Internet diffusion: killing time prevents crime?

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Abstract

How does Internet diffusion affect crime rates? I use a panel of state-level yearly data on broadband penetration and criminal activity in the US to shed light on the question. I adopt an instrumental variable approach relying on the fact that the most widespread broadband technologies in the US employ the pre-existing telephone and Cable TV networks to transmit data. The deployment of such networks in early times provides a relevant source of exogenous variation in recent broadband diffusion. Results show that Internet diffusion is associated with a significant and substantial decrease in total and property crime rates, suggesting that a substitution mechanism is at play: online activities crowd out offline activities that more likely lead to crime. A number of tests suggest that my estimates may be interpreted in a causal fashion.

Research area: Applied Microeconomics

Key-words: Internet · Broadband · Crime · Substitution effect

JEL codes: K42, L96

Resumo

A difusão da Internet afeta crime? O presente estudo busca pesquisar o impacto da penetração da Internet sobre as taxas de criminalidade nos EUA. Com o uso de variáveis instrumentais, analisou-se um painel de dados anuais de crime e penetração da banda larga em nível estadual nos EUA. A escolha das variáveis instrumentais se apoia no fato de que as tecnologias de banda larga mais comuns utilizam as pré-existentes redes de telefonia e TV a cabo para transmitir dados. Tal uso de redes pré-implantadas fornece uma fonte de variação exógena na difusão recente da banda larga ao longo do território. Os resultados mostram que a penetração da Internet está associada a uma redução significativa e substancial nos índices de criminalidade. Isto sugere que um mecanismo de substituição está em jogo: atividades on-line substituem atividades off-line que mais provavelmente levariam a algum crime. Uma série de testes sugerem que minhas estimativas podem ser interpretadas de uma forma causal.

Área de pesquisa area: Microeconomia Aplicada

Palavras-chave: Internet · Banda Larga · Crime · Efeito de substituição

Classificação JEL: K42, L96

1 Introduction

The Internet has revolutionised many aspects of society and people's lives. Invented at the end of the 1980s, this technology penetrated the US in two waves. The first one involved dial-up connections and started in the early 1990s. The second one began short before the turn of the Millennium, with the introduction of broadband or high-speed Internet technologies. These quickly crowded out dial-up connections, which were down at a 3% penetration rate in 2010, after peaking at about 40% in 2000 (NTIA, 2011). Remarkably, it was only with the introduction of high-speed connections that the Internet reached preponderant levels of penetration in US homes – by 2012, about 70% of American households had broadband Internet at home (NTIA, 2013).

The impact of Internet penetration – especially broadband technologies (see NTIA, 2004; NTIA, 2011) – has been dramatic and far-reaching. In line with this, scholars have put effort in investigating the effect of Internet diffusion on a wide range of outcomes, concerning for instance the labour market (see Kuhn and Skuterund, 2004; Kuhn and Mansour, 2014), marriage rates (see Bellou, 2015), and television viewership (see Liebowitz and Zentner, 2012). One connection that remains relatively unexplored is the possible link between Internet diffusion and crime. Overall, researchers and policy-makers agree that some sort of impact is plausible. However, there is no consensus as to its sign. On the one hand, there is a concern, backed by some results in empirical research (for instance, Bhuller *et al*., 2011; Anderson *et al*., 2010), that the abundant supply of sensitive content made accessible by the Internet may positively affect criminal activity, by means of a behavioural or arousal effect. On the other hand, criminological theory suggests that the Internet is capable of affecting crime by altering users' allocation choices. In this sense, the diffusion of the Internet is expected to hinder crime by reason of a substitution effect: online activities crowd out offline activities that more likely lead to crime. The substitution effect may deploy through two closely-connected mechanisms. On the one hand, a catharsis effect (Zimring and Hawkins, 1997): potential criminals substitute actual crime with online activities that inhibit or satisfy their aggressive impulses. On the other hand, a time substitution or voluntary incapacitation mechanism may be at play: having people spend more time online and less time unoccupied on the street *per se* reduces crime. All in all, the substitution effect implies that Internet diffusion negatively affects crime. Evidence in support of this effect has been encountered in previous empirical research (for instance, Dahl and Della Vigna, 2009; Kendall, 2007). Taking a step further, theory has suggested that the substitution effect may be heterogeneous across offense types and/or demographic groups. In particular, it may have a stronger impact on that portion of crime that can be understood as recreational rather than as predetermined and calculated (Zimring and Hawkins, 1997), so that a negative effect of Internet diffusion on this kind of delinquency may be interpreted as the substitution of one diversionary activity with another (for a similar argument see Laqueur and Copus, 2014). The effect may also be more intense on the youth, who typically contribute more than proportionally to crime and are particularly keen on new technologies (see Griffiths and Sutton, 2013).

In summary, theoretical research indicates that Internet diffusion may impact criminal activity both positively, through an arousal effect, and negatively, through the substitution effect. Then, figuring out the overall impact of Internet diffusion on crime is ultimately an empirical matter. Previous empirical literature has investigated some narrowly-defined effects and closely related issues, leaving room for the investigation of the overall effect of Internet diffusion on the most common categories of crime. The main contribution of this research is to shed light on this issue. It is useful to stress that this paper focuses on the most common types of offenses. These do not include cybercrime which, despite being an intriguing phenomenon, is still relatively uncommon. For instance, in 2013 in the US about 6 million larceny-thefts were reported, against 0.26 million cybercrime complaints (see FBI – UCR, 2013; FBI – IC3, 2013).

I exploit the variation in broadband penetration and criminal activity in the US over time and use an instrumental variable (IV) approach with fixed effects to investigate the link between Internet diffusion and crime. The most widespread broadband technologies in the US in the period 2000-2012 technically relied on the pre-existing telephone and Cable TV networks. As a result, the deployment of residential telephone and Cable TV networks in early years may provide a relevant source of exogenous variation in recent broadband diffusion. I investigate this hypothesis through a number of tests, and outcomes provide support to the validity of this approach. Thus, I instrument the fraction of residential broadband Internet subscribers in each state and year with the rate of residential telephone adoption in 1955 and the share of population employed in the Cable TV sector in 1990, each multiplied by year indicators.

I estimate the model by Two Stage Least Squares (2SLS). Results show a negative and significant effect of broadband Internet on total and property crime rates. All else being equal, a broadband penetration increase by one additional line per 100 people is associated with a 1.4% - 1.5% decrease in crime rates. This effect is rather substantial and should be interpreted as a local average treatment effect (LATE, Imbens and Angrist, 1994). I complement my analysis by presenting the results from estimation by Ordinary Least Squares (OLS) with fixed effects. Again, results uniformly indicate that Internet diffusion is associated with a statistically significant decrease in total and property crime rates, of about 0.6%. 2SLS estimated coefficients are approximately 2.3 times larger in absolute value than OLS estimated coefficients. This discrepancy in the point estimates leads to two considerations. First, the OLS approach is likely to suffer from the omitted variable bias. Secondly, the LATE may be overstating the effect of Internet diffusion for the population at large. Nonetheless, the core result holds that such effect is negative, significant and substantial.

I perform a number of robustness tests to enhance confidence in my IV results and the plausibility of their causal interpretation. To begin with, I run two falsification tests to check that outcomes are not driven by underlying state-specific trends in crime. Then, I estimate my IV model using the limited information maximum likelihood (LIML) estimator, and get to estimates that are remarkably close to the 2SLS ones. Finally, I replicate the analysis using a different source for Internet diffusion data at the state level, as well as at a more disaggregated level. In both cases, results are in line with my baseline estimations.

To develop a deeper understanding of the effect of Internet diffusion on crime, I run two heterogeneity tests along the lines of the hypotheses proposed by previous literature. First, I look at specific types of offenses, and find that broadband Internet diffusion significantly affects each kind of property crime, while it does not seem to have a significant impact on any class of violent offenses. Then, I consider the effect of broadband diffusion on arrest rates for different combinations of age and gender to investigate the hypothesis of heterogeneous effects across demographic groups. None of the estimated coefficients appears to be significantly different from zero in this analysis.

Overall, my results indicate that the effect of Internet diffusion on total and property crime rate is negative and substantial. Relating this outcome to previous theoretical literature, it appears that the substitution effect of the Internet more than outweighs any arousal effect, so that the net impact on crime is negative. This result is aligned with the findings of previous empirical studies analysing the effect on crime of watching violent content over different technological platforms (such as videogames and movies). Outcomes are robust to many falsification and specification tests, enhancing confidence in my baseline results and the plausibility of their causal interpretation. The heterogeneity analyses provide some indication that the substitution effect may have a stronger impact on recreational crime, while heterogeneity of impacts across demographic groups could not be detected.

My research speaks to two policy-relevant debates. Since the beginning of the (broadband) Internet era, policies have been put in place to subsidise its underlying infrastructure and promote its universal deployment, by reason of the positive economic effect predicted for connected communities (see Lehr *et al*. 2006, ITU 2012). However, the impact of Internet diffusion on some social outcomes – such as crime – is ambiguous. Pursuant to this, policy-makers in many countries debate about whether and how internet traffic should be restricted or monitored, to prevent potential adverse effects. The finding that the overall effect of Internet diffusion on crime is negative and significant is relevant to such ongoing debate. In addition, this research relates to the stream of literature investigating the crime drop experienced by many countries in the Developed World since the since the early 1990s. The drop was unforeseen – quite the opposite, leading experts such as Fox (1996) and DiIulio (1996) had prophesised an explosion in delinquency – and has been object of a great deal of research aimed at pinning down its determinants. There is some consensus on a few factors that have concurred to falling crime rates (see Levitt, 2004). However, given the complexity of the phenomenon, research on this topic is likely never to be exhausted. The present study relates to this literature and suggests that Internet diffusion has played a role in sustaining the crime drop.

The remainder of this paper is organised as follows. Section 2 describes the conceptual framework that motivates the relationship between Internet diffusion and crime. Section 3 introduces the data. In Section 4, I describe the empirical strategy. Section 5 presents the results. I perform robustness and heterogeneity tests in Section 6. Section 7 relates my results to the previous literature and discusses their economic significance. Section 8 concludes.

2 Conceptual framework

2.1 Criminological theory

Routine-changing technologies, such as the Internet, are capable of altering the crime patterns. This is an important conclusion in Routine Activity Theory, a branch in criminology that focuses on how variations in lifestyle (or routine activities) affect the opportunities for – and thus the occurrence of – crime. Routine Activity Theory itself is a sub-field of Crime Opportunity Theory, which maintains that the occurrence of a crime crucially depends on the idiosyncrasies of an immediate situation or context. Crime can be prevented by removing the opportunity to commit it and, if not committed today, it will not necessarily occur tomorrow. Changes in everyday technologies, such as the advent of the Internet, may affect the opportunity for crime and thus criminal activity. The question is: how?

Some criminologists have hypothesised a substitution effect: online activities crowd out alternative offline activities that are more likely to lead to opportunities for crime. The literature seems to identify two relevant and closely-connected mechanisms for the deployment of the substitution effect. On the one hand, a content-driven catharsis mechanism (analogous to the one Zimring and Hawkins, 1997, referred to while studying the effects of mass entertainment on violence): the availability of certain kinds of contents online (for instance: pornography, violence) can inhibit or satisfy aggressive impulses of potential offenders. Then, online activities would serve as a substitute for crime. On the other hand, a time substitution or voluntary incapacitation mechanism may be at play: spending less time unoccupied on the street *per se* reduces the opportunities of committing or being victim of a crime, regardless of the alternative activity that is pursued instead (see Cashmore, 2012; Griffiths and Sutton, 2013). Given that at least until the mid-2000s Internet was mainly accessed from indoor locations, this technology may have negatively affected crime simply by keeping people off the streets for longer. All in all, both mechanisms entail a negative expected impact of Internet diffusion on criminal activity, so that the substitution effect would be negative overall. Taking a step further, some scholars have suggested that this effect may be heterogeneous. Griffiths and Sutton (2013) suggest that the impact may be stronger on the youth, who typically contribute more than proportionally to delinquency and are particularly keen on new technologies.[1] In the words of the authors, "all the time spent online must equate to less time on the street leading to less potential offending time and a smaller population of available victims of violence and robbery". A further potential source of heterogeneity is that the substitution effect may be more intense on that portion of crime that can be understood as recreational (Zimring and Hawkins, 1997), so that a negative effect of Internet diffusion on this kind of delinquency may be interpreted as the substitution of one diversionary activity with another (see Laqueur and Copus, 2014).

There are other possible ways in which the diffusion of the Internet may affect criminal activity. This technology brought about an unprecedented supply of content, including sensitive material such as violence or pornography, which is available to users with very limited control. Zimring and Hawkins (1997) mention that access to sensitive content may make aggression more likely through a behavioural effect, for instance by altering the emotional state of the audience (the 'excitement effect') or by giving them the impulse to re-enact what they have viewed (the 'ideational' effect). Similar concerns have been put forward by policy-makers and the public in general, so that the debate as to whether and how internet traffic should be restrained remains open.

In summary, criminological theory has remarked that the diffusion of the Internet is capable of affecting criminal activity both positively, through a behavioural mechanism, and negatively, through the substitution mechanism. Thus, figuring out the actual effect of the Internet on delinquency is ultimately an empirical matter.

[1] According to Wallsten (2013) "people between 15 and 17 spend the most time online, followed by 18-24 year olds".

2.2 Empirical studies

The literature on the effects of Internet diffusion on delinquency has focused on a specific kind of offenses – sex crimes – reaching non-homogeneous outcomes. Bhuller *et al.* (2011) investigate the impact of Internet use on sex crimes in Norway, in an IV setup. They find that Internet use is associated with a significant increase in sex crimes, likely as a result of increased consumption of pornography. The authors consider among the possible mechanisms both a direct effect of Internet use on the propensity for sex crime (a behavioural effect) and an indirect impact similar to the substitution effect (Internet may affect matching between victim and criminal as its use displaces alternative activities that are more or less associated with sex crimes). Results suggest that, although the indirect effect cannot be ruled out, the net impact of Internet use on sex crime is positive, implying that the behavioural effect is dominant. Kendall (2007) reaches opposite conclusions on the association between Internet use and rape by studying US state-level data over the period 1998-2003. He explains his results in view of a substitution effect through catharsis: criminals are substituting actual rape with pornography. The discrepancy in results between the two studies suggests that underlying differences among geographical contexts may also matter.

Non-Internet-specific empirical research has been carried on in related fields, providing support to the existence of both the behavioural and the substitution effects.

Psychological research provides evidence that subjects exposed to violent material tend to act more aggressively (e.g., Anderson *et al*., 2010; Anderson, Gentile, and Buckley, 2007). Results are typically derived from experiments in the lab, where a pool of subjects is randomly exposed to some violent content, while the control group watches less violent material. Outcomes usually display statistically significantly heightened cardiovascular activity and hostility measures associated with being exposed to more intense violence. These results are consistent with the existence of a behavioural effect. However, it remains to be established whether higher aggressiveness actually translates into more crimes in the field. Also, because of their experimental setting, these studies cannot provide any indication as to the substitution effect and its relative importance with respect to the behavioural one. Using real-world data, empirical research in economics has analysed the effects on specific kinds of crime of watching sensitive material over platforms other than the Internet. These studies find evidence that both a behavioural and a substitution (through voluntary incapacitation) effects exist. However, the latter more than outweighs the former, so that the net effect on crime is negative. Dahl and Della Vigna (2009) exploit time series variation in the violence level of blockbuster movies from 1995 to 2004 to study the overall short run effect of violent content on violent crime. They estimate that violent movie attendance reduces violent crime in the short term by between 1% and 2%. The authors interpret this finding as a substitution (voluntary incapacitation) effect: potential criminals who choose to go to the movie theatre substitute away from other activities that have higher crime rates. They accept that violent movies may generate a behavioural or arousal effect, evidenced by their finding that there are smaller reductions in violence after more violent movies relative to mildly violent movies. Nonetheless, results show that any arousal effect is dominated by the substitution one. Likewise, Cunningham, Engelstätter and Ward (2011) use a time series approach to estimate the impact of the increased weekly volume of violent video game sale on weekly violent crime. They instrument video game sales with video games ratings in order to only exploit the part of variation in sales due to variation in quality. Their results show that increased violent video games sales produce an overall decrease in violent crime. In line with Dahl and Della Vigna (2009), the authors suggest that this net effect is made up of two components. On the one hand, the finding that violent video games reduce violent crime by a smaller amount than non-violent video games lends support to the existence of a positive behavioural effect. On the other hand, the latter is more than outweighed by a voluntary incapacitation effect, resulting in a negative net impact of violent video games on crime.

In summary, from a theoretical standpoint, the overall effect of Internet diffusion on crime may go in either direction, as the two proposed underlying mechanisms (behavioural and substitution effects) hold opposite signs. Empirical findings provide evidence that both mechanisms exist. Studies analysing the impact of watching sensitive material over platforms other than the Internet mostly agree that the substitution effect dominates the behavioural one. Research on the effects of Internet diffusion itself is scarce, focuses on a very specific kind of crimes (sex crimes) and delivers ambiguous results. Thus, the overall effect of Internet diffusion on the most common categories of crime remains *a priori* unclear. The purpose of this paper is to empirically address this matter.

3 Data

To investigate the link between Internet diffusion and crime evolution, I exploit the variation in broadband penetration and criminal activity in the US, in a panel data setup. I employ data on crime (the dependent variable), Internet penetration (the explanatory variable of interest), household telephone adoption and employment in the Cable TV sector (the instruments), as well as on a number of demographic and socio-economic controls. Data is organised in a panel covering a thirteen-year period (2000-2012) for 51 territories (50 states and the federal district). The information used in this study comes from several sources.

Crime data
State-level, annual data on crime occurrences are taken from the Uniform Crime Reports (UCR) issued by the Federal Bureau of Investigation (FBI). These data have been used in mainstream crime literature, for instance by Kelly (2000) and Donohue and Levitt (2001). Data refer to seven felony offenses entailing both violent and property crimes. Violent crimes consist of murder and non-negligent manslaughter, forcible rape, robbery and aggravated assault; property crimes include burglary, larceny-theft and motor vehicle theft.[2] The FBI selects these crime categories because they are the most likely to be reported and to occur with sufficient frequency to provide an adequate basis for comparison.[3] Total, violent and property crime rates per 100,000 residents represent the main dependent variables in the analysis. I use the logarithmic transformation because I expect the variation in crime to be proportional to its initial level.
In a robustness check, I replicate the analysis at a more disaggregated level. Local data on crime are from FBI's UCR too.
Finally, in a heterogeneity test, I use as dependent variables arrest rates for different combinations of age and gender. Data on arrests by age and sex are from the FBI's UCR.

Internet data
The explanatory variable of interest must reflect Internet penetration. To the best of my knowledge, there are no available yearly, state-level data on the diffusion of Internet technologies other than broadband. Thus, the data I use actually picture the diffusion of broadband Internet. Although this is not ideal, it shall be kept in mind that, starting from their introduction short before year 2000, broadband platforms have largely replaced other connections (NTIA, 2011; NTIA, 2013). In addition, the impact of broadband technologies has arguably been more intense than that of previous technologies (see NTIA, 2004; NTIA, 2011), and it was only with the introduction of broadband platforms that the Internet reached preponderant levels of penetration in US homes. Thus, it does not seem unsound to approximate the effect of the Internet diffusion in the period 2000-2012 using broadband penetration. Still, I perform a robustness check using a different Internet data source to get an indication as to whether this approximation is reasonable (see Section 6.1.3).
In my baseline analysis, I use data on broadband diffusion from the Federal Communications Commission's (FCC) Statistical Reports on Broadband Deployment. These data have already been employed in the literature. For instance, Bellou (2015) uses them to examine the impact of broadband Internet penetration on marriage rates in the US. The FCC's Statistical Reports on Broadband Deployment provide information on subscribership to Internet access services gathered through the Form 477, which qualifying providers are required to file twice a year. Information includes data on the number of broadband or high-speed lines (connections to end-user locations that deliver services at speeds exceeding 200 kilobits per second in at least one direction) by type of user (residential or business) and per state. I focus on the residential segment because the literature has suggested that Internet availability may have an impact on crime by affecting people's spare time allocation choices. Data on residential

[2] For felonies' definitions, see this link.
[3] FBI's website.

broadband penetration has been recorded half-yearly since December 2000.[4] Because of this data limitation, my analysis will cover the period starting from 2000 although broadband deployment actually started at the end of the 1990s. I use for each year the second semester's report, portraying the situation as of the end of the year. Data are not available for Hawaii in the period 2000-2005 and for Wyoming in 2000. My explanatory variable of interest is built as the number of residential broadband lines per 100 people in a certain state and year.

In a robustness check at both state and local level, I employ as an alternative source for Internet diffusion data the Internet and Computer Use Supplement data collected by the US Census as part of its Current Population Survey (CPS). This source has been used in previous studies. For instance, Kuhn and Mansour (2011) used it to investigate the impact on unemployment duration of using the Internet in the job search strategy. CPS Internet data were only collected sporadically during the period of interest, which is why this is not my baseline source. I focus on a variable indicating whether the household has an Internet connection, regardless of the connection technology – the survey question is: "Does anyone in this household connect to the Internet from home? Yes/No". Over the period of interest, this question was asked in years 2000, 2001, 2003, 2007, 2009 and 2010. The fact that this variable is not broadband-specific allows me to get an indication as to whether the effects of broadband penetration can soundly approximate those of Internet diffusion at large.

Further data

I use data on state-level residential telephone adoption and employment in the Cable TV sector in early years to build my instrumental variables. Data on residential telephone adoption in 1955 are from the 1956 City and County Data Book collected by the US Bureau of Census. Information is unavailable for Hawaii and Alaska. In a robustness test, I replicate the analysis at a more disaggregated level. Local data on residential telephone adoption in 1986 are from the CPS. State- and local-level data on employment in the Cable TV sector in 1990 are available by the US Bureau of Labor Statistics. I use US Standard Industrial Classification code 4841, referring to "Cable and other pay TV services".

I include a number of controls in my regressions. Data about states' characteristics (area, population, age and race structure) are from the US Bureau of the Census. State-wide annual averages of unemployment rates come from the US Bureau of Labor Statistics. Data on per capita personal income are available by the US Bureau of Economic Analysis. I consider the logarithmic transformation of this variable throughout the analysis.

Descriptive statistics

Table 1 displays the mean and standard deviation in years 2000 and 2012 for the state-level, time-varying variables described above, as well as their percentage variation in mean over the said period. The pace of broadband Internet diffusion reflected by the FCC data has been exorbitant over the period 2000-2012, at more than 4000%. On the other hand, the increase in Internet penetration (all technologies) portrayed by the CPS data has been less outstanding as dial-up connections were already quite diffused in 2000, when they started being replaced by broadband platforms. All crime rates have substantially fallen since the beginning of the Millennium. In fact, much of the Developed World has experienced a sharp drop in crime rates since the early 1990s.

4 Empirical strategy

4.1 Baseline model

I estimate the effect of broadband Internet penetration on crime rates evolution in the US using a panel that covers a thirteen-year period (2000-2012) for 51 territories (50 states and the federal district). I employ an IV approach, which is summarised by the following equations:

(1) $$y_{st} = \beta_0 + \beta_1 bbrate_{st} + \beta_2 X_{st} + \rho_t + \theta_s + \varepsilon_{st}$$

(2) $$bbrate_{st} = \beta_0 + \beta_1(\rho_t * phonerate_s) + \beta_1(\rho_t * cableTV_s) + \beta_2 X_{st} + \rho_t + \theta_s + \varepsilon_{st}$$

[4] Until the second release of 2004, Residential and Small Business are recorded as a single user type. Afterwards, the Residential and Business segments are recorded separately.

Where the subscripts s and t denote state and year respectively; y_{st} is the crime rate per 100,000 residents; $bbrate_{st}$ is the number of residential high-speed Internet lines per 100 residents; $phonerate_s$ is the number of residential phone lines per 100 residents in 1955; $cableTV_s$ is the number of Cable TV employees per 100,000 residents in 1990; ρ_t and θ_s are year and state fixed effects respectively; and X_{st} is a vector of demographic and socio-economic controls, namely: population density, unemployment rate, personal income per capita, percentage of Black or African American, percentage of males aged 15-24. In my baseline analysis, I estimate the model above by 2SLS, whereby Equation (1) represents the second stage and Equation (2) represents the first stage. I use the robust matrix variance estimator with standard errors clustered at the state level throughout the analysis.

4.2 IV approach

Broadband diffusion is unlikely to be random with respect to the determinants of crime, even conditional on the model covariates. For example, states where cities are growing faster may envisage faster broadband penetration and higher crime growth rates. As a consequence, standard OLS estimation of the relationship between Internet diffusion and crime would likely suffer from the omitted variable bias, and estimates would reflect a measure of association rather than a causal effect. To (more) plausibly attach a causal interpretation to estimation results, it is necessary to somehow filter the overall variation in broadband penetration and only use the part of it that is exogenous with respect to the determinants of crime evolution. The IV approach aims at implementing this intuitive strategy.

Instrument definition

I use as instrumental variables for my analysis the number of residential telephone lines per 100 residents in 1955 and the number of people employed in the Cable TV sector per 100,000 residents in 1990. I interact the instruments with the time fixed effects because they are time invariant, while the endogenous variable (crime rate) is not. More specifically, for each state and year, I instrument $bbrate_{st}$, the fraction of population with a residential broadband Internet subscription, with $(\rho_t * phonerate_s)$ and $(\rho_t * cableTV_s)$, respectively the fraction of population that had a residential telephone in 1955 and the fraction of population that was employed in the Cable TV segment in 1990, multiplied by year indicators.

In the next paragraphs I motivate the validity of my instruments in terms of both relevance and exogeneity.

Instrument motivation

Broadband connection can be provided over different platforms, which entail different technologies. As shown in Figure 1, at least until the end of the years 2000s, the two most widely diffused platforms for residential clients in the US were the Digital Subscriber Line (DSL) and the Cable Modem – whereas the Mobile Wireless technology took over starting from year 2011. The DSL and Cable Modem platforms rely on the physical networks of previously-existing communication technologies: the telephone's copper lines and the Cable TV's coaxial cables. This fact suggests that residential broadband Internet diffusion has followed along the penetration path of these earlier communication technologies. Also, this line of reasoning relates to a more general notion in previous literature (see Stevenson, 2006; Bellou, 2015) suggesting that the adoption of communication technologies by households follows some long-standing patterns driven by state-specific factors that are rather stable over time. My IV definition starts from the hypothesis that the deployment of residential telephone and Cable TV networks in early years represents a good predictor for recent broadband diffusion.

To support my reasoning, I discuss some technological features of the DSL and Cable Modem technologies. As explained by the FCC, "DSL is a wireline transmission technology that transmits data faster over traditional copper telephone lines already installed to homes".[5] "With the advent of the modem, telephone networks were the first networks to provide Internet access. After all, millions of homes were already 'wired' with twisted-pair copper lines".[6] Initially, dial-up Internet used the same analogue network designed for voice to deliver Internet access at lower speeds. To offer high speed access, the network needed to be upgraded. Then, the DSL technology envisaged a cost advantage

[5] FCC's website.

[6] FCC (2010).

because, since it is “deployed over the same existing twisted-pair copper network used to deliver telephone service, it benefits from sunk costs incurred when first deploying the telephone network”.[7] Similar considerations hold for the Cable Modem technology. According to the FCC, this platform “enables cable operators to provide broadband using the same coaxial cables that deliver pictures and sound to your TV set”.[8] “Cable systems were originally constructed to provide one-way video signals […]. In the 1990s with the advent of the Internet and passage of the 1996 Telecommunications Act, cable companies began upgrading their networks to provide the two-way transmission capabilities required for Internet data traffic […]. Such upgrades were seen as attractive since millions of homes were already ‘wired’ with high capacity coaxial cable”.[9]

Data seem to confirm that telephone and Cable TV early deployment is relevant to the pattern of recent broadband diffusion. Figure 2 displays actual state-level broadband Internet penetration rates plotted against those predicted by the rate of residential telephone ownership in 1955 and the fraction of population employed in the Cable TV sector in 1990, for years 2000, 2004, 2008 and 2012. In each year, the state dots are clustered around the 45 degree line (at different penetration levels). Although only four cases are displayed as an example, an analogous outline extends to all sample years. The predictive power of the historical telephone and Cable TV diffusion patterns for broadband Internet penetration is remarkable and confirmed by the first-stage estimation results (see Table 2). This outcome was expected, given that broadband technologies rely on the pre-existing networks of the telephone and Cable TV. What is more, these results are in line with the more general notion that some unobserved, state-specific factors drive the penetration pattern of all residential communication technologies and are rather stable over time (see Stevenson, 2006; Bellou, 2015). Then it seems reasonable that the deployment of residential telephone and Cable TV networks in early years is relevant to recent broadband diffusion.

Further than relevant, a good instrument in this context must also be exogenous with respect to the time-varying determinants of recent crime evolution. In general, instrument exogeneity cannot be tested. At best, having more instruments than endogenous variables, the Hansen J test for overidentifying restrictions can be performed. This test assumes that at least one of the instruments is exogenous and verifies whether all instruments are exogeneous. Results from the Hansen J-test are displayed in the last two rows of Table 3. They lend some support to the validity of the exogeneity condition for my instruments. To further enhance the plausibility that this condition is satisfied, the following considerations hold: (i) I take the value of my instrumental variables in early times (1955 for the telephone and 1990 for Cable TV) in order to help rule out any reverse effect of the dependent variable (crime rates in the period 2000-2012) on the instruments – as well as to have a higher level of heterogeneity among states; (ii) both telephone and Cable TV technologies had virtually reached their full deployment by the turn of the Millennium, when the broadband Internet diffusion began. This helps rule out possible direct effects of the instruments on recent crime rates; (iii) among the factors that may be correlated with both broadband and crime evolution, it is important to distinguish between time-varying and time-invariant ones. As argued above, I do not rule out that the pattern of broadband Internet adoption reflects some state-specific features, such as housing or cultural characteristics, which may well be correlated with recent crime patterns. However, given that these characteristics are stable over time, their effect will be absorbed by the state indicators. As regards time-varying factors, I perform falsification tests to check that my results are not driven by underlying state-specific trends (see Section 6.1.1).

In summary, the crucial hypothesis in my IV approach is that the deployment of the telephone and Cable TV networks in early years provides a relevant source of exogenous variation in broadband penetration. Although this hypothesis cannot be verified with certainty, outcomes from a number of tests reinforce my confidence in its validity.

[7] FCC (2010).
[8] FCC’s website.
[9] FCC (2010).

5 Results

In my baseline analysis I estimate the model by 2SLS, whereby Equation (1) represents the second stage and Equation (2) represents the first stage. I begin by presenting the first stage outcomes. Second stage results follow suit. I also report the results from OLS estimation of Equation (1) and display summary outcomes from the reduced form regression of the dependent variables directly on the instruments.

5.1 First stage estimates

First stage estimation results reported in Table 2 suggest that my instruments are relevant. Telephone and Cable TV deployment variables are highly correlated with crime rates after controlling for the exogenous covariates. As expected, the estimated coefficients are positive: a higher level of penetration of residential telephone and Cable TV technologies in early years is associated with greater broadband Internet diffusion in recent times. The coefficients are highly significant starting from year 2003. Plausibly, in the initial period broadband Internet was not widespread enough for a significant effect to be detected. Starting from 2003, the effect is precisely captured, also thanks to the utter prevalence of DSL and Cable Modem technologies against other broadband platforms (see Figure 1). Around the end of the sample period, again significance is eroded, especially as far as the telephone adoption instrument is concerned. This may be due to the relatively higher expansion of Mobile Wireless broadband connections – which do not rely on the telephone's network – with respect to the DSL and Cable Modem technologies. The F-statistic for a test on whether the excluded instruments are significant is close to 10, reinforcing my confidence that the instruments are not weak.

5.2 IV and OLS estimates

Turning on to second stage estimation, outcomes are displayed in the first three columns of Table 3. Results point to a negative and significant effect of broadband Internet on total and property crime rates. All else being equal, a broadband penetration increase by one additional line per 100 people is associated with a 1.4% - 1.5% decrease in total and property crime rates. On the other hand, the estimated effect on violent crime is not significant. These coefficients should be interpreted as a LATE: by construction of my IV model, they represent the effect of broadband Internet deployment on crime rates for that sub-population ('compliers') for which broadband penetrated according to the patterns of pre-existing telephone and Cable TV networks. The last two rows in columns 1 to 3 of Table 3 report the Hansen J statistic and associated p-value. As mentioned, the Hansen J test assumes that at least one of the instruments is exogenous and tests whether all instruments are exogenous. The joint null hypothesis is that the over-identifying restrictions are uncorrelated with the error term, and that the excluded instruments are correctly excluded from the estimated equation. The test does not reject the null hypothesis, thus it does not rule out that my instruments are indeed exogenous.

The last three columns in Table 3 display the outcomes from OLS estimation of Equation (1). Again, results envisage a negative association between broadband diffusion and total and property crime rates. The estimated coefficients indicate that, all else being equal, a broadband penetration increase by one additional line per 100 people is associated with a 0.6% decrease in crime rates. OLS estimated coefficients are about 2.3 times smaller in absolute value than 2SLS estimated coefficients. Two considerations help explain this discrepancy. First of all, the OLS approach is likely to suffer from the omitted variable bias because broadband diffusion is probably non-random with respect to the determinants of crime (conditional on other covariates). In particular, it seems to be the case that OLS estimates do not account for some heterogeneity that sets back the real effect of Internet penetration on crime rates. A consistent explanation for this bias would be, for instance, that states with faster growing cities record both faster Internet penetration rate and slower crime declines. The second consideration is that some compliers' characteristics relevant to crime evolution may not be homogenous with respect to the overall population, so that the LATE may be overstating the effect of Internet diffusion on crime for the population at large. OLS estimates do not suffer from this kind of bias and thus may more closely reflect the effect of Internet diffusion on crime for the population at large. All in all, considering the results from the two approaches jointly suggests that the effect of Internet diffusion on total and property crime is negative and significant.

Relating outcomes to previous theoretical literature, a negative net impact of broadband Internet diffusion on crime suggests that any arousal effect is dominated by the substitution effect through which online activities crowd out alternative offline activities that are more likely to lead to crime. In connection with to previous empirical research, my finding that the net effect of broadband diffusion on crime is negative is in line with the conclusions reached by those studies analysing the impact on crime of technological platforms other than the Internet. In addition, my results are not inconsistent with the notion of heterogeneous effects by type of offense, as broadband Internet diffusion seems to affect property but not violent crime. I further assess this hypothesis in Section 6.2.1.

5.3 Reduced form relation

Figure 3 reports summary results from the reduced form estimation, which entails regressing crime rates directly against the instruments and further covariates.[10] The reduced form estimates envisage a negative and significant relation between telephone adoption rate and total and property crime rates. Importantly, the reduced form relation parallels the pattern displayed by the first stage regression, whereby the link between the variables is not precisely estimated in the first years of the sample, it becomes significant in central years, and finally fades away towards the end of the sample period. This parallel outline reinforces the plausibility that this significant reduced form association in fact reflects the underlying relationship between broadband Internet penetration and crime, and is motivated by the link between the early deployment of the telephone network and recent broadband Internet diffusion.
On the other hand, the reduced form estimation detects no significant relationship between crime rates and the share of population employed in the Cable TV sector in 1990, as displayed in Figure 4.

6 Robustness and heterogeneity tests

6.1 Robustness tests

In this section, I perform additional tests to enhance confidence in my IV results and the plausibility of their causal interpretation.
To begin with, I run two falsification tests to further assess the validity of my instrumental approach. Secondly, I estimate the IV model using the limited information maximum likelihood (LIML) estimator. Then, I replicate the baseline analysis at both state and local level using a different source for Internet diffusion data.

6.1.1 Falsification tests

An important requirement for my IV setup to be valid is that the instruments are unrelated to the time-varying determinants of crime evolution. In fact, if the exogeneity condition were violated, no causal interpretation could plausibly be attached to the results, as they would just reflect the relationship between Internet diffusion and the underlying state-specific trends in crime. I assess this concern by performing two falsification tests. In the first one, I exploit the timing of the advent of broadband Internet to increase confidence that the instruments are unrelated to underlying trends in crime across states. In the second test, I allow crime evolution to be related to state-specific trends in the exogenous covariates, to check whether the significant effect detected in my baseline analysis holds or is absorbed by such trends.
Broadband penetration occurred starting from the late 1990s – even though the analysis takes 2000 as the baseline year due to lack of available data for the previous period. If the instruments are exogenous, there should not be a significant association between them and crime rates prior to the late 1990s. On the other hand, a systematic relationship would suggest that the exogeneity condition is violated. I take 1996 to be the year in which broadband penetration started because literature (for instance, Bellou, 2015) indicates the 1996 Telecommunications Act – deregulating the broadcasting market and promoting competition in the telecommunications industry – as the turning point in broadband history. This falsification test studies the association between the instruments and crime rates over the period 1990-2012. Summary results for the telephone adoption instrument are presented in

[10] Extensive results are available upon request.

Figure 5.[11] Remarkably, the estimated coefficients for total and property crime associated with telephone adoption start being consistently significant in 1996 and highly so (at the 1% level) in 1997. In addition, the share of people employed in the Cable TV sector in 1990 is not significantly associated to crime rates in the pre-broadband years. These results enhance confidence that my instruments are exogenous with respect to the underlying state-specific trends in crime.

A limitation to this test is that, before broadband technologies, dial-up Internet diffused to US households starting from the early 1990s – its penetration rate was at about 40% in 2000 (NTIA, 2011). Like the DSL platform, the dial-up technology physically relies on the telephone network. Thus, a finding of some negative and significant effect in the pre-broadband would not totally rule out the exogeneity of my instruments, as it may reflect the dial-up Internet effect on crime. In particular, this may explain why the estimated coefficients for total and property crime in year 1994 are significant. Still, starting from the beginning of the broadband era (1996-1997), the effect is consistent and more precisely estimated, in line with the facts that (i) the impact of broadband technologies has arguably been more intense than that of dial-up connections (see NTIA, 2004; NTIA, 2011), and (ii) it was only with the introduction of broadband technologies that the Internet reached preponderant levels of penetration in US homes. It is useful to stress that the said limitation only applies to this specific test and does not extend to the overall analysis. In fact, my purpose is to investigate the impact of the diffusion of Internet (regardless of the technology) on crime. Therefore, as long as my instruments are capturing the effect of the diffusion on crime of some kind of Internet technology, my analysis is not dampened. As explained in Section 3, I am limited by data availability issues to approximate overall Internet diffusion by broadband Internet diffusion. This does not seem unreasonable given the above-mentioned points (i) and (ii) together with the fact that broadband technologies have quickly crowded out dial-up connections since their introduction. Still, I provide some indication as to the reliability of this approximation by replicating the analysis using a different source of Internet diffusion data (the CPS) that covers all types of Internet connections for a more limited number of years (see Section 6.1.3).

All in all, this first falsification test reinforces my confidence that the instruments are exogenous.

I further assess this condition with another test. Following Duflo (2001), I include as further covariates in Equation (1) the interactions between baseline year (2000) exogenous covariates and either a linear time trend or time dummies. This falsification test allows crime evolution to be related to state-specific trends in the exogenous covariates. The purpose of this analysis is to check whether the significant effect detected in my baseline analysis holds even in this setting.

Equation (1) becomes:

(3) $y_{st} = \beta_0 + \beta_1 bbrate_{st} + \beta_2 X_{st} + \mathrm{t} \sum_j \lambda_j x_{(s,2000),j} + \theta_s + \varepsilon_{st}$, with a time trend; or

(4) $y_{st} = \beta_0 + \beta_1 bbrate_{st} + \beta_2 X_{st} + \rho_t \sum_j \lambda_j x_{(s,2000),j} + \theta_s + \varepsilon_{st}$, with time dummies.

Where x_j, $j = (1, \dots, J)$, are the covariates I am using in my baseline model.

Table 4 displays outcomes from the 2SLS estimation of Equation (3) – columns 1 to 3 – and Equation (4) – columns 4 to 6. Remarkably, these outcomes show that the negative and significant relationship between broadband diffusion and total and property crime rates is not accounted for by underlying state-specific trends in the determinants of crime. In fact, the estimated coefficients for total and property crime remain negative and significant. Point estimates from the estimation of Equation (3) are very close to my baseline results, while those from Equation (4) are a bit larger in absolute value. These results also suggest that the effect of Internet diffusion may be significant also on violent crime rates, once underlying state-specific trends in the determinants of crime are accounted for. Overall, the analysis reinforces my confidence that the instruments are exogenous.

6.1.2 LIML estimation of the IV model

The 2SLS estimator is consistent but biased, and the bias is an increasing function of the number of instruments. In my IV model, I have one endogenous variable and twenty-four instruments. Therefore, biasedness of estimates may be an issue. To address this concern, I follow Angrist and Pischke (2009) and estimate my IV model through LIML. The LIML estimator is less precise than the 2SLS one, but it is

[11] Extensive results are available upon request.

approximately median-unbiased for over-identified fixed effects models. Therefore, similar outcomes from the 2SLS and LIML estimations would suggest that biasedness in 2SLS estimates is not much of a concern. This appears to be the case, as shown in Table 4. LIML results confirm a negative and significant relationship between broadband diffusion and total (-1.6%) and property (-1.7%) crime. In terms of sign and significance, these outcomes are identical to results from the 2SLS estimation. In terms of exact point estimates, LIML estimated coefficient are slightly higher in absolute value with respect to 2SLS ones, but still very close. Overall, these outcomes suggest that biasedness of my baseline IV estimates does not raise serious concerns.

6.1.3 Analysis using CPS Internet data

I further test my results by replicating the analysis with a different source of data for Internet diffusion. I use the Internet and Computer Use Supplement data collected by the US Census as part of the CPS. This source has been widely used in previous literature on the effects of Internet penetration on socio-economic outcomes (for instance, Kendall, 2007; Kuhn and Mansour, 2011). I focus on a variable indicating whether the household has an Internet connection, regardless of the connection technology – the survey question is: "Does anyone in this household connect to the Internet from home? Yes/No". This variable is available in six years over the period 2000-2012 (namely: 2000, 2001, 2003, 2007, 2009 and 2010), and has been used in previous related literature (for instance, Kendall, 2007).

Equation (1) and Equation (2) become, respectively:

(5) $$y_{st} = \beta_0 + \beta_1 HHint\_rate_{st} + \beta_2 X_{st} + \rho_t + \theta_s + \varepsilon_{st}$$

(6) $$HHint\_rate_{st} = \beta_0 + \beta_1(\rho_t * phonerate_s) + \beta_1(\rho_t * cableTV_s) + \beta_2 X_{st} + \rho_t + \theta_s + \varepsilon_{st}$$

Where $HHint\_rate_{st}$ is the natural logarithm of the percentage of households that have an Internet connection in state s and year t.

The purpose of this specification check is twofold. First, since CPS Supplement has been widely used by previous literature, it is sensible to replicate my analysis using this information to check whether my baseline results are confirmed. Secondly, this analysis provides some indication as to whether it is reasonable to approximate the effect of the Internet diffusion at large using broadband penetration. In my baseline analysis, I have assumed that such approximation is sound based on the facts that (i) starting from their introduction around year 2000, broadband platforms have largely replaced dial-up connections (NTIA, 2011; NTIA, 2013); (ii) the impact of broadband technologies has arguably been more intense than that of dial-up connections (see NTIA, 2004; NTIA, 2011), and (iii) it was only with the introduction of broadband technologies that the Internet reached preponderant levels of penetration in US homes. In line with this, the Internet diffusion variable I employ in my baseline analysis only refers to broadband technologies. This choice was also dictated by data limitation issues, as overall Internet diffusion data are only available by the CPS on sporadic years. In this specification check, however, I use CPS data for the available years and consider a variable that covers all types of Internet connections. The idea is that if the analysis were to generate substantially different results with respect to my baseline outcomes, this could imply that the effect on crime of broadband technologies is considerably different with respect to the effect of the Internet at large.

The first three columns in Table 5 present the second stage results of the IV model. For completeness, I include in the last three columns the outcomes from OLS estimation of Equation (5). Even using a different source of data for Internet diffusion, this is estimated to have a negative and significant impact on total (-1.6%) and property (-1.7%) crime rates. The IV estimated coefficients are considerably close in magnitude to my baseline results. In addition, these outcomes do not discredit my assumption that the effect on crime of broadband penetration in the period 2000-2012 approximates that of the Internet diffusion at large. In conclusion, this specification check furtherly enhances confidence in my baseline IV estimation results.

6.1.4 Local level analysis

States are huge aggregates and a great deal of variation goes on within their boundaries. Because of this, a concern with my baseline analysis is that the estimation method may not be appropriate as too big entities are being considered. To address this issue, I replicate the analysis at a more disaggregated level. To the best of my knowledge, the only source of Internet data at local level is represented by the CPS Internet

and Computer Use Supplements, which report data at the Metropolitan Statistical Area (MSA) level. MSAs are geographic entities institutionally delineated for statistical purposes and consisting of one or more counties.[12] Caution shall be paid because CPS data are not representative for all parts of the US at the MSA level.[13] Still, this is the only source available to perform a specification check at a disaggregated level. I focus on a variable indicating whether the household has an Internet connection, regardless of the connection technology – the survey question is: "Does anyone in this household connect to the Internet from home? Yes/No". This variable is available in six years over the period 2000-2012 (namely: 2000, 2001, 2003, 2007, 2009 and 2010), and has been used in previous related literature (Kendall, 2007).
Local data on crime are available by FBI's UCR at the county level. They include a coverage indicator (increasing from 0 to 100) which represents a measure of data quality for each county per year combination. I set a minimum threshold for acceptable data quality at 90/100 and replaced all entries that did not satisfy such requirement with missing values (I replicated the analysis using different floor thresholds to make sure results do not change significantly). Finally, I transformed county-level data into MSA-level data and merged them with the Internet diffusion data in a yearly (six years with gaps), MSA-level panel. MSAs are re-delineated periodically. I focus on the 112 MSAs for which data on the dependent and control variables are available in all sample years. This number corresponds to about one third of the total number of MSAs. Table 6 displays the mean and standard deviation for the MSA-level, time-varying variables described above in years 2000 and 2010, as well as their percentage variation in mean over such period. Data are in line with state-level figures presented in Table 1 (even though those statistics referred to years 2000 and 2012). Data confirm that crime rates have been falling while the Internet was expanding. Crime rates are a bit higher at the MSA level in comparison with the state level. This is likely to be due to the fact that MSAs are by definition densely populated areas.
For this local level study, I implement both an IV and an OLS setup that parallel the state level analysis. As instrumental variables, I use residential telephone adoption rate in 1986 and the share of population employed in the Cable TV sector in 1990, both at the MSA level. Telephone adoption data are available by the CPS at the MSA level, and 1986 is the first year in which information is reported for a considerable number of MSAs. Data on employment in the Cable TV segment at the MSA level is provided by the US Bureau of Labor Statistics.
Equation (1) and Equation (2) become, respectively:

(7) $y_{st} = \beta_0 + \beta_1 HHint\_rate_{st} + \rho_t + \theta_s + \varepsilon_{st}$

(8) $HHint\_rate_{st} = \beta_0 + \beta_1(\rho_t * phonerate_s) + \beta_1(\rho_t * cableTV_s) + \rho_t + \theta_s + \varepsilon_{st}$

Where the subscript s denotes MSA, $HHint\_rate_{st}$ is the natural logarithm of the percentage of households that have an Internet connection and θ_s are MSA fixed effects. I use the robust matrix variance estimator with standard errors clustered at the MSA level.
In contrast with respect to the state level outcomes, my instruments do not seem to work well in the local setup. In fact, first stage results in Table 7 show that there is no significant association between the instruments and the endogenous variable in any of the sample years, implying a lack of relevance for the instruments at the local level.
The first three columns in Table 8 present the second stage results from the IV model, whereas the last three columns display the outcomes from OLS estimation of Equation (7). All estimated coefficients are negative and point estimates are not distant in magnitude from those obtained in my baseline analysis. However, possibly as a result of the lack of relevance of the instruments, only the OLS estimated coefficients for total and property crime are significant in this setting.
Although no considerations on causality of effects can be drawn from the local analysis, outcomes from this specification lend support to the finding of a negative and significant association between Internet diffusion and crime, in line with my state-level results.

6.2 Heterogeneity analyses

Results uniformly point to a negative and significant relationship between Internet diffusion and total and property crime. Relating to previous literature, these outcomes suggest that any content-driven

[12] See http://www.census.gov/population/metro/.
[13] See http://www.census.gov/cps/about/faq.html#Q3

behavioural effect is dominated by the substitution effect. Previous research put forth that the latter may be heterogeneous across offense types and/or demographic groups. This section aims at testing these heterogeneity hypotheses.

6.2.1 Effect of broadband diffusion on specific crimes

The negative effect of broadband diffusion on crime may be more intense on that portion of delinquency that can be understood as recreational rather than predetermined and calculated. The rationale behind this stems directly from the very concept of substitution effect. Theory suggests that the negative net effect of Internet diffusion on crime reflects a modification in people's allocation choices, so that in terms of both time and energy online diversionary activities crowd out offline diversionary activities that more likely lead to crime. If this line of reasoning is correct, we shall observe that those types of offenses that are more likely to be committed in a recreational fashion have been more intensely affected by broadband penetration. The concept of recreational crime is usually associated with drug use and related offenses. Unfortunately, this is not one of the categories included in the crime data I am using. Then, the only hypothesis which seems reasonable to make is that especially severe offenses, like murder and, more generally, violent crimes are less likely to be pursued with a recreational intent – at least, this should be the case given that violent crimes are typically associated with more severe punishments. Then, if the suggested heterogeneity across offense types existed, data should display that property offenses have been affected more intensely with respect to violent offenses. My baseline results already lend some support to this hypothesis, in that a significant effect of Internet penetration is found on overall property crime and not on overall violent crime at large. A further step in this direction can be taken by replicating the baseline IV analysis using, as dependent variables, specific violent and property offenses.

Table 9 shows the findings. Remarkably, the effects on each property crime are significant. All else being equal, a broadband penetration increase by one additional line per 100 people is associated with a 1% - 2.3% decrease in burglary, larceny theft and motor vehicle theft rates. On the other hand, the estimated impact of broadband expansion on each of the violent offenses is not significantly different from zero. These results are consistent with the hypothesis that the diffusion of the Internet had a more intense impact on that portion of crime that can be understood as recreational, implying the substitution of one diversionary activity with another.

Previous empirical research studied the link between Internet and sex crimes. In particular, Bhuller *et al.* (2011) used data referring to Norway in an IV setup and found that Internet use is associated with a significant increase in sex crimes, likely as a result of a behavioural effect driven by the increased consumption of pornography. On the other hand, Kendall (2007) reached opposite conclusions on the association between Internet use and rape by studying US state-level data over the period 1998-2003. My analysis suggests yet another conclusion – that Internet diffusion does not significantly impact the occurrence of forcible rapes.

6.2.2 Effect of broadband diffusion on arrest rates

It has been suggested that the effect of Internet penetration may be heterogeneous across different demographic groups. In particular, Griffiths and Sutton (2013) consider that the substitution effect may be stronger on the youth, who typically contribute more than proportionally to delinquency and are particularly keen on new technologies. In the words of the authors, "all the time spent online must equate to less time on the street leading to less potential offending time and a smaller population of available victims of violence and robbery". I aim at empirically testing this hypothesis. An important data limitation is that there is no direct measure of the number of crimes committed by age group. Only when a crime is cleared by an arrest is it possible to attach an age to the criminal. I employ FBI's UCR data on arrests by age and sex to and replicate my baseline IV analysis taking, as dependent variables, arrest rates for different combinations of age and gender. In particular, I consider the natural logarithm of the number of people arrested at age 0-14, 0-19, 0-24, 15-19, 15-24, 20+, 30+ as a percentage of people in that age range. I also consider the percentage of males only arrested at age 0-19, 15-19 and 15-24 – this is because males are arrested at a considerably higher rate than females.

Second stage results are shown in Table 10. The data does not seem to endorse the heterogeneous effect proposed by Griffiths and Sutton (2013). In fact, none of the estimated coefficients is significantly different from zero. Therefore, I cannot detect a systematic variation in the effect of Internet diffusion across different demographic groups.

7 Discussion and economic significance

Results uniformly point to a negative and significant relationship between broadband Internet diffusion and total and property crime rates. Relating these outcomes to previous theoretical literature, a negative net impact of broadband Internet diffusion on crime suggests that any content-driven behavioural effect is dominated by the substitution effect – time and energy focused online crowd out alternative activities that are more likely to lead to crime. In addition, my results lend support to the notion of heterogeneous effects by type of offense, as broadband Internet diffusion seems to significantly affect property but not violent crime. In particular, I argue that this outcome fits the prevision that recreational offenses are being substituted by alternative forms of diversion. This is because I expect mostly property crimes rather than violent crimes to be committed with a diversionary intent – at least, this should be the case given that violent offenses are typically associated with more severe punishments. Linking my results to previous empirical research, the finding that the net effect of broadband diffusion on crime is negative is in line with the conclusions reached by those studies that analysed the effects on crime of technological platforms other than the Internet. These studies find evidence that both an arousal and a substitution effects exist, and that the latter more than outweighs the former – so that the net effect on crime is negative. The setup of the present research does not allow me to separate between arousal and substitution effects. However, the finding of a negative net effect is consistent with the notion that the most relevant mechanism through which the Internet, just like videogames and movies, affects crime is by making people substitute away from alternative activities that would more likely lead to delinquency.

It is important to put the size of my baseline estimates into perspective. My IV estimates indicate a 1.4% decrease in total crime rates as broadband penetration increases by one additional line per 100 people. Broadband diffusion went from 2 to 67 lines per 100 people between 2000 and 2012 (see Table 1). Then, the estimated variation in total crime rate due to broadband expansion (holding all other covariates fixed) in the period 2000-2012 can be calculated as:

(9) $\Delta\, ln(y) = \beta \Delta x$

This leads to a substantial effect on crime, of roughly -60%. This figure is huge, especially considering that the actual variation in total crime rate over the period was about -20.4%. Two factors may help explain the magnitude of the estimated impact. First, the calculation assumes that all other covariates are held constant while in reality they are not, so that the overall evolution of crime depends on the combination of a variety of factors pressuring delinquency both upwards and downwards. Secondly, my IV estimates must be interpreted as a LATE. The source of exogenous variation in my IV setup comes from the deployment of the telephone and Cable TV networks in early years. This allows me to identify the effect of broadband internet deployment on crime rates for the sub-population ('compliers') for which broadband penetrated according to the patterns of pre-existing telephone and Cable TV networks. Then, if some compliers' characteristics relevant to crime evolution are not homogenous with respect to the overall population of users, the LATE will represent a biased estimate of the effect of Internet diffusion on the population at large. In the case at issue, since DSL and Cable Model broadband technologies were by far the most widely spread until the end of the 2000s, I can expect the bias to be small. In addition, it is reasonable to think that such bias would be upwards, so that the LATE actually overstates the impact of the Internet diffusion on crime for the population at large. The reasoning behind this goes as follows. By construction, the estimated LATE is plausibly capturing the effect of fixed broadband Internet connections. In fact it is sound to believe that compliers have a DSL or Cable Modem connection – exactly because these technologies rely on the pre-existing telephone and Cable TV networks. Both of these are fixed residential technologies, and this implies that an individual must be at home to use them. On the other hand, the non-complier users are likely to mostly rely on a Mobile Wireless connection. This is because the latter (i) does not rely on the pre-existing telephone and Cable TV networks, so it is not be captured by the instruments; and (ii) over the period 2000-2012, it has represented the third most widespread residential broadband platform after DSL and Cable Modem (see Figure 1). Then, relating to the discussion about the substitution mechanisms in Section 2.1, it seems reasonable to expect that the effect is more intense on compliers – who surf the Internet from home – rather than on the rest of users – who access the Internet from their mobiles. This is because, while a content-drive catharsis effect may be at play for all users, the voluntary incapacitation mechanism – by which Internet negatively affect crime by simply keeping people off the streets – only affects the compliers. Because of this underlying difference between the sub-populations, the estimated LATE is likely to be higher than the effect for the population at large. In this context, the OLS estimates may be of some help. As already mentioned, these coefficients are likely to suffer from an omitted variable bias. However, they are not biased towards a specific sub-population and in this sense more closely reflect the effects of Internet diffusion on crime for the population at large. The OLS estimated coefficients indicate that, all else being equal, a broadband penetration increase by one additional line per 100 people is associated with a 0.6% decrease in total crime rates, implying an estimated variation in total crime rate due to broadband expansion about half the magnitude of the 2SLS estimated effect. This suggests that the LATE may indeed be overstating the magnitude of the impact of Internet diffusion on crime. Importantly, though, the ongoing considerations do not notch the core result of the analysis – that the overall effect of Internet diffusion on crime is negative, significant and substantial.

I have performed a number of falsification and specification checks to enhance confidence in my outcomes. Overall, these analyses lend support to validity of my IV approach and show that results are robust with respect to the chosen source of Internet data and level of disaggregation.

Further insights from the analysis suggest that the diffusion of the Internet has a more intense impact on that portion of crime that can be understood as recreational, implying the substitution of one diversionary activity with another. On the other hand, I find no evidence that the effects of Internet diffusion on crime are heterogeneous across demographic groups. Still, this piece of analysis suffers from the limitation that there is no direct measure of the number of crimes committed by age group.

8 Conclusions

How does Internet diffusion affect crime? Theoretical studies have pointed to both a positive behavioural impact and a negative substitution effect. The empirical literature on the effects of Internet expansion on delinquency is scarce and mainly focused on a specific kind of offenses – sex crimes. Non-Internet-specific empirical research has been carried on in related fields, providing support to the existence of both the behavioural and the substitution effects. Thus, the overall impact of the Internet diffusion on the most common types of crime is *a priori* unclear. This paper aims at casting light on the issue.

I exploit the variation in broadband penetration and criminal activity in the US over the period 2000-2012. To avoid the omitted variable bias which is likely to affect the OLS estimates, I resort to an IV approach. My underlying assumption is that the deployment of residential telephone and Cable TV networks in early years provides a relevant source of exogenous variation in recent broadband diffusion. This is because the two most widespread non-mobile residential broadband platforms in the US rely on the pre-existing physical networks of these communication technologies. I investigate this hypothesis through a number of tests, and outcomes lend support to the validity of this approach. My IV results suggest that the overall impact of Internet diffusion on the most common property crimes is negative, significant and substantial. On the other hand, violent crimes seem not to be affected. A number of tests enhance confidence in the plausibility of a causal interpretation of my results.

This study speaks to the ongoing debate as to the far-reaching social impacts of the Internet, and whether and how data traffic should be restricted or monitored to prevent potential adverse effects. Overall, my findings advise against these actions. Still, caution is in order. From a policy perspective, it is important to disentangle the behavioural and substitution effects. In cases where the former is relevant (although more than outweighed by the latter), monitoring or restricting some types of contents for some ranges of users may make the overall negative effect even more substantial.

In addition, this research contributes to the stream of literature investigating the crime drop experienced by the US since the since the early 1990s. My findings suggest that Internet diffusion should be enlisted among the factors that have jointly concurred to sustaining the decline.

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Figures and tables

Figure 1: Residential broadband Internet lines by technology (%), 2000-2012

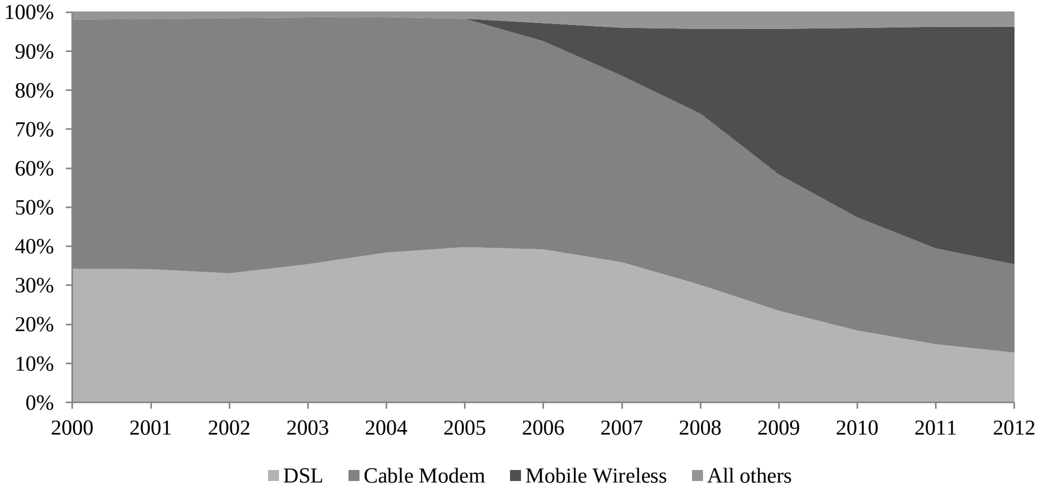


Figure 2: Residential broadband lines (per 100 people): actual *vs* predicted by rate of residential telephone adoption in 1955 and rate of employment in the Cable TV sector in 1990

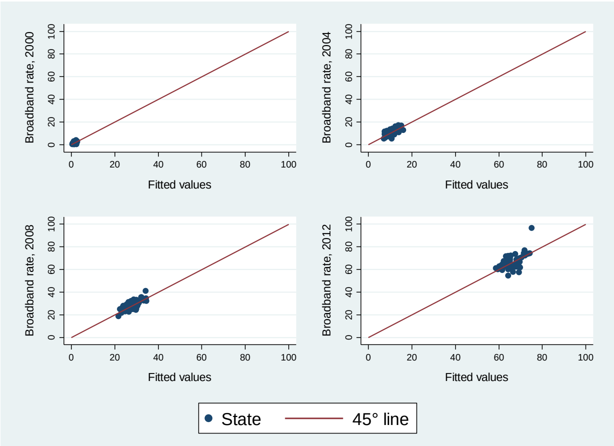
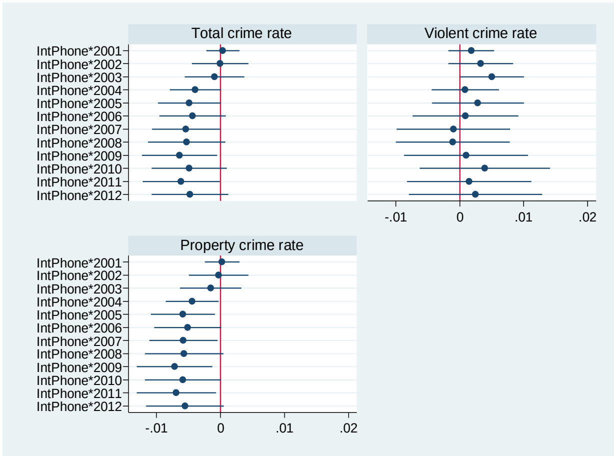
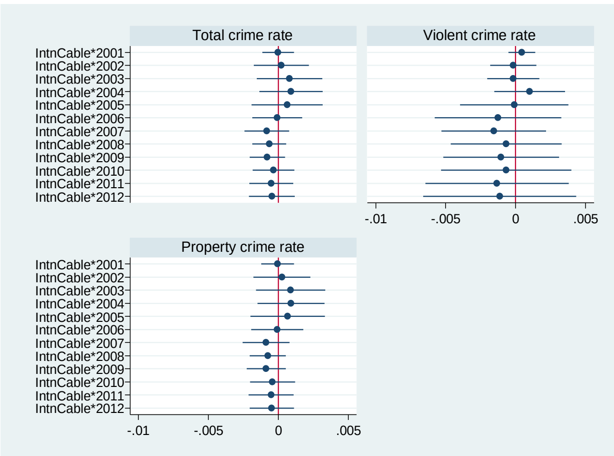


Figure 3: Reduced form estimation, $\rho_t * phonerate_s$



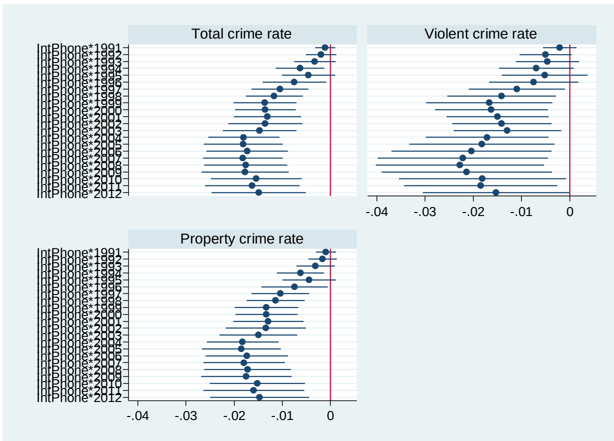
Note: The estimated coefficients are displayed with their respective 95% confidence intervals.

Figure 4: Reduced form estimation, $\rho_t * cableTV_s$



Note: The estimated coefficients are displayed with their respective 95% confidence intervals.

Figure 5: Falsification test, $\rho_t * phonerate_s$, 1990-2012



Note: The estimated coefficients are displayed with their respective 95% confidence intervals.

Table 1: Descriptive statistics, 2000 and 2012

Variable	2000 Mean	2000 SD	2012 Mean	2012 SD	Change (%)
Total crime rate	4,052.73	1,040.01	3,225.61	737.87	-20.41
Violent crime rate	443.33	241.14	371.27	178.66	-16.25
Property crime rate	3,609.40	868.12	2,854.33	606.76	-20.92
Residential broadband lines per 100 people – FCC	1.58	0.94	66.95	6.77	4,137.34
Households with Internet connection (%) – CPS	45.11	6.70	73.96(*)	6.11(*)	64
Black or Afro-Americans (%)	11.15	11.91	11.54	10.99	3.50
Male population aged 15-24 (%)	7.27	0.64	7.17	0.39	-1.38
Population density (/sqmi)	315.78	1,172.75	345.24	1,294.97	9.33
Personal income per capita ($)	29,441.35	4,804.47	44,014.27	7,956.04	49.50
Unemployment rate (%)	3.91	0.93	7.37	1.71	88.49

Note: Crime rates are per 100,000 people. (*) These values refer to year 2010.

Table 2: First stage estimation

DV: Residential broadband lines rate		
Interaction	*Phone adoption rate	*Rate of employment in Cable TV sector
(year==2001)*	0.0217	0.0241*
	[0.0209]	[0.0127]
(year==2002)*	0.044	0.0364***
	[0.0344]	[0.0138]
(year==2003)*	0.1551***	0.0525***
	[0.0578]	[0.0186]
(year==2004)*	0.2083***	0.0665***
	[0.0630]	[0.0247]
(year==2005)*	0.2848***	0.0600**
	[0.0811]	[0.0236]
(year==2006)*	0.2885***	0.0491*
	[0.0672]	[0.0277]
(year==2007)*	0.3023***	0.0886***
	[0.0715]	[0.0183]
(year==2008)*	0.3103***	0.0967***
	[0.0734]	[0.0142]
(year==2009)*	0.2699***	0.1240***
	[0.0667]	[0.0149]
(year==2010)*	0.2085**	0.1084***
	[0.0846]	[0.0235]
(year==2011)*	0.2323*	0.0851**
	[0.1204]	[0.0359]
(year==2012)*	0.1905*	0.1222***
	[0.0993]	[0.0362]
Year effects	Yes	
Further controls	Yes	
N	636	
F-test for IV	9.7528	
F-test for IV - Prob > F	0	

*Note: Robust standard errors (in brackets) are clustered at the state level. Further controls include population density, unemployment rate, personal income per capita, percentage of Black or African American, percentage of males aged 15-24. ***, **, * denote statistical significance at 1%, 5% and 10% respectively.*

Table 3: Second stage and OLS estimation

DV: Crime rate	2SLS Total	2SLS Violent	2SLS Property	OLS Total	OLS Violent	OLS Property
Broadband lines rate	-0.0141***	-0.0094	-0.0153***	-0.0060**	-0.0032	-0.0065**
	[0.0051]	[0.0114]	[0.0051]	[0.0026]	[0.0040]	[0.0027]
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Further controls	Yes	Yes	Yes	Yes	Yes	Yes
N	636	636	636	656	656	656
Hansen J statistic	24.757	27.982	23.777			
p-value	0.3629	0.2165	0.4163			

*Note: Robust standard errors (in brackets) are clustered at the state level. Further controls include population density, unemployment rate, personal income per capita, percentage of Black or African American, percentage of males aged 15-24. ***, **, * denote statistical significance at 1%, 5% and 10% respectively.*

Table 4: Second stage estimation – Robustness test with time interactions and LIML

DV: Crime rate	Time trend (A) Total	Time trend (A) Violent	Time trend (A) Property	Time dummies (B) Total	Time dummies (B) Violent	Time dummies (B) Property	LIML (C) Total	LIML (C) Violent	LIML (C) Property
Broadband lines rate	-0.0154***	-0.0217**	-0.0153***	-0.0204***	-0.0200**	-0.0205***	-0.0155***	-0.01	-0.0170***
	[0.0051]	[0.0106]	[0.0051]	[0.0054]	[0.0094]	[0.0057]	[0.0059]	[0.0124]	[0.0059]
Year effects	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes
Further controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	636	636	636	636	636	636	636	636	636

*Note: Robust standard errors (in brackets) are clustered at the state level. ***, **, * denote statistical significance at 1%, 5% and 10% respectively. For column sets (A) and (B): Further controls include contemporaneous exogenous covariates and interactions between baseline year (2000) exogenous covariates and a linear time trend (column set A) or time dummies (column set B). Contemporaneous exogenous covariates are population density, unemployment rate, personal income per capita, percentage of Black or African American, percentage of males aged 15-24. I use the 2SLS estimator. For column set (C): Further controls include population density, unemployment rate, personal income per capita, percentage of Black or African American, percentage of males aged 15-24*

Table 5: Second stage and OLS estimation – CPS Internet data

DV: Crime rate	2SLS			OLS		
	Total	Violent	Property	Total	Violent	Property
HH has Internet (%)	-0.0157**	-0.0092	-0.0170**	-0.0041**	-0.0029	-0.0043**
	[0.0075]	[0.0089]	[0.0077]	[0.0019]	[0.0027]	[0.0020]
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Further controls	Yes	Yes	Yes	Yes	Yes	Yes
N	294	294	294	306	306	306

*Note: Robust standard errors (in brackets) are clustered at the state level. Further controls include population density, unemployment rate, personal income per capita, percentage of Black or African American, percentage of males aged 15-24. ***, **, * denote statistical significance at 1%, 5% and 10% respectively.*

Table 6: Descriptive statistics – MSA-level data, 2000 and 2010

Variable	2000		2010		Change (%)
	Mean	SD	Mean	SD	
Total crime rate	4357.87	2023.63	3745.89	1979.23	-14.04
Violent crime rate	453.05	262.11	417.92	271.81	-7.75
Property crime rate	3904.83	1813.73	3327.97	1745.6	-14.77
CPS – HH with Internet connection (%)	47.94	10.76	74.95	9.58	56.34

Note: Crime rates are per 100,000 people.

Table 7: First stage estimation – MSA-level analysis

DV: Household has Internet connection (%)			
Interaction	*Phone adoption rate		*Rate of employment in Cable TV sector
(year==2001)*	1.871		-0.0359
	[5.4539]		[0.0371]
(year==2003)*	6.8351		-0.0406
	[5.6994]		[0.0382]
(year==2007)*	-4.361		-0.0249
	[4.9199]		[0.0379]
(year==2009)*	4.6845		-0.0074
	[4.9342]		[0.0365]
(year==2010)*	-2.5501		-0.0343
	[6.2585]		[0.0398]
Year effects		Yes	
Further controls		No	
N		540	
F-test for IV		1.16	
F-test for IV - Prob > F		0.2382	

*Note: Robust standard errors (in brackets) are clustered at the MSA level. No further controls are included. ***, **, * denote statistical significance at 1%, 5% and 10% respectively.*

Table 8: Second stage and OLS estimation – MSA-level analysis

DV: Crime rate	2SLS			OLS		
	Total	Violent	Property	Total	Violent	Property
HH has Internet (%)	-0.0118	-0.0057	-0.0126	-0.0046**	-0.0034*	-0.0047**
	[0.0120]	[0.0137]	[0.0120]	[0.0019]	[0.0020]	[0.0020]
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Further controls	No	No	No	No	No	No
N	531	531	531	658	658	658

*Note: Robust standard errors (in brackets) are clustered at the MSA level. No further controls are included. ***, **, * denote statistical significance at 1%, 5% and 10% respectively.*

Table 9: Second stage estimation – Specific crimes

DV: Crime rate	Violent crimes				Property crimes		
	Murder	Forcible rape	Robbery	Aggravated assault	Burglary	Larceny theft	Motor vehicle theft
Broadband lines rate	0.0026	-0.0121	-0.002	-0.0129	-0.0235***	-0.0100**	-0.0231**
	[0.0130]	[0.0106]	[0.0088]	[0.0149]	[0.0074]	[0.0050]	[0.0101]
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Further controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	636	636	636	636	636	636	636

*Note: Robust standard errors (in brackets) are clustered at the state level. Further controls include population density, unemployment rate, personal income per capita, percentage of Black or African American, percentage of males aged 15-24. I use the 2SLS estimator. ***, **, * denote statistical significance at 1%, 5% and 10% respectively.*

Table 10: Second stage estimation – Arrests rates by demographic group

DV: Arrest rate	Age 0-14	Age 0-19	Age 0-24	Age 15-19	Age 15-24	Age 20+	Age 25+	Age 30+	Age 0-19 Males	Age 15-19 Males	Age 15-24 Males
Broadband lines rate	-0.012	0	-0.0014	0.0017	0.0004	-0.0105	-0.0143	-0.0155	-0.0009	0.0007	0.0003
	[0.0195]	[0.0159]	[0.0174]	[0.0165]	[0.0176]	[0.0214]	[0.0225]	[0.0228]	[0.0162]	[0.0166]	[0.0179]
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Further controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	621	621	621	621	621	621	621	621	621	621	621

*Note: Robust standard errors (in brackets) are clustered at the state level. Further controls include population density, unemployment rate, personal income per capita, percentage of Black or African American, percentage of males aged 15-24. I use the 2SLS estimator. The estimation was replicated without the latter control: results do not change significantly. ***, **, * denote statistical significance at 1%, 5% and 10% respectively.*