individual fixed effects. This assumption might be valid if the average distance from the LE proxies other time-varying characteristics of the local area. To address this concern, we include MSOA-specific linear trends, $MSOA_{it} \times t$, in all our main regressions.[19]

In the Appendix, we also provide evidence suggesting that deviations from the parallel trends assumption are not likely in our context. We conduct an event study analysis in the spirit of Autor (2003). The term $\gamma Distance_{it} \times Post_t$ is replaced by $\sum_t \gamma_t Distance_{it} \times Wave_t$, a set of interactions between our treatment variable and wave dummies for all years except the first in which information about y_{it} is available.[20] Figure A.1 in the Appendix contains plots of the estimated coefficients γ_t for each of

[17]The survey reports whether the respondent has a different address than the one of the previous wave. We include this variable because moving to a new neighborhood can have a direct effect on our measures of social capital.

[18]In the Appendix, we report the result of a related exercise where we split the households into 2 groups – *Low-Distance* and *High-Distance* – based on the distance between the LSOA of residence and the LE. We set a threshold of 3.1km, and we assign households at a distance of 3.1km or less to the *Low-Distance* group. We then estimate the model in (3):

$$y_{it} = \sum_t \gamma_t Low\text{-}Distance_{it} \times Wave_t + \beta X_{it} + MSOA_{it} \times t + Wave_t + \eta_i + \varepsilon_{it} \tag{3}$$

where we control for the same set of controls as in (2), thus including time FE, individual FE, and MSOA linear trends. Due to the substantial attrition at the end of the sample and the split of the households into two groups, we exclude the last wave of the data (i.e. wave 27 corresponding to year 2017) from the sample. We plot the estimated coefficients, together with confidence intervals (standard errors are clustered at the level of the LSOA), in Figure A.5 in the Appendix. Results are discussed in Section 4.2 together with the results of our main identification strategy.

[19]The MSOA is the next narrowest geographical areas in the UK census after the LSOA. While LSOAs have on average 1500 households and correspond to blocks in urban areas, MSOAs have on average 6000 households, corresponding to neighborhoods in urban areas. On average, an MSOA contains four LSOAs. An example is in Figure A.3, which reports a map of the LSOAs and of the MSOAs in Colchester.

[20]The model specification is identical to the one in equation (1) where the interaction term $Distance_{it} \times Post_t$ is replaced by a full set of interaction terms between wave dummies and the variable *Distance*, i.e., $\sum_t \gamma_t Distance_{it} \times Wave_t$. The set of controls is identical to the one used in the main regressions and includes time FE, individual FE, and MSOA linear trends. Standard errors are clustered at the level of the LSOA.

the dependent variables considered. The graphs suggest that our continuous treatment variable is not associated with statistically significant patterns in the dependent variables in the *Pre-Broadband* period. This result is confirmed by a battery of tests of joint significance of the coefficients in the *Pre-Broadband* period, which do not reject the null hypothesis of 0 (p-values are reported in the Appendix together with the graphs).

Finally, we explore the possibility to follow the identification strategy of Gavazza et al. (2019), who exploit exogenous weather conditions to instrument for broadband take-up, as rainfall affects investments, Internet quality and take-up. However, the sample size of the BHPS-UKHLS, and the noise in the answers to the questions related to broadband, make this exercise not conclusive, although results are in line with our main findings (see in the Appendix).

3.2 Summary statistics

Tables 1 and A.1 (the latter in the Appendix) report the descriptive statistics of the dependent and control variables, respectively. To compute the summary statistics, we consider each individual/wave observation that we use in our empirical analysis. Since not all the questions related to our outcomes of interest are available for all waves, the sample size differs across variables.[21]

Table 1 reports the summary statistics of the indicators employed as dependent variables. In our sample, which is representative of the UK's population, 15% of people regularly go to the cinema, and 5% attend concerts and theatre shows. A large majority declares meeting friends and regularly talking with neighbors, while approximately 40% believe that most people can be trusted. Less than 30% of the population is a member or participates in the organizations we consider, with Olson-type organizations attracting more participation (22%) than Putnam-type ones (9%). Finally, the average household lives 2.4 kilometers from the LE providing Internet access, with a significant variation, the standard deviation being equal to 1.8 kilometers.

Table A.1 in the Appendix reports summary statistics of the socio-demographic information collected in the BHPS and the UKHLS that we employ in our empirical analysis.[22]

3.3 Effect of distance on Internet take-up

Our identification strategy relies on the fact that, in the years we consider, the distance between the geographical location of the households and the respective LE crucially

[21] Figure A.2 in the Appendix describes the availability of information about each of the considered outcomes in the BHPS waves

[22] Notice that these variables are a subset of the socio-demographic information collected in the BHPS and the UKLS. We focus on key demographics as estimates account for individual's fixed effects.

Table 1: Descriptive statistics

Variable	Mean	St.Dev.	Min	Max	Obs
Any organization	0.28	0.45	0.00	1.00	138054
Olson organizations	0.22	0.41	0.00	1.00	138054
- Political parties	0.03	0.16	0.00	1.00	138054
- Trade unions	0.15	0.36	0.00	1.00	138054
- Professional organizations	0.08	0.27	0.00	1.00	119344
Putnam organizations	0.09	0.29	0.00	1.00	138054
- Environmental organizations	0.03	0.18	0.00	1.00	138054
- Voluntary organizations	0.05	0.22	0.00	1.00	138054
- Scout organizations	0.02	0.13	0.00	1.00	119344
Cinema attendance	0.15	0.36	0.00	1.00	78592
Theater and concerts attendance	0.05	0.22	0.00	1.00	78606
Talks to neighbors	0.39	0.49	0.00	1.00	142268
Meets people	0.46	0.50	0.00	1.00	142264
Most people can be trusted	0.38	0.48	0.00	1.00	68300
Changed neighborhood	0.19	0.39	0.00	1.00	260403
Broadband internet	0.75	0.43	0.00	1.00	82358
Daily use of internet	0.57	0.50	0.00	1.00	73081
Distance house-LE (km)	2.43	1.84	0.01	28.98	260403

Note: the number of observations depends on the BHPS and the UKHLS waves considered.

affected the quality of broadband access. The use of technological factors as a source of exogenous variation in Internet access conditions is grounded in a large body of evidence provided by public institutions and the previous literature. Technical reports produced by the industry and the UK's communications regulator emphasize the role of distance as a crucial determinant of connection speed (Ofcom, 2010; Ofcom, 2011; Ofcom, 2012; Ofcom, 2013). Recent studies also exploit factors affecting the quality of Internet access (such as the distance of the dwellings from the LE) to identify the causal effect of broadband penetration on a range of hypothetical outcomes (see, for instance, Falck et al., 2014; Miner, 2015; Campante et al., 2018; Billari et al., 2018; Amaral-Garcia et al., 2021; McDool et al., 2020).

Most of those studies took the effect of the distance between the premises and the LEs on fast 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 and UKHLS to provide evidence that distance from the LE indeed affected broadband access in the UK.

To this purpose, we use a question on broadband Internet access included in some waves of the BHPS. 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 the 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 discourage exploiting 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 giving a positive answer even though they had a slow DSL connection (such as an ISDN) or an only in theory broadband connection that suffered from substantial decay due to the distance from the LE.[23] In addition, respondents might give a positive answer even when the connection was not at home (which is crucial in the allocation of leisure time) but, for example, at the workplace.

The second limitation relates to the waves in which this information was collected and the sample of households interviewed, which is not entirely consistent with the other samples employed in the rest of the empirical analysis.[24]

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 (4), is similar to (1) that we employ in the main empirical analysis.

$$Internet_{it} = \gamma Distance_i + \beta X_{it} + Wave_t + \eta_i + \varepsilon_{it} \tag{4}$$

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 do not employ a fixed-effect

[23] In our period of analysis, broadband packages were typically advertised referring to their *theoretical* maximum speed, while providers omitted information about the actual or average speed. As a result, consumers largely ignored the fact that the actual speed depended on the distance from LEs. According to Ofcom reports focusing on consumer protection issues, this has been a source of significant 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 compares 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 wholly reliable (most likely upward biased) and therefore only weakly informative (OECD, 2008).

[24] As reported in Figure A.2 in the Appendix, questions on broadband Internet access started to be included only in wave 16 of the BHPS.

estimator but a random-effect estimator (with controls) because our main variable of interest, the distance between the respondent's telephone line and the LE, is constant over time (it only changes for those who move) and the Internet questions were asked only starting from the last waves of the BHPS, i.e., only in the *Post-Internet* period.

A clear negative relationship between the distance and broadband access emerges 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). We illustrate this negative relationship in Figure 2, which results from the estimation of our model, and a straightforward application of the Frisch-Waugh-Lovell theorem (see, for instance Davidson et al., 2004), which enables us to partial-out the role of socio-demographics when we examine the relation between take-up and distance. We split 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 4 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.

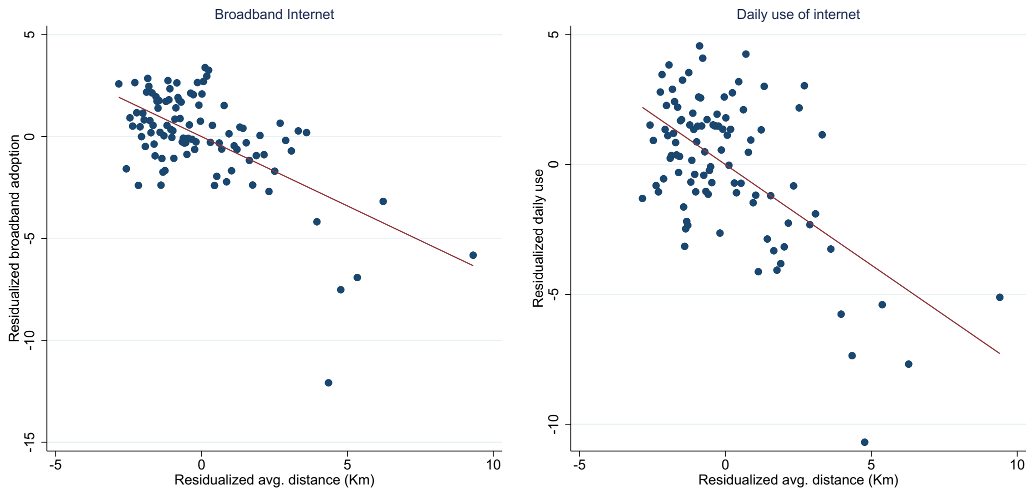

Figure 2: Internet access and distance between the house and the LE. Both panels report on the x-axis the residuals of a regression of the distance between the house and the respective LE on the socio-demographic control variables. The y-axis of the left panel reports the residual of a regression for the presence of broadband at home on the socio-demographic control variables. The y-axis of the right 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 (4), whose estimates are reported in Table 2.

Column (1) of the table shows the estimated effect of distance between the house

Table 2: Effect of distance from the LE on fast Internet take-up.

Dep. Variables:	Broadband internet (1)	Daily use of internet (2)
Distance	-0.50***	-0.58***
	(0.14)	(0.13)
Controls	✓	✓
Time FEs	✓	✓
Individual REs	✓	✓
Mean of Dep.Var.	73.67	55.17
Observations	99034	87715
R^2	0.33	0.28
Num. PIDs	17447	15938

Dependent variables in (1) and (2) are indicators for having a broadband internet connection at home and the daily use of the Internet, respectively. Dependent variables are re-scaled such that 1=100. The variable *Distance* is the average distance from the LE in the respondent's LSOA, measured in Km. The sample includes all respondents in the BHPS waves for which the relevant information was collected and available (waves 16-17-18 in column 1 and 18 in column 2). Controls included in each regression: wave indicators, average distance from the LE in the LSOA, age, log of real annual household income, indicators for (i) occupation type, (ii) occupational status, (iii) type of housing tenure, (iv) type of household, (v) education level, (vi) change of address from previous year, (vii) a set of monthly indicator variables for the month of the interview. Standard errors in parentheses are clustered at the level of the LSOA. Standard errors in parentheses are clustered at the level of the LSOA. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

and the respective LE on the adoption of a broadband connection. As expected, the coefficient is negative and statically significant, thus indicating that distance influences Internet access (the *extensive margin*). Furthermore, column (2) of the table reports the estimated impact of distance on the time spent online (the *intensive margin*), showing a strong, negative effect of distance. Thus, we can conclude that the distance between dwellings and the LE serving the area was crucial for broadband take-up and the time users spent online. Distance exerted its effect by affecting Internet providers' running costs, the quality and reliability of the connection, and possibly its very availability since the connection speed could be so low beyond 4.2 kilometers that broadband connections could not be available until 2008.

4 The effect of fast Internet on social capital

In this section, we present the results of the estimations of model (1). We start by analyzing how the quality of Internet access (increasing with proximity to the LE) affects two forms of cultural consumption that people usually enjoy in company (Section 4.1). We then present results regarding participation in organizations (4.2), trust, and some forms of offline interaction (4.3). Finally, we discuss our findings in light of the previous literature in Section 5.

4.1 Fast Internet and cultural consumption

As discussed in section 3, the BHPS and UKHLS neither provide a precise measure of the time spent in leisure activities nor report detailed information on the composition of individuals' leisure time. We thus focus on two forms of cultural consumption that usually entail social interaction: watching movies at the cinema and attending concerts or theater shows. Our dependent variable is a dichotomous indicator taking value 0 if the attendance is less than once a month and 1 if at least once a month.

Since these outcome variables are only available in the BHPS, we cannot perform our main specification based on the interaction term between distance and the *Post* dummy, covering years from 2005 to 2017. Therefore, we only rely on our second specification and interact the distance between respondents' dwelling and the network's node serving the area with a dummy for the period 2005-2008. Results are illustrated in Table 3, where column (1) refers to cinema attendance and column (2) to the attendance of concerts or theater shows.

Table 3: Effect of fast Internet on cultural consumption.

Dep. Variables:	Go to cinema	Go to concerts or to theater
	(1)	(2)
Distance × Post(1)	0.27	0.03
	(0.17)	(0.13)
Controls	✓	✓
Time FEs	✓	✓
Individual FEs	✓	✓
MSOA linear trend	✓	✓
Mean of Dep.Var.	14.10	5.02
Observations	73441	73459
R^2	0.61	0.55
Num. PIDs	16071	16073

Dependent variables in (1) and (2) are indicators for cinema attendance at least once a month, and the attendance of concerts and theatre shows at least once a month, respectively. Dependent variables are re-scaled such that 1=100. The variable *Distance* is the average distance from the LE in the respondent's LSOA, measured in Km. *Post(1)* takes value 1 for waves from 15 (2005) to 18 (2008), representing the post-internet period captured by the BHPS (the variable has not been collected in UKHLS). The sample includes all respondents in the BHPS waves for which the relevant information was collected and available. Controls included in each regression: wave indicators, average distance from the LE in the LSOA, age, log of real annual household income, indicators for (i) occupation type, (ii) occupational status, (iii) type of housing tenure, (iv) type of household, (v) education level, (vi) change of address from previous year, (vii) a set of monthly indicator variables for the month of the interview. Standard errors in parentheses are clustered at the level of the LSOA. Standard errors in parentheses are clustered at the level of the LSOA. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

The sign of the main coefficient of interest, Distance × Post, which captures the quality of Internet access, is positive, and its size implies that one standard deviation increase in the distance from the LE (equal to 1.8 km), resulting in a slower connection, is associated with an increase in the likelihood of attending cinema shows of 3.31 percent.[25] However, the estimated coefficient is not statistically significant. Thus our evidence does not support the claim that fast Internet crowded out cultural consumption in the UK, in line with the findings of Bauernschuster et al. (2014) for Germany over the period 2007-2009. The lack of a statistically significant relationship may be due to a double-sided impact of the Internet on offline cultural activities. On the one hand, the better quality of the Internet access may encourage users to replace the attendance of cinema, theater, and music shows with online activities. However, the availability of richer and faster information on the offline supply of cultural events may well encourage consumption, compensating for the potential substitution effect.

4.2 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 reliable indicators of social capital because 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 formal membership in the organization or the active engagement in its initiatives. We include both behaviors to get a more comprehensive measure of civic engagement, as not every member declares having being involved in the organization's activities, and not all those declaring to have taken part in the activities are members. As explained in Section 4, we distinguish between Olson- and Putnam-type organizations in line with the social capital literature (e.g. Knack and Keefer, 1997). Our dependent variables are dichotomous indicators taking value 1 if the respondent is a member of the organization or declares to participate in its activities. Tables 4, 5, and 6 report estimation results. In Table 4, columns (1) and (2) report the coefficient when the outcome variable is participation in any organization with no distinction. Columns (3) and (4) refer to Olson-type organizations, and columns (5) and (6) refer to Putnam-type organizations.

Our results suggest that 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 reported in column (1) implies that a reduction of one standard deviation in the distance from the LE (equal to 1.8 km), resulting in a higher connection speed, causes a reduction in the likelihood of participation of 4.7 percent over the period 2005-2017 (*Post*). This result is also in line with the evidence reported in Figure A.5 in the Appendix, which plots the coefficients of an alternative

[25]The percent effect is computed as: $\frac{\beta(x_i)\times\sigma(x_i)}{\mu(Y)}$.

Table 4: Effect of fast Internet on civic engagement.

Dep. Variables:	Any organization		Olson organizations		Putnam organizations	
	(1)	(2)	(3)	(4)	(5)	(6)
Distance × Post	0.71***		0.61***		0.38**	
	(0.19)		(0.18)		(0.16)	
Distance × Post(1)		0.74***		0.58***		0.45**
		(0.20)		(0.19)		(0.18)
Distance × Post(2)		0.62**		0.72***		0.11
		(0.30)		(0.26)		(0.21)
Controls	✓	✓	✓	✓	✓	✓
Time FEs	✓	✓	✓	✓	✓	✓
Individual FEs	✓	✓	✓	✓	✓	✓
MSOA linear trend	✓	✓	✓	✓	✓	✓
$\gamma_1 = \gamma_2$ (p-val)		0.70		0.60		0.14
Mean of Dep.Var.	28.17	28.17	22.02	22.02	9.31	9.31
Observations	131085	131085	131085	131085	131085	131085
R^2	0.59	0.59	0.62	0.62	0.51	0.51
Num. PIDs	19953	19953	19953	19953	19953	19953

Dependent variables in (1)-(2), (3)-(4), and (5)-(6) are indicators capturing membership or participation in the activities of, respectively, any organization, Olson organizations, and Putnam organizations. Dependent variables are re-scaled such that 1=100. The variable *Distance* is the average distance from the LE in the respondent's LSOA, measured in Km. The indicator variable *Post* takes value 1 for wave 15 and after. *Post(1)* takes value 1 for waves from 15 (2005) to 18 (2008). The indicator variable *Post(2)* takes value 1 for waves from 19 (2010) to 26 (2017). The sample includes all respondents in the BHPS and UKHLS waves for which the relevant information was collected and available. Controls included in each regression: wave indicators, average distance from the LE in the LSOA, age, log of real annual household income, indicators for (i) occupation type, (ii) occupational status, (iii) type of housing tenure, (iv) type of household, (v) education level, (vi) change of address from the previous year, (vii) a set of monthly indicator variables for the month of the interview. Standard errors in parentheses are clustered at the level of the LSOA. Standard errors in parentheses are clustered at the level of the LSOA. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

model, discussed in footnote 18 of Section 3.1. Under this approach, we split the households into two categories – *Low-Distance* and *High-Distance* – based on the distance between the LSOA of residence and the LE, and we estimate the model in (3). Our findings confirm that the effect of the Internet on participation started to appear in 2005 when households close to the respective LE went online.

To provide a more meaningful estimate of the effect size, we calculate the population's distribution across 100 meters intervals of distance from the LE throughout the UK. This information allows us to estimate that the increase in connection speed reduced the likelihood of participation of 447,442 residents. This negative effect also holds after splitting the period of analysis into the two sub-periods encompassing the first stage of rapid broadband diffusion over 2005-2008 (*Post(1)*, covered by BHPS data) and the following completion of fast Internet penetration between 2010 and 2017 (*Post(2)*, covered by UKHLS data). The estimated coefficients in Column (2) imply that one standard deviation decrease in the distance from the LE, resulting in a faster connection, causes a reduction in the likelihood of participation by 4.9 percent over 2005-2008 – *Post(1)* – and 4.1 over 2010-2017 – *Post(2)* – .

In columns (3)-(4) and (5)-(6), we report results for Olson- and Putnam-type organizations separately. In our main specification with the *Post-Broadband* period covering the years from 2005 onward, the estimated coefficients are positive and highly statistically significant for both types of organization, suggesting that participation decreases with connection speed (shorter distance from the LE). In the case of Olson-type organizations, the estimates imply that a one-standard deviation decrease in the distance from the LE, resulting in a faster connection, reduces the likelihood of participation by 5.1 percent. The effect amounts to 4.9 percent in the *Post(1)* period covering the initial stage of broadband penetration and is slightly bigger in magnitude (6.0 percent) in the *Post(2)* period covering 2010-2017. The estimated effect is larger for Putnam-type organizations and amounts to 7.8 percent, though slightly less statistically significant. Estimates in column (4) are entirely consistent with the main specification. For Putnam-type organizations, estimates in column (6) suggest that the overall impact of broadband penetration observed over 2005-2017 is mainly driven by the years of rapid broadband penetration between 2005 and 2008 (the *Post(1)* period). In this period, a one standard deviation reduction in the distance from the LE, resulting in a faster connection, causes a 9.2 percent reduction in the likelihood of participation in Putnam organizations. In the following years (the *Post(2)* period from 2010 to 2017), the effect of proximity to the LE is still negative, though losing statistical significance. In Tables 5 and 6, we report disaggregated results for specific types of Olson and Putnam organizations. We first focus on three forms of Olson organizations in Table 5: political parties, trade unions, and professional associations. Table 6 reports results about three forms of Putnam organization: environmental, voluntary service, and scout associations.

Column (1) of Table 5 shows that the exposure to broadband Internet has a sizable and statistically significant impact on participation in political parties. The estimated coefficient implies that a reduction of one standard deviation in the distance from the LE, resulting in a faster connection, reduces the likelihood of participation by 19 percent. In the years of fast broadband penetration from 2005 to 2008 (the *Post(1)* period in our analysis), a one standard deviation reduction in the distance from the LE, resulting in a faster connection, leads to a 17.8 percent decrease in political participation. In the *Post(2)* period, the effect is still significant and slightly bigger in magnitude (23.3 percent). Column (3) shows that the negative impact of fast Internet also affects participation in trade unions, even though to a lesser extent. A reduction of one standard deviation in the distance from the LE, resulting in a faster connection, causes a 3.6 percent reduction in the likelihood of participation in trade unions over the *PostBroabdband*

Table 5: Effect of fast Internet on Olson organizations.

Dep. Variables:	Political parties		Trade unions		Professional organizations	
	(1)	(2)	(3)	(4)	(5)	(6)
Distance × Post	0.31***		0.29*		0.14	
	(0.09)		(0.15)		(0.11)	
Distance × Post(1)		0.29***		0.30*		0.13
		(0.09)		(0.16)		(0.11)
Distance × Post(2)		0.38***		0.24		0.20
		(0.12)		(0.22)		(0.19)
Controls	✓	✓	✓	✓	✓	✓
Time FEs	✓	✓	✓	✓	✓	✓
Individual FEs	✓	✓	✓	✓	✓	✓
MSOA linear trend	✓	✓	✓	✓	✓	✓
$\gamma_1 = \gamma_2$ (p-val)		0.31		0.78		0.66
Mean of Dep.Var.	2.76	2.76	15.37	15.37	7.79	7.79
Observations	131085	131085	131085	131085	113038	113038
R^2	0.63	0.63	0.64	0.64	0.59	0.59
Num. PIDs	19953	19953	19953	19953	18780	18780

Dependent variables in (1)-(2), (3)-(4), and (5)-(6) are indicators for membership or participation in the activities of, respectively, political parties, trade unions, professional organizations. The main sample includes all respondents in the BHPS and Understanding Society waves for which the relevant information was collected and available. Dependent variables are re-scaled such that 1=100. The variable *Distance* is the average distance from the LE in the respondent's LSOA, measured in Km. The indicator variable *Post* takes value 1 for wave 15 (year 2005) and after. The indicator variable *Post(1)* takes value 1 for waves from 15 (2005) to 18 (2008). The indicator variable *Post(2)* takes value 1 for waves from 19 (2010) to 26 (2017). Controls included in each regression: wave indicators, average distance from the LE in the LSOA, age, log of real annual household income, indicators for (i) occupation type, (ii) occupational status, (iii) type of housing tenure, (iv) type of household, (v) education level, (vi) change of address from previous year, (vii) a set of monthly indicator variables for the month of the interview. Standard errors in parentheses are clustered at the level of the LSOA. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

period (from 2005 onward). The effect is significant at the 10 percent level. Estimates in column (4) show that the effect is driven by the years of rapid broadband penetration (2005-2008, corresponding to the *Post(1)* period). In the following years, the effect of proximity is still negative, though losing statistical significance. The different extent to which participation in the two kinds of organizations declined with access to fast Internet may be connected with the strength of the distributional action they exert. While political parties only indirectly safeguard their supporters' particular interests, trade unions have a stronger and more explicit commitment to advocate for distributive measures in favor of their members. Thus, the incentive to participate in trade unions may have been more weakly affected by the displacement effect of fast Internet.

On the other hand, access to fast Internet does not affect participation in professional organizations (columns 5 and 6), which is self-interestedly aimed at pursuing particular goals and mostly takes place in the context of individuals' professional life, instead of during their leisure time.

Table 6: Effect of fast Internet on Putnam organizations.

Dep. Variables:	Environmental organizations		Voluntary organizations		Scout organizations	
	(1)	(2)	(3)	(4)	(5)	(6)
Distance × Post	0.07		0.28**		0.09	
	(0.10)		(0.13)		(0.07)	
Distance × Post(1)		0.11		0.32**		0.08
		(0.10)		(0.14)		(0.08)
Distance × Post(2)		-0.09		0.12		0.11
		(0.16)		(0.18)		(0.10)
Controls	✓	✓	✓	✓	✓	✓
Time FEs	✓	✓	✓	✓	✓	✓
Individual FEs	✓	✓	✓	✓	✓	✓
MSOA linear trend	✓	✓	✓	✓	✓	✓
$\gamma_1 = \gamma_2$ (p-val)		0.13		0.32		0.83
Mean of Dep.Var.	3.41	3.41	5.18	5.18	1.89	1.89
Observations	131085	131085	131085	131085	113038	113038
R^2	0.55	0.55	0.45	0.45	0.51	0.51
Num. PIDs	19953	19953	19953	19953	18780	18780

Dependent variables in (1)-(2), (3)-(4), and (5)-(6) are indicator variables for membership or participation in the activities of, respectively, environmental organizations, voluntary service organizations, and scout organizations. Dependent variables are re-scaled such that 1=100. The variable *Distance* is the average distance from the LE in the respondent's LSOA, measured in Km. The indicator variable *Post* takes value 1 for wave 15 (year 2005) and after. The indicator variable *Post(1)* takes value 1 for waves from 15 (2005) to 18 (2008). The indicator variable *Post(2)* takes value 1 for waves from 19 (2010) to 26 (2017). Controls included in each regression: wave indicators, average distance from the LE in the LSOA, age, log of real annual household income, indicators for (i) occupation type, (ii) occupational status, (iii) type of housing tenure, (iv) type of household, (v) education level, (vi) change of address from the previous year, (vii) a set of monthly indicator variables for the month of the interview. Standard errors in parentheses are clustered at the level of the LSOA. Standard errors in parentheses are clustered at the level of the LSOA. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

As it concerns Putnam-type organizations, Table 6 shows that broadband penetration substantially displaced participation in service-oriented associations providing social care through volunteering activities. In this case, broadband availability causes a statistically significant reduction of participation by 10.3 percent. Coefficients in Column 4 show that the effect of proximity to the LE is negative in both periods, though losing statistical significance in *Post(2)*.

Columns (1)-(2) and (5)-(6) show no statistically significant effect of broadband penetration on environmental and scout organizations. However, coefficients are oriented in the expected direction, thus indicating a general tendency towards a decrease in participation with faster Internet access.

Overall, the pattern of results does not meaningfully change between the two periods. Columns 2, 4, and 6 of Tables 4, 5, and 6 show that the coefficients of the treatment interaction with *Post(1)* and *Post(2)* are not significantly different. This finding has two major implications. First, proximity to the LE likely continued to play a critical role in access to fast Internet in more recent years, when broadband coverage extended to approximately 90 percent of the British population. Ofcom, 2017 explains that broadband speed was still low in many areas in 2017, as the *last mile* still primarily relied on copper wires, and full-fiber investments for the supply of FTTH connections were only starting to happen.

To delve deeper into the persistent role of distance over the second stage of broadband penetration (*Post(2)*), we exploit UKHLS data to explore the correlation between proximity to the LE and aspects of Internet use that require a fast connection, such as online gaming and the active use of social media. We derive a dummy for social media use from the question "How many hours do you spend chatting or interacting with friends through social websites on a typical week day, that is Monday to Friday?", available in three waves of the UKHLS (2011-12, 2014-15, and 2017-18), with possible answers being *none*, *less than one hour*, *between one and three hours*, *between four and six hours*, and *seven hours or more*. The social media use dummy is equal to 1 if respondents declare using them one hour or more per day. We derive the online gaming dummy from the question "Do you ever play multi-player online games?", available in four waves (2010-11, 2012-13, 2014-15, and 2016-17). Both dummies are re-scaled so that 1=100 as in the main analysis. Table 11 in the Appendix shows that online gaming and the active use of social media significantly decrease with distance from the LE.

The second implication of the consistency of results across the two periods lies in the persistence of the treatment effects despite the advent of social media likely introduced significant changes in the way people use the Internet in *Post(2)* years. Even if the most popular social networking sites launched in the second half of the 2000s, social media usage substantially took up around the second half of the 2010s in the UK, with the share of adults aged 16 or more that subscribed to one or more social platforms rising from 45 percent in 2011 to 66 percent in 2017 (ONS, 2020). In Section 5, we discuss this issue more in depth in light of the literature on the societal impact of social media.

4.3 Fast Internet, social interaction and trust

We conclude the analysis by focusing on social interaction and the cognitive dimension of social capital. We estimate our empirical model on three different outcomes: trust in others, the frequency with which respondents talk to neighbors, and the frequency of meetings with other people. We collect our results in Table 7.

Our measure of trust is a binary variable taking value 1 if the respondent says that most people can be trusted and 0 otherwise. As for social interaction, our dependent variable is a dichotomous indicator equal to 0 if the frequency of the talks or meetings is less than once or twice a week and 1 otherwise.

Since these outcome variables are only available in the BHPS, we cannot perform our main specification based on the interaction term between distance and the *Post* dummy, covering the period from 2005 to 2017. Therefore, we only rely on our second specification and interact the distance between respondents' dwelling and the network's node serving the area with a dummy for the period 2005-2008. Given the lack of information about cultural consumption in the UKHLS panel, we cannot estimate the coefficient relative to the *Post(2)* period (from 2010 to 2017).

We find a positive but negligible and not statistically significant association between broadband Internet and the frequency of conversations with neighbors (column 1). The association between fast Internet and the frequency of meetings with friends is negative but not statically significant (column 2).

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

Dep. Variables:	Talks to neighbors (1)	Meets people (2)	Trusts people (3)
Distance × Post(1)	0.04	0.02	-0.21
	(0.22)	(0.24)	(0.29)
Controls	✓	✓	✓
Time FEs	✓	✓	✓
Individual FEs	✓	✓	✓
MSOA linear trend	✓	✓	✓
Mean of Dep.Var.	39.41	46.01	37.97
Observations	138629	138622	63553
R^2	0.54	0.47	0.63
Num. PIDs	18577	18578	15281

Dependent variables in (1), (2), and (3) are indicators for, respectively, more than weekly conversations with neighbors, more than weekly meeting with friends, and social trust. Dependent variables are re-scaled such that 1=100. The variable *Distance* is the average distance from the LE in the respondent's LSOA, measured in Km. The indicator variable *Post(1)* takes value 1 for waves from 15 (2005) to 18 (2008), representing the post-internet period captured by the BHPS (the variable has not been collected in UKHLS) (the variable has not been collected in UKHLS). The sample includes all respondents in the BHPS waves for which the relevant information was collected and available. Controls included in each regression: wave indicators, average distance from the LE in the LSOA, age, log of real annual household income, indicators for (i) occupation type, (ii) occupational status, (iii) type of housing tenure, (iv) type of household, (v) education level, (vi) change of address from the previous year, (vii) a set of monthly indicator variables for the month of the interview. Standard errors in parentheses are clustered at the level of the LSOA. Standard errors in parentheses are clustered at the level of the LSOA. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

On the other hand, chats with neighbors 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.

Column (3) shows no evidence that fast Internet has a significant impact on social trust. Social trust is a cognitive phenomenon that depends on individuals' values and perceptions, unrelated to time constraints and less sensitive to the risk of crowding out. Our result is consistent with the economic literature suggesting that trust is a persistent trait mainly inherited from ancestors and only limitedly affected by life experiences (Guiso et al., 2006; Guiso et al., 2009; Algan and Cahuc, 2010).

5 Discussion

Our empirical analysis shows that fast Internet substantially displaced several dimensions of social capital in the UK. Time-consuming activities oriented to the pursuit of the common good suffered the most from broadband penetration. Putnam et al. (1993) labeled these activities as forms of bridging social capital, with the term "bridging" referring to the ability to create bridges that connect groups of people with different backgrounds. The effect is statistically significant and sizable. Considering all associations together, one standard deviation reduction in the distance from the LE, resulting in a faster connection, causes a 4.7 percent decline in the likelihood of participation in our period of analysis. Back of the envelope calculations based on the population's distribution across the distance from local exchanges suggest that the increase in connection speed reduced the likelihood of participation for 447,442 residents. The displacement effect spared relationships between friends, which are generally considered as a form of bonding social capital (Putnam et al., 1993; Gittel and Vidal, 1998). While bridging social capital is commonly credited with a positive role in the diffusion of information and trust, supporting economic activities and development, bonding social capital is a potential obstacle to cooperation (Putnam et al., 1993).

Our finding that broadband penetration displaced civic engagement must be understood in relation to the work of Bauernschuster et al. (2014), who find no statistically significant effect of fast Internet on political engagement and volunteering in East Germany. The authors exploit a wrong technological choice made by the state-owned provider of Internet services that slowed down substantially the supply of fast Internet in some areas of East Germany to study the impact of broadband penetration on social capital. Reduced form estimates show that people living in areas excluded from the broadband network are less socially engaged than the control group over 1999-2009. However, the difference is not statistically significant for any social capital indicator but the attendance of theaters and exhibitions. Two stages estimates using treated areas as a binary instrument for Internet access suggest that the broadband's impact is never statistically different from zero. Our finding of a significant and sizable detrimental effect of broadband penetration in the UK catches another fragment of a larger and complex picture, suggesting that fast Internet may have differentially affected social and civic engagement across countries depending on the baseline levels of social capital and the most popular online activities. As shown in Table A.2 in the Appendix, German citizens reported significantly higher social and civic engagement than the UK in the early 2000s. In the years of fast Internet take-up, Germany reported higher levels of voluntary work for cultural, sport, or hobby associations, participation and unpaid work for political parties, and membership in humanitarian organizations. Compared to British respondents to the European Social Survey (Eurostat, 2002), Germans were significantly more likely to declare that politics and volunteerism are important in life and that voting in elections and being active in voluntary organizations and political parties is essential to be a good citizen. At the same time, Internet use also differed between the two countries. Table A.3 in the Appendix shows the most popular online activities among Internet users in the UK and Germany in the year of broadband's take-up.[26] In 2005, British users browsed the Internet for commercial purposes significantly more than Germans. In the UK, people were significantly more likely to consider the Internet as a tool for e-shopping, online gaming, and other forms of private entertainment than the Germans. By contrast, German users were significantly more eager than Britons to use the Internet for online learning, keeping in touch with others, gathering health information, keeping themselves posted on public affairs, and interacting with public institutions.

This descriptive evidence helps make sense of the differential impact of broadband penetration, suggesting that the most popular online activities and the initial endowments of social capital may affect the societal impact of broadband penetration across countries. In Germany, where bridging social capital was significantly higher than the UK, and transitioning regions were catching up with the Western levels of participation, social and civic engagement may have taken advantage of the availability of fast Internet, which offered new tools for participation to citizens eager to be involved in community affairs. Conversely, in the UK, where bridging social capital was lower than in Germany and users were more inclined to exploit the web for commercial purposes, fast Internet may have diverted users away from time-consuming relational activities oriented to the common good.

The treatment effects do not significantly differ across the two periods we address in the empirical analysis (*Post(1)* and *Post(2)*), strikingly suggesting that the take-up of social media in the 2010s did not appreciably alter the impact of fast Internet. However, this result does not necessarily imply that social media did not influence bridging social capital. Instead, online networking could affect offline connectedness in conflicting ways, leaving the displacement effect of fast Internet substantially unchanged in more recent years.

On the positive side, social networking sites can strengthen civic engagement by facilitating coordination and supporting collective action. Zhuravskaya et al. (2020) suggest that low entry barriers make it easier to spread political information and exchange ideas

[26]The table is based on Gareis et al. (2005).

on public affairs, thereby triggering interest in politics and possibly political engagement. Dissatisfaction with specific public policies or the government circulates more rapidly, raising people's eagerness for political participation. Recent experimental results provide evidence of these mechanisms. For example, Allcott et al. (2020) and Mosquera et al. (2020), use randomized experiments to show that social media support the diffusion of political information and interest in politics.

In addition, the multitude of interaction tools typical of social media can help solve coordination issues and make it easier to organize and participate in protests (Zhuravskaya et al., 2020). For example, Enikolopov et al. (2020) exploit the exogenous variation in the penetration of VK created by a peculiar subscription rule to show that the social network significantly reduced coordination costs and increased participation in protests against a massive electoral fraud in Russian parliamentary elections. Still, the network's penetration overall increased government support, consistently with previous findings on the role of Sina Weibo in China (Qin et al., 2017). Social media may also trigger peer effects more widely than offline interaction, as social image concerns create compelling incentives to join political protests (Enikolopov et al., 2017; Larson et al., 2019; Qin et al., 2019).

However, the ability to spread information at unprecedented speed and extensiveness across horizontal networks also makes social media an ideal vehicle for diffusing false information and extremist views (Allcott and Gentzkow, 2017). Moreover, social media's capacity to create filter bubbles can also limit the exposure to counter-attitudinal news and opinions, fostering polarization (Levy, 2021). The polarizing effect has proven to be more potent for individuals or groups already having extreme views. For example, Bursztyn et al. (2019) show that the penetration of VK increased hate crimes in cities with a pre-existing high level of nationalist sentiments, suggesting that the spreading of racist ideas online has tangible implications offline. Similarly, Müller and Schwartz (2020a,b) exploit exogenous Facebook and Internet outages to find that the exposure to social media fed anti-refugee sentiments, which in turn predict crimes against refugees in Germany and Muslim in the US.

Overall, the literature suggests that social media facilitate the spreading of false information, increase polarization, and exacerbate anti-minority sentiments, with real implications for hate crime. These phenomena may be detrimental to bridging social capital to the extent that they could erode trust and undermine the willingness to contribute to the common good. There is evidence that polarization causes a decline in social capital and public goods in offline communities (Bazzi et al., 2019) and reduces political participation (Rogowski, 2014). Still, it is not clear if these conclusions can be generalized. The existing evidence suggests that social media's impact may differ depending on the specific characteristics of users and the institutional and cultural background. In general, a speculative interpretation of the non-significant impact of social media as resulting from the balance between opposing forces strengthening and weakening social capital at the same time finds some support in previous studies. However, turning this speculation into empirical evidence requires further research retrieving exogenous sources of variation in specific online activities to identify the causal impact of social media on civic engagement.

The multiple effects of social media on human relations could be as conflicting as their political outcomes. For example, Allcott et al. (2020) identify a crowding-out effect of Facebook use on offline activities such as face-to-face socialization, playing sports and carrying out physical exercise, suggesting that active participation in social media may compete with offline social engagement in users' time choices. This evidence contrasts with Bauernschuster et al. (2014), who find no significant effect of broadband access on similar outcomes in Germany. Our finding of the lack of a statistically significant impact of fast Internet on the frequency of meetings with friends and chats with neighbors is consistent with Bauernschuster et al. (2014).

However, our analysis on bonding social capital is limited to the *Post(1)* period covered by BHPS data, as the UKHLS does not collect information on respondents' relational habits. This limitation does not allow us to speculate further on the potential role of social media. The statistical insignificance of the relationship between distance and bonding social capital in the *Post(1)* period could result from opposite effects rather than the lack of any effect.

Early Internet studies suggest that surfing the web for leisure necessarily steals time from social activities such as communicating with friends, neighbors, and family members, thereby leading ICTs to crowd out face-to-face interaction (e.g., DiMaggio et al., 2001). In *Bowling Alone*, Putnam (2000) builds on the concept of "community without propinquity" (Webber, 1963) to suggest that Internet penetration may have triggered a broader societal transformation that weakens the incentives for face-to-face interaction. 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). According to Putnam (2000), this line of reasoning can be applied to the Internet, which has the potential to fragment local communities into new virtual realities of shared interests that may negate the necessity of face-to-face encounters.

From this perspective, even e-commerce and online banking may be detrimental to socialization, as they decrease the need and chances for face-to-face interaction (see for example Antoci et al., 2011, and Conrads and Reggiani, 2017).

Though focused on social media, the field experiment by Allcott et al. (2020) provides causal evidence of online entertainment's ability to displace offline meetings. On the other hand, fast Internet helps users preserving existing relationships despite time and distance constraints, thanks to the supply of a wide range of communication tools. Case studies in applied psychology suggest that social media could also support social relationships in specific communities in the early stages of their penetration. For example, Ellison et al. (2007) and Steinfield et al. (2008) find significant associations between Facebook use and offline interactions with friends and family among groups of college students in 2006 and 2007.[27]

The differential impact of broadband penetration on bridging and bonding social capital may also relate to their different weight in users' utility functions. Online activities are unlikely to undermine the marginal utility of self-interested behaviors like meetings with family and friends, which are crucial for individual well-being (Heliwell and Huang, 2013). On the other hand, time-consuming tasks more oriented to the public good such as civic engagement are likely more vulnerable to time constraints and the competition with alternative ways of spending leisure time.

In any case, broadband access outcomes depend on the most popular ways of using fast Internet. Further research is needed to understand how the specific online activities that rely on fast Internet interact with different institutional and cultural contexts. More detailed knowledge of Internet users' online activities is necessary to understand better the mechanisms channeling the impact of broadband and social media penetration on social capital and derive reliable implications for policy and regulation.

6 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 could exploit discontinuities in Internet connection speed to test whether the availability of fast Internet displaced various forms of social capital. Our results paint a complex picture. We do not find evidence that broadband access displaced bonding social capital in the forms of meetings with friends, conversations with neighbors, and cultural activities that people usually enjoy in company. By contrast, our empirical analysis shows that fast Internet significantly crowded out time-consuming activities oriented to the pursuit of the common good, commonly referred to as bridging social capital, in the form of Putnam-type associations that pursue other-regarding, non-particularistic goals, and

[27] The *Post(1)* period in our analysis spans from 2005 to 2008. Facebook launched in 2004, and activated photo features and news feeds in 2005 and 2006, respectively. Twitter and VK launched in 2006, FriendFeed and Tumblr in 2007.

Olson-type associations mainly devoted to redistributive goals. While bonding social capital seems resilient to technological change, bridging social capital proves fragile and vulnerable to the pressure of technology-intensive entertainment on the agents' time allocation choices. This result is disturbing as it suggests that progress in ICT can undermine an essential factor of the economic activity and the well-functioning of democratic institutions (Putnam et al., 1993). However, the pattern we have detected in the case of the UK may not necessarily have general validity. Our results must be understood in connection with previous, conflicting evidence on the outcomes of broadband penetration. The behavioral and societal impact of fast Internet may vary depending on the institutional background, the initial stock of social capital, and the most popular online activities. Countries with higher endowments of bridging social capital, where people are eager to use the Internet to connect with others and engage in public affairs, may suffer less from the displacement effect we detect for the UK. These considerations also urge caution in extrapolating implications from ours and previous studies on the societal impact of broadband penetration. This body of research only assesses the outcomes of fast Internet use or availability. Further research is needed to understand the potential impact of specific ways of exploiting faster connection speeds, especially in light of the growing role of the few social media platforms that monopolize the online discourse, such as Twitter and Facebook.

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Appendix

Additional Figures

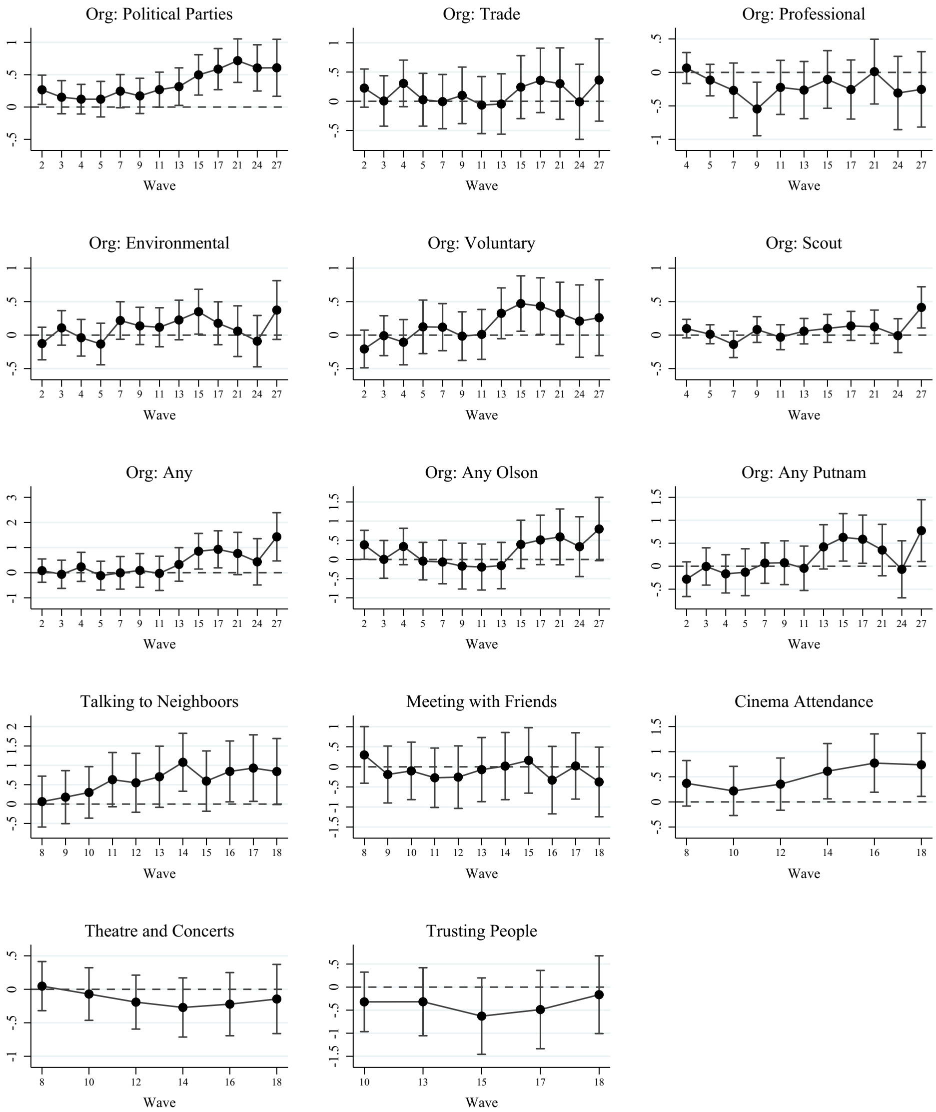

Figure A.1: Event Study Analysis. Each panel plots the coefficients and 90% confidence intervals associated with the interactions between wave dummies and the variable *Distance*, using the first available wave as baseline. Plots are presented separately for each of the dependent variables considered in the analysis. The model specification is identical to the one in equation (1) where the interaction term $Distance_{it} \times Post_t$ is substituted by a full set of interaction between wave dummies and the variable *Distance*, i.e., $\sum_t \gamma_t Distance_{it} \times Wave_t$. The set of controls is identical to the one used in the main regressions and includes time FE, individual FE, and MSOA linear trends. Standard errors are clustered at the level of the LSOA. We test the null hypothesis of joint significance for the coefficients in the *Pre-Broadband* period for participation in *Any organization*, *Olson organizations* and *Putnam organizations*, and in all cases we do not reject the null hypothesis of 0 (p-values are 0.738, 0.568, and 0.147 respectively.

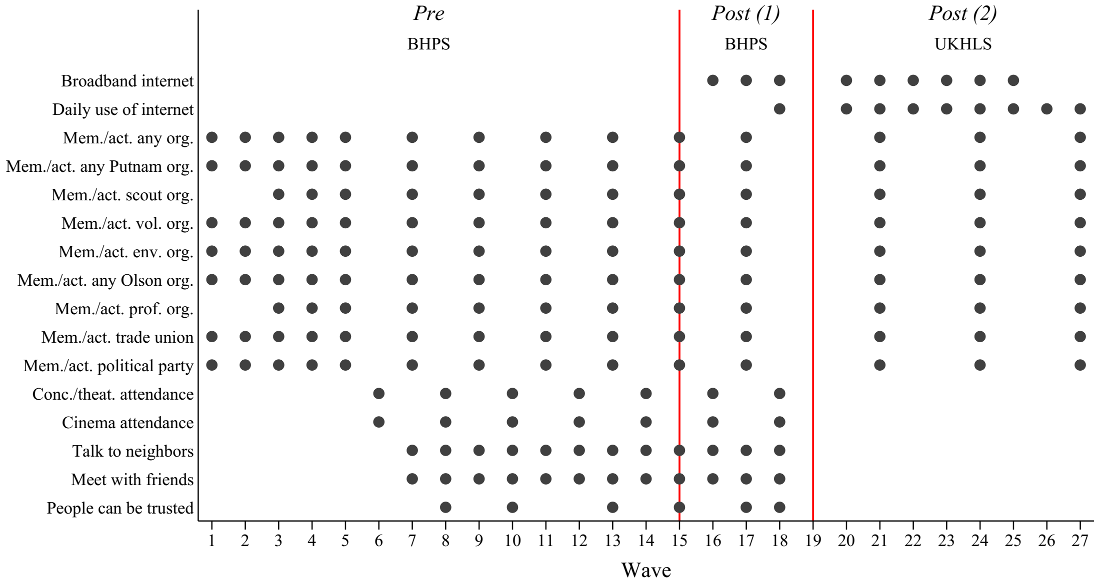

Figure A.2: Event Study Analysis

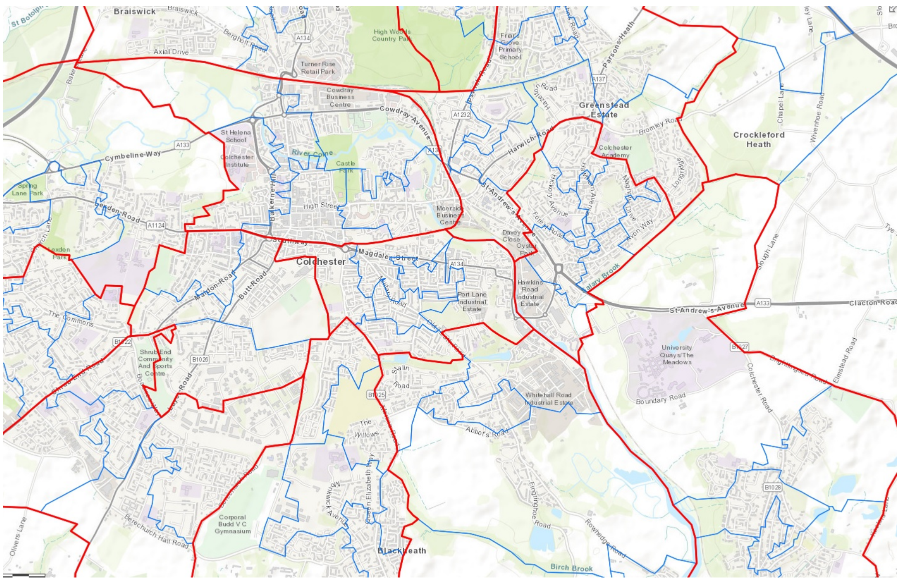

Figure A.3: LSOAs and MSOAs of Colchester. Borders of MSOAs are reported in red while boarders of LSOAs are reported in blue.

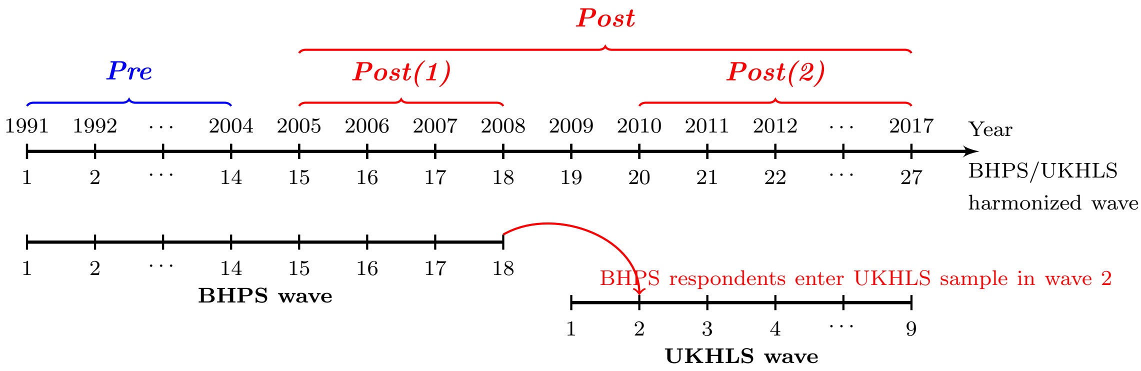

Figure A.4: Timeline

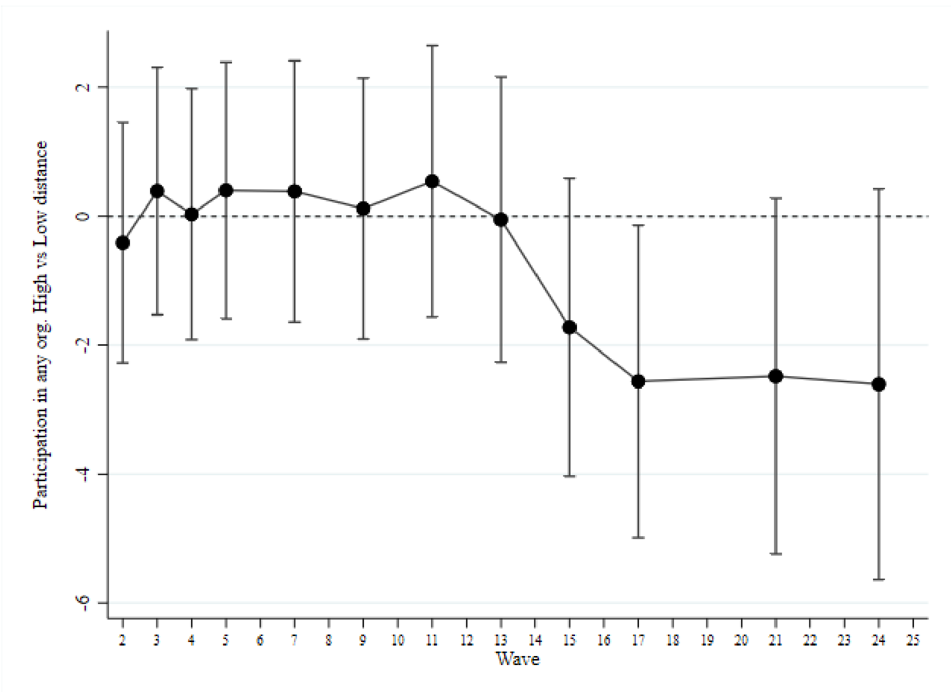

Figure A.5: Participation in *Any organization* splitting households by High and Low Distance to the LE and estimating model (3). The figure reports the estimated coefficients of the interaction between the indicator variables *Low-Distance* (which is 1 if the household's LSOA is at 3.1 kilometers or less to the respective LE) and the $Wave$. Standard errors are clustered at the LSOA level and 90% confidence intervals are reported.

Additional Tables

Table A.1: Descriptive statistics – Demographic information BHPS and UKHLS.

Variable	Mean	St.Dev.	Min	Max	Obs
Age	46.13	18.74	15.00	102.00	260403
Log of real household income	8.08	0.78	-2.35	11.75	260403
Household type:					
- Single: elderly	0.08	0.27	0.00	1.00	260403
- Single: non-elderly	0.06	0.24	0.00	1.00	260403
- 1 Adult with kids	0.01	0.09	0.00	1.00	260403
- 1 Couple: no kids	0.29	0.45	0.00	1.00	260403
- 1 Couple: with kids	0.21	0.41	0.00	1.00	260403
- 2+ Adults (no couple): no kids	0.07	0.25	0.00	1.00	260403
- 2+ Adults (no couple): with kids	0.04	0.20	0.00	1.00	260403
- 3+ Adults (at least one couple): no kids	0.14	0.35	0.00	1.00	260403
- 3+ Adults (at least one couple): with kids	0.10	0.30	0.00	1.00	260403
- Other	0.00	0.02	0.00	1.00	260403
Occupation:					
- Large employers	0.02	0.15	0.00	1.00	260403
- Higher management	0.04	0.20	0.00	1.00	260403
- Intermediate management	0.09	0.28	0.00	1.00	260403
- Lower management	0.16	0.36	0.00	1.00	260403
- Small employers and own account	0.06	0.23	0.00	1.00	260403
- Lower supervisory and technical	0.06	0.23	0.00	1.00	260403
- Semi-routine	0.09	0.28	0.00	1.00	260403
- Routine	0.07	0.25	0.00	1.00	260403
- Unemployed	0.04	0.19	0.00	1.00	260403
- Retired	0.22	0.41	0.00	1.00	260403
- Inactive	0.17	0.38	0.00	1.00	260403
Housing tenure:					
- Owned Outright	0.28	0.45	0.00	1.00	260403
- Owned with Mortgage	0.46	0.50	0.00	1.00	260403
- Local Authority rented	0.13	0.33	0.00	1.00	260403
- Housing Assoc. rented	0.05	0.21	0.00	1.00	260403
- Rented from Employer	0.01	0.09	0.00	1.00	260403
- Rented private unfurnished	0.05	0.21	0.00	1.00	260403
- Rented private furnished	0.03	0.18	0.00	1.00	260403
- Other rented	0.00	0.03	0.00	1.00	260403
Education:					
- Degree	0.14	0.34	0.00	1.00	260403
- Other higher degree	0.09	0.29	0.00	1.00	260403
- A-level etc.	0.21	0.41	0.00	1.00	260403
- GCSE etc.	0.24	0.43	0.00	1.00	260403
- Other qualification	0.10	0.30	0.00	1.00	260403
- No qualification	0.21	0.41	0.00	1.00	260403

Note: the number of observations depends on the BHPS and the UKHLS waves considered. We 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 4.

Table A.2: GER vs UK social capital

Survey question	UK	GER	UK vs GER	Variable description
Sports/outdoor activity club, last 12 months: member	0.261	0.296	$<^{***}$	0,1: 0=no, 1=yes
	(0.439)	(0.456)		
Sports/outdoor activity club, last 12 months: participated	0.211	0.192	$>^{*}$	0,1: 0=no, 1=yes
	(0.408)	(0.393)		
Sports/outdoor activity club, last 12 months: voluntary work	0.055	0.102	$<^{***}$	0,1: 0=no, 1=yes
	(0.229)	(0.302)		
Cultural /hobby activity organisation, last 12 months: member	0.165	0.156	$>$	0,1: 0=no, 1=yes
	(0.363)	(0.371)		
Cultural/hobby activity organisation, last 12 months: participated	0.159	0.134	$>^{**}$	0,1: 0=no, 1=yes
	(0.366)	(0.340)		
Cultural/hobby activity organisation, last 12 months: voluntary work	0.047	0.068	$<^{***}$	0,1: 0=no, 1=yes
	(0.213)	(0.253)		
Trade union, last 12 months: member	0.151	0.139	$>$	0,1: 0=no, 1=yes
	(0.357)	(0.346)		
Trade union, last 12 months: participated	0.025	0.034	$<^{***}$	0,1: 0=no, 1=yes
	(0.157)	(0.181)		
Trade union, last 12 months: voluntary work	0.005	0.012	$<^{***}$	0,1: 0=no, 1=yes
	(0.069)	(0.110)		
Business/profession/farmers organisation, last 12 months: member	0.127	0.079	$>^{***}$	0,1: 0=no, 1=yes
	(0.333)	(0.269)		
Business/profession/farmers organisation, last 12 months: participated	0.053	0.029	$>^{***}$	0,1: 0=no, 1=yes
	(0.224)	(0.170)		
Business/profession/farmer organisation last 12 months: voluntary work	0.014	0.013	$>$	0,1: 0=no, 1=yes
	(0.120)	(0.113)		
Humanitarian organisation etc., last 12 months: member	0.033	0.052	$<^{***}$	0,1: 0=no, 1=yes
	(0.033)	(0.223)		
Humanitarian organisation etc., last 12 months: participated	0.028	0.026	$>$	0,1: 0=no, 1=yes
	(0.165)	(0.160)		
Humanitarian organisation etc., last 12 months: voluntary work	0 .021	0.017	$>$	0,1: 0=no, 1=yes
	(0.144)	(0.128)		
Environmental/peace/animal organisation, last 12 months: member	0.059	0.056	$>$	0,1: 0=no, 1=yes
	(0.237)	(0.229)		
Environmental/peace/animal organisation, last 12 months: participated	0.031	0.032	$<$	0,1: 0=no, 1=yes
	(0.175)	(0.176)		
Environment/peace/animal organisation, last 12 months: voluntary work	0.016	0.015	$>$	0,1: 0=no, 1=yes
	(0.125)	(0.123)		
Political party, last 12 months: member	0.028	0.031	$<$	0,1: 0=no, 1=yes
	(0.172)	(0.167)		
Political party, last 12 months: participated	0.009	0.032	$<^{***}$	0,1: 0=no, 1=yes
	(0.092)	(0.178)		
Political party, last 12 months: voluntary work	0.006	0.020	$<^{***}$	0,1: 0=no, 1=yes
	(0.079)	(0.139)		
Other voluntary organisation, last 12 months: member	0.048	0.069	$<^{***}$	0,1: 0=no, 1=yes
	(0.214)	(0.253)		
Other voluntary organisation, last 12 months: participated	0.042	0.034	$>$	0,1: 0=no, 1=yes
	(0.201)	(0.182)		
Other voluntary organisation, last 12 months: voluntary work	0.042	0.018	$>^{***}$	0,1: 0=no, 1=yes
	(0.202)	(0.134)		
Important in life: politics	3.74	5.091	$<^{***}$	0-10: 0=not important at
	(2.499)	(2.473)		all - 10=extremely important
Important in life: voluntary organisations	3.594	4.002	$<^{***}$	0-10: 0=not important at
	(2.953)	(2.830)		all - 10=extremely important
Discuss politics/current affairs, how often	4.209	3.158	$>^{***}$	1-7: 1=every day, 7=never
	(2.114)	(1.817)		
To be a good citizen: how important to vote in elections	7.189	7.465	$<^{***}$	0-10: 0=not important at
	(2.790)	(2.683)		all - 10=extremely important
Good citizen: how important to be active in voluntary organisations	5.171	4.775	$<^{***}$	0-10: 0=not important at
	(2.530)	(2.667)		all - 10=extremely important
To be a good citizen: how important to be active in politics	3.438	4.200	$<^{***}$	0-10: 0=not important at
	(2.422)	(2.451)		all - 10=extremely important
Total survey sample	2,052	2,919		

Source: European Social Survey 2002- EUROSTAT. $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.10$.

Table A.3: GER vs UK internet use

Survey question	UK	GER	UK *vs* GER	Variable description
E-commerce use (last 3 months)	0.611	0.305	$>^{***}$	0,1: 0=no, 1=yes
	(0.019)	(0.017)		
E-commerce: annoyed by online advertising?	3.097	4.081	$<^{**}$	1-5: 0=does not annoy at
	(1.314)	(1.191)		all - 5=annoys me very much
Internet: important e-commerce motives	3.544	3.095	$>^{***}$	0-5: 0=not important at
	(1.344)	(1.298)		all - 5=very important
Internet: important for leisure (online games, music)	2.368	2.174	$>^{**}$	0-5: 0=not important at
	(1.413)	(1.288)		all - 5=very important
E-mail: important to keep in touch with people	3.760	3.875	$<^{***}$	0-5: 0=not important at
	(1.300)	(1.339)		all - 5=very important
Internet: important for information gathering	4.346	4.411	$<^{*}$	0-5: 0=not important at
	(0.872)	(0.864)		all - 5=very important
Internet: used for online learning (last 12 months)	0.389	0.488	$<^{***}$	0,1: 0=no, 1=yes
	(0.488)	(0.501)		
Internet: search for health-related information	0.366	0.429	$<^{**}$	0,1: 0=no, 1=yes
	(0.495)	(0.495)		
Internet: would like to use more e-gov services	0.458	0.474	$<^{**}$	0,1: 0=no, 1=yes
	(0.498)	(0.499)		
Total survey sample	1,001	1,001		

Source: eUSER 2005 - EUROSTAT/Empirica. $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.10$.

Table A.4: Distance and online activities

Dep. Variables:	Use of social media (Adults)		Online gaming (Kids 10-15)	
	(1)	(2)	(3)	(4)
Distance	-0.40***	-0.26**	-1.61**	-1.29**
	(0.14)	(0.11)	(0.74)	(0.65)
Controls		✓		✓
Time FEs	✓	✓	✓	✓
MSOA FEs	✓	✓	✓	✓
Mean of Dep.Var.	21.22	19.91	51.36	51.46
Observations	108356	102794	12406	10940
R^2	0.18	0.31	0.33	0.50
Num. PIDs	53857	51296	7771	6975

Dependent variable in (1),(2) is an indicator for the use of social media to chat and interact with friends more than one hour per day. Information on social media use for adults is available for waves 3 (2011-2012), 6 (2014-2015), and 9 (2017-2018) of Understanding Society. Dependent variable in (3),(4) is an indicator for playing multi-player online games. Information on online gaming for kids (10-15 years) is available for waves 2 (2010-2011), 4 (2012-2013), 6 (2014-2015), and 8 (2016-2017) of Understanding Society. Dependent variables are re-scaled such that 1=100. The variable *Distance* is the average distance from the LE in the respondent's LSOA, measured in Km. Controls included in (1), (2) are wave indicators, sex, age dummies, log of real annual household income, indicators for (i) occupation type, (ii) occupational status, (iii) type of housing tenure, (iv) type of household, (v) education level, (vi) month of interview. Controls in (3) and (4) include: wave indicators, sex, age dummies, log of real annual household income, indicators for (i) occupation type of the mother and the father (if present), (ii) education of the mother and the father (if present), (iii) type of housing tenure, (iv) type of household, (v) month of interview. Standard errors in parentheses are clustered at the level of the LSOA. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

Alternative identification based on rainfall

We tested also the possibility to employ the same IV strategy as in Gavazza et al. (2019). Unfortunately, this identification strategy is not suitable in the context of this study, the main reasons being: i) Noise in the response to the question on broadband access (see the discussion in Section 3.3); ii) Small sample size due to the inclusion of the question on broadband access in only 3 waves (16^{th} to 18^{th}) which overlap with the question on participation in organizations only in 1 case (17^{th} wave); iii) Small sample size in terms of households sampled. The combination of these elements weakens the IV strategy and makes it inconclusive, although the results are in line with what we find with our current identification strategy.

The first stage of the IV, i.e., the effect of rain on internet, implies to regress the self-declared broadband access status (connected with a broadband connection) on the level of rainfall. Thus, the equation we seek to estimate is:

$$Internet_{ilt} = \gamma Rain_{ilt} + \beta X_{it} + Wave_t + Area_{it} + \varepsilon_{it} \tag{5}$$

where $Internet_{ilt}$ is an indicator variable for declaring to have a broadband connection by household i living in LSOA l at time t. The regressor we are interested in is $Rain_{ilt}$ which can be computed at the LSOA level in each year and it's the amount of rainfall (in millimeters) during the previous year. As we report in Table A.5, we have estimated the model with several functions of the rainfall. Then X_{it}, $Wave_t$, and $Region_{it}$ are controls for observed household characteristics, and wave/area fixed-effects. We introduced the latter both at the level of the Local Authority District (smaller area, corresponding to counties) and at the level of the Region (much larger areas, such as West Midlands or Scotland).

For this regression, we can use all waves from the 16^{th} to 18^{th} (the first stage that makes use of only wave 17^{th} is reported later in Table A.7 which shows the 2SLS estimates). Results in columns (1) and (5) indicate a negative effect of rainfall on the probability that households declare to have internet at home, conditional on a large set of characteristics and on county (or region) fixed effects. When we introduce further powers of the rainfall we do not find support for a non-linear relationship and the estimated coefficients become all insignificant. Thus, we use the linear term of the rain as our instrument in the subsequent analysis.

The ITT of the IV is estimated as follows:

$$y_{ilt} = \gamma Rain_{ilt} + \beta X_{it} + Wave_t + Area_{it} + \varepsilon_{it} \tag{6}$$

where y_{ilt} is the outcome of interest (participation into Putnam or Olson organiza-

Table A.5: Rainfall and broadband internet access.

Dependent variable: Internet	Local authority FEs				Region FEs			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rain	-0.063*	0.025	0.115	-0.076*	-0.054**	0.066	0.247	-0.067**
	(0.035)	(0.112)	(0.284)	(0.040)	(0.021)	(0.088)	(0.279)	(0.029)
$Rain^2$		-0.036	-0.118			-0.051	-0.214	
		(0.046)	(0.268)			(0.038)	(0.250)	
$Rain^3$			0.023				0.045	
			(0.079)				(0.070)	
Rain max				0.072				0.073
				(0.105)				(0.108)
LAD FEs	Yes	Yes	Yes	Yes	No	No	No	No
Region FEs	No	No	No	No	Yes	Yes	Yes	Yes
Time FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.341	0.341	0.341	0.341	0.294	0.294	0.294	0.294
Observations	32276	32276	32276	32276	32799	32799	32799	32799

Dependent variable is an indicator for having broadband internet at home. *Rain* is the (lagged) yearly amount of rainfall in the LSOA where the household lives. *Rain max* is the rainfall of the month of the previous year that experienced the largest rainfall.The sample includes all respondents in the BHPS waves for which the relevant information was collected and available. *, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

tions, or the other measures of social capital that we consider in the paper) for the household i living in LSOA l at time t. The regressor we are interested in is $Rain_{ilt}$. Then, as before, X_{it}, $Wave_t$, and $Region_{it}$ are controls for observed household characteristics, and wave/area fixed-effects. As the question on the participation into organizations is asked only in the 17th wave, we restrict the analysis to this wave. Results are reported in Table A.6.

Table A.6: Rainfall and broadband internet access.

Dep variable: Participation in organizations	Any organization	Olson organizations	Putnam organizations	Any organization	Olson organizations	Putnam organizations
	(1)	(2)	(3)	(4)	(5)	(6)
Rain	0.051	0.047	0.023	0.031*	0.026*	0.004
	(0.039)	(0.034)	(0.031)	(0.017)	(0.016)	(0.012)
LAD FEs	Yes	Yes	Yes	No	No	No
Region FEs	No	No	No	Yes	Yes	Yes
Time FEs	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.215	0.241	0.095	0.127	0.157	0.023
Observations	10958	10958	10958	10952	10952	10952

Dependent variable is an indicator participation in Olson, Putnam or any organization. *Rain* is the (lagged) yearly amount of rainfall in the LSOA where the household lives.*, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.

The estimated coefficients are, as expected, all positive, indicating that more rainfall induces a larger participation into organizations, possibly through the reduction of the internet access. However, the coefficient is statistically significant only when we use Region FEs (although in that case it is smaller in size, suggesting a negative bias), and only at the 10% level.

Finally, Table A.7 reports the 2SLS estimates for the IV regression of the outcome (here we report the participation into organizations but we do not find any evidence also for the other outcomes that we consider in the paper) on Internet access, which we instrument using (lagged) rainfall. The table is divided in 3 panels for: i) Any organization; ii) Olson organizations; iii) Putnam organizations. Within each panel, the first pair of columns are the two stages of the IV where we employ LAD FEs while the second pair are the two stages of the IV where we use the Region FEs.

The first thing to notice is the lack of identification power coming from the first-stages (reported in the even columns) when we use only 1 wave. The coefficient of the rain is negative as expected but it is never significant, which is reflected by the very low value of the first-stage F-test. The second stages, reported in the even columns, are negative in all cases, but also never statistically significant.

Overall, we consider this exercise useful, but inconclusive. The estimated coefficients suggest that our main findings could be confirmed using the IV identification strategy of Gavazza et al. (2019), but the lack of identification power makes it not feasible.

Table A.7: Rainfall and broadband internet access.

Dep variable:	**Internet**	**Any org.**	**Internet**	**Any org.**	**Internet**	**Olson org.**	**Internet**	**Olson org.**	**Internet**	**Putnam org.**	**Internet**	**Putnam org.**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Internet		-1.159		-0.876		-1.173		-0.742		-0.206		-0.026
		(2.251)		(0.889)		(2.155)		(0.770)		(0.940)		(0.379)
Rain	-0.034		-0.033		-0.034		-0.033		-0.034		-0.033	
	(0.054)		(0.024)		(0.054)		(0.024)		(0.054)		(0.024)	
LAD FEs	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes	No	No
Region FEs	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes
Time FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.349	0.217	0.286	0.128	0.349	0.243	0.286	0.159	0.349	0.096	0.286	0.023
F-test		0.409		1.778		0.409		1.778		0.409		1.778
Observations	10834	10834	10828	10828	10834	10834	10828	10828	10834	10834	10828	10828

IV First-stages. Dependent variable in columns (1), (3), (5), (7), (9) and (11) is an indicator for having broadband internet at home. *Rain* is the (lagged) yearly amount of rainfall in the LSOA where the household lives. *IV Second-stages.* Dependent variable in columns (2), (4), (6), (8), (10) and (12) is an indicator participation in Olson, Putnam or any organization.*, **, and *** denote significance at the 10, 5, and 1 percent level, respectively.