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ABSTRACT

High Speed Internet and the Widening Gender Gap in Adolescent Mental Health: Evidence from Hospital Records*

This paper studies the impact of internet access on adolescent's mental health. Exploiting the exogenous variation in the deployment of optic fiber in different areas of Spain between 2007 and 2019, we find that high-speed internet (HSI) increased mental health diagnoses among girls. Exploring the mechanisms behind this effect, we show that HSI increases addictive internet use while reducing time spent on sleep, homework, and socializing with family and friends, with girls driving all these effects. We also provide evidence that HSI contributes to a significant increase in suicide among adolescents, with the effects again being larger among girls.

JEL Classification: J13, J16, I10, I12, I18, H31, L86
Keywords: high-speed internet, adolescents, mental health, digital media

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* This revised version has a more detailed explanation of the empirical strategy and adds an analysis of the effects of high-speed internet on adolescents' fatalities due to suicide.

I. Introduction

Recent years have seen a growing concern regarding a mental health crisis among adolescents, which is characterized by increasing rates of depression, anxiety, and suicidal ideation (Orben et al., 2022; Sohn, 2022; Twenge, 2020). The United States has witnessed a doubling in hospital admissions for suicide attempts and suicidal ideation in adolescents from 2008 to 2015, with rates of up to 500% in the case of younger girls (CDCP, 2020; Plemmons et al., 2018; Twenge et al., 2019a). In Spain, the focus of this paper, hospital discharge diagnoses for self-harm and suicide attempts by adolescents aged 15 to 19 increased fivefold for girls and quadrupled for boys between 2012 and 2019.[1] Similar trends have been reported in other countries[2], with girls experiencing greater increases than boys and rates growing faster after 2010.

Despite mounting evidence suggestive of a severe problem, little is known about its causes and how to tackle it. Understanding the roots of mental health problems in early ages is essential, given the substantial role of mental health in explaining later education and employment (Currie et al. 2010). A usual suspect in public debates is social media and teens' exposure to other content via the Internet, as increases in diagnoses of mental health problems among adolescents have been concurrent with increases in digital media use[3]. Based on this hypothesis, recently, Utah passed a law prohibiting social media services from allowing users under 18 to have accounts without the explicit consent of a parent or guardian.[4] However, causal evidence about the relationship between online

[1] Information available at: https://www.sanidad.gob.es/estadEstudios/estadisticas/cmbdhome.htm.
[2] For example, in the U.K., episodes of admission completed with a primary diagnosis of self-harm and self-intoxication increased by 42% for boys ages 11-17 and 60% for girls the same age between 2005 and 2019, with most of the increase also occurring after 2010. Information available at: https://digital.nhs.uk/.
[3] In Spain, the country on which this article focuses, the wide distribution of HBO began in 2015, Netflix also in 2015, Instagram in 2012, and TikTok in 2017.
[4] https://www.nytimes.com/2023/03/27/podcasts/the-daily/social-media-instagram-tiktok-utah-ban.html

media and adolescent's mental health is still very scarce. Initial studies coming from the fields of medicine and psychology, tend to be based on small sample sizes and while they find associations or correlations between teens' screen time and mental health problems (Orben and Przybylski, 2019; Kelly et al., 2019; Lin et al., 2016; Riehm et al., 2019), they tend to be inconclusive as to the direction of causality. One problem is that teens are just as likely to turn to the Internet to alleviate feelings of loneliness and anxiety as it is for the Internet to be the cause of these same problems. Also, Internet use is often correlated with other socio-demographic characteristics, which might be the true cause of mental health issues. Another problem arises from studies using self-reported mental health measures (e.g., Golin, 2022), as the Internet is a frequent source of information about emotional issues, which can affect a person's perception regardless of whether there is an actual effect on health or not. Finally, the few studies that have analyzed a specific platform to see its effects on mental health have focused on Facebook (Braghieri et al., 2022; Tromholt, 2016; Yuen et al., 2019), a platform rarely used by teens.

This paper addresses a crucial gap in the literature by examining the causal relationship between high-speed Internet (HSI) access and the mental health of adolescents. To achieve this, we employ a triple approach. First, we utilize hospital records to mitigate the issue of awareness bias that can arise in survey data. Second, we take advantage of exogenous variation in the deployment of optic fiber across Spanish provinces from 2007 to 2019 [5] to investigate the causal effect of HSI access on the incidence of behavioral and mental health (BMH) diagnoses among adolescents aged 15 to 19. Third, we provide additional and multiple types of evidence that converge to support our main findings (Occam's razor). We explore the mechanisms underlying the link between HSI and the surge in mental health cases among adolescents and find highly

5 A time period when mental health indicators among adolescents deteriorated greatly while new online media platforms surged to become extremely popular among teens.

consistent results. Our analysis also reveals a significant association between HSI access and suicides among teens, which cannot be easily explained by increased awareness or information about mental health issues. All these pieces of evidence, BMH cases, mechanisms and suicides point to a similar pattern due to the expansion of HSI. A salient element of that pattern is the contrast between boys and girls, more specifically a very negative impact of HIS on girls but not as much on boys.

Although Spain is a leader in the implementation of HSI through fiber[6], with more than 80% of the population covered by fiber networks in 2019, fiber use (or fiber penetration) did not increase homogeneously throughout the territory. Instead, fiber use came after the deployment of fiber infrastructure, which was the result of a strategic decision by the industry leader, Telefónica, whose presence in the different territories had more to do with historical and political factors than with socioeconomic or demographic ones. We leverage this plausibly exogenous variation in fiber infrastructure to instrument access to HSI. The use of exogenous variation in the rollout of the Internet infrastructure as an identification strategy is common in this literature (Bhuller et al. 2013; Akerman et al. 2015; Hvide et al. 2022; Falck et al. 2014; Donati et al. 2022; and Golin, 2022) although papers differ by the outcomes of interest and the source of exogeneity.[7]

We find that fiber penetration significantly increases BMH cases in adolescents aged 15 to 19. One standard deviation (SD) increase in fiber penetration increases cases

[6] For example, the report "Fiber to the Home (FTTH) in Europe - 2021" by the FTTH Council Europe, states that Spain has the highest fiber penetration rate in Europe, also noting that Spain has consistently been a leader in fiber deployment in Europe in recent years. Another example is the "Digital Economy and Society Index (DESI) 2021" report published by the European Commission. This report ranks Spain as the second-best country in the EU for connectivity, with a score of 68.4 out of 100. The report notes that Spain has made significant progress in improving its broadband infrastructure, with a high share of fiber-to-the-home subscriptions and increasing coverage of high-speed mobile broadband.

[7] Bhuller et al. (2013) study the effect of Internet on sex crime, Akerman et al. (2015) on skill complementarity, and Hvide et al. (2015) on stock market investments. In these three papers the source of exogenous variation in the rollout of broadband infrastructure comes from a public program with limited funding. Falck et al. (2014) study the effect of Internet on voting behavior. Donati et al. (2022) and Golin (2022) also analyze the effect of Internet access on youth mental health, but their source of exogenous variation is different from ours as it comes from the distance of households to older pre-existing infrastructure (also in the case of Falck et al. 2014).

of BMH by 13.3%. Girls entirely drive this effect. When we analyze older individuals (20 to 24 years old), we do not find statistically significant results. Instead, we do find negative effects of Internet exposure for younger girls (ages 10-14) but, again, no effect for boys of that age. When we look at BMH cases by condition type, we find that fiber penetration increases the incidence of anxiety, mood disorders, drug abuse, self-harm, and suicide attempts, with most effects again due to girls. We document an exceptionally large effect on cases of self-harm and suicide attempts among girls aged 15 to 19 years (+112.3%) but no significant effect for boys.

Studies in the fields of medicine and psychology have identified several channels through which Internet access can affect the mental health of adolescents, which can be broadly categorized into three groups. Firstly, a compulsive or addictive use of the Internet, such as the FOMO or 'fear-of-missing-out' effect[8] (Alt and Nissim, 2018), can displace healthier activities like socializing, exercise, and sleep, leading to a progressive isolation of the individual and negative emotional consequences (Hale and Guan, 2015; Sachs, 2017; Sachs 2018; Twenge, 2019; Twenge et al., 2019b). Secondly, adolescents may rely on online stimuli to shape their self-image and self-esteem, but they may struggle to process the overwhelming influx of information, leading to confusion, emptiness, anxiety, and depression[9], especially when exposed to platforms that promote

[8] FOMO has been defined as the feeling of apprehension that one is either not in the know or missing out on information, events, experiences, or life decisions that could make one's life better and is often associated with anxiety and compulsive use of Internet.

[9] To make matters worse, there is evidence that the age of puberty onset dropped markedly for girls, to 12 years old today from 14 years old in 1990, with similar trends for boys (see, *Puberty Starts Earlier Than It Used To. No One Knows Why*. NYT, May 19th, 2022). According to this view, when puberty hits, the brain becomes hypersensitive to social and hierarchical information, and the ability to maturely grapple with the resulting self-identity questions lags behind.

unhealthy social comparison (Braghieri et al., 2022)[10]. Finally, anonymity and the 'online disinhibition effect' (Lapidot and Barak, 2012)[11] can contribute to bullying, either from third parties or even self-inflicted, as in the recent phenomenon of 'digital self-harm' (Patchin et al., 2022).

To study these mechanisms, we use data from the biannual cross-sectional survey ESTUDES, which gathers information on the Internet usage patterns of adolescents aged between 14 and 18 years old. Our findings suggest a causal link between HSI and addictive behavior. Moreover, we found that HSI tends to displace healthier activities such as sleep, socializing with family and friends, and completing homework. Additionally, our analysis revealed that HSI is often employed as a coping mechanism to alleviate feelings of sadness and emptiness. Interestingly, our analysis showed that these effects were mainly driven by girls, with no significant effects observed in boys. Furthermore, we find that fiber expansion had a detrimental impact on the quality of relationships between parents and girls, but no effect was found for boys. Finally, and consistent with other sources (CDC, 2023), we do not find any effect of HIS on the incidence of online bullying during this period. Overall, our analysis of the mechanisms confirms our previous results regarding mental health issues, as the gender-specific mechanisms identified align with the increase in mental health cases observed in girls but not in boys.

Finally, we delved into publicly available administrative data on the causes of deaths by gender and age and provide suggestive evidence that HSI is a contributing factor to a significant increase in deaths related to suicide or self-harm among adolescents. The effects are, again, more prominent among girls. This finding further strengthens the

[10] For example, a recent correlational study found that teen suicide in the United States spiked 28.9% in the month after the debut of Netflix's '13 Reasons Why' (Bridge, et al., 2020).
[11] The online disinhibition effect relates to the increase in incivility and aggressive behavior in online environments due to anonymity.

overall consistency of our results and challenges criticisms that the rise in diagnoses is solely a consequence of increased awareness and information dissemination on these mental health issues.

This paper makes several contributions to the existing literature. First, we are the first to investigate the impact of HSI access on adolescent mental health using hospital records in the post-2010 era, a period marked by a decline in adolescent mental health and a surge in the popularity of online media platforms. Second, we provide insights into the debate around whether HSI worsens mental health in adolescents due to crowding-out effects or other factors such as reliance on the internet to cope with feeling low or online bullying. We find that the first two channels are supported by our results, while we find no evidence of online bullying. Third, we are the first to demonstrate the negative impact of HSI on the quality of the parent-teen relationship. Finally, our findings support prior research indicating that girls are more susceptible to the negative consequences of online media exposure than boys.

Our study adds to the small but growing body of economics literature that has established causal links between access to online media and youth mental health. Our findings complement and are consistent with Braghieri et al. (2022), who found that the gradual introduction of Facebook in US universities worsened the mental health of college students due to unfavorable social comparisons. Similarly, Nieto and Suhrcke (2021) found that access to digital television in the UK led to unhealthy habits and ultimately worsened children's mental health. Our results also align with those of Braghieri et al. (2022), Golin (2022)[12], and McDool et al. (2020)[13], who have documented

[12] Golin (2022) uses self-reported measures of wellbeing and mental health from the German Socio Economic Panel (SOEP) and finds that broadband Internet leads to worse mental health for women (primarily those aged 17–30) but not for men, thus widening the gender gap in mental disorders.

[13] They find that internet use is negatively associated with wellbeing across a number of domains for children aged 10 to 14 in England. The strongest effect is for how children feel about their appearance, and the effects are worse for girls than boys.

a more negative effect of broadband internet on girls than boys. Our study, which focuses on a later period characterized by the emergence of new and popular media and content platforms among teens such as Instagram, Tik-Tok, Netflix, and HBO, complements the work of Donati et al. (2022), who found a negative effect of broadband internet (ADSL) on youth mental health in Italy between 2001 and 2013. Additionally, our study sheds light on the marginal effects of an increase in internet quality and speed, as our data covers a period where ADSL preceded fiber. Given that new popular apps, social media, and video streaming platforms rely heavily on excellent bandwidth, it is not surprising that we find large negative effects on girls' mental health, who are more sensitive than boys to social interactions, especially during adolescence (LaFontana and Cillessen, 2010; Flook, 2011; Shih, 2006).

The rest of the paper is organized as follows. Section II describes the fiber rollout in Spain and its links with teens' exposure to online media. Section III presents the empirical methodology and the main results. Section IV discusses some potential mechanisms, and section V concludes.

II. Fiber penetration in Spain and teen's exposure to online media

In this section we discuss the importance of FTTH to provide the necessary infrastructure for the development of many of the media platforms that are so popular among teens. We also discuss the rollout of FTTH in Spain and how FTTH has enhanced the role of smartphones as teens' preferred technology to access online media.

2.1 FTTH and online media

As online media platforms advanced beyond the early 2010s, they required higher bandwidths, highlighting the limitations of older xDSL technologies in providing faster download speeds. In 2013, the U.S. National Telecommunications and Information Administration[14] emphasized the significance of upgrading to high-speed broadband networks, stating that "*as more Americans rely on the internet for streaming video, downloading music, and other bandwidth-intensive applications, the limitations of older, slower broadband technologies become increasingly clear*." Among these high-speed broadband networks, FTTH promised download speeds from 100 Mbps up to 10 Gbps or more, which is 20 to 100 times faster than typical cable modem or xDSL connections. Additionally, FTTH networks offered greater symmetry in data upload and download speeds, making it highly valuable for popular social media apps and content platforms, where users exchange video and audio content.

Therefore, it's not surprising that many popular teen apps and content platforms emerged around the same time as service providers invested in upgrading their networks to FTTH, ensuring they could deliver the necessary bandwidth to support the evolving needs of consumers. Figures 1 and 2 illustrate this for Spain. With the exception of YouTube, all other apps and online media platforms popular among teens were launched or gained popularity coinciding with increased FTTH penetration. Put differently, and as noted by many, without the bandwidth provided by FTTH many of the newly popular apps and media platforms would not have been possible (FCC, 2016; FTTH Council Americas, 2017; NBC, 2010).

[14] The National Telecommunications and Information Administration (NTIA), located within the U.S. Department of Commerce, is the Executive Branch agency that is principally responsible by law for advising the President on telecommunications and information policy issues.

2.2 FTTH rollout in Spain

Spain thrived amidst the ongoing technological revolution, particularly in regards to the deployment of FTTH infrastructure. According to a report by the FTTH Council Europe, Spain is the leading country in Europe in terms of FTTH (Fiber To The Home) coverage. As of September 2021, Spain had an FTTH coverage rate of 80.6%, far ahead of the European average of 44.9%.[15] In another report by the Organization for Economic Cooperation and Development (OECD), Spain was ranked first in the world in terms of fiber connectivity. The report noted that Spain has the highest fiber-to-the-premises (FTTP) penetration rate among OECD countries, with 63.8% of fixed broadband subscriptions being FTTP as of June 2020.[16]

To get a sense of the rapid pace of change in fiber deployment in Spain, panel (a) of Figure 2 shows that in only twelve years, between 2007 and 2019, the number of installed (not necessarily in use) fiber lines in Spain increased from nearly zero to an average of 121 lines per 100 inhabitants. Interestingly, and crucial for our identification strategy, these increases in fiber deployment were not evenly distributed among provinces, with Málaga recording 156 lines per hundred inhabitants in 2019, compared to Lugo's 62. These differences cannot be entirely explained by socioeconomic factors, including GDP per capita and population density, as evidenced by provinces with comparable baseline characteristics having different trajectories in fiber deployment and varying levels of fiber coverage (panel b in Figure 2). In contrast, some provinces with vastly different baseline characteristics achieved similar levels of fiber coverage in 2019 (panel c), while others followed similar paths in fiber deployment despite significant differences in baseline characteristics (panel d).

[15] https://www.ftthcouncil.eu/documents/Press-Releases/2021/FTTH-Council-Europe-releases-2021-European-FTTH-Market-panorama
[16] https://www.oecd.org/spain/Spain-telecommunication-market-overview.pdf

The reasons why the deployment of fiber optics has been so uneven between provinces can range from government subsidies and regulatory issues to the average age of buildings[17] or the need to compete strategically in the *premium* content market (García-Menéndez, 2016).

2.2.1 Government subsidies

Spain has been offering subsidies for the deployment of FTTH networks in low population density areas since 2013. The Spanish government's first program to promote the deployment of FTTH networks in rural areas was launched in 2013, and it offered subsidies of up to 80% of the deployment costs. The program was known as PEBA or Plan for the Extension of Broadband and aimed to provide high-speed broadband access to all households in the country, with a particular focus on rural and remote areas. Since then, the Spanish government continued to offer subsidies and incentives to ISPs for the deployment of FTTH networks in low-density areas, with the latest program being launched in 2019 to provide €150 million in subsidies to ISPs for the deployment of high-speed broadband networks in rural areas.

However, the implementation of the PEBA program was not homogeneous across Spanish provinces since it was subject to political and other factors, such as budget constraints, bureaucratic processes, and competing interests from different stakeholders. Some regions faced delays or obstacles in accessing the subsidies, while others were able to deploy the infrastructure more quickly and smoothly. A report by the Spanish National

[17] To install FTTH in older buildings, providers may need to undertake structural work to make the necessary changes to the building's infrastructure. This can include drilling holes through walls and floors, running cables along exterior walls, or installing cable ducts where none existed before. These modifications can be time-consuming and expensive, adding to the overall cost of deploying fiber-optic networks.

Commission on Markets and Competition (CNMC) in 2016[18] noted that the implementation of the PEBA program faced delays and difficulties due to bureaucratic processes, budget constraints, and lack of coordination between the different government agencies involved. The report also noted that some regions had not been able to access the subsidies due to administrative issues. Similarly, a report by the European Court of Auditors in 2018[19] found that the implementation of broadband programs in Spain, including the PEBA program, had faced delays and had not achieved their full potential due to inadequate planning, monitoring, and evaluation mechanisms, as well as budgetary and regulatory constraints which varied across regions.

2.2.2. Strategic competition

Regarding the strategic competition, by 2010, the view of most telecommunication operators was that future competitive advantages would largely depend on the position in the *premium* content market. Given that this market is subject to significant economies of scale, telecommunications operators saw the need to build a broad customer base. Fiber networks, as opposed to the local loop of copper that was inherited and represents a sunk cost for operators, require new and significant levels of investment to be deployed. It's been estimated that operators have invested in Spain a total of 8 billion euros in the deployment of fiber networks, with civil engineering works

[18] National Commission on Markets and Competition (CNMC) report, "Informe sobre el desarrollo de la banda ancha en España 2015," 2016. Available in Spanish on the CNMC website: https://www.cnmc.es/sites/default/files/814520-fichero/Informe%20Banda%20Ancha%202015%20-%20CNMC.pdf

[19] European Court of Auditors report, "EU broadband investment in Spain: better infrastructure but incomplete digital single market," 2018. Accesible at: https://www.eca.europa.eu/en/Pages/DocItem.aspx?did=46303

accounting for up to 75% of FTTH CapEx spending.[20] Telefónica (or Movistar, its branding name), being the industry leader in Spain and the operator with the largest customer base, had the incentives and the financial muscle to lead this investment process. Successful fiber rollout models have been driven by incumbents in other countries as well.[21] In addition, the Spanish regulator kept fiber networks closed to access by competitors in order to encourage investment efforts. Competitors could use Telefónica's old physical infrastructure to offer their services, but not so with the fiber networks that were excluded from the regulatory framework called MARCo until 2015. [22] It is in this context that Telefónica's strategy is clear: to reach the most far and as quickly as possible with the FTTH footprint, leaving the commercial effort for customers to switch to fiber for the future. This resulted in a large excess capacity whereby the percentage of lines in use did not exceed 10% of the total lines installed during much of the initial period.[23] Not surprisingly, the rush to develop this infrastructure was greater in those provinces where Telefónica faced greater competition in older xDSL technologies, which depended on factors such as the presence of newer operators (Vodafone, Orange, etc.) or operators with historical ties to certain northern regions.[24] Thus, Telefónica's ADSL market share in 2007 varied greatly between provinces, ranging from a minimum of 36% in Albacete to a maximum of 80% in Teruel. Note that these are two Spanish provinces that are quite similar in terms of GDP per capita and population density,[25] and yet Telefónica's presence

[20] https://think.ing.com/articles/fibre-rollout-the-hardest-part-is-yet-to-come
[21] https://www.adlittle.com/sites/default/files/viewpoints/ADL_RacetoGigabitFiber.pdf
[22] MARCo stands for Wholesale Access to Registers and Conduits Offer.
[23] Source: http://data.cnmc.es/datagraph/jsp/inf_anual.jsp
[24] This pattern has been seen in other countries as well: https://www.adlittle.com/sites/default/files/viewpoints/ADL_RacetoGigabitFiber.pdf
[25] In 2007 Albacete had a GDP per capita of 17,910€ compared to 25,005€ in Teruel. Albacete's population density in 2007 was 26 inhabitants per 100 sq km, compared to 10 in Teruel. By means of comparison, Madrid's GDP per capita that same year was 31,887€ and its population density was 756 inhabitants per sq km.

in each of them was radically different. Interestingly, the increase in FTTH lines per 100 inhabitants made by Telefónica between 2007 and 2014 was 10 times greater in Albacete (16 lines) than in Teruel (1.63 lines), in line with the idea that the operators, led by Telefónica, used the deployment of fiber as a competitive strategy, especially in those provinces with neck-to-neck competition.

This competitive strategy was intensified in 2015 when the regulatory framework, MARCo, was modified, forcing Telefónica to offer competitors equal access to its infrastructure but only in those geographic areas identified by the Spanish regulator as 'low competition' areas, that is, areas in which Telefónica had a relatively high market share.[26] This did nothing more than amplify the differential in the incentives on the part of Telefónica to invest in the 'competitive' areas versus the other areas, since from that moment on, the greater need to compete in the 'competitive' areas was combined with the greater relative protection granted to the investment made there.

In summary, the deployment of fiber networks in Spain has been uneven due to a combination of regulatory, non-regulatory factors, and competitive strategies. As a result, the penetration rates have varied greatly across provinces over the years. In the next section, we will show that the timing of fiber deployment is orthogonal to province baseline characteristics that might be correlated with adolescent mental health. Additionally, we will provide evidence that the level of competition in broadband services significantly influenced the timing of fiber expansion in each province. This plausibly

[26] According to the CNMC (Spanish National Commission for Markets and Competition), these 'low competition' areas represented 42% of the broadband market and Telefónica's market share climbed up to 64%, compared to the rest of areas where Telefónica's market share was significantly lower (34%). (https://blog.cnmc.es/2015/01/14/la-competencia-en-banda-ancha-segmentacion-geografica/)

exogenous variation in fiber deployment provides an opportunity to explore the causal impact of high-speed internet on adolescent mental health.

2.3 FTTH and teen's exposure to online media via smartphones

According to a 2018 Pew Research Center report[27], 95% of teenagers in the United States had a smartphone and saw it as the preferred technology to access the internet, reflecting a similar trend observed in Spain with comparable smartphone penetration rates.[28] Given this strong preference for the smartphone to access the internet, it's worth discussing the impact of fiber optic penetration on teenagers' exposure to online media via smartphones.

Fiber optics have greatly enhanced the role of smartphones as a means of internet access for adolescents, for several reasons. Firstly, in terms of location, research indicates that 89% of teenagers use their phones mainly at home, with only 37% using them while out. This suggests that fiber optic, which is typically deployed in residential areas, is most relevant for improving home-based smartphone usage.

Secondly, fiber optics are significant for content consumption. Teenagers increasingly use smartphones for streaming videos, playing online games, and accessing social media platforms to exchange videos and photos (see, Appendix table A5 for apps popular among teens by launch year). Popular apps and video streaming platforms require excellent bandwidth for downloading and uploading data-intensive content. Research indicates that teens are more likely to use social media, entertainment apps, and streaming

[27] "Teens, Social Media & Technology 2018" and was published on May 31, 2018. https://www.pewresearch.org/internet/2018/05/31/teens-social-media-technology-2018/

[28] "Panel de Hogares CNMC: Banda Ancha Fija, Móvil y Redes Sociales. Tercer Trimestre 2019": https://www.cnmc.es/sites/default/files/864347-03%20Pan%20hogares%203T19%20Banda%20ancha%20fija%20m%C3%B3vil%20y%20redes%20sociales.pdf

platforms when they are at home with good connectivity, and for less bandwidth-intensive purposes when they are outside.[29]

Thirdly, fiber optic has implications for privacy. The same Pew report revealed that 62% of parents of teenagers aged 13-17 reported their child spends time online alone every day, with only 8% indicating their child was online with a parent or caregiver. Another study by Common Sense Media[30] showed that 60% of teens were the sole users of their smartphones, indicating they often use the internet without adult supervision. Additionally, this study found a low use of adult supervision apps, and a large decrease in the time both tweens and teens spend watching TV on a television set. This suggests that fiber optic deployment enables access to online media in privacy, allowing several members of a household to download or upload content simultaneously and in isolation from each other.

In conclusion, fiber optic connectivity enables adolescents and other members of a household to consume large amounts of online content through their smartphones, in an environment of absolute privacy, and at any time. With fiber optic, smartphones become a powerful tool in teenagers' hands, amplifying the effects of the internet on their mental health.

III. Empirical Methodology and Results

3.1 Hospital diagnoses of behavior and mental health problems

To measure the prevalence of mental health problems among adolescents we use publicly available administrative data from Spanish public and private hospital discharge

[29] Liu, S., & Tsai, W. (2018). Differences in mobile phone use in outdoor and indoor contexts among adolescents in Taiwan: A mixed-methods study. Journal of Adolescent Health, 63(6), 723-729. doi: 10.1016/j.jadohealth.2018.08.016

[30] Rideout, V., & Robb, M. B. (2018). The Common Sense census: Media use by teens and tweens. Common Sense Media.

diagnoses of behavioral and mental health cases (BMH). We used all diagnoses (primary and secondary) to avoid the effects of shifts between these two categories due to increased awareness among healthcare professionals of adolescent mental health problems. They include nutrition disorders, anxiety, ADHD[31], mood disorders, personality disorders, schizophrenia, alcohol abuse, drugs abuse and, self-harm and suicide attempts.[32] [33] To measure fiber penetration, we use administrative data from the National Commission of Markets and Competition at province level. Our data comes at the province level and covers the period 2007 to 2019.

As a starting point, we explore the raw data to check the existence of patterns or relationships between our outcomes of interest and fiber penetration. Figure 3 displays on the left vertical axis the incidence of behavior and mental health cases (BMH) among boys and girls aged 15 to 19 years against fiber penetration, which is shown on the right vertical axis. The incidence of BMH cases is defined as the number of hospital diagnoses of BMH divided by one hundred inhabitants. Fiber penetration is the number of fiber lines in use per inhabitant. The three series remain stable until 2013, the year after which they grow with similar intensity, although BMH cases grow slightly more among girls than in boys.

The patterns shown in Figure 3 are only illustrative or suggestive of a relationship between fiber penetration and BMH cases among adolescents. Obviously, they could be explained by underlying trends correlated with our outcomes of interest and with fiber

[31] ADHD stands for attention deficit hyperactivity disorder.

[32] We choose chapter 5 of the International Classification of Diseases (ICD-10) and add self-harm and suicide attempt.

[33] Data on health outcomes are available here: https://pestadistico.inteligenciadegestion.sanidad.gob.es/publicoSNS/C/rae-cmbd/serie-historica/diagnosticos-hospitalizacion-incluye-sector-privado/diagnosticos-todos-incluye-sector-privado, and data on fiber penetration are available here: http://data.cnmc.es/datagraph/

penetration. To try to correct this, Figure 4 shows the results of removing province and year fixed effects from our raw data in the context of the following specification:

$$Y_{pt} = \propto_p + \tau_t + \varepsilon_{pt} \quad (1)$$

Where Y_{pt} is our outcome of interest, $\propto_p$ are province fixed effects and τ_t are year fixed effects. Panel a displays the residuals of separate regressions of equation (1) using fiber penetration and BMH cases as the dependent variables. We can see a substantial variation across provinces in the paste at which fiber penetration and mental health changed, something that later we will exploit as our source of identification. Also, and more importantly, there is a positive relationship between fiber penetration and mental health of adolescents: the provinces that compared to the general trend had a higher growth in fiber penetration also experienced a higher growth in BMH cases among adolescents aged 15 to 19 years. This pattern is confirmed in panel b of the same figure, which shows the coefficient estimates, β_i, of a regression of BMH cases, BMH_{pt}, against a set of dummy variables capturing five different levels of fiber penetration, $FiberP_{pt}^{i}$, and after controlling for year and province fixed effects (equation 2). Increasing fiber penetration has a positive and significant effect on the incidence of BMH cases among adolescents, with the maximum level of fiber penetration (>0.30) increasing BMH cases by 0.232 percentage points (35% of the sample average – 0.65).

$$BMH_{pt} = \sum_{i=1}^{5} FiberP_{pt}^{i}\beta_i + \propto_p + \tau_t + \varepsilon_{pt} \quad (2)$$

Despite the addition of province and year fixed effects, an OLS estimate of β_i will be biased if province-specific time-varying omitted variables are correlated with both mental health and fiber use. To address this concern, we propose that a source of exogenous variation in fiber use comes from the gradual expansion of fiber infrastructure over the period 2007-2019. More specifically, our main analysis is based on two-stage least-squares (2SLS) estimation of β with equation (3) as the "second stage":

$$BMH_{pt} = FiberP_{pt}\beta + X'\gamma + Z'\theta + \propto_p + \tau_t + \varepsilon_{pt} \quad (3)$$

and equation (4) as the "first-stage":

$$FiberP_{pt} = FiberI_{pt-1}\mu + X'\gamma + Z'\theta + \propto_p + \tau_t + \sigma_{pt} \quad (4)$$

$FiberI_{pt}$ in equation (4) is the number of lines of optic fiber installed (not necessarily in use) in province p and time t-1 and measures the deployment of fiber infrastructure. Note that equation (3) expands equation (2) by adding two new sets of controls: $X' \; and \; Z'$. X' includes time-varying, i.e., contemporaneous, controls for the level of GDP, GDP per capita, population, population density and the total number of hospital diagnoses for the entire population of each province and year (expressed as hospital cases per one hundred inhabitants). This last variable allows us to capture all factors that affect the general health of the population as well as factors that might influence the access to health services in a given province and year. Additionally, Z' includes the interaction of year dummies with the same covariates as in X' evaluated at their baseline level, that is in 2007. This allows us to control not only for time-invariant province characteristics but also for differential trends related to key demographics. Hence, our identification strategy requires that – once we account for those demographic related trends – the correlation between fiber infrastructure and adolescents' mental health did not change other than through the use of fiber-optic internet.

Although the exogeneity assumption of our instrument cannot be evaluated empirically, we can provide suggestive evidence in support of that assumption. One concern with our instrument is that provinces with different fiber infrastructure shocks could be also different in terms of their baseline characteristics and outcomes before the

shocks.[34] One way to assess this concern is to estimate the following specification separately for each calendar year of the deployment of fiber-optic:

$$\Delta FiberI_{pt} = S'_{p,2007}\beta + \varepsilon_{pt} \quad (5)$$

where, $\Delta FiberI_{pt} = FiberI_{pt} - FiberI_{pt-1}$, and $S'_{p,2007}$ is a vector that includes the same characteristics as Z' (GDP, GDP per capita, population, population density, GDP per capita * population density) and the incidence of BMH cases among adolescents, all measured in the initial year 2007. Note that this is the same diagnostic test as the one used in Bhuller et al. (2013), Akerman et al. (2015) and Hvide et al. (2022). Figure 5 plots the estimated coefficients from the vector β for every year, with associated 95% confidence intervals. Importantly, we find no general correlation between changes in the instrument and baseline levels of key demographics including the baseline level of adolescent mental health. Put differently, neither the level nor the timing of the roll-out of optic fiber seem to be correlated with our key demographics. In those few instances in which the estimated coefficients are statistically significant, there is no clear or consistent pattern of a relationship between the deployment of optic fiber and a given demographic. Recall also, that any residual correlation between our instrument and baseline levels of key demographics will be captured by the inclusion of Z' in our regressions. Interestingly, panel g of Figure 5 shows a clear pattern between the roll-out of optic fiber and the market share of the leader, Movistar, in 2007. Those provinces in which Movistar enjoyed a bigger xDSL market share in 2007 had a later expansion of fiber infrastructure, that is, the growth of installed lines was significantly lower in the initial years, between 2014 and 2017, to then catch-up in 2018 and 2019. Also relevant for our analysis, the market share

[34] In reality, because our specifications include different trends related to key demographics, the exogeneity assumption is that the instrument is exogenous conditional on those controls.

of Movistar in 2007 seems to be orthogonal to the key demographics of our model (panel h).

3.1.1. Results from the IV specification

Columns (2) to (6) in Table 1 report IV estimates of β from equation (3). Moving from one column to the next shows the impact of adding controls progressively. For the sake of comparability, we also show the results of OLS regressions (in column 1) and of IV estimates for young individuals aged 20 to 24 (columns 7 to 9). The OLS fixed-effects estimate (column 1) shows a positive and significant impact of fiber penetration on BMH cases of adolescents aged 15 to 19. A one standard deviation (SD) increase of fiber penetration raises BMH cases by 13.3%. Moving from the OLS to the IV estimate in column (2) leads to a bigger and statistically significant impact. The coefficient grows from 1.295 to 1.822, and the economic effect of one SD increase of fiber penetration, from 13.3% to 18.8%. Adding contemporaneous controls (X') decreases the coefficient, but adding trends interacted with baseline levels of the covariates (Z') increases it. At the end, moving from the unadjusted estimate of column (2) to the fully adjusted estimate of column (4) results in a larger coefficient, with the economic impact increasing from 13.3% to 24.5%, statistically significant at the 10% level. Columns (5) and (6) report the IV estimates by gender and show that the positive effect of fiber penetration on BMH cases is driven by girls. The estimated coefficient for males is 1.199, not statistically significant, whereas the estimated coefficient for females is 3.631, significant at the 5% level, and with an economic impact of 35.3%. These results are consistent with the patterns shown in Figure 2 displaying a stronger correlation between fiber penetration and BMH cases among girls than boys. Finally, columns (7) to (9) show the IV fully adjusted estimates for young individuals aged 20 to 24 (column 7) and for boys (column

8) and girls (column 9) of the same age, separately. All three estimated coefficients are statistically insignificant and of a much smaller magnitude than the ones found for adolescents. Similarly insignificant effects for individuals 20 to 24 years of age across different types of BMH cases are shown in appendix table A.1. Overall, Table 1 indicates that optic fiber penetration worsens the mental health of adolescent girls and has smaller and insignificant effects for adolescent boys and individuals of an older age.

We turn now to the results of Table 2 which shows the impact of fiber penetration on adolescents' BMH by type of medical condition. The table shows the IV estimates for cases of: nutrition disorders, anxiety, ADHD, mood disorders, personality disorders, schizophrenia, alcohol abuse, Drugs abuse and, self-harm and suicide attempts. We present results for all individuals in Panel (a), for boys in Panel (b) and for girls in Panel (c). A first thing to note from Table 2 is the pervasiveness of positive coefficients (negative health effects of fiber penetration) across the nine dimensions, except for nutrition disorders. Being quite rare events and given the small number of observations it is not surprising that standard errors are often high and some of the coefficients are not statistically significant despite their large magnitudes. Focusing on the statistically significant effects, fiber penetration increases the incidence of cases of anxiety (column 2), mood disorder (column 4), drugs abuse (column 8) and self-harm and suicide attempts (column 9). The economic effects of a one SD increase of fiber penetration are large, ranging from 52.4% in the case of mood disorders to 81.5% in the case of self-harm and suicide attempts. A third clear pattern from Table 2 is that those significant effects are driven by girls and not by boys. This is true for all medical conditions with significant effects except for mood disorders, where the coefficient and the economic effect for girls are bigger than those of boys but not statistically significant. The case of self-harm and suicide attempts is quite striking with an exceptionally large positive and significant effect

for girls (+112.3%) but no significant effect for boys. Overall, Table 2 portrays a picture that again is consistent with the patterns observed in Figure 2. Interestingly, appendix table A.2 shows a quite similar pattern for boys and girls aged 10-14 years. In that table, fiber penetration is shown to increase the incidence of drugs abuse cases and self-harm and suicide attempts cases among girls aged 10-14 years but not among boys. As already mentioned, appendix table A.1 shows no significant effects for individuals aged 20-24 years.

3.1.2. Placebo and robustness tests

Table 3 shows the results of two placebo tests. In panel (a) we show the results of estimating the impact of fiber penetration on the mental health of adolescents during the period prior to 2013, when fiber penetration increased very modestly from 0.03 to 0.04 lines per inhabitant. The first stage estimate of the coefficient on installed fiber infrastructure is statistically significant and with the correct sign, but the IV estimates of the effects of fiber penetration (step 2) are all statistically insignificant and only positive (but of a much smaller magnitude) in the case of girls. In panel (b) we show the results of estimating our preferred specification but in which the variable to be instrumented is xDSL penetration instead of fiber penetration. We perform this analysis for the period between 2007 and 2012 because during that period the xDSL penetration was growing and, that technology was still not being substituted by optic fiber. One concern is that our IV (fiber infrastructure at t-1) could be spuriously correlated with another technology (e.g., xDSL) and this be the cause of the evolution of BMH cases. Reassuringly, our first stage parameter estimates are not statistically significant, and the second stage coefficients are also statistically insignificant. Overall, the results of both panel (a) and

(b) of Table 4 indicate that our results are not picking up the effect of xDSL on the mental health of adolescents.

Table 4 shows the results of various sensitivity tests. We focus on the main results, that is, the aggregate effects for the entire population, for boys and for girls, separately, and for the three types of BMH cases with significant effects (anxiety, drugs abuse and self-harm and suicide attempts). Panel (a) shows the results of our preferred specification to facilitate comparison with the rest of the results. In panel (b) we estimate our preferred specification removing the contemporaneous population and population density controls. This is to rule out that these controls are absorbing the effect of fiber penetration on BMH cases due to changes in the population of a province caused by the expansion of fiber infrastructure. If the improvement of fiber optic networks in a province attracted more population and if more population had effects on the mental health of its inhabitants, the inclusion of population controls in our regression would not allow our variable of interest to capture this effect. As can be seen in panel (b) of Table 5, excluding population controls from our specification has little or no effect in our estimated results.

In panel (c) we estimate the effects of fiber penetration on BMH cases, evaluated at the extensive margin. We estimate linear probability models using the same IV technique as before but where the dependent variable is a dummy variable which takes value 1 if that province-year had a positive number of cases of a given medical condition. We do not report the estimated effects for all BMH cases (columns 1 to 3) because the lack of variability in the dependent variable, which takes value 1 across all provinces and years. The results of this exercise should be taken with caution given the reduced number of zeroes of the dependent variable in some cases (for example, only 5% of province-year observations had no drugs abuse cases among males). The effect of fiber penetration on anxiety cases and self-harm and suicide attempts cases among girls continues to be

positive and statistically significant, not so for drugs abuse cases, with a negative and statistically insignificant coefficient.

We move now to panel (d), where we show the results of estimating our main specification using only the years from 2012 to 2019. We perform this test to rule out that our estimates are capturing the effect of xDLS expansion, rather than fiber optics, on adolescent mental health. By excluding the years 2007-2011 from our sample, we exclude a time period in which xDSL was still being expanded contrary to fiber optics, which remained close to nonexistent in most provinces. Note that the exclusion of 2007-2011 reduces the efficiency of our estimates, by eliminating more than 40% of our sample. Therefore, it's not surprising to see an overall increase of standard errors in panel (d). Despite this, most estimates remain close to their previous values and statistically significant, with the exception of the coefficient of all BMH cases and all genres (2.405 in column 1), which has a very similar value than before but is not statistically significant. Panel (e) reports the p-values of the estimated coefficients after implementing the Romano-Wolf (2016) step-down multiple hypothesis correction method of the standard errors on each of the nine outcomes (the nine medical conditions displayed in Table 2). Intuitively, the multiple hypothesis correction methods adjust p-values for the fact that the number of false positives (type-1 error) increases with the number of tests performed. Typically, these methods result in considerable increases of the p-values. The estimated effect of fiber penetration on drugs abuse cases and on self-harm and suicide attempts cases among girls continues to be statistically significant, not so the coefficient on anxiety cases.

Finally, Appendix table A.3 replicates the estimates of Table 1 but excluding from our measure of BMH the cases of self-harm and suicide attempts. We perform this final robustness test for two reasons. One, to be consistent with the international classification

system ICD-10, which excludes self-harm and suicide attempts from mental health cases, included in chapter 5. Second, to check to what extent our BMH aggregate effects are driven by self-harm and suicide attempts, the type of behavioral disorder that shows the strongest effects. Overall, Table A.3 shows a similar pattern than Table 1: fiber penetration increases the incidence of BMH cases among adolescents aged 15-19 years, a result that is driven by girls of that age group.

3.2 Deaths due to suicide or intentional self-inflicted harm

This section delves into the connection between HSI and adolescent deaths caused by suicide or intentional self-harm. Data comes from administrative records stating the cause of each death in each province and year and is publicly available at the Spanish national Statistics web page (www.ine.es). Based on our earlier findings, one would anticipate a significant rise in the number of deaths among girls compared to boys resulting from suicide or self-inflicted harm. While this relationship is not necessarily inevitable, such as when timely medical attention prevents a fatal outcome, proof of an increase in deaths linked to the behavioral and mental health issues outlined above would help confirm our prior findings and dispel any doubts that these results are simply due to heightened awareness of mental health problems among adolescents.

The results of this analysis should be approached with caution due to the rarity of this type of event and the use of data at the year-province level, separated by gender.[35] Nonetheless, our findings suggest a causal relationship between HSI and teen deaths resulting from suicide and self-harm. Figure 6 provides descriptive evidence of the trend in the number of deaths due to suicide or self-inflicted injuries, segregated by gender,

[35] In 68.9% of the province-year observations no boy or girl aged 15 to 19 years old committed suicide or died due to self-inflicted harm.

from 1980 to 2019. Boys' data is displayed on the left vertical axis, and girls' data is displayed on the right vertical axis. The data for boys and girls show a clear pattern, oscillating in tandem with the Spanish business cycle. However, this pattern changes after 2010, when the number of deaths among girls increases significantly compared to the number of deaths among boys.

To move beyond descriptive evidence, we present the results of our analysis in Table 5, where we provide two different specifications. The first and second columns present the results of our IV specification using the number of deaths caused by suicide or self-inflicted harm. We use IV Poisson regression, which is a more suitable model for count data than linear regression.[36] In columns three and four, we present the results of our IV specification using the death rate as the dependent variable. To ensure robustness, we also compare the results for two different age groups, individuals aged 15 to 19 years old in columns one, and three, and those aged 20 to 24 years old in columns two, and four. By doing so, we provide a comparative analysis that strengthens the validity of our findings.

The table results present a striking contrast between adolescent girls and older girls. The estimated coefficients for girls aged 20 to 24 years old are small in magnitude and non-significant, while those for adolescent girls are large and statistically significant. Specifically, a one standard deviation increase in fiber penetration raises deaths due to suicide or self-inflicted harm between 34.5% and 71%, depending on the specification. Both estimates are statistically significant at standard confidence levels. In comparison, for boys aged 15 to 19 years old, the coefficient in the IV Poisson specification is statistically significant but much smaller in magnitude than for girls in the same age group

[36] We implement the two-step estimator proposed by Wooldridge (2010), for addressing the endogeneity issue in Poisson regression models with fixed effects.

(23-1% for boys versus 71% for girls) and the estimate from the linear regression model using death rates as the dependent variable is non-significant. Furthermore, the estimated effects for older boys are all non-statistically significant.

The findings presented in Table 5 indicate a positive and significant effect of HSI on the deaths of teens due to suicide or self-inflicted harm, with significantly larger effects observed in girls compared to boys. However, caution must be taken in interpreting these results due to the noisiness of some estimates and the low incidence of these types of events. Nevertheless, these results are consistent with our earlier findings and confirm that the expansion of HSI has resulted in a significant deterioration of adolescent mental health. Moreover, the severity of these incidents calls into question the possibility that these findings are merely the result of increased awareness. In the next section, we complement these findings with evidence on the mechanisms driving the observed patterns, which strongly aligns with our estimates for the effect of HIS on mental health cases.

IV. Mechanisms

In this section, we investigate whether the expansion of fiber has altered adolescents' internet usage patterns and affected their time use. To this end, we use data from ESTUDES, a biannual cross-sectional survey of adolescents aged 14 to 18, which tracks their behaviors such as drug use, internet use, and relationships with family and friends. The sample size varies, but each wave typically includes about 30,000 respondents. We examine internet usage patterns and their impact on time use in section 4.1. Unfortunately, these questions were only included in surveys from 2014 onwards, so we must exercise caution when interpreting the analysis due to the short time span and limited sample size. Nevertheless, we have a sample size of 95,998 individuals, with 48,842 girls and 47,156 boys. In section 4.2, we explore the effect of internet use on the

relationship between teens and their parents. For this analysis, we use data from all waves of ESTUDES starting from 2006, with a total sample size of 184,587 individuals (94,649 girls and 89,938 boys).

To estimate the impact of fiber expansion on other uses of time and on the relationship between adolescents and their parents we follow the same 2SLQ specification as before and fit the following equation:

$$IUD_{ipt} = FiberP_{ipt}\beta + X'\gamma + \propto_p + \tau_t + \varepsilon_{pt} \quad (6)$$

with equation (7) as the "first-stage":

$$FiberP_{ipt} = FiberI_{ipt-1}\mu + X'\gamma + \propto_p + \tau_t + \sigma_{pt} \quad (7)$$

$FiberI_{pt}$ in equation (7) is again the number of lines of optic fiber installed (not necessarily in use) in province p and time t-1. $FiberP_{pt}$ are fiber lines in use per 100 inhabitants in province p, at time t, and IUD_{ipt} are dummies indicating patterns of internet use by individual i living in province p, at time t. The vector X includes individual controls (age and country of origin) plus household level controls (the work status and level of education of each parent). Finally, $\propto_p$ are province fixed effects and τ_t are year fixed effects.

4.1 Patterns of Internet use and impact on alternative uses of time

In this section we explore patterns of internet use and its impact on other uses of time by adolescents. The detail of the questions is shown in Appendix Table 4. We construct an indicator of signs of addictive behavior towards internet use. This indicator is a dummy variable taking value 1 if the individual answers frequently or very frequently to any of statements 1, 2, 3, 6, 7, 8, 9 or 14. All these statements point to the difficulty or anxiety in trying to reduce internet use. We then construct an indicator of internet use potentially crowding-out sleep time by means of a dummy variable taking value 1 if the individual answers frequently or very frequently to statement 5; an indicator of internet

use crowding-out time devoted to homework if the individual answers frequently or very frequently to statement 10 or 11; an indicator of internet use crowding-out time devoted to socializing if the individual answers frequently or very frequently to statement 4; an indicator of internet use to cope with feelings of sadness if the individual answers frequently or very frequently to statements 12 or 13; and an indicator of bullying through the internet if the individual answer frequently or very frequently to statement 15. These dummy variables are our outcomes of interest in equation (6).

Table 6 presents the results of the analysis, which examines the impact of the expansion of fiber on internet use patterns and other uses of time, stratified by gender. A noteworthy observation is that the expansion of fiber has a significant impact on the patterns of internet use for girls, but not for boys, which is consistent with our previous findings of a gender gap in the mental health effects of the internet. Specifically, we find that the expansion of fiber significantly increases addictive internet use among girls, with a one standard deviation increase in fiber penetration leading to an almost 9% increase in addictive internet use, which is statistically significant at the 5% level. Conversely, the effect for boys is 3.6% and statistically insignificant. The results also show that exposure to high-speed internet reduces sleep time by 21%, homework time by 30%, and time spent socializing with family and friends by 44% for girls, but not for boys. Although the effect on homework time is statistically significant for boys, it is much smaller in magnitude than the effect for girls (+17% versus +30%). Furthermore, the analysis indicates that the expansion of fiber increases the proportion of girls who rely on the internet as a coping mechanism to deal with negative feelings or when they feel low. Consistent with evidence in the U.S. (CDC, 2023), the results also show that fiber expansion has no effect on the probability of being a victim of online bullying, neither for girls nor for boys, as indicated in column (6) of Table 5.

Overall, the findings presented in Table 6 indicate that the expansion of fiber has a significant impact on the internet use habits of girls, which can be characterized as "unhealthy." And even though girls report an increased reliance on the internet as a coping mechanism to manage negative emotions, particularly as network quality improves, it is uncertain whether this usage benefits them, as we will explore further in the next section.

4.2 Internet use and the relationship between adolescents and their parents

Previous research in the fields of medicine and psychology has established a negative association between pathological internet use (PIU) and the quality of the parent-adolescent relationship (Matalí-Costa et al., 2014; Liu et al., 2019; Alt and Boniel, 2018; Özaslan et al., 2022). However, the direction of causality is often ambiguous and could work both ways. Adolescents, particularly girls, tend to turn to the internet to cope with anxiety problems caused by a strained relationship with their parents. Conversely, excessive internet use can create a wedge between teens and their parents, leading to strained relations. There could be a self-reinforcing effect whereby adolescents in conflict with their parents develop patterns of excessive internet use and isolation that further deteriorate their relationship. High-speed internet could exacerbate these effects by making it easier for parents and teens to view content in silos, away from each other. The ultimate question of whether the internet, especially the expansion of fiber, is detrimental to the parent-teen relationship is empirical.

To investigate this question, we utilize data from ESTUDES, which includes two questions that directly inquire about adolescents' relationships with their parents. The first

question asks whether the adolescent has had any significant arguments or conflicts with their parents or siblings within the past year. Approximately 34% of individuals answered affirmatively to this question, with 30% of boys and 38% of girls reporting conflict. We use this question to identify potentially conflictive relationships. The second question inquires about the current quality of the relationship with each parent, providing five response options (1 – very bad; 2 – quite bad; 3 – neither good nor bad; 4 – quite good; 5 – very good). We create a binary variable that takes a value of 0 if the individual reports a response of 1, 2, or 3, and 1 otherwise. On average, 80% of adolescents report a fairly good or very good relationship with their father, and this figure increases to 86% for the mother. Girls report more conflict with their parents than boys, particularly in regards to their relationship with their father. While 83% of boys report a good or very good relationship with their father, this percentage drops to 77% for girls. Similarly, 87% of boys report a good or very good relationship with their mother, while the figure for girls is 84%.

To assess the impact of fiber expansion on the relationship between adolescents and parents, we utilize 2SLQ to estimate equations (6) and (7), with the results presented in Table 7. The table reveals two noteworthy findings: (1) fiber expansion has a negative effect on the quality of parent-adolescent relationships, primarily driven by girls; (2) the impact of fiber expansion on the father-adolescent relationship is more negative when this relationship is already conflict-prone, as evidenced by significant conflict in the previous year. For instance, in panel (a) of column (4), a one standard deviation increase in fiber penetration decreases the likelihood of a good relationship between girls and their fathers by 1.57% (significant at the 5% level). This effect is smaller for the girl-mother relationship (-1.01% in panel (b) of the same column) and statistically insignificant for the boy-father relationship (column 7). Moreover, the adverse effect of high-speed

internet on the girl-father relationship magnifies to -2.43% when the relationship already suffered from significant conflicts in the previous year, while it is zero when no such conflict existed. The reasons why fiber expansion has a detrimental impact on girls' relationships with their parents but not on boys' are unclear. One possibility is that girls, more than boys, develop a tendency to use the internet pathologically when experiencing anxiety or trouble in their relationships with their parents, displacing healthier strategies for dealing with family conflicts. Another possibility is that the behavioral and mental health issues caused by inappropriate internet use, which we have demonstrated to affect girls more than boys, impede the development of positive and healthy relationships between girls and their parents.

V. Conclusion

Suicide ideation and attempts among adolescents, particularly girls, have been increasing in many countries since the mid-2010s. This study provides consistent evidence of a causal link between access to high-speed internet and behavioral and mental health (BMH) issues in 15- to 19-year-old adolescents, with girls being the primary drivers of this effect. Using data from 2007 to 2019, a period marked by a decline in adolescent mental health and a surge in the popularity of online media platforms, we find that fiber penetration significantly increases BMH cases in this age group, with a one standard deviation increase resulting in a 13.3% increase in cases. We observe an alarming effect on cases of self-harm and suicide attempts among girls in this age group (+112.3%), while no significant effect is found for boys. Contrary to the hypothesis that these results could be due to increased awareness, we find that HSI is a factor contributing to a significant increase in suicide-related deaths among adolescents, with the effects again being larger among girls.

We offer support for the crowding-out hypothesis as our findings suggest that access to high-speed internet increases addictive internet use while reducing time spent on sleep, homework, and socializing with family and friends, with girls driving all these effects. We also found evidence of girls' greater reliance on the internet to alleviate feelings of sadness or being down, with apparently unsatisfactory results. We did not find evidence of increased online bullying. Additionally, we find that fiber expansion has a negative effect on the quality of the relationship between parents and girls, but no effect is found for boys.

Adolescence is a critical stage for social and emotional development, and mental health problems during this period can impact education and employment outcomes. Therefore, understanding the effects of social media on adolescent mental health is crucial. We believe that the evidence presented in this paper emphasizes the need for policy interventions to mitigate the impact of social media on adolescents' mental health.

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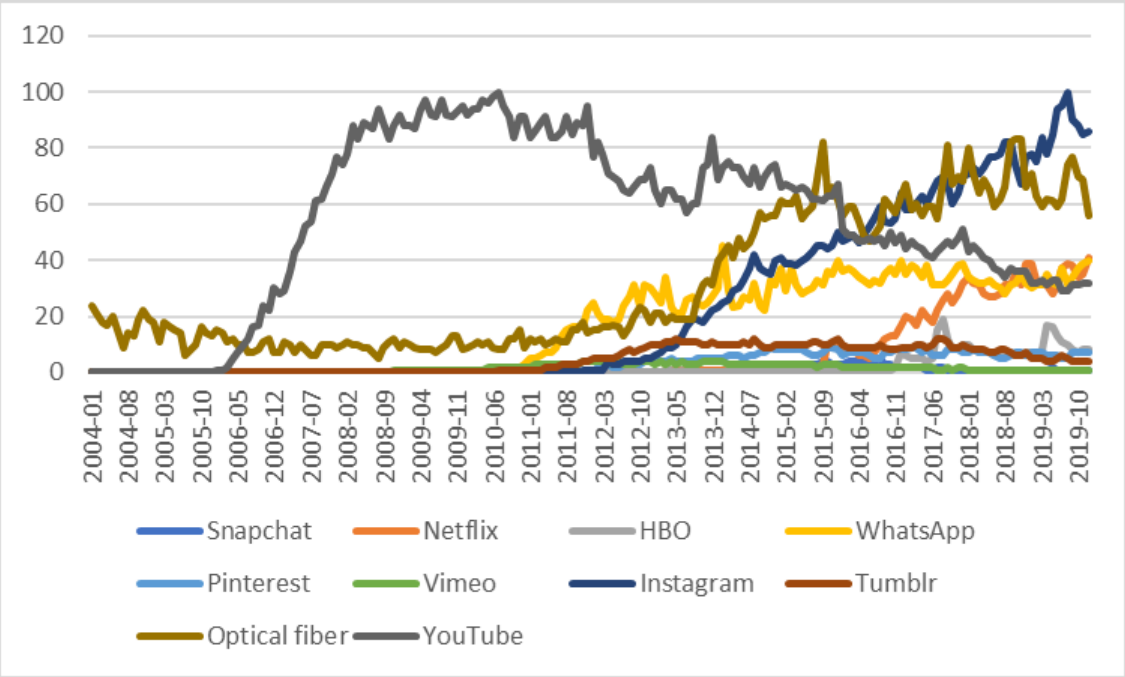
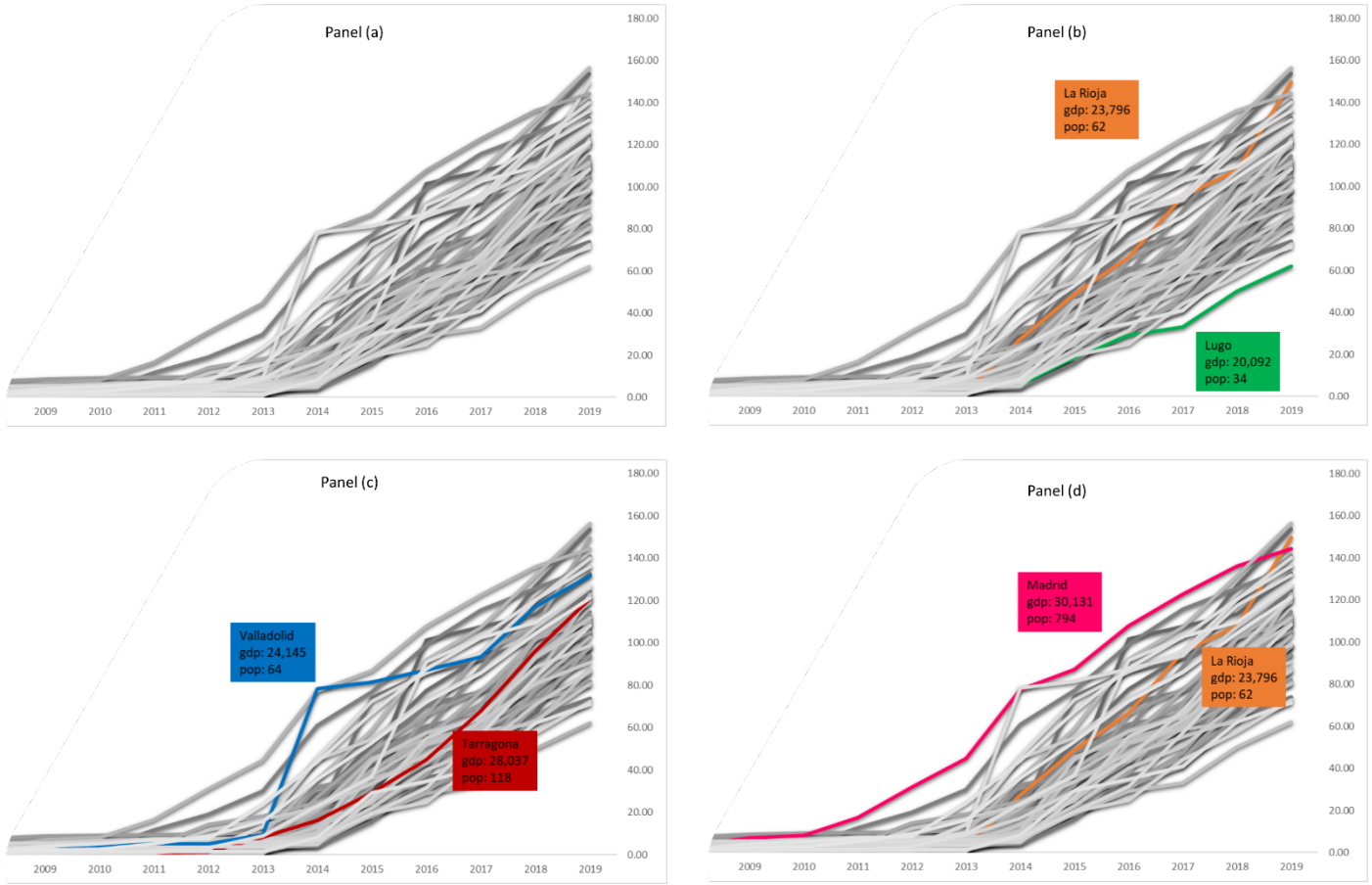
Figures and Tables

Figure 1. Search popularity of terms associated to apps and online media platforms popular among teens. Spain: 2004-2019



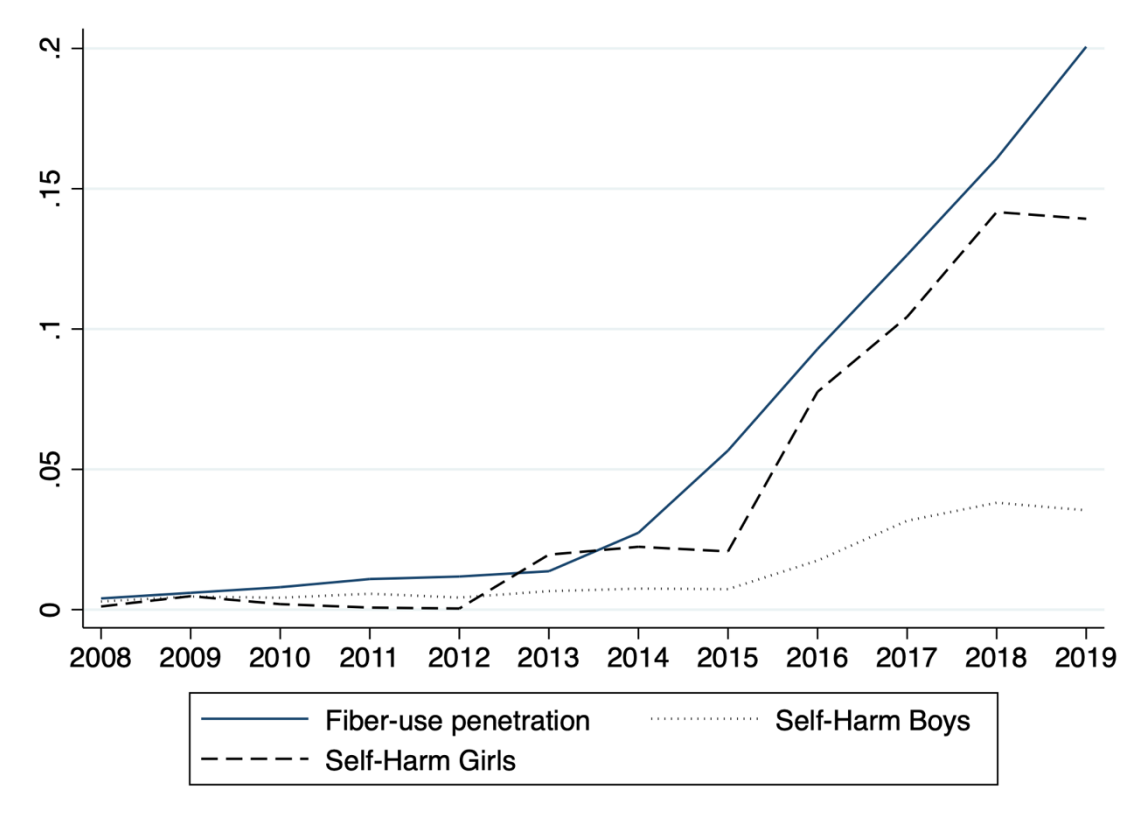
Source: Google Trends

Figure 2. Fiber rollout across Spanish provinces between 2009 and 2019. Lines per hundred inhabitants



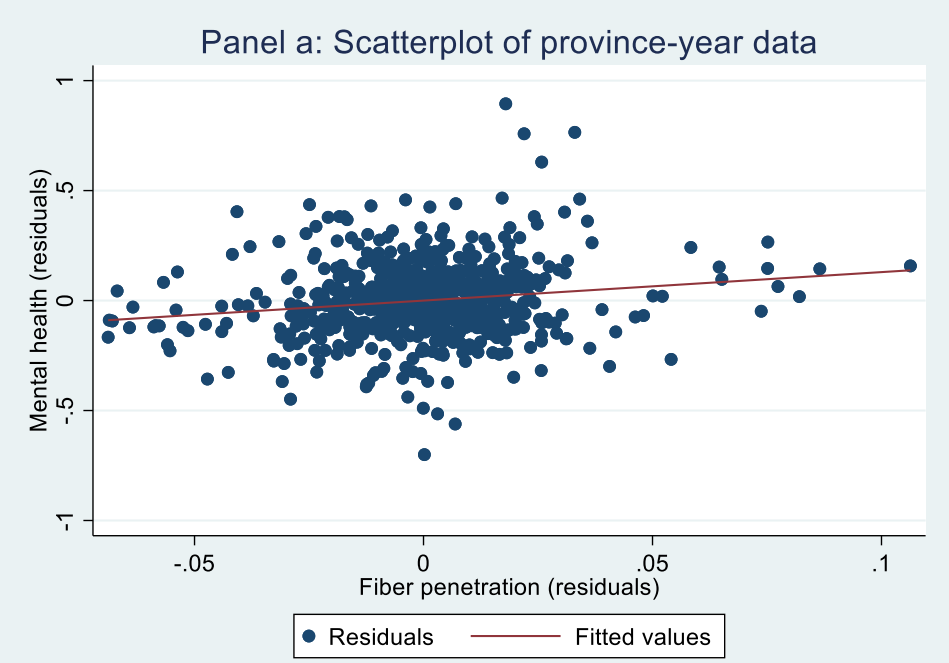
Source: Elaborated by the authors based on official data available in http://data.cnmc.es/datagraph/index.jsp. 'gdp' shows the level of GDP per capita (€) in the province in 2007. 'pop' shows the population density (inhabitants per km^2) in the province in 2007.

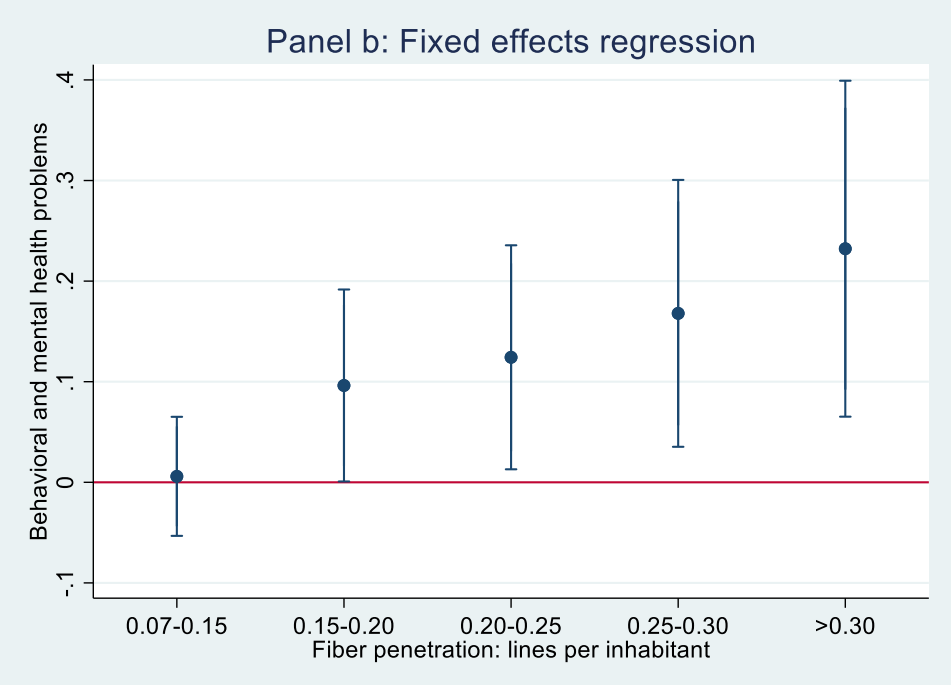
Figure 3. Fiber penetration and hospital cases of self-harm and suicide attempt among boys and girls aged 15 to 19 years – Raw Data: 2007-2019.



Notes: Elaborated by the authors based on administrative data from Spanish public and private hospital discharge diagnoses of behavioral and mental health cases and data from of fiber use from the National Commission of Markets and Competition.

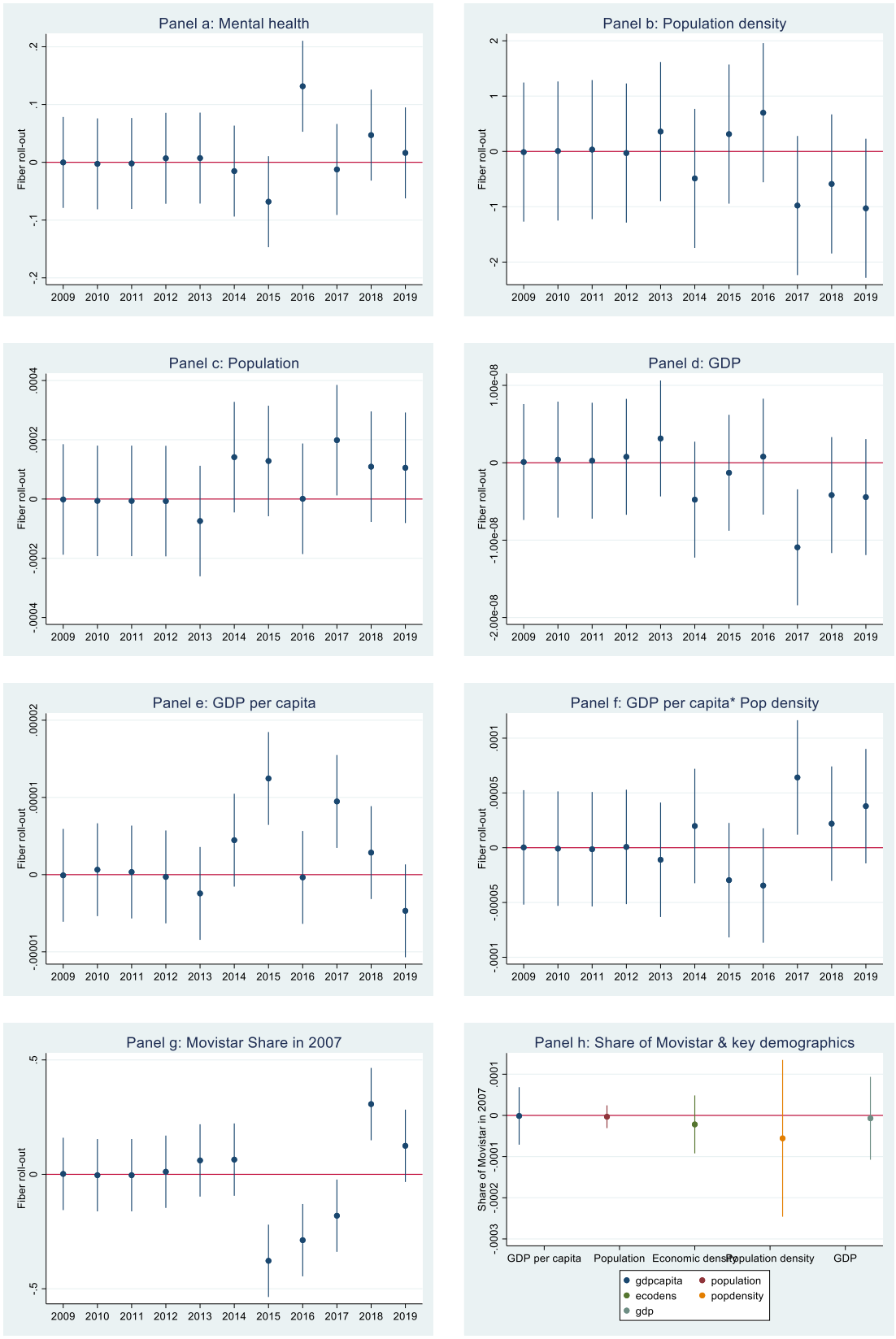
Figure 4. Fiber penetration and behavioral and BMH cases among boys and girls aged 15 to 19 years – Raw data after removing province and year fixed effects: 2007-2019.





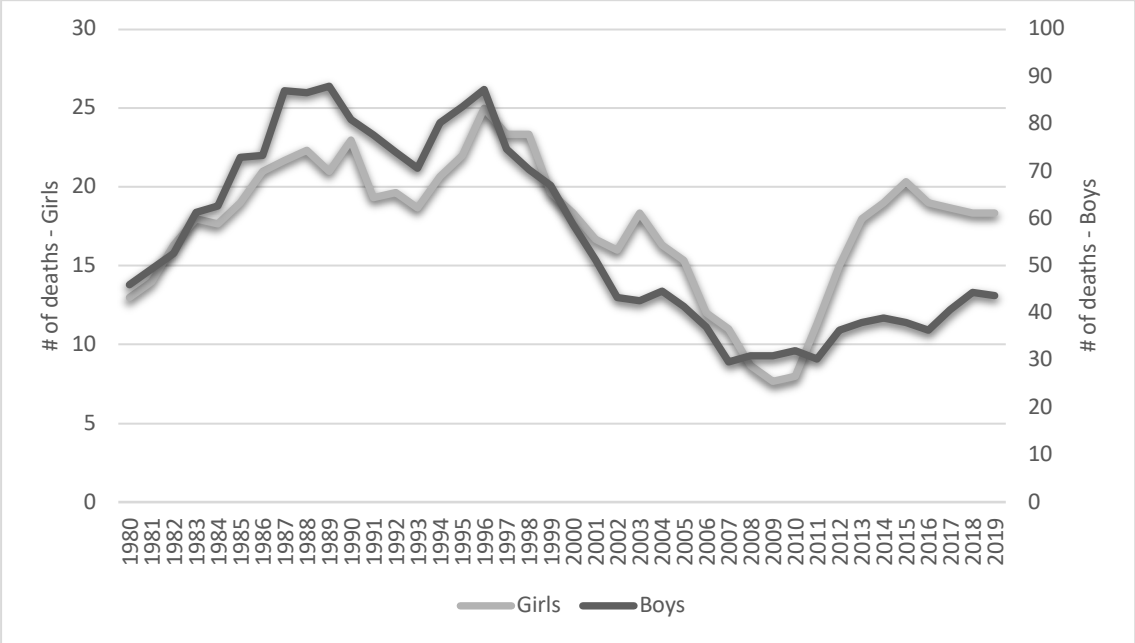
Notes: Panel a) plot the residuals of our mental health indicator (BMH cases) versus the residuals of fiber penetration after removing province and year fixed effects from both series (see equation 1). Panel b) shows the coefficient estimates of a regression of BMH cases by province-year against a set of dummy variables capturing five different levels of fiber penetration and after controlling for year and province fixed effects (equation 2).

Figure 5. Timing of fiber roll-out and baseline covariates



Notes: Panels a) to g) display the coefficient estimates of regressing, speparately for each calend year, the increase of fiber infraestructure (annual change in the number of lines installed) versus a vector of province characteristics in the initial year 2007. Panel h) displays the coefficient estimates from regressing the Movistar market share in 2007 versus socioeconomic characteristics of different provinces.

Figure 6. Deaths due to suicide or self-inflicted injuries. Boys and girls 15-19 years old.



Notes: 3-year moving averages. Source: Spanish National Statistics Institute (INE).

Table 1. The effect of fiber penetration on the mental health of adolescents aged 15 to 19 years: 2007-2019

	Dependent variable: hospital cases of BMH per one hundred inhabitants								
		15 to 19 years old					20 to 24 years old		
	OLS	IV							
	All	All	All	All	Boys	Girls	All	Boys	Girls
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Fiber penetration (lines per inhabitant)	**1.295****	**1.822****	1.300	**2.378***	1.199	**3.631****	0.282	1.295	-0.727
SE	**(0.607)**	**(0.935)**	(0.888)	**(1.419)**	(1.750)	**(1.629)**	(1.085)	(1.755)	(1.724)
Impact of a one SD increase in fiber penetration	13.3%	18.8%	13.4%	24.5%	13.2%	35.3%	1.9%	7.7%	-5.7%
Mean of dependent variable	0.65	0.65	0.65	0.65	0.61	0.69	1.00	1.12	0.86
First stage coefficient		0.146***	0.138***	0.111***	0.111***	0.111***	0.111***	0.111***	0.111***
SE		(0.026)	(0.020)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
N	650	600	600	600	600	600	600	600	600
Adj R2	0.30	0.31	0.41	0.44	0.24	0.42	0.32	0.21	0.29
State and year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Contemporaneous controls (X')	NO	NO	YES	YES	YES	YES	YES	YES	YES
Baseline covariates interacted with year effects (Z')	NO	NO	NO	YES	YES	YES	YES	YES	YES

Notes: * Significant at 10%, ** significant at 5%, and *** significant at 1%. Robust standard errors clustered at the province level. Behavior & BMH cases is chapter 5 of the International Classification of Diseases (ICD-10). Self-harm and suicide attempt does not belong to chapter 5 of ICD-10 and it's added to the calculation of BMH. IV regression (except for column 1) of BMH against fiber penetration, where fiber penetration (lines in use) is instrumented with installed FTTH infrastructure at t-1. The SD of fiber penetration is 0.067 for the entire sample period. Contemporaneous controls X' include population density, total population, real GDP per capita, aggregate real GDP and the total incidence (cases per 100 inhabitants) of hospital cases for all age groups and all medical conditions. All controls are measured at the province level. Baseline characteristics at the province level interacted with year dummies (Z') are the same covariates as in X measured at their value in 2007.

Table 2. The effect of fiber penetration on the mental health of adolescents aged 15 to 19 years by type of medical condition: 2007-2019

	IV estimates Dependent variable: hospital cases of BMH per one hundred inhabitants								
	Nutrition disorder (1)	Anxiety (2)	ADHD (3)	Mood disorder (4)	Personality disorder (5)	Schizophrenia (6)	Alcohol abuse (7)	Drugs abuse (8)	Self-harm and suicide attempt (9)
Panel a. all adolescents									
Fiber penetration	-0.142	**0.319***	0.082	**0.297***	0.130	0.075	0.017	**0.953****	**0.499***
SE	(0.130)	**(0.191)**	(0.280)	**(0.177)**	(0.185)	(0.139)	(0.168)	**(0.488)**	**(0.268)**
Impact of a one SD increase in fiber penetration	-45.3%	68.9%	13.4%	52.4%	19.8%	17.3%	3.8%	50.7%	81.5%
Mean of dependent variable	0.021	0.031	0.041	0.038	0.044	0.029	0.030	0.126	0.041
panel b. boys									
Fiber penetration	0.014	0.098	0.171	0.171	-0.051	0.086	-0.061	0.761	-0.089
SE	(0.123)	(0.202)	(0.379)	(0.129)	(0.171)	(0.208)	(0.284)	(0.634)	(0.181)
Impact of a one SD increase in fiber penetration	6.3%	34.6%	21.2%	45.8%	-14.2%	14.1%	-10.0%	33.5%	-33.1%
Mean of dependent variable	0.015	0.019	0.054	0.025	0.024	0.041	0.041	0.152	0.018
panel c. girls									
Fiber penetration	-0.309	**0.551***	-0.008	0.427	0.318	0.066	0.102	**1.157****	**1.123*****
SE	(0.257)	**(0.323)**	(0.219)	(0.288)	(0.346)	(0.128)	(0.089)	**(0.577)**	**(0.463)**
Impact of a one SD increase in fiber penetration	-76.7%	83.9%	-1.8%	56.1%	33.3%	26.0%	36.0%	79.1%	112.3%
Mean of dependent variable	0.027	0.044	0.029	0.051	0.064	0.017	0.019	0.098	0.067
N	600	600	600	600	600	600	600	600	600
State and year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Contemporaneous controls (X')	YES	YES	YES	YES	YES	YES	YES	YES	YES
Baseline covariates interacted with year effects (Z')	YES	YES	YES	YES	YES	YES	YES	YES	YES

Notes: * Significant at 10%, ** significant at 5%, and *** significant at 1%. Robust standard errors clustered at the province level. Behavior & BMH cases is chapter 5 of the International Classification of Diseases (ICD-10). Self-harm and suicide attempt does not belong to chapter 5 of ICD-10. IV regression (except for column 1) of BMH against fiber penetration, where fiber penetration (lines in use) is instrumented with installed FTTH infrastructure at t-1. The SD of fiber penetration is 0.067 for the entire sample period. Contemporaneous controls X' include population density, total population, real GDP per capita, aggregate real GDP and the total incidence (cases per 100 inhabitants) of hospital cases for all age groups and all medical conditions. All controls are measured at the province level. Baseline characteristics at the province level interacted with year dummies (Z') are the same covariates as in X measured at their value in 2007.

Table 3. Placebo estimates. The effect of fiber penetration on the mental health of adolescents aged 15 to 19: 2007-2012

	IV estimates Dependent variable: hospital cases of BMH per one hundred inhabitants		
	All (1)	Boys (2)	Girls (3)
Panel a. IV for fiber penetration			
Fiber penetration	-5.208	-11.333	1.304
SE	(10.539)	(10.099)	(12.363
Mean of dependent variable	0.56	0.57	0.55
First-stage coefficient on fiber infrastructure	0.215***	0.215***	0.215***
SE	(0.054)	(0.054)	(0.054)
R2	0.07	0.05	0.11
N	250	250	250
Panel b. IV for xDSL penetration			
XDSL penetration	-61.259	-133.287	15.344
SE	(339.058)	(771.401)	(201.91)
Mean of dependent variable	0.56	0.57	0.55
First-stage coefficient on fiber infrastructure	0.018	0.018	0.018
SE	(0.108)	(0.108)	(0.108)
R2	0.33	0.69	0.19
N	250	250	250
State and year FE	YES	YES	YES
Contemporaneous controls (X')	YES	YES	YES
Baseline covariates interacted with year effects (Z')	YES	YES	YES

Notes: * Significant at 10%, ** significant at 5%, and *** significant at 1%. Robust standard errors clustered at the province level. Panel (a) shows the results of estimating the impact of fiber penetration on the mental health of adolescents during the period prior to 2013, when fiber penetration increased very modestly from 0.03 to 0.04 lines per inhabitant.. Panel (b) shows the results of estimating our preferred specification but in which the variable to be instrumented is xDSL penetration instead of fiber penetration.

Table 4. The effect of fiber penetration on the mental health of adolescents aged 15 to 19. Robustness tests.

	IV estimates Dependent variable: hospital cases of BMH per one hundred inhabitants								
	All behavior and mental Health problems			Anxiety		Drugs abuse		Self-harm and suicide attempts	
	All	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel a. Main specification									
Fiber penetration	**2.378***	1.199	**3.631****	0.098	**0.551***	0.761	**1.157****	-0.089	**1.123*****
SE	**(1.419)**	(1.750)	**(1.629)**	(0.202)	**(0.323)**	(0.634)	**(0.577)**	(0.181)	**(0.463)**
Panel b. Excluding population									
Fiber penetration	**2.395***	1.300	**3.557****	0.097	**0.550***	0.821	**1.150****	-0.096	**1.152*****
SE	**(1.465)**	(1.773)	**(1.716)**	(0.204)	**(0.336)**	(0.639)	**(0.599)**	(0.187)	**(0.478)**
Panel c. Extensive margin									
Fiber penetration	n.a	n.a	n.a	0.421	**2.422***	0.664	-1.530	-0.061	**2.466***
SE				(2.285)	**(1.502)**	(0.958)	(1.854)	(2.389)	**(1.540)**
Panel d. 2012-2019									
Fiber penetration	2.405	0.273	**4.660****	0.178	**0.801***	0.697	**1.700****	-0.137	**1.715*****
SE	(1.802)	(2.214)	**(2.074)**	(0.191)	**(0.484)**	(0.714)	**(0.735)**	(0.230)	**(0.666)**
Panel e. Romano-Wolf correction									
P-value of fiber penetration	n.a	n.a	n.a	[0.992]	[0.243]	[0.597]	**[0.091]***	[1.000]	**[0.050]****

Notes: * Significant at 10%, ** significant at 5%, and *** significant at 1%. Robust standard errors clustered at the province level. Panel (a) shows the results of our preferred specification to facilitate comparison with the rest of the results. In panel (b) we estimate our preferred specification removing the contemporaneous population and population density controls. Panel (c) shows the results from estimating linear probability models where the dependent variable is a dummy variable which takes value 1 if that province-year had a positive number of cases of a given medical condition. We do not report the estimated effects for all BMH cases (columns 1 to 3) because the lack of variability in the dependent variable, which takes value 1 across all provinces and years. Panel (d) displays the results of estimating our main specification using only the years from 2012 to 2019. Panel (e) reports the p-values of the estimated coefficients after implementing the Romano-Wolf (2016) step-down multiple hypothesis correction method of the standard errors on each of the nine outcomes (the nine medical conditions displayed in Table 2).

Table 5. The effect of fiber penetration on deaths due to suicide or self-inflicted harm. IV specification.

	IV Poisson – number of deaths		IV specification – death rate (per 10,000 inhabitants)	
	15-19 years old	20-24 years old	15-19 years old	20-24 years old
	(1)	(2)	(3)	(4)
Panel a. Girls				
Fiber penetration	**3.040*** **	0.437	**0.720***	0.208
SE	**(0.743)**	(0.759)	**(0.386)**	(0.451)
Impact of a one SD increase in fiber penetration	71.0%	7.1%	34.5%	7.4%
Mean of dependent variable	0.287	0.411	0.140	0.188
N	600	600	600	600
Panel b. Boys				
Fiber penetration	**2.446*** **	-0.463	0.716	1.508
SE	**(0.648)**	(0.663)	(0.717)	(1.065)
Impact of a one SD increase in fiber penetration	23.1%	-2.0%	14.8%	15.04%
Mean of dependent variable	0.709	1.552	0.324	0.672
N	600	600	600	600

Notes: * Significant at 10%, ** significant at 5%, and *** significant at 1%. Robust standard errors clustered at the province level. IV regression where fiber penetration (lines in use) is instrumented with installed FTTH infrastructure at t-1. The SD of fiber penetration is 0.067 for the entire sample period. All first-stage coefficients have the expected sign and are statistically significant at the 1% level. All specifications include year and province fixed effects and controls for real gdp and population density at the year-province level.

Table 6. The effect of fiber penetration on Internet use of adolescents aged 14 to 18: ESTUDES 2014-2018. IV specification.

	Dependent variable: Dummy variable indicating reason for using the Internet or impact on alternative uses of time.					
	Internet use has signs of addiction (1)	Internet use crowds-out sleep (2)	Internet use crowds-out homework (3)	Internet use crowds-out socializing (4)	Internet use as coping mechanism (5)	Online bullying (6)
Panel a. Girls						
Fiber penetration	**0.683*** **	**0.531*** **	**0.637*** **	**0.624*** **	**0.726*** **	-0.053
SE	**(0.331)**	**(0.187)**	**(0.237)**	**(0.226)**	**(0.264)**	(0.158)
Impact of a one SD increase in fiber	8.96%	21.18%	30.49%	44.48%	13.25%	-15.40%
Mean of dependent variable	0.511	0.168	0.140	0.094	0.367	0.023
N	48,842	48,842	48,842	48,842	48,842	48,842
Panel b. Boys						
Fiber penetration	0.240	0.061	**0.374***	0.298	0.017	0.073
SE	(0.483)	(0.259)	**(0.210)**	(0.233)	(0.247)	(0.109)
Impact of a one SD increase in fiber	3.65%	2.55%	16.82%	18.84%	0.42%	18.11%
Mean of dependent variable	0.440	0.160	0.149	0.106	0.273	0.027
N	47,156	47,156	47,156	47,156	47,156	47,156

Notes: * Significant at 10%, ** significant at 5%, and *** significant at 1%. Robust standard errors clustered at the province level. IV regression where fiber penetration (lines in use) is instrumented with installed FTTH infrastructure at t-1. The SD of fiber penetration is 0.067 for the entire sample period. Quality of relationship between adolescents and parents comes from ESTUDES, waves of 2006 to 2018. All first-stage coefficients have the expected sign and are statistically significant at the 1% level. All specifications include age, year and province fixed effects and controls for the country of birth of the individual, the work status and the level of education of each parent.

Table 7. The effect of fiber penetration on the relationship of adolescents aged 14 to 18 years with their parents: ESTUDES 2007-2018. IV specification.

	Boys and girls			Girls			Boys		
	All	Conflict in relation	No conflict in relation	All	Conflict in relation	No conflict in relation	All	Conflict in relation	No conflict in relation
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel a. Good relation with the father									
Fiber penetration (lines per inhabitant)	**-0.131****	**-0.162****	-0.038	**-0.181****	**-0.225****	-0.036	-0.083	-0.083	-0.042
SE	**(0.066)**	**(0.081)**	(0.070)	**(0.075)**	**(0.097)**	(0.079)	(0.081)	(0.109)	(0.083)
Impact of a one SD increase in fiber penetration	-1.10%	-1.70%	-0.29%	-1.57%	-2.43%	-0.28%	-0.67%	-0.83%	-0.32%
Mean of dependent variable	0.80	0.64	0.88	0.77	0.62	0.87	0.83	0.67	0.89
N	180,156	61,080	119,076	92,040	34,949	57,091	88,116	26,131	61,985
Panel b. Good relation with the mother									
Fiber penetration (lines per inhabitant)	**-0.093***	-0.121	-0.008	**-0.126***	-0.138	-0.021	-0.059	-0.097	0.004
SE	**(0.048)**	(0.092)	(0.035)	**(0.073)**	(0.143)	(0.044)	(0.042)	(0.093)	(0.045)
Impact of a one SD increase in fiber penetration	-0.72%	-1.13%	-0.06%	-1.01%	-1.30%	-0.15%	-0.45%	-0.89%	0.03%
Mean of dependent variable	0.86	0.72	0.93	0.84	0.71	0.93	0.87	0.73	0.93
N	184,587	62,878	121,709	94,649	36,092	58,557	89,938	26,786	63,152

Notes: * Significant at 10%, ** significant at 5%, and *** significant at 1%. Robust standard errors clustered at the province level. IV regression where fiber penetration (lines in use) is instrumented with installed FTTH infrastructure at t-1. The SD of fiber penetration is 0.067 for the entire sample period. Quality of relationship between adolescents and parents comes from ESTUDES, waves of 2006 to 2018. All first-stage coefficients have the expected sign and are statistically significant at the 1% level. All specifications include age, year and province fixed effects and controls for the country of birth of the individual, the work status and the level of education of each parent.

Appendix Tables and Figures

Table A.1. The effect of fiber penetration on the mental health of adolescents aged 20 to 24 years by type of medical condition: 2007-2019

IV estimates

Dependent variable: hospital cases of BMH per one hundred inhabitants

	Nutrition disorder (1)	Anxiety (2)	ADHD (3)	Mood disorder (4)	Personality disorder (5)	Schizophrenia (6)	Alcohol abuse (7)	Drugs abuse (8)	Self-harm and suicide attempt (9)
Panel a. all adolescents									
Fiber penetration	-0.025	-0.022	-0.072	0.122	0.034	-0.287	-0.002	-0.862	0.056
SE	(0.143)	(0.136)	(0.079)	(0.119)	(0.264)	(0.192)	(0.213)	(1.117)	(0.193)
Impact of a one SD increase in fiber penetration	-9.3%	-3.4%	-37.1%	14.6%	3.3%	-24.0%	-0.2%	17.7%	10.1%
Mean of dependent variable	0.018	0.044	0.013	0.056	0.069	0.080	0.070	0.326	0.037
Panel b. boys									
Fiber penetration	-0.110	0.038	-0.024	-0.061	-0.111	**-0.467***	-0.012	-0.087	0.081
SE	(0.159)	(0.150)	(0.161)	(0.199)	(0.282)	**(0.262)**	(0.333)	(1.486)	(0.232)
Impact of a one SD increase in fiber penetration	-49.1%	8.2%	-8.0%	-8.9%	-12.2%	-25.9%	-0.8%	-1.4%	18.1%
Mean of dependent variable	0.015	0.031	0.020	0.046	0.061	0.121	0.106	0.419	0.030
Panel c. girls									
Fiber penetration	0.064	-0.093	**-0.118***	0.323	0.188	-0.093	0.010	-1.631	0.029
SE	(0.186)	(0.220)	**(0.071)**	(0.231)	(0.416)	(0.247)	(0.141)	(1.357)	(0.271)
Impact of a one SD increase in fiber penetration	19.5%	-10.9%	-	32.3%	16.4%	-16.0%	2.1%	-47.7%	4.3%
Mean of dependent variable	0.022	0.057	0.005	0.067	0.077	0.039	0.032	0.229	0.045
N	600	600	600	600	600	600	600	600	600
State and year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Contemporaneous controls (X')	YES	YES	YES	YES	YES	YES	YES	YES	YES
Baseline covariates interacted with year effects (Z')	YES	YES	YES	YES	YES	YES	YES	YES	YES

Notes: * Significant at 10%, ** significant at 5%, and *** significant at 1%. Robust standard errors clustered at the province level. Robust standard errors clustered at the province level. Behavior & BMH cases is chapter 5 of the International Classification of Diseases (ICD-10). Self-harm and suicide attempt does not belong to chapter 5 of ICD-10. IV regression (except for column 1) of BMH against fiber penetration, where fiber penetration (lines in use) is instrumented with installed FTTH infrastructure at t-1. The SD of fiber penetration is 0.067 for the entire sample period. Contemporaneous controls X' include population density, total population, real GDP per capita, aggregate real GDP and the total incidence (cases per 100 inhabitants) of hospital cases for all age groups and all medical conditions. All controls are measured at the province level. Baseline characteristics at the province level interacted with year dummies (Z') are the same covariates as in X measured at their value in 2007.

Table A.2. The effect of fiber penetration on the mental health of teenagers aged 10 to 14 years by type of medical condition: 2007-2019

	IV estimates Dependent variable: hospital cases of BMH per one hundred inhabitants								
	Nutrition disorder (1)	Anxiety (2)	ADHD (3)	Mood disorder (4)	Personality disorder (5)	Schizophrenia (6)	Alcohol abuse (7)	Drugs abuse (8)	Self-harm and suicide attempt (9)
Panel a. all teenagers									
Fiber penetration	-0.037	-0.027	-0.170	0.062	0.021	-0.181	-0.005	**0.121****	0.181
SE	(0.093)	(0.150)	(0.175)	(0.070)	(0.030)	(0.196)	(0.024)	**(0.051)**	(0.121)
Impact of a one SD increase in fiber penetration	-19.1%	-12.9%	-24.8%	51.9%	35.2%	-202,1%	-16.8%	101.3%	101.1%
Mean of dependent variable	0.013	0.014	0.046	0.008	0.004	0.006	0.002	0.008	0.012
Panel b. boys									
Fiber penetration	-0.092	-0.074	-0.254	0.095	-0.001	-0.126	-0.030	0.064	-0.001
SE	(0.146)	(0.116)	(0.218)	(0.061)	(0.043)	(0.090)	(0.029)	(0.068)	(0.058)
Impact of a one SD increase in fiber penetration	-56.0%	-55.1%	-25.8%	159.1%	-3.4%	-211,0%	-201.0%	71.5%	-3.4%
Mean of dependent variable	0.011	0.009	0.066	0.004	0.002	0.004	0.001	0.006	0.002
Panel c. girls									
Fiber penetration	0.021	0.022	-0.082	0.028	0.047	-0.237	0.021	**0.183****	**0.373***
SE	(0.122)	(0.199)	(0.231)	(0.119)	(0.067)	(0.322)	(0.029)	**(0.084)**	**(0.210)**
Impact of a one SD increase in fiber penetration	9.4%	7.8%	-22.0%	17.1%	52.5%	-198,4%	70.4%	111.5%	113.6%
Mean of dependent variable	0.015	0.019	0.025	0.011	0.006	0.008	0.002	0.011	0.022
N	600	600	600	600	600	600	600	600	600
State and year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Contemporaneous controls (X')	YES	YES	YES	YES	YES	YES	YES	YES	YES
Baseline covariates interacted with year effects (Z')	YES	YES	YES	YES	YES	YES	YES	YES	YES

Notes: * Significant at 10%, ** significant at 5%, and *** significant at 1%. Robust standard errors clustered at the province level. See notes of Table A.1.

Table A3. The effect of fiber penetration on the mental health of adolescents aged 15 to 19 years: 2007-2019. Excluding self-harm and suicide attempts.

	Dependent variable: hospital cases of BMH per one hundred inhabitants								
		15 to 19 years old					20 to 24 years old		
	OLS	IV							
	All	All	All	All	Boys	Girls	All	Boys	Girls
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Fiber penetration (lines per inhabitant)	**1.095****	**1.550****	1.090	1.880	1.289	**2.509****	0.226	1.213	-0.756
SE	**(0.538)**	**(0.804)**	(0.803)	(1.244)	(1.669)	**(1.310)**	(1.038)	(1.733)	(1.620)
Impact of a one SD increase in fiber penetration	12.0%	17.0%	12.0%	20.6%	14.4%	27.1%	1.6%	7.5%	-6.2%
Mean of dependent variable	0.61	0.61	0.61	0.61	0.60	0.62	0.96	1.09	0.82
First stage coefficient		0.146***	0.138***	0.111***	0.111***	0.111***	0.111***	0.111***	0.111***
SE		(0.026)	(0.020)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
N	650	600	600	600	600	600	600	600	600
Adj R2	0.22	0.23	0.34	0.37	0.23	0.32	0.30	0.20	0.27
State and year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Contemporaneous controls (X')	NO	NO	YES	YES	YES	YES	YES	YES	YES
Baseline covariates interacted with year effects (Z')	NO	NO	NO	YES	YES	YES	YES	YES	YES

Notes: * Significant at 10%, ** significant at 5%, and *** significant at 1%. Robust standard errors clustered at the province level. Behavior & BMH cases is chapter 5 of the International Classification of Diseases (ICD-10). Self-harm and suicide attempt does not belong to chapter 5 of ICD-10 and it's excluded from the calculation of BMH. IV regression (except for column 1) of BMH against fiber penetration, where fiber penetration (lines in use) is instrumented with installed FTTH infrastructure at t-1. The SD of fiber penetration is 0.067 for the entire sample period. Contemporaneous controls X' include population density, total population, real GDP per capita, aggregate real GDP and the total incidence (cases per 100 inhabitants) of hospital cases for all age groups and all medical conditions. All controls are measured at the province level. Baseline characteristics at the province level interacted with year dummies (Z') are the same covariates as in X measured at their value in 2007.

Table A4. ESTUDES. Questions about patterns of Internet use. Waves of 2014, 2016, 2018.

INT4. PLEASE READ THE FOLLOWING STATEMENTS REGARDING THE USE OF THE INTERNET (chatting, sending or receiving e-mails, whatsapps, using social networks, playing with or without money, listening to or downloading music, watching or downloading videos...). INDICATE HOW OFTEN THE FOLLOWING SITUATIONS HAPPEN TO YOU. (Do not take into account the time you spend on the internet to do homework or work, only indicate here the time you spend on the internet for fun). Check one box per line.					
	Never	Rarely	Sometimes	Frequently	Very frequently
1. How often have you found it difficult to stop using the internet when you were online?	0	1	2	3	4
2. How often have you stayed connected to the internet despite wanting to stop?	0	1	2	3	4
3. How often do your parents or friends tell you that you should spend less time on the internet?	0	1	2	3	4
4. How often do you prefer to connect to the internet instead of spending time with others (parents, friends...)?	0	1	2	3	4
5. How often do you sleep less because you are connected to the internet?	0	1	2	3	4
6. How often do you find yourself thinking about the internet, even when you're offline?	0	1	2	3	4
7. How often are you looking forward to connecting to the internet?	0	1	2	3	4
8. How often do you think you should use the internet less?	0	1	2	3	4
9. How often have you tried to spend less time online and failed?	0	1	2	3	4
10. How often do you try to finish your work in a hurry to get online?	0	1	2	3	4
11. How often do you neglect your obligations (homework, being with the family...) because you prefer to connect to the internet?	0	1	2	3	4
12. How often do you connect to the internet when you are "low"?	0	1	2	3	4
13. How often do you connect to the internet to forget your sorrows or negative feelings?	0	1	2	3	4
14. How often do you feel restless, frustrated, or irritated if you can't use the internet?	0	1	2	3	4
15. How often have you felt harassed, threatened or do you think you have been bullied through the internet?	0	1	2	3	4

Table A5. Popular apps and streaming platforms among teens by launch year.

App/Streaming Platform	*Launch Year*	*For the visualization or exchange of video?*	*For the visualization or exchange of photos?*
Netflix	1997	YES	NO
Vimeo	2004	YES	YES
YouTube	2005	YES	NO
Reddit	2005	YES	YES
Twitter	2006	YES	YES
Hulu	2007	YES	NO
Tumblr	2007	NO	YES
WhatsApp	2009	YES	YES
Kik Messenger	2010	NO	YES
Pinterest	2010	NO	YES
Instagram	2010	YES	YES
Facebook Messenger	2011	YES	YES
Snapchat	2011	YES	YES
Twitch	2011	YES	YES
YouNow	2011	YES	YES
Vine	2012	YES	YES
Yik Yak	2013	NO	NO
Avakin	2013	YES	YES
Dubsmash	2014	YES	NO
Musical.ly	2014	YES	NO
Triller	2015	YES	NO
YouTube Kids	2015	YES	NO
Discord	2015	NO	YES
VSCO	2015	NO	YES
Periscope	2015	YES	YES
Tik-Tok	2016	YES	NO
Amino	2016	YES	YES
Houseparty	2016	YES	YES
Marco Polo	2016	YES	YES
Sarahah	2017	NO	NO
Lasso	2018	YES	YES
Disney+	2019	YES	NO
Byte	2019	YES	YES
Likee	2019	YES	YES
HBO Max	2020	YES	NO
Quibi	2020	YES	NO